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Abstract

This document presents the results of the evaluation activities carried out within Solution 0520. It provides consolidated results obtained in the two exercises, and detailed results with respect to the objectives defined in the Exploratory Research Plan [5]. Finally, the document outlines the overall project conclusions and provides recommendations for the next R&I phase and related R&I activities.

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Author(s) of the document

Organisation name	Date
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Organisation name	Date
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U-AGREE

U-SPACE AIR AND GROUND RISK MODELS ENHANCEMENT

U-AGREE

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Table of contents

1 Executive summary 21
2 Introduction 22
2.1 Purpose of the document 22
2.2 Intended readership 22
2.3 Background 22
2.4 Structure of the document 23
2.5 Glossary of terms 23
2.6 List of acronyms 24
3 Context of the exploratory research report 29
3.1 Project / SESAR solution 0520: a summary 29
3.2 Summary of the exploratory research plan 30
3.3 Deviations 43
4 Validation results 46
4.1 Summary of project / SESAR Solution 0520 validation results 46
4.2 Detailed analysis of project / SESAR solution validation results per validation objective 66
4.3 Confidence in validation results 79
5 Conclusions and recommendations 81
5.1 Conclusions 81
5.2 Recommendations 89
6 References 92
6.1 Applicable documents 92
6.2 Reference documents 92
Appendix A Validation exercise #01 report 94
A.1 Summary of the validation exercise #01 plan 94
A.1.1 Validation exercise description and scope 94
A.1.2 Summary of validation exercise #01 validation objectives and success criteria 94
A.1.3 Summary of validation exercise #01 validation scenarios 94
A.1.4 Summary of validation exercise #01 validation assumptions 95
A.2 Deviation from the planned activities 96
A.3 Validation exercise #01 results - ENGage 99
A.3.1 Summary of validation exercise #01 results 99
A.3.2 Analysis of validation exercise #01 results per validation objective 108
A.3.2.1. OBJ-SOL0520-ERP-001 Results 110
A.3.2.2. OBJ-SOL0520-ERP-002 Results 116
A.3.2.3. OBJ-SOL0520-ERP-003 Results 125

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A.3.2.4. OBJ-SOL0520-ERP-004 Results ... 131
A.3.3 Unexpected behaviours/results ... 136
A.3.4 Confidence in results of validation exercise #01 ... 137
A.3.4.1. Level of significance/limitations of validation exercise results ... 137
A.3.4.2. Quality of validation exercises results ... 137
A.3.4.3. Significance of validation exercises results ... 137

A.4 Validation exercise #01 results - UPV ... 138
A.4.1 Summary of validation exercise #01 results ... 138
A.4.2 Analysis of validation exercise #01 results per validation objective ... 148
A.4.2.1. OBJ-SOL0520-ERP-001 Results ... 150
A.4.2.2. OBJ-SOL0520-ERP-002 Results ... 167
A.4.2.3. OBJ-SOL0520-ERP-003 Results ... 208
A.4.2.4. OBJ-SOL0520-ERP-004 Results ... 224
A.4.3 Unexpected behaviours/results ... 238
A.4.4 Confidence in results of validation exercise #01 ... 239
A.4.4.1. Level of significance/limitations of validation exercise results ... 239
A.4.4.2. Quality of validation exercises results ... 239
A.4.4.3. Significance of validation exercises results ... 240

A.5 Validation exercise #01 results - CRA ... 241
A.5.1 Summary of validation exercise #01 results ... 241
A.5.2 Analysis of validation exercise #01 results per validation objective ... 246
A.5.2.1. OBJ-SOL0520-ERP-001 Results ... 246
A.5.2.2. OBJ-SOL0520-ERP-002 Results ... 248
A.5.2.3. OBJ-SOL0520-ERP-003 Results ... 251
A.5.2.4. OBJ-SOL0520-ERP-004 Results ... 253
A.5.3 Unexpected behaviours/results ... 254
A.5.4 Confidence in results of validation exercise #01 ... 255
A.5.4.1. Level of significance/limitations of validation exercise results ... 255
A.5.4.2. Quality of validation exercises results ... 255
A.5.4.3. Significance of validation exercises results ... 255

A.6 Conclusions ... 256
A.6.1 Conclusions on concept clarification ... 256
A.6.2 Conclusions on technical feasibility ... 257
A.6.3 Conclusions on performance assessments ... 258
A.6.4 Conclusions on Human Performance ... 260

A.7 Recommendations ... 261

Appendix B Validation exercise #02 report ... 263

B.1 Summary of the validation exercise #02 plan ... 263
B.1.1 Validation exercise description and scope ... 263
B.1.2 Summary of validation exercise #02 validation objectives and success criteria ... 263
B.1.3 Summary of validation exercise #02 validation scenarios ... 263
B.1.4 Summary of validation exercise #02 validation assumptions ... 264

B.2 Deviation from the planned activities ... 265

B.3 Validation exercise #02 results - ENGage ... 279
B.3.1 Summary of validation exercise #02 results ... 279
B.3.2 Analysis of validation exercise #02 results per validation objective ... 287
B.3.2.1. OBJ-SOL0520-ERP-001 Results ... 287
B.3.2.2. OBJ-SOL0520-ERP-005 Results ... 288
B.3.2.3. OBJ-SOL0520-ERP-006 Results ... 295

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B.3.2.4. OBJ-SOL0520-ERP-007 Results ... 296
B.3.2.5. OBJ-SOL0520-ERP-008 Results ... 298
B.3.2.6. OBJ-SOL0520-ERP-009 Results ... 299
B.3.3 Unexpected behaviours/results ... 300
B.3.4 Confidence in results of validation exercise #02 ... 300
B.3.4.1. Level of significance/limitations of validation exercise results ... 300
B.3.4.2. Quality of validation exercises results ... 300
B.3.4.3. Significance of validation exercises results ... 301

B.4 Validation exercise #02 results - UPV ... 301
B.4.1 Summary of validation exercise #02 results ... 301
B.4.2 Analysis of validation exercise #02 results per validation objective ... 316
B.4.2.1. OBJ-SOL0520-ERP-001 Results ... 316
B.4.2.2. OBJ-SOL0520-ERP-005 Results ... 317
B.4.3 Unexpected behaviours/results ... 349
B.4.4 Confidence in results of validation exercise #02 ... 349
B.4.4.1. Level of significance/limitations of validation exercise results ... 350
B.4.4.2. Quality of validation exercises results ... 350
B.4.4.3. Significance of validation exercises results ... 351

B.5 Validation exercise #02 results - CRA ... 352
B.5.1 Summary of validation exercise #02 results ... 352
B.5.2 Analysis of validation exercise #02 results per validation objective ... 360
B.5.2.1. OBJ-SOL0520-ERP-001 Results ... 360
B.5.2.2. OBJ-SOL0520-ERP-005 Results ... 360
B.5.3 Unexpected behaviours/results ... 364
B.5.4 Confidence in results of validation exercise #02 ... 364
B.5.4.1. Level of significance/limitations of validation exercise results ... 364
B.5.4.2. Quality of validation exercises results ... 365
B.5.4.3. Significance of validation exercises results ... 365

B.6 Conclusions ... 365
B.6.1 Conclusions on concept clarification ... 365
B.6.2 Conclusions on technical feasibility ... 366
B.6.3 Conclusions on performance assessments ... 367
B.6.4 Conclusions on automation levels ... 370

B.7 Recommendations ... 371

Annex A – Representative scenarios ... 373

Annex A.1 Scenario Selection Methodology ... 373

Annex A.2 Scenario Descriptions and Risk Mitigation ... 374
Annex A.2.1 Urban U-space operations in uncontrolled airspace ... 374
Annex A.2.1.1 Operational Characteristics ... 375
Annex A.2.1.2 U-space Architecture and Governance ... 376
Annex A.2.1.3 Designated Testing Areas ... 376
Annex A.2.1.4 Environmental and Regulatory Considerations ... 377
Annex A.2.1.5 Identified Hazards and Risk Mitigation through U-space Services ... 377
Annex A.2.2 U-space BVLOS operations in low-density peri-urban and rural areas within Class-C ... 379
Annex A.2.2.1 Operational Characteristics ... 380
Annex A.2.2.2 Environmental and Regulatory Constraints ... 382
Annex A.2.2.3 Identified Hazards and Risk Mitigation through U-space Services ... 383
Annex A.2.3 Dynamic U-space operations for infrastructure inspection ... 385
Annex A.2.3.1 Operational Characteristics ... 385

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Annex A.2.3.2 Key operational characteristics 385
Annex A.2.3.3 Environmental and Regulatory Constraints 387
Annex A.2.3.4 Operational Constraints and Risk Mitigation 388
Annex A.2.4 Medical transport operations from suburban to urban areas 390
Annex A.2.4.1 Operational Characteristics 391
Annex A.2.4.2 Environmental and Regulatory Constraints 393
Annex A.2.4.3 Identified Hazards and Risk Mitigation through U-space services 394

Annex B – Application of the air risk model to the U-AGREE Manduria scenario 398

Annex B.1 Methodology for the wildlife presence estimation 403
Annex B.1.1. Manduria: Daily commuting movements by crows 403

Annex C – Safety Assessment 405

Annex C.1 Methodological approach and scope 405
Annex C.1.1 Methodological approach 405
Annex C.1.2 Scope of the safety assessment 406
Annex C.1.3 Mapping of Safety Assessment Exercises and Operational Configurations 406

Annex C.2 Safety assessment 0 – Safety Criteria Assessment 407
Annex C.2.1 Definition phase 407
Annex C.2.2 Safety specification phase 409

Annex C.3 Safety assessment 1 – Initial barriers 413
Annex C.3.1 Definition phase 413
Annex C.3.2 Safety specification 417

Annex C.4 Safety assessment 2 – Final barriers 431
Annex C.4.1 Definition phase 431
Annex C.4.2 Safety specification 439

List of figures

Figure 1: SESAR Solution 0520 - Integrated risk models for UAS in the U-space (U-AGREE) 30

Figure 2: Reference and Solution scenarios for TVAL.01.0 32

Figure 3: Reference and Solution scenarios for TVAL.02.0 32

Figure 4: New KPA and KPI introduced 44

Figure 5: Distribution of the reaction time for the Human Performance 97

Figure 6: Rules of Air 98

Figure 7: Imported trajectories in Benidorm scenario - ENGage simulator 110

Figure 8: Baseline NMAC values for Benidorm 111

Figure 9: Imported trajectories in Manduria scenario - ENGage simulator 112

Figure 10: Baseline NMAC values for Manduria 113

Figure 11: Imported trajectories for Shannon-Limerick scenario - ENGage simulator 114

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Figure 12: Baseline NMAC values for Shannon-Limerick 115

Figure 13: UAS-UAS NMAC Values for Benidorm with FAS 117

Figure 14: Authorisation approval rate in Benidorm 118

Figure 15: UAS-UAS NMAC Values for Manduria with FAS 120

Figure 16: Authorisation approval rate in Manduria 121

Figure 17: UAS-UAS NMAC Values for Shannon Limerick with FAS 123

Figure 18: Authorisation approval rate in Shannon-Limerick 124

Figure 19: NMAC vs simultaneous vehicles in Benidorm - FAS + CM (without pre-alerting)..... 126

Figure 20: NMAC vs simultaneous vehicles in Manduria - FAS + CM (without pre-alerting)..... 128

Figure 21: NMAC vs simultaneous vehicles in Shannon-Limerick - FAS + CM (without pre-alerting). 130

Figure 22: NMAC vs simultaneous vehicles in Benidorm - FAS + CM (with pre-alerting) 132

Figure 23: NMAC vs simultaneous vehicles in Manduria - FAS + CM (with pre-alerting) 133

Figure 24: NMAC vs simultaneous vehicles in Shannon- Limerick - FAS + CM (with pre-alerting) 135

Figure 25: UPV - Baseline below VLL UAS-UAS frequency 151

Figure 26: UPV - Baseline below VLL UAS-manned frequency in UAS flight hours..... 153

Figure 27: UPV - Baseline below VLL UAS-manned frequency in manned flight hours 155

Figure 28: UPV - Baseline above VLL UAS-UAS frequency 157

Figure 29: UPV - Baseline above VLL UAS-manned frequency in UAS flight hours..... 159

Figure 30: UPV - Baseline above VLL UAS-manned frequency in manned flight hours 161

Figure 31: UPV - Baseline providence 164

Figure 32: TIS baseline-selection metrics by validation traffic mix for UAS–UAS encounters, using the selected Uniform (1/3) reporting profile. Raw ratios are shown before the separate reporting factor of two..... 172

Figure 33: TIS baseline-selection metrics by validation traffic mix for UAS–manned encounters, using the selected Uniform (1/3) reporting profile. Raw ratios are shown before the separate reporting factor of two. 173

Figure 34: TIS UAS–UAS sensitivity to the horizontal separation factor, with all other dimensions fixed at the nominal baseline and equal-weight traffic used to isolate the parameter effect. 174

Figure 35: TIS UAS–manned sensitivity to the horizontal separation factor, with all other dimensions fixed at the nominal baseline and equal-weight traffic used to isolate the parameter effect. 175

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Figure 36: TIS UAS–UAS robustness to manoeuvre failure, random turns and climb/descent perturbations. Each sweep changes one dimension from the baseline. 176

Figure 37: TIS UAS–manned robustness to manoeuvre failure, random turns and climb/descent perturbations. Each sweep changes one dimension from the baseline. 176

Figure 38: TIS UAS–UAS sensitivity to nominal/degraded GNSS and same/asymmetric latency and packet-loss configurations. 177

Figure 39: TIS UAS–manned sensitivity to nominal/degraded GNSS and same/asymmetric latency and packet-loss configurations. 178

Figure 40: TIS UAS–UAS comparison across the five original postprocessor profiles; Uniform (1/3) is the baseline reference. 179

Figure 41: TIS UAS–manned comparison across the five original postprocessor profiles; Uniform (1/3) is the baseline reference. 180

Figure 42: UPV - FAS+TIS below VLL UAS-UAS frequency 182

Figure 43: UPV - FAS+TIS below VLL UAS-manned frequency in UAS flight hours 184

Figure 44: UPV - FAS+TIS below VLL UAS-manned frequency in manned flight hours 186

Figure 45: UPV - FAS+TIS above VLL UAS-UAS frequency 188

Figure 46: UPV - FAS+TIS above VLL UAS-manned frequency in UAS flight hours 190

Figure 47: UPV - FAS+TIS above VLL UAS-manned frequency in manned flight hours 192

Figure 48: UPV - Approval Rate of the FAS across all scenarios 198

Figure 49: UPV - FAS Providence for UAS-UAS 201

Figure 50: UPV - FAS Providence for UAS-manned 203

Figure 51: UPV - Risk Ratio Conformance Monitoring without pre-alert UAS-UAS below VLL 210

Figure 52: UPV - Risk Ratio Conformance Monitoring without pre-alert UAS-UAS above VLL 212

Figure 53: UPV - UAS non-conformance in deviation-boundary limit in CM without pre-alert per UAS flight hour 215

Figure 54: UPV - UAS non-conformance in the TSE-boundary in CM without pre-alert per UAS flight hour 217

Figure 55: UPV - Risk Ratio Conformance Monitoring with pre-alert UAS-UAS below VLL 226

Figure 56: UPV - Risk Ratio Conformance Monitoring with pre-alert UAS-UAS above VLL 228

Figure 57: UPV - UAS non-conformance in CM with pre-alert per UAS flight hour 231

Figure 58: Baseline capacity evaluation for Benidorm 247

Figure 59: Baseline capacity evaluation for Manduria 247

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Figure 60: Baseline capacity evaluation for Shannon 247

Figure 61: Flight authorisation capacity evaluation for Benidorm; MAC (left), NMAC (right) 249

Figure 62: Flight authorisation capacity evaluation for Manduria; MAC (left), NMAC (right) 249

Figure 63: Flight authorisation capacity evaluation for Shannon; MAC (left), NMAC (right) 249

Figure 64: Encounter numbers in Benidorm 250

Figure 65: Encounter numbers in Manduria 250

Figure 66: Encounter numbers in Shannon 251

Figure 67: Traffic information service effectiveness in encounter model 251

Figure 68: Conformance monitoring capacity evaluation for Benidorm (without pre-alert) 252

Figure 69: Conformance monitoring capacity evaluation for Manduria (without pre-alert) 252

Figure 70: Conformance monitoring capacity evaluation for Shannon (without pre-alert) 252

Figure 71: Conformance monitoring capacity evaluation for Benidorm (with pre-alert) 253

Figure 72: Conformance monitoring capacity evaluation for Manduria (with pre-alert) 253

Figure 73: Conformance monitoring capacity evaluation for Shannon (with pre-alert) 254

Figure 74: Reduced Shannon-Limerick U-space for the DAR zone 267

Figure 75: Benidorm - Medical facilities Geozones 270

Figure 76: Benidorm - Public service facility Geozone 270

Figure 77: Benidorm - Public transportation Facilities Geozones 270

Figure 78: Benidorm - Police related Geozones 270

Figure 79: Benidorm - General picture and Serra Gelada Natural Park (pink) 270

Figure 80: Manduria – *Mura Messapiche* (archaeological site) Geozone 271

Figure 81: Shannon - Limerick - Estuary Geozone (in yellow) inside the operational volume (in purple) 271

Figure 82: Tactical conflict detection and resolution architecture in the U-space [9] 272

Figure 83: Tactical conflict prediction and resolution service steps 273

Figure 84: ENGage TCP&R Implementation 276

Figure 85: Automation-level reaction-time distributions used in the definitive UPV TCP&R campaign. 277

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Figure 86: Communication-latency and surveillance-delay distributions used in the definitive UPV TCP&R campaign. 278

Figure 87: NMAC/fh vs DT in Benidorm with manned aircrafts deconflicted 289

Figure 88: UAS–manned NMAC/fh vs DT — manned-aware FAS vs manned-blind references 290

Figure 89: NMAC/fh vs DT in Manduria with manned aircrafts deconflicted 290

Figure 90: NMAC/fh vs simultaneous vehicles in Manduria with TCPR 291

Figure 91: NMAC/fh vs DT in Shannon-Limerick with manned aircrafts deconflicted 293

Figure 92: NMAC/fh vs simultaneous vehicles in Shannon-Limerick with TCPR 293

Figure 93: Table 14: Risk Ratios for FAS and TCPR – Shannon Limerick 295

Figure 94: Geozones infringements per flight-hour, Manduria 295

Figure 95: Geozones infringements per flight-hour, Shannon Limerick 296

Figure 96: Authorisation approval rate in Manduria, exercise 2 297

Figure 97: Authorisation approval rate in Shannon Limerick, exercise 2 298

Figure 98: UPV - Shannon traffic density within DAR 318

Figure 99: Benidorm mixed-traffic configurations used for the qualitative SCR assessment. 320

Figure 100: TCP&R sensitivity to look-ahead and horizontal separation factor for UAS–UAS encounters. SFV = 1 and all other parameters are fixed at the nominal baseline; the selected SFH = 1 curve is shown in black. 322

Figure 101: TCP&R sensitivity to look-ahead and vertical separation factor for UAS–UAS encounters. The crossed campaign mesh evaluates SFV at SFH = 0.5625; the selected SFV = 1 curve is shown in black. 322

Figure 102: Effect of random turns and climb/descent perturbations on UAS–UAS RR and LR at LA = 45 s. The black point identifies the zero-perturbation reference. 323

Figure 103: TCP&R sensitivity to look-ahead and horizontal separation factor for UAS–manned encounters. SFV = 1 and all other parameters are fixed at the nominal baseline; the selected SFH = 1 curve is shown in black. 323

Figure 104: TCP&R sensitivity to look-ahead and vertical separation factor for UAS–manned encounters. The crossed campaign mesh evaluates SFV at SFH = 0.5625; the selected SFV = 1 curve is shown in black. 324

Figure 105: Effect of random turns and climb/descent perturbations on UAS–manned RR and LR at LA = 45 s. The black point identifies the zero-perturbation reference. 324

Figure 106: Raw RR and LR comparison between the executed Autonomous and RPAS response assumptions for UAS–UAS encounters at the definitive reporting baseline. The values precede the separate reporting factor of two. 326

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Figure 107: Matched RPAS minus Autonomous change in UAS–UAS RR and LR across horizontal and vertical separation, CNS, manoeuvre-failure, random-turn and climb/descent sensitivity slices. Positive values mean that the RPAS response assumption produces the higher conditional ratio. 327

Figure 108: Raw RR and LR comparison between the executed Autonomous and RPAS response assumptions for UAS–manned encounters at the definitive reporting baseline. The manned aircraft retains its reference trajectory in both response families. 328

Figure 109: Matched RPAS minus Autonomous change in UAS–manned RR and LR across the same admitted sensitivity slices. The diverging RR response shows why the operation comparison cannot be reduced to a universal response-family ranking. 329

Figure 110: Combined UAS–UAS and UAS–manned raw Risk Ratio (RR) for Benidorm BVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0. 331

Figure 111: Combined UAS–UAS and UAS–manned raw Loss-of-separation Ratio (LR) for Benidorm BVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0. 331

Figure 112: Combined UAS–UAS and UAS–manned raw Risk Ratio (RR) for Benidorm AVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0. 332

Figure 113: Combined UAS–UAS and UAS–manned raw Loss-of-separation Ratio (LR) for Benidorm AVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0. 332

Figure 114: Combined UAS–UAS and UAS–manned raw Risk Ratio (RR) for CORUS BVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0. 333

Figure 115: Combined UAS–UAS and UAS–manned raw Loss-of-separation Ratio (LR) for CORUS BVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0. 333

Figure 116: Combined UAS–UAS and UAS–manned raw Risk Ratio (RR) for CORUS AVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0. 334

Figure 117: Combined UAS–UAS and UAS–manned raw Loss-of-separation Ratio (LR) for CORUS AVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0. 334

Figure 118: Combined UAS–UAS and UAS–manned raw Risk Ratio (RR) for Shannon BVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0. 335

Figure 119: Combined UAS–UAS and UAS–manned raw Loss-of-separation Ratio (LR) for Shannon BVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0. 335

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Figure 120: Combined UAS–UAS and UAS–manned raw Risk Ratio (RR) for Shannon AVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0. 336

Figure 121: Combined UAS–UAS and UAS–manned raw Loss-of-separation Ratio (LR) for Shannon AVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0. 336

Figure 122: UPV – Final FAS+TCP&R above VLL UAS-UAS frequency..... 338

Figure 123: UPV – Final FAS+TCP&R above VLL UAS-manned frequency in UAS flight hours 340

Figure 124: UPV – Final FAS+TCP&R above VLL UAS-manned frequency in manned flight hours 342

Figure 125: CRA–TCPR conditional UAS–UAS NMAC risk ratio and UAS–UAS loss-of-separation ratio in Benidorm, evaluated through a look-ahead-time sweep using the reference protection volume and a protection-volume sweep using a fixed 45 s look-ahead time. 362

Figure 126: CRA–TCPR conditional UAS–UAS NMAC risk ratio and UAS–UAS loss-of-separation ratio in Manduria, evaluated through a look-ahead-time sweep using the reference protection volume and a protection-volume sweep using a fixed 45 s look-ahead time. 362

Figure 127: CRA–TCPR conditional UAS–UAS NMAC risk ratio and UAS–UAS loss-of-separation ratio in Shannon, evaluated through a look-ahead-time sweep using the reference protection volume and a protection-volume sweep using a fixed 45 s look-ahead time. 363

Figure 128: CRA– Aggregate NMAC risk ratio across the three scenarios. 364

Figure 129: Aerial view of Benidorm - Urban U-space operations in uncontrolled airspace scenario 375

Figure 130: Geographical delimitation of the Benidorm U-space area - Urban U-space operations in uncontrolled airspace scenario 375

Figure 131: Testing areas for U-space operations in Benidorm - Urban U-space operations in uncontrolled airspace scenario 376

Figure 132: Aerial view of Shannon, Ireland - U-space BVLOS operations in low-density peri-urban and rural areas within Class-C 380

Figure 133: Example of key routes - U-space BVLOS operations in low-density peri-urban and rural areas within Class-C..... 381

Figure 134: Transition from Class C to Class G airspace - U-space BVLOS operations in low-density peri-urban and rural areas within Class-C..... 381

Figure 135: CNS Infrastructure Architecture - U-space BVLOS operations in low-density peri-urban and rural areas within Class-C 382

Figure 136: EBHN and EBAW next to geographical area of port, partly in CTR of EBAW. The violet rectangle frames the area of the port, enlarged in the image on the right. 385

Figure 137: Drone used in the flight tests in the port of La Spezia. 387

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Figure 138: Flight test in the port of La Spezia, Italy (Project Labyrinth, 2023). The drone appears inside the blue circle. 389

Figure 139: Last mile delivery trajectory 391

Figure 140: Techno Sky UAS: PPL 612 PLUS EVO XL 391

Figure 141: UAS Tracking Display on D-flight USSP Platform 392

Figure 142: Airspace CTR 3 Grottaglie 393

Figure 143: Manduria “Marianna Giannuzzi” Hospital 394

Figure 144: Surroundings of Manduria with control zone. 398

Figure 145: Local conflict probabilities for the Manduria area for an entire year. 399

Figure 146: Conflict probabilities for the altitude band 150-250 m. 400

Figure 147: Bird conflict probabilities. 401

Figure 148: Exemplary mission trajectory from Aerotre Aviosuperficie di Manduria to Manduria City Center. 402

Figure 149: Sleeping (blue) and feeding (green) locations of crows 404

Figure 150: E-SRM method process for the safety assessment in ARA 405

Figure 151: Benidorm population density (left) and residential map (right) 435

Figure 152: Manduria population density (left) and residential map (right) 436

Figure 153: Shannon-Limerick population density (left) and residential map (right) 436

Figure 154: Look-up table from D3.5 [22] 437

Figure 155: CasEx details 437

Figure 156: Weight Limits related to land use typology 438

List of tables

Table 1: glossary of terms 24

Table 2: list of acronyms 28

Table 3: validation assumptions overview 38

Table 4: Validation exercise #01 layout 41

Table 5: Validation exercise #02 layout 43

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Table 6: Removed KPI 44
Table 7: summary of validation exercises results 65
Table 8: validation exercise #01 assumptions overview 96
Table 9: Distribution of the reaction time for the Human Performance parameters 97
Table 10: validation exercise #01 results - ENGage 107
Table 11: KPIs for OBJ-SOL0520-ERP-001 Benidorm, exercise 1 112
Table 12: KPIs for OBJ-SOL0520-ERP-001 Manduria, exercise 1 113
Table 13: KPIs for OBJ-SOL0520-ERP-001 Shannon-Limerick, exercise 1 115
Table 14: Risk Ratios for FAS - Benidorm 118
Table 15: KPIs for OBJ-SOL0520-ERP-002 Benidorm 119
Table 16: Risk Ratios for FAS - Manduria 121
Table 17: KPIs for OBJ-SOL0520-ERP-002 Manduria 122
Table 18: Risk Ratios for FAS - Shannon Limerick 124
Table 19: KPIs for OBJ-SOL0520-ERP-002 Shannon Limerick 125
Table 20: Risk Ratios for CM (without pre-alerting) for Benidorm 127
Table 21: KPIs for OBJ-SOL0520-ERP-003 Benidorm 127
Table 22: Risk Ratios for CM (without pre-alerting) for Manduria 129
Table 23: KPIs for OBJ-SOL0520-ERP-003 Manduria 129
Table 24: Risk Ratios for CM (without pre-alerting) for Shannon-Limerick 130
Table 25: KPIs for OBJ-SOL0520-ERP-003 Shannon-Limerick 131
Table 26: Risk Ratios for CM (with pre-alerting) for Benidorm 132
Table 27: KPIs for OBJ-SOL0520-ERP-004 Benidorm 133
Table 28: Risk Ratios for CM (with pre-alerting) for Manduria 134
Table 29: KPIs for OBJ-SOL0520-ERP-004 Manduria 134
Table 30: Risk Ratios for CM (with pre-alerting) for Shannon-Limerick 135
Table 31: KPIs for OBJ-SOL0520-ERP-004 Shannon-Limerick 136
Table 32: validation exercise #01 results - UPV 147
Table 33: UPV - Baseline capacity results for batch 1 163

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Table 34: UPV - KPIs for OBJ-SOL0520-ERP-001 (Baseline) 167

Table 35: UPV - TIS Risk Ratio for the different scenarios 181

Table 36: UPV – FAS updated success criterion when applying TIS 181

Table 37: UPV – FAS independent of the number of simultaneous vehicles parameter on the UAS-UAS NMAC frequency 195

Table 38: UPV – FAS independent of the number of simultaneous vehicles parameter on the UAS-manned NMAC frequency 195

Table 39: UPV - Capacity results for the FAS+TIS 196

Table 40: UPV - KPIs for OBJ-SOL0520-ERP-002 (FAS+TIS) 208

Table 41: UPV - KPIs for OBJ-SOL0520-ERP-003 (FAS+TIS+CMS without pre-alert) 224

Table 42: UPV - KPIs for OBJ-SOL0520-ERP-004 (FAS+TIS+CMS with pre-alert) 238

Table 43: validation exercise #01 results – CRA 245

Table 44: Baseline capacity evaluation summary 247

Table 45: Flight authorisation capacity evaluation summary 249

Table 46: Traffic information service capacity evaluation summary 251

Table 47: Conformance monitoring capacity evaluation summary 253

Table 48: validation exercise #02 assumptions overview 265

Table 49: TCR&R service level of implementation 272

Table 50: validation exercise #02 results - ENGage 286

Table 51: KPIs for OBJ-SOL0520-ERP-001 Benidorm, exercise 2 287

Table 52: KPIs for OBJ-SOL0520-ERP-001 Manduria, exercise 2 287

Table 53: KPIs for OBJ-SOL0520-ERP-001 Shannon Limerick, exercise 2 288

Table 54: KPIs for OBJ-SOL0520-ERP-005 Benidorm, exercise 2 290

Table 55: KPIs for OBJ-SOL0520-ERP-005 Manduria, exercise 2 292

Table 56: Risk Ratios for FAS and TCPR - Manduria 292

Table 57: KPIs for OBJ-SOL0520-ERP-005 Shannon Limerick, exercise 2 294

Table 58: KPIs for OBJ-SOL0520-ERP-006 Manduria, exercise 2 296

Table 59: KPIs for OBJ-SOL0520-ERP-006 Shannon Limerick, exercise 2 296

Table 60: KPIs for OBJ-SOL0520-ERP-007 Manduria, exercise 2 297

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Table 61: KPIs for OBJ-SOL0520-ERP-007 Shannon Limerick, exercise 2 298

Table 62: KPIs for OBJ-SOL0520-ERP-008 Manduria, exercise 2 299

Table 63: KPIs for OBJ-SOL0520-ERP-008 Shannon Limerick, exercise 2 299

Table 64: KPIs for OBJ-SOL0520-ERP-009 Shannon Limerick, exercise 2 300

Table 65: validation exercise #02 results - UPV 315

Table 66: UPV - Exercise #02 baseline capacity. 316

Table 67: UPV - DAR results..... 318

Table 68: UPV - U-plan acceptance results for the qualitative SCR assessment. 320

Table 69: UPV – TCP&R Risk Ratio for the different scenarios..... 337

Table 70: UPV - Final FAS updated success criterion when applying TCP&R 337

Table 71: UPV – Final FAS independent of the number of simultaneous vehicles parameter on the UAS-UAS NMAC frequency..... 345

Table 72: UPV – Final FAS independent of the number of simultaneous vehicles parameter on the UAS-manned NMAC frequency per UAS FH..... 345

Table 73: UPV – Final FAS independent of the number of simultaneous vehicles parameter on the UAS-manned NMAC frequency per manned FH 346

Table 74: UPV - Capacity results for the Final FAS+TCPR 346

Table 75: UPV - KPIs for OBJ-SOL0520-ERP-005. 349

Table 76: validation exercise #02 results - CRA..... 359

Table 77: CRA - UAS–manned baseline capacity. 360

Table 78: Type of missions - Urban U-space operations in uncontrolled airspace scenario 377

Table 79: Key Hazards and Mitigation Strategies for U-space Operations in Benidorm - Urban U-space operations in uncontrolled airspace scenario..... 378

Table 80: Key Hazards and Mitigation Strategies for U-space BVLOS operations in low-density peri-urban and rural areas within Class-C scenario 384

Table 81: Comparison of the Port of La Spezia and the Port of Antwerp 386

Table 82: Environmental and regulatory constraints for Dynamic U-space operations for infrastructure inspection scenario..... 388

Table 83: UAS Technical Specifications 392

Table 84: Stakeholder Involvement in Last-Mile Medical Cargo Delivery Operations..... 393

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Table 85: Key Hazards and Associated Metrics - Medical transport operations from suburban to urban areas scenario 395

Table 86: Distribution of traffic per altitude. 399

Table 87: OSED use cases definition and safety assessment 407

Table 88: Hazards inherent to aviation related to the Safety Assessment 0 408

Table 89: Safety Criteria adopted within U-AGREE Safety Assessment 0. 409

Table 90: safety specification for normal conditions of operation of Safety Assessment 0 410

Table 91: Abnormal conditions of Safety Assessment 0 411

Table 92: safety specification for abnormal conditions of operation of Safety Assessment 0 412

Table 93: operational hazards and analysis for Safety Assessment 0 412

Table 94: SAC expressed in terms of hazard-related proxies for Safety Assessment 0 413

Table 95: additional safety specification items to mitigate operational hazards and potential degraded modes for Safety Assessment 0 413

Table 96: Hazards inherent to aviation identified by U-AGREE in scenario 1 (Benidorm) 414

Table 97: Hazards inherent to aviation identified by U-AGREE in scenario 2 (Manduria) 415

Table 98: Hazards inherent to aviation identified by U-AGREE in scenario 3 (Shannon-Limerick) 415

Table 99: Hazards inherent to aviation identified by U-AGREE according to the GATMOC 415

Table 100: Abnormal conditions identified by U-AGREE 416

Table 101: Initial SAC identified by U-AGREE for the relevant hazard in each scenario 417

Table 102: Safety specification items for UC1.2 422

Table 103: Safety specification items specific for UC1.3. 424

Table 104: Safety specification items specific for UC1.4. 425

Table 105: safety specification for abnormal conditions for Safety Assessment 1 427

Table 106: operational hazards and analysis for Safety Assessment 1 429

Table 107: SAC expressed in terms of hazard-related proxies for Safety Assessment 1 430

Table 108: additional safety specification items to mitigate operational hazards and potential degraded modes for Safety Assessment 1 431

Table 109: Values that estimate the actual hazard to human lives given the pair of airspace users involved [12] 433

Table 110: Categories of airspace users [12] 433

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Table 111: Population distribution per validation scenario 434

Table 112: Benidorm detailed sheltering assumption 435

Table 113: Manduria detailed sheltering assumption 435

Table 114: Shannon detailed sheltering assumption 435

Table 115: Initial SAC identified by U-AGREE final models for the relevant hazard in each scenario 439

Table 116: safety specification for normal conditions of the Final FAS 442

Table 117: safety specification for normal conditions of the Final CMS 445

Table 118: safety specification for normal conditions of the Final TCPR 447

Table 119: safety specification for abnormal conditions for Safety Assessment 2 450

Table 120: operational hazards and analysis for Safety Assessment 2 452

Table 121: SAC expressed in terms of hazard-related proxies for Safety Assessment 2 453

Table 122: additional safety specification items to mitigate operational hazards and potential degraded modes for Safety Assessment 2 454

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1 Executive summary

This Exploratory Research Report (ERR) presents the results of the validation activities conducted within the U-AGREE project to assess the performance of the integrated risk models and U-space-based mitigation barriers developed within the project. Validation activities generated quantitative evidence on the contribution of U-space services to improving safety, capacity, security and access & equity within representative scenarios chosen for the project by integrating air/ground/collision risk models.

The validation campaign comprised two exercises carried out on three independent high-fidelity U-space simulation platforms owned by the consortium partners UPV, ENGage and CRA. The activities supported a maturity progression from TRL0 to TRL2. Both exercises relied on Monte Carlo simulation technique and were applied to three scenarios defined in the project's OSED version 1 [6] and illustrated in Annex A. For each scenario, fast-time simulations were conducted to derive statistically robust results through the computation of dedicated Key Performance Indicators.

The first exercise, conducted between September and December 2025 at each partners' premises, focused on the assessment of strategic U-space services acting as mitigation barriers, namely Flight Authorisation, Traffic Information, and Conformance Monitoring, in accordance with EU Regulation 2021/664 [7][8] and the U-AGREE Strategic Barrier Model defined in the U-AGREE D4.2 Final Barriers Characterisation deliverable [9]. The results obtained on the three platforms were subsequently compared and consolidated to gain relevant conclusions. The second exercise, carried out from January to July 2026, extended the analysis to advanced tactical services as defined in the CORUS U-space ConOps Edition 4.0 [10], and further detailed in D4.2 [9], including Conformance Monitoring and Tactical Conflict Prediction and Resolution services.

Across both exercises, the assessment was performed progressively by introducing U-space services according to predefined use cases defined in the U-AGREE D2.3 Initial Concept Outline deliverable [11] and their effects were quantified through specific performance indicators. In particular, the simulations enabled the identification of the baseline airspace capacity for each scenario and the measurement of the incremental capacity gains resulting from the stepwise introduction of mitigation measures, while simultaneously evaluating their impact on safety. In parallel, the baseline rate of geographical zone infringements per flight-hour was determined and compared with the corresponding variations observed following the implementation of U-space services. The analysis also included an evaluation of the impact of fauna on air risk within the simulated environments through the introduction of dedicated modelling assumptions. A more comprehensive assessment of fauna-related air risk consideration is presented in the deliverable D3.4 Final Air Risk Model [12], whereas the detailed simulation results are reported in Annex B. Overall, the validation activities provide a structured and quantitative assessment of how the proposed models and U-space-based mitigation barriers contribute to supporting the scalable integration of UAS into European airspace.

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2 Introduction

2.1 Purpose of the document

The purpose of the Exploratory Research Report (ERR) is to present the results of the validation activities carried out within the U-AGREE project and to document the assessment of the integrated risk models and U-space-based mitigation barriers developed.

It describes how these elements were evaluated across the two validation exercises, highlighting their performance and level of maturity. The report consolidates the main outcomes and supports conclusions on the U-AGREE project and concept clarification, covering technical aspects and performance assessment against defined KPIs, together with recommendations for further research and development.

2.2 Intended readership

As a public deliverable, this document is intended for a broad community of stakeholders involved in U-space research and development activities. Stakeholders and their interests in the validation activities include:

- **Researchers**: Gain access to advanced simulation-based validation methods and corresponding results.
- **Regulatory and standardization bodies**: Obtain robust evidence to support risk-based regulations and guidance material ensuring compliance with safety performance requirements (e.g. Target Level of Safety).
- **Air Navigation Service Providers (ANSPs)**: Understand how the U-AGREE solution can support the quantification and mitigation of risks associated with UAS operations in controlled airspace, thereby contributing to safer and more efficient operations.
- **U-space Service Providers (USSPs)**: Assess the performance of U-space services as mitigation measures across different traffic environments and evaluate the robustness of the project's risk models, with a specific focus on their contribution to enhancing safety and increasing airspace capacity.
- **UAS Operators**: Understand how they can leverage the risk models developed by U-AGREE to simplify the process to get the operational approval.

2.3 Background

U-AGREE is an Exploratory Research Project that focuses on the characterization and mitigation of the potentially negative effects of UAS operations through the provision and use of U-space services. On the safety side, the project addresses the hazards posed by UAS to people on the ground and to other actors operating within U-space airspace, whether manned or unmanned, particularly in relation to mid-air collisions.

From a regulatory perspective, IR (EU) 2021/664 [7] establishes the framework for the provision and use of U-space services in designated U-space airspace. Within this framework, the regulation requires

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the definition of U-space service performance and UAS capabilities to ensure that risks are reduced to acceptable levels based on an Air Risk Assessment (ARA).

In the first exercise, the project assesses the U-space services defined in Reg. 664 and the accompanying Acceptable Means of Compliance and Guidance Material [7][8]. In the second one, the evaluation is extended to more advanced U-space services (U3) described in the Concept of Operations developed by the CORUS and CORUS-XUAM projects (U-space ConOps Ed. 4.0) [10] and alignment with CORUS V project was also conducted.

2.4 Structure of the document

This document is structured as follows:

- *Section 2* outlines the purpose of the document, identifies the intended readership and introduces the background of the project.
- *Section 3* establishes the context of the exploratory research report, including a summary of the project, a review of the exploratory research plan, and any deviations from it.
- *Section 4* presents consolidated validation results, including a summary of overall findings, detailed results per validation objective, and an assessment of confidence in the outcomes.
- *Section 5* provides the conclusions and recommendations derived from the validation activities and offers guidance for future research and innovation.
- *Appendix A* contains the detailed report of Validation Exercise #01, covering the plan summary, deviations, results, conclusions, and recommendations. It is further subdivided into three main chapters presenting the results of the simulation activities carried out by the three simulator-holding project partners (ENGage srl, UPV, CRA).
- *Appendix B* contains the detailed report of Validation Exercise #02, mirroring Appendix A.
- *Annex A* details the scenarios chosen for the project, provided in OSED version1 [6] and reported here for the sake of completeness.
- *Annex B* provides detailed results of the air risk model applied to the Manduria scenario.
- *Annex C* constitutes the safety assessment for exercise #02, conducted by integrating the final risk models developed in the second half of the project.

2.5 Glossary of terms

Term	Definition	Source of the definition
Deviation threshold	An additional 4D volume around each planned 4D volume for a flight.	European Commission, Commission implementing regulation (EU) 2021/664 of 22 April 2021 on a regulatory framework for the U-space. [7]
Encounter	An event associated with the presence of an intruder.	ASTM, F3442/F3442M-20 Standard Specification for Detect and Avoid System Performance

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		Requirement, May 1st, 2020. [13]
small Near Mid-air Collision	A situation in which two small UAS come within 30 ft vertically and 100 ft horizontally of each other while in flight.	ASTM, F3442/F3442M-20 Standard Specification for Detect and Avoid System Performance Requirement, May 1st, 2020. [13]
Mid-air Collision	An accident where two aircraft come into contact with each other while both are airborne.	ICAO Common taxonomy team, Aviation occurrence categories, definitions and usage notes IACO 4.2, 2011. [14]
Near Mid-air Collision	A situation in which two aircraft come within 100 ft vertically and 500 ft horizontally of each other while in flight.	RTCA, Minimum Operational Performance Standards for Airborne Collision Avoidance Systems sXu (ACAS sXu), 15 December 2022. [15]
Total system Error (TSE)	It is the distance between the true position of the UA and the desired path. It is composed of: • Flight Technical Error (FTE): distance from the estimated position to the intended flight trajectory and it is related to the autopilot's ability to follow that trajectory. • Navigation System Error (NSE): difference between true position and estimated position. It depends on on-board navigation system inaccuracies. • Path Definition Error (PDE): difference between the defined trajectory and the intended flight trajectory at a specific point. It depends typically on the quality of the database of terrain as well as the vertical reference to define the altitude/height along the trajectory.	EUROCAE, ED-301 Guidelines for the use of Multi-GNSS solutions for UAS Specific Category- low risk operations SAIL I & II, 2022. [16]

Table 1: glossary of terms

2.6 List of acronyms

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Term	Definition
A&E	Acess & Equity
ADS-B	Automatic Dependent Surveillance–Broadcast
AGL	Above Ground Level
AMSL	Above Mean Sea Level
ARA	Airspace Risk Assessment
ATC	Air Traffic Control
ATM	Air Traffic Management
BVLOS	Beyond Visual Line Of Sight
CM	Conformance Monitoring
CMXS	Conformance Monitoring Exchange Service
CRT	Criteria
CTA	Control Area
CTR	Control Zone
DAR	Dynamic Airspace Reconfiguration
DES	Digital European Sky
DOP	Diluition Of Precision
DSD	Digital Sky Demonstrator
DT	Deviation Threshold
ERP	Exploratory Research Plan
ERR	Exploratory Research Report
EU	European Union
EVLOS	Extended Visual Line Of Sight
EXE	Exercise
FAS	Flight authorisation Service
FAT	Fatality
FAXS	Flight Authorisation Exchange Service
FTE	Flight Technical Error

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FTS	Fast-Time Simulation
GA	Grant agreement
GCS	Ground Control Station
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HAZ	Hazard
HAZID	Hazard Identification
ID	Identifier
KPA	Key performance Area
KPI	Key performance Indicator
LR	Loss-of-separation Ratio
MAC	Mid Air Collision
ML	Machine Learning
NIS	Network Identification Service
NIXS	Network Identification Exchange Service
NMAC	Near Mid Air Collision
NSE	Navigation System Error
OBJ	Objective
OH	Operational Hazard
OSED	Operational Service and Environment Definition
PBN	Performance-Based Navigation
PDE	Path Definition Error
PDRA	Predefined Risk Assessment
PI	Performance Indicator
RPAS	Remotely Piloted Aircraft System
RR	Risk Ratio
RRT	Rapidly-exploring Random Tree

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SAC	Safety Criteria
sNMAC	Small Near Mid Air Collision
SESAR	Single European sky ATM Research
SESAR 3 JU	SESAR 3 Joint Undertaking
SAIL	Specific Assurance and Integrity Level
SCR	Strategic Conflict Resolution
SAR	Search and Rescue
SID	Standard Instrument Departures
SITL	Software In The Loop
SNR	Signal-to-Noise Ratio
SORA	Specific Operations Risk Assessment
SSI	Safety Specification Item
STAR	Standard Terminal Arrival Routes
STS	Standard Scenario
SV	Simultaneous vehicles
TCP&R	Tactical Conflict Prediction and Resolution
TIS	Traffic Information Service
TLS	Target Level of Safety
TRL	Technology Readiness Level
TS	Traffic Information
TSE	Total System Error
UA	Unmanned Aircraft
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UC	Use Case
USSP	U-space Service Provider
UTM	UAS Traffic Management
VLL	Very Low Level
VLOS	Visual Line of Sight

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VTOL	Vertical Take-off and Landing
WWR	Window-to-Wall Ratio

Table 2: list of acronyms

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3 Context of the exploratory research report

3.1 Project / SESAR solution 0520: a summary

Advanced integrated risk models enhance capacity, safety, and security for Unmanned Aerial Systems (UAS) operations in U-space. Current risk models, such as the Specific Operations Risk Assessment (SORA), are essential to aviation safety but have limitations in addressing the growing complexity of drone operations within U-space. These limitations make it challenging to ensure both safety and regulatory compliance in increasingly complex operational environments, potentially slowing down the safe and scalable deployment of drone services. The proposed SESAR Solution 0520 – *Integrated Risk Models for Unmanned Aerial Systems (UAS) in the U-space* – extends risk assessment approaches by introducing integrated risk models tailored to U-space. These models provide a more complete understanding of risks by linking drone operations with their potential impacts, including the risk of mid-air collisions (between drones or with manned aircraft), as well as broader impacts on security, privacy, and the environment. The solution also takes into account how U-space services, such as strategic and tactical conflict management, can contribute to reducing these risks.
To provide evidence of the benefits, fast-time, large-scale simulations in realistic operational environments are conducted to show how the solution supports safer, more efficient, and more accessible drone operations.
The European Union Aviation Safety Agency (EASA) will support the development of the solution to ensure alignment with the evolving U-space regulatory framework. In addition, the solution will contribute to standardisation activities, including EUROCAE WG-105, supporting the development of future U-space services and systems. Key Benefits:

- Increased capacity, access, and equity for drone operations in U-space
- Improved safety and security through a more comprehensive understanding of risks
- More efficient and consistent assessment of drone operations
- Support to regulatory evolution and standardisation
- Enhanced public confidence in drone operations

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Figure 1: SESAR Solution 0520 - Integrated risk models for UAS in the U-space (U-AGREE)

3.2 Summary of the exploratory research plan

3.2.1 Exploratory research plan purpose

The overall aim of the Exploratory Research Plan (ERP) is to validate, at TRL 2, the U-space mitigation barriers developed within the U-AGREE project, while integrating the developed risk models. Validations aim to provide quantitative evidence of the impact of these mitigation barriers on safety, capacity, security, access & equity and environmental performance in U-space operations.

Validation activities were carried out on high-fidelity fast-time simulation platforms developed by ENGage srl, Cranfield University and Universitat Politècnica de València[2]. The use of three simulators strengthens the validation process by increasing the robustness and credibility of the results, enabling cross-verification of assumptions and modelling approaches, and fostering continuous improvement through the comparative development of complementary simulation capabilities.

Three representative European scenarios (further detailed in Annex A) were chosen for the project:

S1 The city of Benidorm, in Spain. This area is representative of a densely populated urban area in uncontrolled airspace (class G) and different U-space operations have been conducted therein in the context of the DSD project U-ELCOME [17].

[2] A detailed description of each simulator can be found in the *Exploratory Research Plan*.

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S2 The city of Manduria, in South of Italy, in which medical transport operations from suburban to urban areas have been conducted in the context of the European Project CORUS-XUAM [18]. This area is representative of a mixed urban-suburban area, and it lies beneath the Zone 3 of Grottaglie CTR, starting at 1,500 ft AMSL and classified as airspace class D.

S3 The Shannon-Limerick Area, in which U-space BVLOS operations in low-density peri-urban and rural areas within Class-C were conducted as part of the Irish DSD project ÉALÚ–AER [19]. The Shannon–Limerick area is representative of a suburban and sparsely populated rural areas.

For each of the three selected scenarios, simulation activities considered mixed traffic composed of unmanned aircraft and e-conspicuous manned aircraft. The unmanned traffic was generated according to the traffic mix defined in the ERP and included different operational patterns, namely random, scan, fixed-route, and delivery trajectories. Manned traffic was represented using ADS-B data[3] and therefore only included e-conspicuous aircraft. Non-conspicuous manned aircraft were not considered, as their presence and trajectories cannot be reliably identified from the available surveillance data.

Two simulation exercises were conducted:

TVAL.01.0 Focused on assessing the impact of basic U-space services **as defined by Regulation 2021/664** [7], namely the strategic Flight Authorisation Service (FAS) and the tactical Conformance Monitoring (CMS) and Traffic Information (TIS) services, on **safety**, **capacity** and **access & equity**[4]. Fast-time Monte Carlo simulations were performed across the three selected operational scenarios to derive the relevant Key Performance Indicators (KPIs). The assessment was conducted by comparing a baseline configuration, where no U-space services were applied, with configurations implementing the selected U-space services according to the use cases defined in D2.3 Initial Concept Outline [11] (Figure 2). This comparison enabled the quantification of the risk mitigation and capacity benefits provided by the basic U-space service set.

TVAL.02.0 Focused on validating the effectiveness of advanced U-space mitigation barriers, namely Tactical Conflict Prediction and Resolution (TCP&R) services. Services that **go beyond the basic U-space services defined in Regulation 2021/664** [7] and belong to the more advanced service set described in the U-space Concept of Operations (Edition 4.0) developed by the CORUS and CORUS-XUAM projects [10] are introduced in this exercise. **Safety**, **capacity**, **security**, **access & equity**[4] and **environmental** performance were assessed through fast-time Monte Carlo simulations across the three selected scenarios. The analysis considered a baseline case without U-space services and solution scenarios that include strategic Flight Authorisation Service and Tactical Conformance Monitoring and Conflict Prediction and Resolution services. The resulting KPIs provided quantitative evidence of the contribution of advanced U-space services and their added value with respect to the basic service set. It should be noted that the FAS implementation adopted in TVAL.02.0 differs from that used in TVAL.01.0, as it has been enhanced with additional features and is therefore defined as *Final Flight Authorisation Service.*

[3] Contains AeroAPI data © FlightAware LLC [2024-2026].

[4] This constitutes a deviation with respect to ERP and is explained in paragraph 3.3 *Deviations.*

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Details on the *Final Flight Authorisation Service* are described in *Appendix B*, where also a detailed explanation of the TCP&R service is provided.

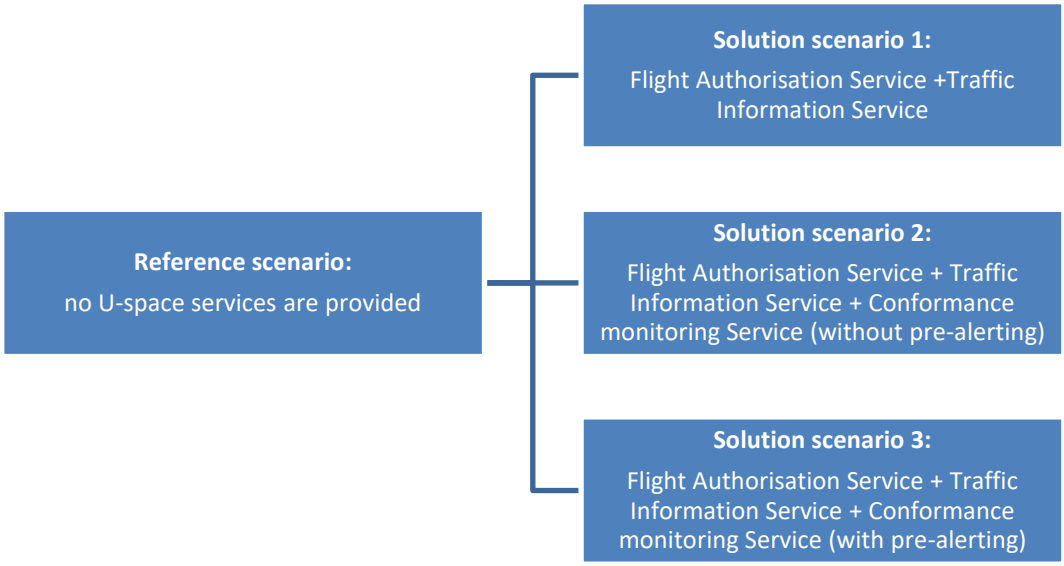


Figure 2: Reference and Solution scenarios for TVAL.01.0

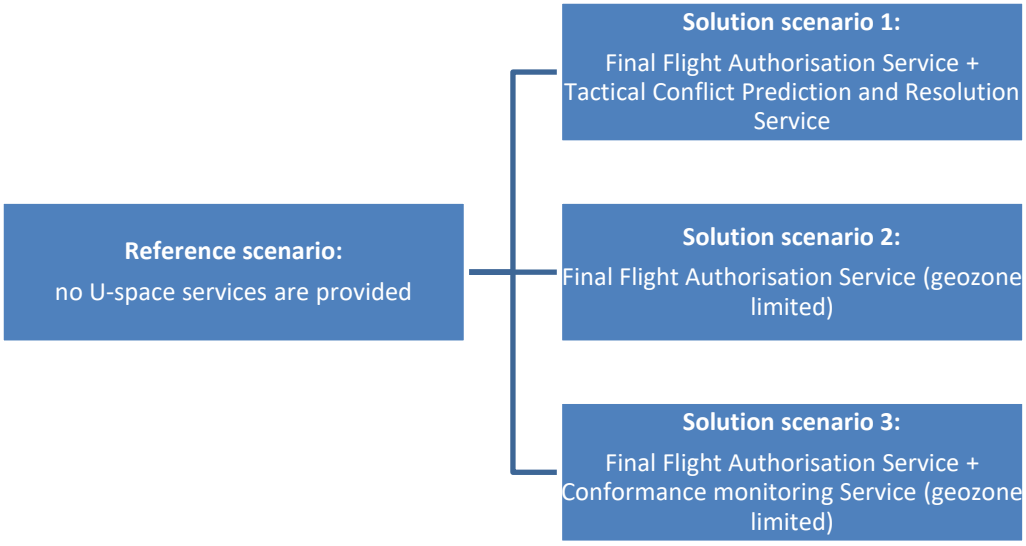


Figure 3: Reference and Solution scenarios for TVAL.02.0[5]

[5] A better explanation of TVAL.02.0 is provided in *Appendix B*, fully dedicated to this exercise.

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With respect to ERP, some deviations have been introduced and are detailed in Paragraph 3.3 *Deviations*.

3.2.2 Summary of validation objectives and success criteria

Validation objectives and success criteria for exercise TVAL.01.0 have not been modified after the ERP submission.

On the other hand, for validation exercise TVAL.02.0, success criteria for **OBJ-U-AGREE-ERP-001** have been updated to reflect the final risk models developed after the submission of the ERP. These updates ensure consistency between the validation activities and the latest version of the U-AGREE risk models.

New success criteria are here shown **in bold**.

Title	Identification of the baseline capacity (N_0)
Category	Capacity, Safety
Key environment conditions	U-space airspace. Flight conducted in Urban / suburban areas. Type of operations: Inspections, agricultural, medical deliveries.
TRL Phase	2

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	SESAR Solution 0520
<COVERS>	<Enabler>	N/A
<COVERS>	<Sub-Operating Environment>	Scenario 1: The city of Benidorm (non U-space sub-OE)
<COVERS>	<Sub-Operating Environment>	Scenario 2: The city of Manduria (non U-space sub-OE)
<COVERS>	<Sub-Operating Environment>	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)

[OBJ Suc]

Identifier	Success Criterion
CRT-SOL0520-TRL2-ERP-001.001	The MAC frequency between UAS shall not exceed 4.35×10^{-5} per flight-hour in Scenario 1, for exercise #01.
CRT-SOL0520-TRL2-ERP-001.002	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 1, for exercise #01 and #02.
CRT-SOL0520-TRL2-ERP-001.003	The MAC frequency between UAS shall not exceed $1{,}5 \times 10^{-4}$ per flight-hour in Scenario 2, for exercise #01.

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CRT-SOL0520-TRL2-ERP-001.004	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 2, for exercise #01 and #02.
CRT-SOL0520-TRL2-ERP-001.005	The MAC frequency between UAS shall not exceed $1{,}7 \times 10^{-2}$ per flight hour in Scenario 3, for exercise #01.
CRT-SOL0520-TRL2-ERP-001.006	The MAC frequency between UAS and manned aircraft in uncontrolled airspace shall not exceed 10^{-7} per flight-hour in Scenario 3, for exercise #01 and #02.
CRT-SOL0520-TRL2-ERP-001.007	The MAC frequency between UAS and manned aircraft in controlled airspace shall not exceed 10^{-9} per flight-hour in Scenario 3, for exercise #01 and #02.
CRT-SOL0520-TRL2-ERP-001.008	**The MAC frequency between UAS shall not exceed 1.41×10^{-4} per flight-hour in Scenario 1, for exercise #02.**
CRT-SOL0520-TRL2-ERP-001.009	**The MAC frequency between UAS shall not exceed 1.29×10^{-4} per flight-hour in Scenario 2, for exercise #02.**
CRT-SOL0520-TRL2-ERP-001.010	**The MAC frequency between UAS shall not exceed 6.25×10^{-3} per flight hour in Scenario 3, for exercise #02.**

Furthermore, success criteria for **OBJ-SOL0520-ERP-006** have been modified. The original success criteria (CRT-SOL0520-TRL2-ERP-006.001, .002, .003) relied on a threshold value (TBD) for the maximum number of UAS infringements per flight hour, which was not available at the time of the ERP definition. As a result, these criteria have been reformulated to reflect the actual purpose of the baseline run: the geographical zones are defined such that at least one UAS infringement is recorded during the baseline exercise, establishing a measurable reference level against which the effect of the progressive introduction of U-space services can be assessed.

The objective with new success criteria is here illustrated:

[OBJ]

Identifier	**OBJ-SOL0520-ERP-006**
Objective	Quantify the total number of UAS infringements in designated geographical zones without any mitigation measures, establishing the reference level of security for each scenario.
Title	**Quantification of baseline geographical zone infringements per flight-hour ($\Delta Ninf_0$).**
Category	Security
Key environment conditions	U-space airspace. Flight conducted in Urban / suburban areas. Type of operations: Inspections, agricultural, medical deliveries.
TRL Phase	2

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[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	SESAR Solution 0520
<COVERS>	<Enabler>	N/A
<COVERS>	<Sub-Operating Environment>	Scenario 1: The city of Benidorm (G class U-space sub-OE)
<COVERS>	<Sub-Operating Environment>	Scenario 2: The city of Manduria (G class U-space sub-OE)
<COVERS>	<Sub-Operating Environment>	Scenario 3: The Shannon-Limerick Area (Airport U-space sub-OE/G class U-space sub-OE)

[OBJ Suc]

Identifier	Success Criterion
CRT-SOL0520-TRL2-ERP-006.001	The geographical zones in Scenario 1 shall be defined such that, during the baseline run, at least one infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.
CRT-SOL0520-TRL2-ERP-006.002	The geographical zones in Scenario 2 shall be defined such that, during the baseline run, at least one infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.
CRT-SOL0520-TRL2-ERP-006.003	The geographical zones in Scenario 3 shall be defined such that, during the baseline run, at least one infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.

Paragraphs 4.1 *Summary of project / SESAR Solution 0520 validation results* and 4.2 *Detailed analysis of project / SESAR solution validation results per validation objective* reflect this deviation.

3.2.3 Validation assumptions

With respect to ERP, new assumptions related to both exercises, have been introduced: namely Assumptions 05, 06, 07 and 08.

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Assumption ID	Assumption title	Assumption description	Justification	Impact Assessment
Assumption 01	Speed variations	Two simulator implementations exist: (1) constant speed, where the UA maintains uniform velocity throughout the flight, and (2) variable speed, where velocity is dynamically adjusted at each tick subject to maximum acceleration and speed constraints. Orthogonally, each implementation may or may not support holding maneuvers, allowing the UA to enter a holding pattern at designated waypoints. All implementations consider avoidance maneuvers based on ICAO Annex II *Rules of the Air* [20] and account for estimated human performance including maneuver delay and reaction time.	Limitation of the simulation platform.	May impact realism in energy consumption, conflict dynamics, and time-to-conflict estimation.
Assumption 02	Sequential Flight Authorisation Requests	Flight authorisation requests are submitted one at a time, rather than in batch mode.	Reflects a simplified implementation of the FAS and reduces complexity in managing simultaneous conflicts.	May underestimate system load and overlook performance issues in high-density scenarios or peak submission times.

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Assumption 03	U-space services implementation	In solution scenarios, for both exercises listed in this ERP, U-space services are implemented as mitigation barriers. Particularly, the following services are implemented: For TVAL.01.0: • Flight Authorisation Service, as strategic mitigation barrier. • Conformance Monitoring Service, as tactical mitigation barrier. • Traffic Information Service, as tactical mitigation barrier. For TVAL.02.0, • Flight Authorisation Service, as strategic mitigation barrier. • Tactical Conflict Prediction and Resolution services, as tactical mitigation barrier.	Validation activities are focused on validating and quantifying the effect of U-space services as mitigation barriers.	Improvements on capacity and security are expected when mitigation, based on U-space services, are implemented, without affecting safety.
Assumption 04	Operations under non-nominal conditions	Deviations from the approved flight plan due to weather or CNS degradations are considered in the validation activities.	Such conditions reflect realistic operational scenarios and may affect safety and performance outcomes.	Improves realism of results.
Assumption 05	NMAC scope filtering	NMAC events, registered in validation activities, between two manned aircraft are not counted in U-AGREE metrics.	NMAC events between manned aircraft are not	No impact expected on UAS-related performance assessment.

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			in the scope of the U-AGREE project.	
Assumption 06	Above VLL surveillance data availability	In above-VLL simulations, only ADS-B data[6] of manned aircraft is available from FlightAware®. e-conspicuous aircraft not transmitting ADS-B are not included.	This assumption is driven by the availability of data inputs provided by Collins, which are limited to ADS-B information for manned aircraft.	May reduce traffic realism by excluding non-cooperative aircraft.
Assumption 07	TSE reference standard	TSE (Total System Error) values are derived from EUROCAE, ED-301 [16] and European Gnss (Galileo) Services Open Service Quarterly Performance Report [21].	Ensures alignment with recognised GNSS performance standards for UAS operations.	Results depend on the documents mentioned.
Assumption 08	Deviation threshold values	The following deviation threshold values are adopted by all partners for the parametric approach in FAS: {8, 16, 32, 64, 128} m. Each simulator could add other deviation threshold with respect to these.	Ensures harmonised parameterisation across partners.	Conservative thresholds, particularly 128 m, may significantly reduce operational capacity.

Table 3: validation assumptions overview

Additional validation assumptions at exercise level are captured in sections A.1.4 and B.1.4, *Summary of validation exercise #0X validation assumptions.*

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3.2.4 Validation exercises list

The following tables summarize the details of each validation exercise.

[EXE1]

Identifier	TVAL.01.0 TRL1 (FTS) ENGage srl (Italy, SC1, SC2, SC3)
Title	Validation of the initial integrated risk models.
Description	The objective of this first validation exercise is to integrate risk models developed within the project and to assess the effectiveness of the initial U-AGREE U-space based mitigation barriers [9]. The exercise will be conducted in parallel across the three simulation platforms developed by ENGage srl, UPV, and CRA. Each simulator will execute the exercise following a common structure consisting of two main steps: 1. **Reference scenarios**: For all the three scenarios chosen for the project, simulations will be run without the provision of any U-space services. Key Performance Indicators (KPI) will be calculated to establish the baseline risk and capacity levels. 2. **Solution scenarios:** The same reference scenarios will then be repeated introducing mitigation barriers: 1. **Flight Authorisation Service (FAS)** as a strategic mitigation barrier. 2. **Conformance Monitoring Service (CM)** as a tactical mitigation barrier. 3. **Traffic Information Service (TI)** as a tactical mitigation barrier. DAR affected volumes are not considered in this exercise for U-space airspaces designated in controlled airspace. When an e-conspicuous manned aircraft not receiving air traffic control instructions enters a U-space airspace, the Traffic Information Service provides information about that aircraft and the responsibility for avoiding collision hazards remains with the UAS operator. Once mitigation barriers are implemented, KPI will be recalculated and compared against the baseline, allowing the derivation of risk ratios that quantify the effectiveness of each barrier. For each scenario, simulations will be conducted until reaching a total number of flight hours that are considered statistically significant. In

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	each scenario, UAS are simulated considering the traffic mix defined in deliverable [11], while manned aircraft data are derived from the analysis of historical ADS-B data[7].
KPA/TA addressed	Safety (SAF), Capacity (CAP), Access & Equity (A&E)
Addressed expected performance contribution(s)	Improvement in capacity in the three simulated scenarios, without degrading safety levels.
Maturity level	TRL2
Use cases	Validation activities will be conducted in these three scenarios: • S1: The city of Benidorm. • S2: The city of Manduria. • S3: The Shannon-Limerick Area.
Validation technique	Fast time simulations.
Validation platform	Platforms from ENGage srl, University of Cranfield (CRA) and Universitat Politècnica de València (UPV).
Validation location	Each organization carries out the validation activities at its own premises, which are: • ENGage srl: Santa Maria Capua Vetere (CE), Italy; • UPV: Valencia, Spain; • CRA: Cranfield, England
Start date	01/09/2025
End date	15/12/2025
Validation coordinator	Maurizio Sodano, ENGage srl
Status	Completed
Dependencies	N/A

[EXE Trace]

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Linked Element Type	N/A
<SESAR Solution>	SESAR Solution 0520
<Project>	U-AGREE
<Sub-Operating Environment>	Scenario 1: The city of Benidorm (G class U-space sub-OE) Scenario 2: The city of Manduria (G class U-space sub-OE) Scenario 3: The Shannon-Limerick Area (Airport U-space sub-OE/G class U-space sub-OE)
<Validation Objective>	OBJ-SOL0520-ERP-001 OBJ-SOL0520-ERP-002 OBJ-SOL0520-ERP-003 OBJ-SOL0520-ERP-004

Table 4: Validation exercise #01 layout

[EXE2]

Identifier	TVAL.02.0 TRL2 (FTS) ENGage srl (Italy, SC1, SC2, SC3)
Title	Validation of the final integrated risk models.
Description	The objective of this second validation exercise is to assess the effectiveness of the final U-AGREE mitigation barriers [9] in mitigating risks within U-space operational environments. The barriers implemented will be evaluated following a methodology that mirrors the one used in TVAL.01.0: S4 **Reference scenarios**: coincide with TVAL.01.0 reference scenario. S5 **Solution scenarios:** The same reference scenarios will then be repeated by introducing tactical mitigation barriers based on the advanced U-space Tactical Conflict Prediction and Resolution Service. In this exercise, DAR affected volumes are considered in the FAS process just for the Shannon-Limerick scenario, that comprises a portion of controlled airspace. Furthermore, when an e-conspicuous manned aircraft not receiving air traffic control instructions enters a U-space airspace, the Traffic Information Service provides information about that aircraft and the responsibility for avoiding collision hazards remains with the UAS operator. For each mitigation barrier, KPI will be recalculated and compared against the reference ones, allowing the derivation of risk ratios that quantify the effectiveness of each barrier.

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	For each scenario, simulations will be conducted until reaching a total number of flight hours that are considered statistically significant. In each scenario UAS are simulated considering the traffic mix defined in deliverable D2.3 [11] and within this document, while manned aircraft data are derived from the analysis of historical ADS-B data[8]. The validation will again be conducted parallelly across the three simulation platforms developed by ENGage srl, UPV, and CRA. Results will be used to validate the improved performance of the U-space based mitigation barriers in enhancing safety and supporting scalable, high-density UAS operations.
KPA/TA addressed	Safety (SAF), Capacity (CAP), Security (SEC), Environment (ENV), Access & Equity (A&E)
Addressed expected performance contribution(s)	Improvement in capacity and security in the three simulated scenarios, while not affecting safety levels and considering environmental related issues.
Maturity level	TRL2
Use cases	Validation activities will be conducted in these three scenarios: • S1: The city of Benidorm. • S2: The city of Manduria. • S3: The Shannon-Limerick Area.
Validation technique	Fast time simulations.
Validation platform	Platforms from ENGage srl, University of Cranfield (CRA) and Universitat Politècnica de València (UPV).
Validation location	Each organization carries out the validation activities at its own premises, which are: • ENGage srl: Santa Maria Capua Vetere (CE), Italy; • UPV: Valencia, Spain; • CRA: Cranfield, England.
Start date	12/01/2026
End date	10/07/2026

[8] Contains AeroAPI data © FlightAware LLC [2024-2026]

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Validation coordinator	Maurizio Sodano, ENGage srl
Status	Completed
Dependencies	N/A

[EXE Trace]

Linked Element Type	N/A
<SESAR Solution>	SESAR Solution 0520
<Project>	U-AGREE
<Sub-Operating Environment>	Scenario 1: The city of Benidorm (G class U-space sub-OE) Scenario 2: The city of Manduria (G class U-space sub-OE) Scenario 3: The Shannon-Limerick Area (Airport U-space sub-OE/G class U-space sub-OE)
<Validation Objective>	OBJ- SOL0520-ERP-001 OBJ- SOL0520-ERP-005 OBJ- SOL0520-ERP-006 OBJ- SOL0520-ERP-007 OBJ- SOL0520-ERP-008 OBJ- SOL0520-ERP-009

Table 5: Validation exercise #02 layout

3.3 Deviations

3.3.1 Deviations with respect to the S3JU project handbook

There are no deviations from the Project Handbook.

3.3.2 Deviations with respect to the exploratory research plan (ERP)

Several refinements and additions have been introduced at ERR level with respect to the ERP. These modifications were enabled by the increased maturity of the validation activities and by the availability of additional information developed after ERP submission. They do not alter the overall validation scope but provide a more complete and representative assessment of the solution under validation. Main deviations are summarised below:

1. Access & Equity KPA and KPI

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The first refinement concerns the introduction of a new KPA and related KPI applicable to both TVAL.01.0 and TVAL.02.0:

KPA	KPI	Reference document
Access & Equity	U-AGREE-KPI-07 **Authorisation approval rate:** Operations approved divided by the total amount of operations requested.	PI U.ACCESS1 from the DES Performance Framework U-space Companion Document [2]

Figure 4: New KPA and KPI introduced

This addition was motivated by the availability of simulation outputs already covering the required underlying variables, which enabled a consistent and post-hoc derivation of the indicator without requiring any modification to the experimental setup or data collection process. The new KPA/KPI was introduced to complement the existing set of performance metrics and to provide a more comprehensive characterisation of the system behaviour, while maintaining full consistency with the originally defined validation objectives and without affecting the execution of the experiments.

2. Capacity KPI Removal

The second refinement concerns the removal of U-AGREE-KPI-05, applicable to both TVAL.01.0 and TVAL.02.0. The KPI was removed because the Monte Carlo simulation outputs only support derivation of average values, whereas the indicator requires the peak number of simultaneously authorised U-plans within the U-space volume, which could not be obtained without modifying the experimental setup or data collection process.

KPA	KPI
Capacity	U-AGREE-KPI-05 **Maximum number of authorised U-plans:** Peak number of authorised simultaneous UAS operations within a U-space volume over a period of time.

Table 6: Removed KPI

3. Validation assumptions

Additional assumptions have been introduced following the analysis and consolidation of the validation results. These assumptions were defined to support a consistent interpretation of the results and are presented in section 3.2.3 *Validation assumptions,* A.1.4 *Summary of validation exercise #01 validation assumptions* (related to exercise TVAL.01.0), B.1.4 *Summary of validation exercise #02 validation assumptions* (related to exercise TVAL.02.0).

4. Human Performance Modelling

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This deviation, applicable to TVAL.01.0, concerns the implementation of the Human Performance Modelling within the tactical Traffic Information Service. This enhancement was introduced to improve the realism and behavioural fidelity of the simulated human responses to tactical information, ensuring a more accurate representation of operator decision-making processes under realistic operational conditions. This concept is further explained in paragraph *A.2: Deviation from the planned activities,* related to exercise TVAL.01.0 in which TIS is implemented.

5. Detailed execution of TVAL.02.0

This deviation concerns the definition and execution of TVAL.02.0, which was not specified in sufficient level of detail at the time of ERP submission. At that stage, only a high-level concept of the exercise was available. The detailed specification was subsequently developed and refined based on Deliverable D4.2 *Final Barrier Characterisation* [9] and further consolidated through dedicated discussions in a WP5 workshop held in Naples (Italy) on 15/04/2026. Additionally, the success criteria related to this exercise were updated to integrate the final risk models developed after ERP submission, ensuring consistency with the most up-to-date risk assessment models. Further information on how exercise TVAL.02.0 is conducted, is provided in paragraph B.2: *Deviation from the planned activities.*

6. Number of exercises conducted

Not all the simulation scenarios originally planned for ENGage could be completed. During the execution of the validation campaign, some scenarios produced results that could not be considered sufficiently reliable for analysis due to limitations affecting the confidence of the outputs and the maturity of the corresponding implementations. As a result, these scenarios were excluded from the final assessment to preserve the robustness of the validation results.

Results have therefore been collected only for the Scenario 3 (The Shannon-Limerick Area (APT-small/non U-space sub-OE)) **below VLL**. Some preliminary results for Scenario 1 (The city of Benidorm (non U-space sub-OE)) have been collected for exercise TVAL.01.0.

This possibility had already been identified as a validation risk during the planning phase. To mitigate its impact, the validation strategy relied on three independent simulation environments. This approach ensured that the overall validation objectives could still be achieved despite the limitations encountered in a subset of the planned scenarios in the ENGage simulator.

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4 Validation results

4.1 Summary of project / SESAR Solution 0520 validation results

The validation campaign of SESAR Solution 0520 comprised two exercises (TVAL.01.0 and TVAL.02.0) executed in parallel on three independently developed fast-time simulation platforms owned by the consortium partners ENGage, UPV and CRA. All platforms applied Monte Carlo simulation to the three sub-operating environments defined in the OSED, Scenario 1 (Benidorm), Scenario 2 Manduria) and Scenario 3 (Shannon), under a common set of validation assumptions (Section 3.2.3), including the harmonised deviation threshold (DT) set {8, 16, 32, 64, 128} m adopted for the parametric assessment of FAS (Assumption 08). The detailed, per-platform results are reported in Appendix A (exercise #01) and Appendix B (exercise #02). This section consolidates them per validation objective, in accordance with the Exploratory Research Plan.

The use of three heterogeneous simulation environments was a deliberate element of the validation strategy: agreement between independently implemented models substantially strengthens the credibility of the conclusions, while systematic disagreement provides direct evidence of the sensitivity of the results to modelling assumptions. Both effects were observed and are analysed in Sections 4.2 and 4.3. The consolidation distinguishes between findings on which the three platforms converge, which are reported as solution-level conclusions, and findings on which the platforms diverge quantitatively, which are reported as ranges together with the methodological factors that explain the dispersion.

The clearest area of convergence concerns the baseline capacity assessment (OBJ-SOL0520-ERP-001). All three simulators independently conclude that, in the absence of any U-space service provision, the UAS–UAS NMAC frequency grows approximately linearly with the number of simultaneous operations and exceeds the applicable TLS already at the lowest tested traffic densities — of the order of two concurrent UAS — in all three scenarios. In other words, the unmitigated airspace has practically no sustainable capacity in Benidorm, Manduria, or Shannon. This conclusion is robust across the three platforms despite their different trajectory, disturbance, and conflict-detection models, and constitutes the reference against which all mitigation results are read. UPV batch 1 results quantify the baseline capacity at approximately one simultaneous aircraft in every scenario and in both the below-VLL and above-VLL configurations (the only exception, a UAS–UAS capacity of five for Shannon above VLL, is still bounded to one by the UAS–manned criterion).

A second area of convergence concerns the qualitative effect of the strategic mitigation layer (OBJ-SOL0520-ERP-002). In all three simulation environments, the introduction of FAS produces a substantial reduction of the residual conflict rate relative to the unmitigated baseline, already at the least restrictive deviation-threshold settings, and the residual risk decreases monotonically as the deviation threshold is increased. The strategic separation of authorised trajectories is therefore confirmed as an effective mitigation barrier by three independent implementations.

The platforms diverge, however, in the quantitative behaviour of the residual risk at large deviation thresholds (DT = 64 m and DT = 128 m), and consequently in the maximum capacity values derived from the TLS crossing point. UPV observes residual UAS–UAS conflict counts decreasing smoothly to zero at large thresholds; CRA observes a saturation of the residual NMAC rate, which does not reach zero even at DT = 128 m; and ENGage records residual conflict counts that are systematically higher than those of the other two platforms. UPV batch 1 reports FAS+TIS capacities rising from one

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simultaneous aircraft at small thresholds to 20 (below VLL) and 141 (above VLL) simultaneous aircraft in Benidorm and 52/87 in Manduria at DT = 64 m, with exposure-limited estimates in Shannon from DT = 32 m onward.

To facilitate the reading of the table, scenarios are here summarized:

Scenario 1 The city of Benidorm (non U-space sub-OE)
Scenario 2 The city of Manduria (non U-space sub-OE)
Scenario 3 The Shannon-Limerick Area (APT-small/non U-space sub-OE)

The table assesses the results against the success criteria and specifies if the validation objective analysis status is:

- OK: the validation objective achieves the expectations (the exercise results achieve the success criteria);
- NOK: the validation objective does not achieve the expectations (the exercise results do not achieve the success criteria);
- Partially OK: the validation objective achieves the expectations to a certain extent.

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Project / SESAR solution validation objective ID	Project / SESAR solution validation objective title	Project / SESAR solution success criterion ID	Project / SESAR solution success criterion	Project / SESAR solution validation results (ENG)	Project / SESAR solution validation results (UPV)	Project / SESAR solution validation results (CRA)	Project / SESAR solution validation objective status
OBJ-SOL0520-ERP-0019	Identification of the baseline capacity (N_0).	CRT-SOL0520-TRL2-ERP-001.001	The MAC frequency between UAS shall not exceed 4.35×10^{-5} per flight-hour in Scenario 1, for exercise #01.	At any tested density, including the minimum simulated concurrency (N = 2) does not meet the TLS. This underlines the necessity to include U-space services in this scenario to obtain the required TLS.	For Benidorm, the UAS–UAS baseline capacity is 1 simultaneous UAS below and above VLL. This value contributes to an overall limiting baseline capacity of 1 UAS.	The baseline capacity is 1.001 UAS. Even two simultaneous UAS exceed the maximum allowable NMAC per hour. These results highlight the need for at least one U-space service in Benidorm..	OK
		CRT-SOL0520-TRL2-ERP-001.002	The MAC frequency between UAS and manned aircraft shall not exceed	At any tested density, including the minimum simulated concurrency (N = 2) does not meet the TLS. This underlines the	Using the U-AGREE thresholds, the UAS–manned capacity is 1 UAS,	The baseline capacity is 1.000 UAS. Even two simultaneous UAS exceed the	OK

[9] Success criteria for this OBJ (related to both exercises) have been changed since the submission of the ERP (3 new success criteria have been added). The reasoning behind this change is detailed in paragraph B.2 *Deviation from the planned activities.*

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Project / SESAR solution validation objective ID	Project / SESAR solution validation objective title	Project / SESAR solution success criterion ID	Project / SESAR solution success criterion	Project / SESAR solution validation results (ENG)	Project / SESAR solution validation results (UPV)	Project / SESAR solution validation results (CRA)	Project / SESAR solution validation objective status
			10^{-7} per flight-hour in Scenario 1, for exercise #01 and #02.	necessity to include U-space services in this scenario to obtain the required TLS.	equal to the Exercise #01 result.	maximum allowable NMAC per hour. These results highlight the need for at least one U-space service in Benidorm.	
		CRT-SOL0520-TRL2-ERP-001.003	The MAC frequency between UAS shall not exceed $1{,}5 \times 10^{-4}$ per flight-hour in Scenario 2, for exercise #01.	The number of concurrent UAS compatible with the required TLS has been calculated. At any tested density, including the minimum simulated concurrency (N = 2). This underlines the necessity to include U-space services in this scenario to obtain the required TLS.	For Manduria, the UAS–UAS baseline capacity is 1 simultaneous UAS below and above VLL. This value contributes to an overall limiting baseline capacity of 1 UAS.	The baseline capacity is 1.002 UAS. Even two simultaneous UAS exceed the maximum allowable NMAC per hour. These results highlight the need for at least one U-space service in Manduria.	OK

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Project / SESAR solution validation objective ID	Project / SESAR solution validation objective title	Project / SESAR solution success criterion ID	Project / SESAR solution success criterion	Project / SESAR solution validation results (ENG)	Project / SESAR solution validation results (UPV)	Project / SESAR solution validation results (CRA)	Project / SESAR solution validation objective status
		CRT-SOL0520-TRL2-ERP-001.004	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 2, for exercise #01 and #02.	The number of concurrent UAS compatible with the required TLS has been calculated. At any tested density, including the minimum simulated concurrency (N = 2). This underlines the necessity to include U-space services in this scenario to obtain the required TLS.	Using the U-AGREE thresholds, the UAS–manned capacity is 1 UAS, equal to the Exercise #01 result.	The baseline capacity is 1.000 UAS. Even two simultaneous UAS exceed the maximum allowable NMAC per hour. These results highlight the need for at least one U-space service in Manduria.	OK
		CRT-SOL0520-TRL2-ERP-001.005	The MAC frequency between UAS shall not exceed $1{,}7 \times 10^{-2}$ per flight hour in Scenario 3, for exercise #01.	The number of concurrent UAS compatible with the required TLS has been calculated. At any tested density, including the minimum simulated concurrency (N = 2). This underlines the necessity to include U-space services in this scenario	For Shannon, the UAS–UAS baseline capacity is 1 simultaneous UAS below VLL and 5 above VLL. The UAS–manned criteria keep the overall baseline capacity at 1 UAS.	The baseline capacity is 1.021 UAS. Even two simultaneous UAS exceed the maximum allowable NMAC per hour. These results highlight the need for at least one U-	OK

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Project / SESAR solution validation objective ID	Project / SESAR solution validation objective title	Project / SESAR solution success criterion ID	Project / SESAR solution success criterion	Project / SESAR solution validation results (ENG)	Project / SESAR solution validation results (UPV)	Project / SESAR solution validation results (CRA)	Project / SESAR solution validation objective status
				to obtain the required TLS.		space service in Shannon.	
		CRT-SOL0520-TRL2-ERP-001.006	The MAC frequency between UAS and manned aircraft in uncontrolled airspace shall not exceed 10^{-7} per flight-hour in Scenario 3, for exercise #01 and #02.	The number of concurrent UAS compatible with the required TLS has been calculated. At any tested density, including the minimum simulated concurrency (N = 2). This underlines the necessity to include U-space services in this scenario to obtain the required TLS.	Using the U-AGREE thresholds, the UAS–manned capacity is 1 UAS; no separate uncontrolled-airspace capacity is reported.	The baseline capacity is 1.000 UAS. Even two simultaneous UAS exceed the maximum allowable NMAC per hour. These results highlight the need for at least one U-space service in Shannon.	OK
		CRT-SOL0520-TRL2-ERP-001.007	The MAC frequency between UAS and manned aircraft in controlled airspace shall not exceed 10^{-9} per	The number of concurrent UAS compatible with the required TLS has been calculated. At any tested density, including the minimum simulated	Using the U-AGREE thresholds, the UAS–manned capacity is 1 UAS; no separate controlled-	UAS-manned baseline capacity of 1.000 simultaneous UAS; no separate controlled and uncontrolled	OK

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Project / SESAR solution validation objective ID	Project / SESAR solution validation objective title	Project / SESAR solution success criterion ID	Project / SESAR solution success criterion	Project / SESAR solution validation results (ENG)	Project / SESAR solution validation results (UPV)	Project / SESAR solution validation results (CRA)	Project / SESAR solution validation objective status
			flight-hour in Scenario 3, for exercise #01 and #02.	concurrency (N = 2). This underlines the necessity to include U-space services in this scenario to obtain the required TLS.	airspace capacity is reported.	airspace values are reported.	
		CRT-SOL0520-TRL2-ERP-001.008	The MAC frequency between UAS shall not exceed 1.41×10^{-4} per flight-hour in Scenario 1, for exercise #02.	The number of concurrent UAS compatible with the required TLS has been calculated. At any tested density, including the minimum simulated concurrency (N = 2). This underlines the necessity to include U-space services in this scenario to obtain the required TLS.	For Benidorm, the UAS–UAS baseline capacity under the U-AGREE threshold is 1 simultaneous UAS below and above VLL.	The baseline capacity is 1.003 UAS. Even two simultaneous UAS exceed the maximum allowable NMAC per hour.	OK
		CRT-SOL0520-TRL2-ERP-001.009	The MAC frequency between UAS shall not exceed 1.29×10^{-4} per flight-hour in	The number of concurrent UAS compatible with the required TLS has been calculated. At any tested density, including the	For Manduria, the UAS–UAS baseline capacity under the U-AGREE threshold is 1 simultaneous	The baseline capacity is 1.002 UAS. Even two simultaneous UAS exceed the maximum	OK

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Project / SESAR solution validation objective ID	Project / SESAR solution validation objective title	Project / SESAR solution success criterion ID	Project / SESAR solution success criterion	Project / SESAR solution validation results (ENG)	Project / SESAR solution validation results (UPV)	Project / SESAR solution validation results (CRA)	Project / SESAR solution validation objective status
			Scenario 2, for exercise #02.	minimum simulated concurrency (N = 2). This underlines the necessity to include U-space services in this scenario to obtain the required TLS.	UAS below and above VLL.	allowable NMAC per hour.	
		CRT-SOL0520-TRL2-ERP-001.010	The MAC frequency between UAS shall not exceed 6.25×10^{-3} per flight hour in Scenario 3, for exercise #02.	The number of concurrent UAS compatible with the required TLS has been calculated. At any tested density, including the minimum simulated concurrency (N = 2). This underlines the necessity to include U-space services in this scenario to obtain the required TLS.	For Shannon, the UAS–UAS capacity under the U-AGREE threshold is 1 UAS below VLL and 2 UAS above VLL. The overall baseline is 1 UAS.	The baseline capacity is 1.078 UAS. Even two simultaneous UAS exceed the maximum allowable NMAC per hour.	OK
OBJ-SOL0520-ERP-002	Quantification of capacity increment (ΔN_1) because of the introduction of mitigation	CRT-SOL0520-TRL2-ERP-002.001	The maximum number of UAS operations in scenario 1 increases with	Only the Flight Authorisation Service is included for this run. The Traffic Information Service is excluded, as its	For Benidorm at deviation thresholds of 4, 32 and 64 m, the UAS–UAS capacities are 1, 1	The capacity increases to 1.19 UAS in average. Benidorm requires further	Partially OK

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	measures based on Flight Authorisation and Traffic Information services.		respect to the unmitigated baseline, while maintaining the same target level of safety.	modelling is not yet validated to a reliable level. Under the same target level of safety, FAS increases the maximum number of simultaneous UAS with respect to the unmitigated baseline: = 0 for DT ≤ 32 meters and = 0.7 at DT64 (Benidorm), = 0 for DT ≤ 16 meters and = +25 at DT64 and =+16 at DT128 (Manduria), and = 6 for DT=4 meters, = 10 at DT16, = 26 at DT64 and 128 meters (Shannon).	and 20 UAS below VLL and 1, 2 and 141 above VLL. UAS–manned capacity remains 1 UAS.	U-Space services to ensure target level of safety.	
		CRT-SOL0520-TRL2-ERP-002.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the	Only the Flight Authorisation Service is included for this run. The Traffic Information Service is excluded, as its modelling is not yet validated to a reliable level. Under the same target level of safety, FAS	For Manduria at deviation thresholds of 4, 32 and 64 m, the UAS–UAS capacities are 1, 1 and 52 UAS below VLL and 1, 2 and 87 above VLL. UAS–	The capacity increases to 1.58 UAS in average. Manduria requires further U-Space services to ensure target level of safety.	Partially OK

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			same target level of safety.	increases the maximum number of simultaneous UAS with respect to the unmitigated baseline: ΔN_1 = 0 for DT ≤ 16 meters and ΔN_1 = +25 at DT64 and ΔN_1 =+16 at DT128.	manned capacity remains 1 UAS.		
		CRT-SOL0520-TRL2-ERP-002.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Only the Flight Authorisation Service is included for this run. The Traffic Information Service is excluded, as its modelling is not yet validated to a reliable level. Under the same target level of safety, FAS increases the maximum number of simultaneous UAS with respect to the unmitigated baseline: ΔN_1 = 6 for DT=4 meters, ΔN_1 = 10 at DT16, ΔN_1= 26 at DT64 and 128 meters.	For Shannon at deviation thresholds of 4, 32 and 64 m, the UAS–UAS capacities are 526, 1181 and 925 UAS below VLL and 2316, 932 and 583 above VLL. UAS–manned capacity remains 1 UAS.	The capacity increases to 45.24 UAS in average. The traffic information service ensures safe operations in Shannon.	Partially OK

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OBJ-SOL0520-ERP-003	Quantification of capacity increment (ΔN_2) because of the introduction of mitigation measures based on Flight Authorisation, Traffic Information, and Conformance Monitoring (without pre-alerting) services.	CRT-SOL0520-TRL2-ERP-003.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	No capacity increment in Benidorm. On the other hand, CM helps address a high number of non-conforming events, preventing them from escalating into NMACs. TIS is not included in simulations.	In Benidorm, Conformance Monitoring without pre-alerting reduces UAS–UAS MAC risk in most configurations, but NMAC risk remains near 1 and the UAS–manned criterion is unchanged. Overall capacity therefore remains generally limited to the FAS+TIS value.	The capacity increases to 1.21 UAS in average. Benidorm requires further U-Space services to ensure target level of safety.	Partially OK
		CRT-SOL0520-TRL2-ERP-003.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	No capacity increment obtained beyond those provided by FAS at DT16, so $\boldsymbol{\Delta N_2 = \Delta N_1}$. For DT64, the capacity increment of FAS+CM with respect to baseline is of $\boldsymbol{\Delta N_2}$=15. TIS is not included in simulations.	In Manduria, Conformance Monitoring without pre-alerting reduces UAS–UAS MAC risk in most configurations. NMAC and UAS–manned results remain broadly unchanged, so the overall capacity	The capacity increases to 1.62 UAS in average. Manduria requires further U-Space services to ensure target level of safety.	Partially OK

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					generally remains at the FAS+TIS level.		
		CRT-SOL0520-TRL2-ERP-003.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	At DT16, the capacity increment with respect to baseline provided by FAS+CM is of $\boldsymbol{\Delta N_2}$=11. No capacity increment obtained beyond those provided by FAS For DT64 so $\boldsymbol{\Delta N_2 = \Delta N_1}$. TIS is not included in simulations.	In Shannon, Conformance Monitoring without pre-alerting reduces UAS–UAS MAC risk in most configurations. NMAC and UAS–manned results remain broadly unchanged, so the overall capacity generally remains at the FAS+TIS level.	The capacity increases to 41.22 UAS in average. The conformance monitoring service without pre-alert ensures safe operations in Shannon.	Partially OK
OBJ-SOL0520-ERP-004	Quantification of the capacity increment (ΔN_3) because of the introduction of mitigation measures based on Flight Authorisation,	CRT-SOL0520-TRL2-ERP-004.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while	For both DT, there is no capacity increase with respect to the one provided by FAS alone, so $\boldsymbol{\Delta N_2 = \Delta N_1}$. On the other hand, CM helps address a high number of non-	In Benidorm, pre-alerting improves TSE containment from about 93.2% to 94.0% and reduces UAS–UAS MAC risk in most configurations.	The capacity increases to 1.21 UAS in average. Benidorm requires further U-Space services	Partially OK

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	Traffic Information, and Conformance Monitoring (with pre-alerting) services.		maintaining the same target level of safety.	conforming events, preventing them from escalating into NMACs TIS is not included in simulations.	NMAC and UAS–manned results remain broadly unchanged, limiting the overall capacity benefit.	to ensure target level of safety.	
		CRT-SOL0520-TRL2-ERP-004.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	For both DT16 and DT64, no capacity increment with respect to those provided by FAS has been observed, so $\Delta N_3 = \Delta N_2 = \Delta N_1$. TIS is not included in simulations.	In Manduria, pre-alerting improves TSE containment from about 93.2% to 94.0% and generally reduces UAS–UAS MAC risk. NMAC and UAS–manned results remain broadly unchanged, so overall capacity generally remains at the FAS+TIS level.	The capacity increases to 1.62 UAS in average. Manduria requires further U-Space services to ensure target level of safety.	Partially OK
		CRT-SOL0520-TRL2-ERP-004.003	The maximum number of UAS operations in scenario 3 increases with respect to the	For DT16, the number of simultaneous UAS flying compatibly with TLS is of 9, so there is an increase in capacity with respect	In Shannon, pre-alerting improves TSE containment from about 93.2% to 94.0% and generally reduces UAS–UAS	The capacity increases to 41.22 UAS in average. The conformance monitoring	Partially OK

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			unmitigated baseline, while maintaining the same target level of safety.	to the baseline levels of $\boldsymbol{\Delta N_3 = 8}$. For DT64, no capacity increment with respect to those provided by FAS has been observed, so with respect to the baseline $\boldsymbol{\Delta N_3 = \Delta N_2 = \Delta N_1}$. TIS is not included in simulations.	MAC risk. NMAC and UAS–manned results remain broadly unchanged, so overall capacity generally remains at the FAS+TIS level.	service with pre-alert ensures safe operations in Shannon.	
OBJ-SOL0520-ERP-005	Quantification of the capacity increment (ΔN_4) because of the introduction of mitigation measures based on Final FAS and adding a Tactical Conflict Prediction and Resolution services.	CRT-SOL0520-TRL2-ERP-005.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	No capacity increment with respect to baseline is observed $(\Delta N_4 = 0)$ for both FAS and tactical services.	For Benidorm above VLL, Final FAS raises safety-based capacity from 1 to 50 UAS at the UAS–manned NMAC separation scale. At smaller thresholds, the UAS–manned criterion or trajectory availability remains limiting.	For Benidorm, at a 45s look-ahead and a protection volume of 32 times the NMAC radius, the conditional UAS-UAS NMAC risk ratio falls to 0.018, increasing the capacity to 2.31 UAS.	OK

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		CRT-SOL0520-TRL2-ERP-005.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	No capacity increment with respect to baseline is observed ($\Delta N_4 = 0$) for both FAS and tactical services.	For Manduria above VLL, Final FAS raises safety-based capacity from 1 to 286 UAS at the UAS–manned NMAC separation scale. TCP&R further reduces residual UAS–UAS collision risk.	For Manduria, at a 45 s look-ahead and a protection volume of 32 times the NMAC radius, the conditional UAS-UAS NMAC risk ratio falls to 0.022, increasing the capacity to 2.19 UAS.	OK
		CRT-SOL0520-TRL2-ERP-005.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	No capacity increment with respect to baseline is observed ($\Delta N_4 = 0$) for both FAS and tactical services.	For Shannon–Limerick above VLL, Final FAS raises safety-based capacity from 1 to 745 UAS. Coordinated DAR improves conflict-free diversions, while TCP&R reduces the residual UAS–UAS risk ratio to 0.00128.	For Shannon-Limerick, at a 45 s look-ahead and a protection volume of 32 times the NMAC radius, the conditional UAS-UAS NMAC risk ratio falls to 0.016, increasing the capacity to 1.92 UAS.	OK

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OBJ-SOL0520-ERP-006[10]	Quantification of baseline geographical zone infringements per flight-hour ($\Delta Ninf_0$).	CRT-SOL0520-TRL2-ERP-006.001	The geographical zones in Scenario 1 shall be defined such that, during the baseline run, at least one infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.	Geozones have not been included in this scenario.	Not assessed by UPV	Not assessed by CRA	NOK
		CRT-SOL0520-TRL2-ERP-006.002	The geographical zones in Scenario 2 shall be defined such that, during the baseline run, at least one	The geozones introduced in the scenario generate a sufficiently high number of infringements, providing the baseline conditions	Not assessed by UPV	Not assessed by CRA	OK

[10] Success criteria for this OBJ (related to exercise TVAL.02.0) have been changed since the submission of the ERP. The reasoning behind this change is detailed in paragraph B.2 *Deviation from the planned activities*

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			infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.	required for the evaluation of the subsequent objectives. The number of geozones infringements is $Ninf_0$ = 0.803 /fh across UAS density.			
		CRT-SOL0520-TRL2-ERP-006.003	The geographical zones in Scenario 3 shall be defined such that, during the baseline run, at least one infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.	The geozones introduced in the scenario generate a sufficiently high number of infringements, providing the baseline conditions required for the evaluation of the subsequent objectives. The number of geozones infringements is $Ninf_0 \in$ [0.45, 1.11] /fh across UAS density.	Not assessed by UPV	Not assessed by CRA	OK
OBJ-SOL0520-ERP-007	Quantification of the variation in geographical zone	CRT-SOL0520-TRL2-ERP-007.001	The total number of geographical zones	Geozones have not been included in this scenario.	Not assessed by UPV	Not assessed by CRA	NOI

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	infringements per flight-hour ($\Delta Ninf_1$) due to the implementation of mitigation measures based on Flight Authorisation service.		infringements varies compared to the baseline in scenario 1.				
		CRT-SOL0520-TRL2-ERP-007.002	The total number of geographical zones infringements varies compared to the baseline in scenario 2.	$\Delta Ninf_1$ of −0.803/fh (−100%) across UAS density and DT values.	Not assessed by UPV	Not assessed by CRA	OK
		CRT-SOL0520TRL2-ERP-007.003	The total number of geographical zones infringements varies compared to the baseline in scenario 3.	$\Delta Ninf_1$ of −0.911/fh (−100%) across UAS density and DT values.	Not assessed by UPV	Not assessed by CRA	OK
OBJ-SOL0520-ERP-008	Quantification of the variation in geographical zone infringements per flight-hour ($\Delta Ninf_2$)	CRT-SOL0520-TRL2-ERP-008.001	The total number of geographical zones infringements varies compared	Geozones have not been included in this scenario.	Not assessed by UPV	Not assessed by CRA	NOK

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	due to the implementation of mitigation measures based on Conformance Monitoring service.		to the baseline in scenario 1.				
		CRT-SOL0520-TRL2-ERP-008.002	The total number of geographical zones infringements varies compared to the baseline in scenario 2.	0 infringements/fh across density, providing $\Delta Ninf_2$=$\Delta Ninf_1$.	Not assessed by UPV	Not assessed by CRA	OK
		CRT-SOL0520-TRL2-ERP-008.003	The total number of geographical zones infringements varies compared to the baseline in scenario 3.	0 infringements/fh across density, providing $\Delta Ninf_2$=$\Delta Ninf_1$.	Not assessed by UPV	Not assessed by CRA	OK
OBJ-SOL0520-ERP-009	Quantification of the impact of fauna on air risk.	CRT-SOL0520-TRL2-ERP-009.001	The TLS defined for scenario 1 is maintained.	Geozones have not been included in this scenario.	Not assessed by UPV	Not assessed by CRA	NOK
		CRT-SOL0520-TRL2-ERP-009.002	The TLS defined for scenario 2 is maintained.	Geozones included in this scenario is not compatible with fauna-related risks.	Not assessed by UPV	Not assessed by CRA	NOK

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		CRT-SOL0520-TRL2-ERP-009.003	The TLS defined for scenario 3 is maintained.	0 infringements/fh at every DT tested.	Not assessed by UPV	Not assessed by CRA	OK

Table 7: summary of validation exercises results

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4.2 Detailed analysis of project / SESAR solution validation results per validation objective

4.2.1 OBJ-SOL0520-ERP-001 Results

OBJ-SOL0520-ERP-001 aimed to identify the baseline capacity of the Benidorm, Manduria and Shannon scenarios before the introduction of any U-space mitigation service. The baseline therefore represents sustained unmitigated traffic and provides the reference against which the capacity and safety improvements delivered by Flight Authorisation, Traffic Information and Conformance Monitoring are assessed.

The three simulation contributions used different traffic-generation and exposure-management approaches. ENGage simulated between 2 and 30 simultaneous vehicles, with randomly selected flight plans and 200 flight-hours of exposure at each density level. UPV maintained a fixed active population by replacing aircraft after route completion or MAC, thereby representing sustained exposure at each traffic density. CRA simulated between 1 and 10 simultaneous UAS over one-week periods and repeated each configuration using 100 random selections of flight plans. In all cases, conflict frequencies were normalised by flight-hour exposure, enabling comparison between traffic-density levels despite the methodological differences.

The consolidated results show a consistent relationship between traffic density and collision risk. In the absence of U-space services, the UAS–UAS NMAC frequency increases approximately linearly with the number of simultaneous UAS. UAS–manned encounters also remain above the applicable safety threshold throughout the tested density range. All simulators found that the relevant thresholds were already exceeded at the minimum tested concurrent traffic level, generally $N = 2$. Consequently, none of the three scenarios has meaningful capacity for concurrent UAS operations in its unmitigated configuration.

ENGage and UPV obtained a baseline capacity of approximately one simultaneous UAS in all scenarios. CRA obtained comparable fitted capacities: approximately 1.001, 1.002 and 1.212 UAS d in Benidorm, Manduria and Shannon respectively. The independent results therefore converge on the same operational conclusion: **scalable concurrent traffic cannot be supported without additional mitigation.**

Although the applicable TLS is defined using MAC frequency, NMAC was used as the principal indicator for estimating baseline capacity. MAC events are comparatively rare and their observed frequency has high variance, making capacity estimates based solely on MAC sensitive to the finite simulation exposure. NMAC provides a more stable proximity indicator across traffic-density levels and produces a conservative capacity estimate because every MAC is contained within the broader set of NMAC events. Accordingly, **a simulation case in which no MAC was observed must not be interpreted as risk-free; its NMAC frequency and accumulated exposure must also be considered**.

The comparison between scenarios also demonstrates that geographical area alone does not determine conflict frequency. Despite Manduria and Shannon covering substantially larger areas than Benidorm, their NMAC frequencies remain of a comparable order of magnitude. This is attributed to their hub-centred traffic patterns, in which departures and arrivals are concentrated around a limited number of locations. Benidorm has a more spatially distributed route structure and therefore produces fewer encounters for a comparable number of flights. The higher MAC-to-NMAC ratio observed in

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Manduria and Shannon further indicates that conflicts arising around concentrated traffic hubs are more likely to develop into closer encounters.

Overall, the validation evidence is sufficient to establish the unmitigated baseline required by OBJ-SOL0520-ERP-001. However, the associated safety success criteria are not satisfied at any operationally meaningful concurrent traffic level. The baseline capacity is effectively limited to one UAS in all three scenarios, confirming that at least one U-space mitigation service is required before scalable UAS operations can be supported.

4.2.2 OBJ-SOL0520-ERP-002 Results

OBJ-SOL0520-ERP-002 aimed to quantify the increase in airspace capacity resulting from the introduction of FAS and TIS, while maintaining the same TLS used for the unmitigated baseline. The three simulation contributions consistently demonstrate that strategic trajectory deconfliction substantially reduces UAS–UAS conflict risk. However, the capacity improvement depends strongly on the operational scenario, the selected deviation threshold (DT), the implementation of the FAS algorithm and the assumptions applied to aircraft deviations.

The FAS acts before a UAS enters the active traffic population. Each proposed trajectory is compared with previously authorised trajectories over their overlapping time intervals and is rejected when the required protected volume would be infringed. Increasing the DT enlarges this protected volume and therefore reduces the opportunity for UAS–UAS conflicts. Nevertheless, this safety benefit is accompanied by a reduction in the proportion of flight plans accepted at the authorisation gate. The results must consequently be interpreted as a trade-off between residual conflict risk, safety-constrained capacity and operational accessibility. A protection buffer that is sufficient to prevent MAC may not eliminate NMAC when it remains small relative to the applicable NMAC distance. UAS–manned results must also be interpreted separately because, **in exercise #01, the FAS primarily deconflicts UAS against other UAS** and does not systematically modify the manned-traffic conflict population.

The ENGage results show a monotonic reduction in the NMAC risk ratio as the DT increases. In Benidorm, the mean risk ratio decreases from approximately 0.19 at DT = 0 m to approximately 0.001 at DT = 64 m. This means that even the least restrictive FAS configuration removes approximately 81% of the baseline NMAC risk, while DT = 64 m provides an almost complete reduction. Nevertheless, the residual risk remains above the safety target for DT values up to 32 m. The safety-constrained capacity therefore remains approximately one simultaneous UAS until DT = 64 m, where a small $\Delta N_1 = 0.7$ capacity increase is observed. The number of simultaneous UAS compatible with TLS is therefore still 1. The authorisation approval rate decreases from approximately 83% at DT = 0 m to 45% at DT = 64 m. This reduction mainly represents an increase in rejected or replanned requests rather than an equivalent reduction in realised throughput, because the retry mechanism continues submitting alternative trajectories until a deconflicted plan is found.

In Manduria, ENGage obtained mean risk ratios of approximately 0.020 at DT = 4 m and 0.010 at DT = 16 m, while no UAS–UAS NMAC was observed at DT = 64 m. A single residual event at DT = 128 m produced a very small non-zero risk ratio and is considered a finite-exposure artefact rather than evidence that DT = 128 m performs worse than DT = 64 m. Although DT = 4 m and DT = 16 m substantially reduce risk, their residual NMAC rates remain above the strict TLS and do not produce a demonstrable capacity increase. DT = 64 m supports an increase of at least $\Delta N_1 = +25$ simultaneous vehicles, with the result being right-censored by the maximum simulated traffic density. The approval

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rate remains comparatively high, decreasing from approximately 84% at DT = 4 m to 75% at DT = 128 m.

Shannon presents the strongest capacity improvement in the ENGage simulations. The mean risk ratio decreases from approximately 0.057 at DT = 4 m to 0.029 at DT = 16 m, 0.0018 at DT = 64 m and 0.0008 at DT = 128 m. These configurations correspond to capacity increments of approximately + 26 simultaneous UAS at DT = 64 m and DT = 128 m, compliance is maintained across the complete simulated density range, so the resulting capacity remains limited by the maximum tested traffic level rather than by an observed TLS crossing. The approval rate decreases from 87% at DT = 4 m to 79% at DT = 128 m.

The UPV simulations likewise confirm that the capacity benefit associated with FAS+TIS is strongly dependent on the deviation threshold, operational scenario and altitude configuration. At deviation thresholds of 4, 32 and 64 m, the UAS–UAS safety-based capacities in Benidorm are respectively 1, 1 and 20 simultaneous UAS below VLL, and 1, 2 and 141 UAS above VLL. The corresponding values for Manduria are 1, 1 and 52 UAS below VLL, and 1, 2 and 87 UAS above VLL. Shannon–Limerick produces substantially higher estimates: 526, 1181 and 925 UAS below VLL, and 2316, 932 and 583 UAS above VLL.

These safety-based estimates must be distinguished from the operationally achievable capacity. Where the estimated capacity exceeds the number of trajectories that FAS can allocate within the available airspace, operational capacity is limited by trajectory availability rather than by the TLS crossing. The UAS–manned capacity remains one simultaneous UAS in every assessed scenario because manned aircraft are not directly included in FAS strategic deconfliction. The UPV results also show that the Authorisation Approval Rate decreases as traffic demand and the deviation threshold increase, confirming the trade-off between strategic separation and access to the airspace.

The CRA simulations confirm the qualitative effectiveness of the FAS but produce more conservative capacity estimates. At DT = 8 m, FAS reduces NMAC by approximately 90% in Benidorm, 98% in Manduria and 99% in Shannon. The reduction increases with DT and reaches approximately 99.5% at the most restrictive configurations. Nevertheless, the fitted FAS-only capacity at DT = 128 m remains approximately 1.17 UAS in Benidorm and 1.53 UAS in Manduria, compared with approximately 40.82 UAS in Shannon. When the CRA TIS encounter-model contribution is included, the corresponding capacities increase to approximately 1.19, 1.58 and 45.24 UAS respectively. Thus, the additional TIS benefit is limited in Benidorm and Manduria but supports a further operationally relevant capacity increase in Shannon.

The quantitative difference between the ENGage and CRA results is mainly attributable to implementation and modelling assumptions. The CRA simulator applies a comparatively high excursion rate, driven by sensor noise, wind effects and a modelled probability of loss of control. Its FAS implementation checks discrete trajectory points at one-second intervals rather than potential intersections between the connecting trajectory segments. These features allow residual conflicts to persist and cause the NMAC risk reduction to saturate at large DT values. By contrast, the ENGage segment-based conflict-detection implementation produces near-zero residual NMAC rates at the widest thresholds. The absence of observed events must nevertheless be treated as an exposure-limited result and not as evidence of zero underlying risk.

Scenario geometry also affects FAS performance. Manduria and Shannon have more hub-centred traffic patterns, so even relatively small protection thresholds remove a large proportion of the conflicts concentrated around arrival and departure locations. Benidorm has a more uniformly

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distributed route structure and therefore exhibits a more gradual reduction at small thresholds, followed by a pronounced improvement at DT = 64 m. At the same time, Benidorm's smaller geographical area produces a larger number of encounters for the same number of active UAS and a stronger reduction in first-attempt authorisation acceptance as the protected volume increases.

The results demonstrate that FAS is an effective strategic mitigation barrier and that increasing the DT generally produces stronger reductions in UAS–UAS risk. However, a substantial risk reduction does not automatically produce an operational capacity increase: the residual rate must cross the applicable TLS, and the resulting safety gain must be considered together with authorisation rejection and replanning costs. The evidence supports capacity increases in all three scenarios at sufficiently large thresholds, with the strongest and most consistent improvement observed in Shannon–Limerick.

4.2.3 OBJ-SOL0520-ERP-003 Results

OBJ-SOL0520-ERP-003 aimed to quantify the capacity increment resulting from the combined implementation of Flight Authorisation, Traffic Information and Conformance Monitoring without pre-alerting, while maintaining the same Target Level of Safety used for the unmitigated baseline. In this configuration, FAS provides the strategic separation layer by establishing initially deconflicted authorised trajectories, while Conformance Monitoring provides a subsequent containment layer by detecting deviations during flight execution. Without pre-alerting, corrective action is initiated only after the monitored aircraft has exceeded the applicable conformance limit.

In the ENGage implementation, the CM alert is triggered when the UAS has breached both the deviation threshold and the assumed TSE bound. Following a sampled communication and pilot-reaction delay, the aircraft is overridden towards its authorised corridor. A 100-flight-hour Monte Carlo campaign evaluated CM without pre-alerting on top of FAS for DT = 16 m and DT = 64 m. This mechanism increases effective containment but does not guarantee that the aircraft remains continuously within its authorised corridor, because a period of excursion can accumulate before the alert and recovery process becomes effective.

The consolidated results show that CM without pre-alerting detects and supports the management of non-conformance events but does not provide a statistically measurable reduction in UAS–UAS NMAC frequency beyond that already achieved by FAS at the same DT. At DT = 16 m, the differences between FAS-only and FAS-plus-CM configurations generally remain within the variability of the Monte Carlo results. At DT = 64 m, FAS has already reduced residual conflicts close to the simulation detection floor, leaving insufficient observable risk for CM to reduce further. The DT applied by FAS is therefore the dominant factor controlling the resulting NMAC frequency and safety-constrained capacity.

For Benidorm, the mean risk ratio obtained with CM without pre-alerting is approximately 0.124 at DT = 16 m and approximately zero at DT = 64 m. At DT = 16 m, neither the FAS-only nor the FAS-plus-CM configuration consistently outperforms the other, and their differences remain within the simulation error bars. At DT = 64 m, both configurations produce essentially zero observed UAS–UAS NMAC across the tested traffic-density range. Consequently, no additional NMAC-based capacity increment can be attributed specifically to CM. Nevertheless, the monitoring layer detects and supports the recovery of a substantial number of non-conformance events, with reported KPI values of approximately 65.1 at DT = 16 m and 54.4 at DT = 64 m. No collisions were observed under either configuration.

The Manduria results show the same general behaviour. The mean risk ratio is approximately 0.012 at DT = 16 m and approximately 0.0001 at DT = 64 m. At the lower threshold, the FAS-only and CM curves cross at different traffic densities and neither configuration demonstrates a consistent advantage. At

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DT = 64 m, both configurations operate close to the detection floor and their minor differences are not statistically meaningful. CM supports the management of reported non-conformance KPI values of approximately 39 at DT = 16 m and 2.4 at DT = 64 m, with a capacity improvement with respect to unmitigated baseline of $\boldsymbol{\Delta N_2}$**=15.** This increase, however, remains attributable primarily to FAS and the larger DT.

In Shannon–Limerick, the mean risk ratio obtained with CM without pre-alerting is approximately 0.029 at DT = 16 m and 0.0032 at DT = 64 m. As in the other scenarios, the residual NMAC results remain statistically comparable with those obtained using FAS alone. At DT = 16 m, CM detects and supports recovery from a reported non-conformance KPI value of approximately 47, demonstrating its functional contribution to containment management even though it does not generate a measurable additional reduction in NMAC-based capacity. At DT = 64 m, the small residual event counts limit the ability to distinguish the effect of the monitoring layer from statistical variability. A capacity increment of ΔN_2=11. UAS is observed at DT16, while no increment is observed at DT64.

The UPV contribution provides an important explanation for these results. Under nominal conditions, the navigation-error model already provides approximately 93–95% containment within the assumed TSE corridor. CM without pre-alerting reacts only after the monitored limit has been crossed; communication and reaction delays therefore allow some excursion time to accumulate before recovery starts. The effectiveness of CM should consequently be assessed using both collision-risk and containment indicators rather than NMAC frequency alone.

The expected CM effect also depends on the spatial scale of the safety indicator. At small protection-buffer values, the available separation margin is close to the MAC scale, and an excursion outside the TSE corridor may consume a significant proportion of that margin. Detecting and reducing such excursions can therefore improve UAS–UAS MAC performance, particularly when the TSE used by the aircraft model is consistent with the TSE assumed by FAS. By contrast, the NMAC distance is substantially larger than the MAC and TSE scales. Improving containment within a relatively narrow authorised corridor may therefore have little visible effect on NMAC frequency unless the protection buffer is also sufficiently large. The absence of a measurable NMAC reduction does not, by itself, demonstrate that CM is ineffective.

The CRA results support this interpretation. Adding CM without pre-alerting increases the conformance ratio from approximately 73% to 93%, demonstrating a substantial improvement in the proportion of time that UAS remain within their assumed TSE corridor. However, the corresponding reduction in NMAC is only marginal, of the order of 10^{-3}NMAC per flight hour. Sensitivity analyses involving the loss-of-control rate, human response time, sensor noise and wind effects indicate that CM produces a greater safety benefit when the underlying FAS implementation has already achieved effective trajectory deconfliction. Where authorised trajectories retain residual conflict opportunities, returning a deviating UAS to its authorised trajectory does not necessarily prevent an NMAC.

The CRA combined FAS-and-CM results report safety-constrained capacities at DT = 128 m of approximately 1.19 UAS in Benidorm, 1.58 UAS in Manduria and 45.24 UAS in Shannon. These values confirm the substantial scenario dependence already observed for FAS. CM without pre-alerting does not transform Benidorm or Manduria into scalable operating environments under the applicable NMAC criteria, while Shannon supports a significantly larger number of simultaneous operations. The Shannon result is mainly enabled by its higher admissible NMAC frequency and the strategic separation provided by FAS rather than by a large independent CM contribution.

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The validation confirms that CM without pre-alerting is operationally effective in detecting excursions, initiating recovery and improving trajectory containment. However, no consistent additional NMAC-based capacity increment can be isolated from CM beyond the improvement already produced by FAS at the same deviation threshold. Capacity increases relative to the unmitigated baseline are demonstrated at the wider thresholds, but these increases are mainly attributable to strategic deconfliction.

4.2.4 OBJ-SOL0520-ERP-004 Results

OBJ-SOL0520-ERP-004 aimed to quantify the capacity increment resulting from FAS, TIS and CM with pre-alerting, while maintaining the TLS applied to the unmitigated baseline. Compared with the configuration assessed under OBJ-SOL0520-ERP-003, pre-alerting advances the monitoring trigger so that the recovery chain can begin closer to the TSE boundary, before the aircraft has progressed farther into the outer protection-buffer region.

The expected benefit of pre-alerting is primarily improved trajectory containment. Earlier detection provides additional time for communication, pilot reaction and corrective action, thereby reducing the expected duration and magnitude of an excursion outside the assumed TSE corridor. This mechanism should help preserve the strategic separation margins established by FAS. It may be particularly relevant at small protection-buffer values, where the residual distance between the authorised corridor and the MAC volume is limited and even a relatively small excursion can consume a significant proportion of the available safety margin.

The effect on NMAC is less direct. NMAC is defined using substantially larger separation distances than MAC or nominal TSE containment. Triggering recovery at or close to the TSE boundary does not itself ensure that two authorised trajectories are separated by an NMAC-scale distance. Consequently, pre-alerting may improve containment and potentially reduce MAC risk without producing a similarly visible change in NMAC frequency. Its effect must therefore be interpreted together with the protection buffer used by FAS and with both containment- and conflict-related indicators.

The ENGage results do not show a statistically measurable NMAC or capacity improvement from pre-alerting when the DT is kept unchanged. In all three scenarios, the FAS-only, CM without pre-alerting and CM with pre-alerting results remain within the variability of the Monte Carlo simulations. At DT = 16 m, the curves interleave across traffic-density levels, with pre-alerting performing marginally better at some densities and marginally worse at others. No consistent ordering is observed. At DT = 64 m, FAS has already reduced the residual event frequency close to the simulation detection floor, so neither monitoring configuration produces a distinguishable additional reduction.

For Benidorm, the mean risk ratio obtained with CM pre-alerting is approximately 0.122 at DT = 16 m and 0.001 at DT = 64 m. At the lower threshold, occasional improvements are observed at individual density points, but these improvements are not maintained at neighbouring traffic levels and therefore cannot be interpreted as evidence of a systematic pre-alert benefit. At DT = 64 m, the residual rate remains close to zero for both FAS-only and CM configurations. The monitoring layer nevertheless supports the management of non-conformance events, with reported KPI values of approximately 60.3 at DT = 16 m and 54.8 at DT = 64 m. The authorisation throughput achieved by FAS is preserved, but no additional safety-constrained capacity increment can be isolated for pre-alerting.

In Manduria, the mean risk ratio is approximately 0.011 at DT = 16 m and 0.0001 at DT = 64 m. At DT = 16 m, pre-alerting is the best-performing configuration at some traffic densities and the worst-performing configuration at others. At DT = 64 m, all configurations operate at the detection floor, and

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the difference between zero events and isolated residual events is insufficient to demonstrate a statistically meaningful performance difference. CM with pre-alerting supports reported non-conformance KPI values of approximately 39.6 at DT = 16 m and 2.7 at DT = 64 m. However, no capacity increase relative to the unmitigated baseline is observed.

The Shannon results are consistent with the other two scenarios. The mean risk ratio obtained with pre-alerting is approximately 0.033 at DT = 16 m and 0.0030 at DT = 64 m. At the lower threshold, pre-alerting is marginally lower than the other configurations at some densities, comparable at intermediate densities and slightly higher at the largest tested densities. The overlapping dispersion ranges demonstrate that these differences are attributable to simulation variability rather than to a systematic benefit from the earlier monitoring trigger. At DT = 64 m, all configurations again remain statistically indistinguishable. The reported non-conformance KPI value at DT = 16 m is approximately 47, showing that the monitoring function remains active even though it does not produce a measurable additional NMAC reduction. no capacity increase relative to the unmitigated baseline is observed.

The UPV interpretation explains why the absence of a measurable NMAC improvement does not necessarily imply that pre-alerting has no operational value. By initiating recovery closer to the TSE boundary, pre-alerting reduces the expected time spent outside the nominal corridor and increases the probability that an excursion is corrected before the outer protection margin is consumed. This benefit is expected to be most visible in containment and MAC-related indicators at relatively small protection buffers. At larger buffers, FAS provides most of the measurable NMAC benefit, and the remaining event frequency may be too small to identify an additional monitoring contribution within the available exposure.

Any configuration with zero observed MAC must also be treated as a finite-exposure result. It demonstrates only that no MAC was recorded for the simulated scenario, traffic density, and exposure. It does not prove that the underlying MAC frequency is zero. A statistically robust demonstration of extremely low MAC frequencies would require a substantially larger simulation exposure.

The CRA results provide further evidence that pre-alerting improves containment without producing an equivalent capacity improvement. Introducing pre-alerting increases the conformance ratio from approximately 93% for CM without pre-alerting to approximately 98%. However, the resulting changes in MAC, NMAC, and safety-constrained capacity remain minimal, and the capacity estimates are effectively unchanged from those obtained without pre-alerting. These results indicate that CM performance depends strongly on the quality of the underlying strategic deconfliction. Improving conformance does not substantially reduce conflict risk when the authorised trajectories themselves retain residual conflict opportunities.

The validation confirms that pre-alerting improves the timing of recovery and increases effective containment. It therefore represents a potentially valuable operational enhancement to Conformance Monitoring. Nevertheless, no consistent additional NMAC reduction or safety-constrained capacity increment can be attributed to pre-alerting beyond the performance already achieved by FAS and the selected DT. The capacity increase relative to the unmitigated baseline is mainly produced by strategic trajectory deconfliction, particularly at DT = 64 m.

4.2.5 OBJ-SOL0520-ERP-005 Results

OBJ-SOL0520-ERP-005 aimed to quantify the capacity increment obtained through the Final FAS and the addition of Tactical Conflict Prediction and Resolution (TCP&R), while maintaining the same Target Level of Safety applied to the unmitigated baseline. The three partners provide complementary

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evidence. ENGage evaluates the services in full-traffic fast-time simulations and reports event frequencies per flight hour. CRA and UPV use paired, conflict-rich encounter campaigns to quantify the conditional risk reduction produced by TCP&R once a relevant encounter has occurred. UPV additionally evaluates Dynamic Airspace Reconfiguration (DAR) and Strategic Conflict Resolution (SCR) as supporting functions of the Final FAS.

The ENGage results can be related directly to traffic density and safety-constrained capacity. By contrast, the CRA and UPV Risk Ratios (RR) are conditional on an encounter and cannot be interpreted as absolute NMAC frequencies per flight hour. They can be used to quantify the mitigation effectiveness of TCP&R and to derive relaxed safety thresholds, but they do not independently determine operational airspace capacity, which remains dependent on the traffic accepted by the Final FAS and on the most restrictive encounter family.

The ENGage results show that extending FAS to consider declared manned-aircraft corridors substantially reduces UAS–manned NMAC frequency. In Benidorm, the UAS–manned rate decreases from the manned-blind baseline of 0.474 NMAC/fh to 0.207 NMAC/fh at DT = 0 m, corresponding to a reduction of approximately 56%, and continues to decrease to approximately 0.00044 NMAC/fh at DT = 64 m. Nevertheless, the available exposure is insufficient to demonstrate compliance with the very restrictive UAS–manned TLS, and the resulting overall capacity remains at the baseline value. No TCP&R campaign was executed for Benidorm, so a tactical capacity increment cannot be evaluated for this scenario.

In Manduria, manned-aware FAS reduces UAS–manned NMAC from 0.291/fh in the baseline to 0.018/fh at DT = 4 m and 0.012/fh at DT = 16 m, corresponding to reductions of approximately 94% and 96%. No residual UAS–manned event was observed at DT = 64 m or DT = 128 m. Six tactical configurations—full-automatic, Human-on-the-Loop and Human-in-the-Loop at DT = 16 m and DT = 64 m—were evaluated. Their UAS–UAS risk ratios remain within the variability of the corresponding FAS-only results. At DT = 16 m, the mean tactical RR ranges from approximately 0.009 to 0.012, compared with approximately 0.010 for FAS alone. At DT = 64 m, all configurations operate at or close to the detection floor. An indicative capacity increment of 12 simultaneous vehicles was derived for the tactical configurations at DT = 64 m, but this estimate is based on a single residual NMAC and is not considered statistically robust.

The Shannon–Limerick results lead to the same conclusion. Manned-aware FAS reduces UAS–manned NMAC from 0.235/fh to 0.023/fh at DT = 0 m and 0.009/fh at DT = 16 m, with no residual events observed at DT = 64 m and DT = 128 m. TCP&R was evaluated at DT = 16 m and DT = 64 m using a 20-second forecast horizon and automation-specific reaction delays. At DT = 16 m, the mean UAS–UAS tactical RR ranges from approximately 0.028 to 0.032, compared with 0.036 for FAS alone. At DT = 64 m, it ranges from approximately 0.0025 to 0.0040, compared with 0.0036 for FAS alone. These differences remain within simulation variability and do not demonstrate an additional capacity increment attributable to TCP&R. The tactical trajectories must also be checked against manned traffic because manoeuvres intended to resolve a UAS–UAS conflict may occasionally move the UAS closer to a manned-aircraft trajectory.

The UPV contribution evaluates three Final FAS enhancements. SCR is assessed in Benidorm, DAR coordinated rerouting in Shannon–Limerick, and TCP&R in all three scenarios. The SCR assessment demonstrates that alternative conflict-free routes can recover U-plans that would otherwise be rejected by the initial Flight Authorisation process. Across predefined sets containing 25, 50, 75 and 100 submitted U-plans, the initial acceptance rate ranges from 79% to 92%. After applying two-dimensional SCR, the accepted proportion increases to between 91% and 98%; the more conservative

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three-dimensional implementation achieves between 86% and 96%. These results demonstrate the functional feasibility of increasing the number of authorised U-plans. However, because the assessment uses four predefined trajectory sets rather than repeated Monte Carlo sampling, it does not establish a statistically representative approval rate or maximum Benidorm capacity.

In Shannon, coordinated DAR rerouting generates mutually compatible routes to predefined safe-landing locations for all assessed traffic levels of 5, 10 and 20 simultaneous affected flights. This prevents an airspace-reconfiguration response from introducing new conflicts between independently diverted UAS. The result constitutes positive safety evidence for the management of ongoing operations, but it does not directly increase the initial Final FAS authorisation rate because DAR is activated after the affected flights have already been authorised.

For TCPR, UPV selected a common reporting baseline comprising a 45-second look-ahead, full horizontal and vertical separation factors, nominal CNS, a unique USSP, no manoeuvre failure and no trajectory perturbations. Autonomous and remotely piloted response assumptions were evaluated separately. Because neither response family is uniformly conservative across every scenario and encounter family, the higher RR was retained and a consortium reporting factor of two was applied. The resulting reported UAS–UAS RR is approximately 0.040 in Benidorm, 0.048 in Manduria and 0.00128 in Shannon. The corresponding UAS–manned RR values are approximately 0.759, 0.801 and 0.792.

These ratios show that TCP&R provides a substantial additional reduction in conditional UAS–UAS risk, particularly in Shannon. The corresponding relaxed maximum allowable UAS–UAS frequencies are approximately 3.530×10^{-3}/fh in Benidorm, 2.964×10^{-3}/fh in Manduria and 4.898/fh in Shannon. However, the UAS–manned criteria remain considerably more restrictive. TCP&R also acts after strategic authorisation and therefore does not directly change the number of U-plans accepted by FAS or the Authorisation Approval Rate. Its contribution is to reduce the residual risk associated with operations that have already been authorised. The relaxed UAS–UAS thresholds therefore represent a potential safety-based capacity improvement, not a complete operational-capacity result.

The CRA contribution confirms that protection-volume selection is more influential than simply extending the look-ahead horizon. Its paired Monte Carlo model simulates 1,000 encounters per configuration, with between 865 and 898 NMAC events in the service-disabled branches. Look-ahead is varied from 2 to 45 seconds, while protection volume is varied from one to thirty-two times the applicable NMAC radius. Instantaneous, autonomous and remotely piloted response assumptions are assessed, with mean reaction delays of zero, three and seven seconds respectively.

At the Final FAS reference protection volume, approximately 2.6 times the NMAC radius, increasing look-ahead produces only a moderate reduction in the conditional UAS–UAS risk ratio and provides little additional improvement beyond approximately 15 seconds. At a fixed 45-second look-ahead, increasing the protection volume is substantially more effective. At thirty-two NMAC radii, the autonomous UAS–UAS RR decreases to approximately 0.018 in Benidorm, 0.022 in Manduria and 0.016 in Shannon. The remotely piloted results converge to similar values of approximately 0.018, 0.026 and 0.017 respectively.

The CRA UAS–manned results are considerably less favourable. Their conditional RR remains between approximately 0.72 and 0.81 and does not improve materially as the protection volume increases. This difference arises because the manned-aircraft NMAC radius is 152.4 m, compared with 15.24 m for the UAS classes, and only the UAS manoeuvres during a mixed encounter. At large protection volumes, the required clearance may exceed the available detection range, meaning that the encounter is

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already inside the required separation when it is first detected. These UAS–manned estimates are based on only 42–74 events per configuration and should therefore be interpreted as a consistent trend rather than as a precise mitigation level.

Across the three contributions, **the qualitative conclusion is consistent**. TCP&R can provide an important additional reduction in residual UAS–UAS risk when a sufficiently large protection volume and adequate response horizon are available. The UPV and CRA paired campaigns demonstrate this conditional mitigation effect clearly. Increasing tactical protection volumes also cannot compensate for an inadequate detection range in mixed UAS–manned encounters.

The Final FAS enhancements provide complementary operational benefits. SCR can recover some U-plans rejected during initial strategic authorisation, while coordinated DAR rerouting prevents airspace reconfiguration from generating secondary conflicts. These functions **improve access, operational resilience and safety**, but the available assessments are primarily functional or qualitative and do not provide a statistically demonstrated maximum-capacity value.

OBJ-SOL0520-ERP-005 demonstrates that Final FAS and TCP&R reduce residual risk and support safer management of authorised operations. However, the validation does not demonstrate a reliable increase in the overall maximum number of UAS operations while satisfying every applicable UAS–UAS and UAS–manned criterion.

4.2.6 OBJ-SOL0520-ERP-006 Results

OBJ-SOL0520-ERP-006 aimed to quantify the baseline rate of UAS infringements into designated geographical zones, expressed as infringements per flight hour, in the absence of mitigation measures. The purpose was to establish a measurable reference level for assessing the effects of the Flight Authorisation and Conformance Monitoring services under the subsequent objectives.

For Scenario 1, Benidorm, the objective could not be evaluated because geographical zones were not implemented in the simulation. Consequently, no infringement rate was obtained and success criterion CRT-SOL0520-TRL2-ERP-006.001 was assessed as NOK. This result should be interpreted as a limitation of the scenario configuration rather than evidence that geographical-zone infringements would not occur in Benidorm.

For Scenario 2, Manduria, the *Mura Messapiche Archaeological park* was implemented as a no-fly zone. During the 100-flight-hour unmitigated simulation campaign, UAS entered the protected area at an overall rate of approximately 0.803 infringements per flight hour. The infringement rate remained broadly constant across the tested UAS traffic-density levels. The geographical-zone configuration therefore generated sufficient infringement events to establish a measurable baseline, and CRT-SOL0520-TRL2-ERP-006.002 was assessed as OK.

For Scenario 3, Shannon, the *Shannon Estuary Special Protection Area* was implemented as a no-fly zone. The unmitigated baseline produced an overall infringement rate of approximately 0.911 infringements per flight hour. Unlike Manduria, the rate increased with traffic density, ranging from approximately 0.45 infringements per flight hour at the lowest tested density to approximately 1.11 infringements per flight hour at the highest density. These results provide a sufficiently populated baseline for evaluating the effectiveness of subsequent mitigation measures.

OBJ-SOL0520-ERP-006 quantitative baseline infringement levels were successfully established for Manduria and Shannon, whereas the objective could not be assessed for Benidorm because no

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geographical zones were included in that scenario. The obtained baselines demonstrate that, without mitigation, UAS operations can generate recurring entries into protected geographical zones and provide the reference values required for the evaluations performed under OBJ-SOL0520-ERP-007 and OBJ-SOL0520-ERP-008.

4.2.7 OBJ-SOL0520-ERP-007 Results

OBJ-SOL0520-ERP-007 aimed to quantify the variation in geographical-zone infringements per flight hour resulting from the implementation of mitigation measures based on FAS. The results were compared with the unmitigated baseline established under OBJ-SOL0520-ERP-006.

For Scenario 1, Benidorm, the objective could not be evaluated because no no-fly zone was implemented in the ENGage simulator. Consequently, neither a baseline infringement rate nor its variation following the activation of FAS could be calculated. Success criterion CRT-SOL0520-TRL2-ERP-007.001 was therefore assessed as NOK.

For Scenario 2, Manduria, activating the geozones-enforcing FAS eliminated the recorded infringements of the *Mura Messapiche Archaeological park* no-fly zone. The infringement rate decreased from the baseline value of approximately 0.803 infringements per flight hour to zero at every evaluated deviation threshold—DT4, DT16, DT64 and DT128—and across all tested UAS traffic-density levels. This corresponds to an absolute reduction of 0.803 infringements per flight hour and a relative reduction of 100%. Success criterion CRT-SOL0520-TRL2-ERP-007.002 was therefore assessed as OK.

The improved geographical-zone protection in Manduria was accompanied by a reduction in flight-authorisation approval rates. Compared with Exercise 1, Exercise 2 introduced additional constraints related to manned-aircraft traffic and no-fly zones, in addition to UAS–UAS strategic deconfliction. The resulting reduction in available airspace caused FAS to reject a larger proportion of candidate flight plans. The approval rate also decreased as the deviation threshold increased because larger protected volumes imposed more restrictive separation requirements.

For Scenario 3, Shannon, the FAS also eliminated all recorded infringements of the Shannon Estuary Special Protection Area. The baseline rate of approximately 0.911 infringements per flight hour decreased to zero for every evaluated deviation threshold—DT0, DT4, DT8, DT16, DT64 and DT128—and at every tested traffic-density level. This represents an absolute reduction of 0.911 infringements per flight hour and a relative reduction of 100%. Success criterion CRT-SOL0520-TRL2-ERP-007.003 was therefore assessed as OK.

As in Manduria, the inclusion of the geographical-zone and manned-aircraft constraints reduced the flight-authorisation approval rate in Shannon compared with Exercise 1. Increasing the deviation threshold further reduced the proportion of authorised flight plans. The security and environmental benefit provided by geographical-zone enforcement must therefore be considered together with its effect on access to the airspace and operational capacity.

OBJ-SOL0520-ERP-007 was partially achieved, and the FAS produced a complete reduction in observed geographical-zone infringements in both scenarios where no-fly zones were implemented. However, the objective could not be assessed in Benidorm. The results demonstrate that FAS can provide an effective strategic barrier against planned entry into protected geographical zones under the evaluated simulation conditions, although this benefit is obtained at the cost of lower flight-authorisation approval rates as the operational constraints and deviation thresholds increase.

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4.2.8 OBJ-SOL0520-ERP-008 Results

OBJ-SOL0520-ERP-008 aimed to quantify the variation in geographical-zone infringements per flight hour resulting from the implementation of the CM service. The evaluated configurations combined CM, with and without pre-alerting, with the FAS. The results were compared both with the unmitigated baseline established under OBJ-SOL0520-ERP-006 and with the FAS-only configuration assessed under OBJ-SOL0520-ERP-007.

For Scenario 1, Benidorm, the objective could not be evaluated because no no-fly zone was implemented in the ENGage simulator. Therefore, no baseline geographical-zone infringement rate was available and the effect of CM on such infringements could not be determined. Success criterion CRT-SOL0520-TRL2-ERP-008.001 was consequently assessed as NOK.

For Scenario 2, Manduria, the configurations using CM alerting at DT16 and DT64, as well as CM pre-alerting at DT16, maintained the geographical-zone infringement rate at zero across all tested UAS traffic-density levels. Compared with the unmitigated baseline of approximately 0.803 infringements per flight hour, the combined FAS-and-CM configurations therefore produced an absolute reduction of 0.803 infringements per flight hour and a relative reduction of 100%. Success criterion CRT-SOL0520-TRL2-ERP-008.002 was assessed as OK.

However, the Manduria results do not demonstrate an additional measurable contribution from CM beyond that already provided by FAS. The FAS-only configuration had already reduced the infringement rate to zero by preventing candidate trajectories that entered the no-fly zone from being authorised. CM does not directly evaluate geographical-zone constraints; it monitors deviations from the authorised trajectory and initiates recovery when the applicable conformance conditions are exceeded. Since no geographical-zone infringements remained after the application of FAS, there was no residual event rate against which an incremental CM benefit could be demonstrated.

For Scenario 3, Shannon, both CM alerting and CM pre-alerting at DT16 maintained the Shannon Estuary infringement rate at zero across the evaluated traffic-density levels. Relative to the unmitigated baseline of approximately 0.911 infringements per flight hour, this represents an absolute reduction of 0.911 infringements per flight hour and a relative reduction of 100%. Success criterion CRT-SOL0520-TRL2-ERP-008.003 was therefore assessed as OK.

As in Manduria, the zero-infringement result in Shannon matched the result obtained with FAS alone at the same deviation threshold. Consequently, no additional reduction in geographical-zone infringements could be attributed specifically to either CM mode. The results indicate that the strategic prevention of infringements was primarily achieved during the flight-authorisation process, while the monitoring layer did not produce a separately measurable geographical-zone protection benefit under the evaluated conditions.

OBJ-SOL0520-ERP-008 was partially achieved. The combined FAS-and-CM configurations reduced geographical-zone infringements by 100% relative to the unmitigated baseline in Manduria and Shannon, whereas the objective could not be assessed in Benidorm. Nevertheless, the validation does not demonstrate an incremental benefit from CM compared with FAS alone. This finding does not imply that CM is unnecessary in general: CM may still provide protection where an aircraft deviates from an authorised trajectory towards a restricted geographical zone. It indicates only that such an additional benefit was not observable in the evaluated scenarios because FAS had already eliminated the infringements recorded by the relevant KPI.

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4.2.9 OBJ-SOL0520-ERP-009 Results

OBJ-SOL0520-ERP-009 aimed to quantify the impact of fauna on air risk and to determine whether the applicable Target Level of Safety (TLS) was maintained. Within the ENGage simulations, fauna-related risk was addressed indirectly through the geographical-zone mechanism evaluated under OBJ-SOL0520-ERP-006, OBJ-SOL0520-ERP-007 and OBJ-SOL0520-ERP-008. Areas associated with fauna protection were represented as no-fly zones, and the number of UAS entries into these zones was used as the relevant proxy indicator.

For Scenario 1, Benidorm, the objective could not be evaluated because no no-fly zone was implemented in the ENGage simulator. Consequently, no fauna-sensitive area was represented and no fauna-related exposure or geographical-zone infringement rate could be calculated. Success criterion CRT-SOL0520-TRL2-ERP-009.001 was therefore assessed as NOK.

For Scenario 2, Manduria, the Mura Messapiche park was implemented as a geographical zone. However, the available scenario data did not identify this area as a fauna-protection zone. Unlike the Special Protection Area used in Shannon, its geographical-zone definition could not be associated with a documented fauna-related risk. Therefore, the absence of UAS entries into this area could not be interpreted as evidence of fauna-risk mitigation, and no fauna-specific result could be derived. Success criterion CRT-SOL0520-TRL2-ERP-009.002 was consequently assessed as NOK.

For Scenario 3, Shannon–Limerick, the River Shannon and River Fergus Estuaries Special Protection Area was represented as a no-fly zone. The area is designated for the protection of its bird population; preventing UAS operations from entering this airspace therefore represents an environmental and fauna-risk mitigation measure as well as an airspace-security measure.

FAS prevented authorised trajectories from entering the estuary no-fly zone. The geographical-zone infringement rate was zero infringements per flight hour across all tested UAS traffic-density levels and at every evaluated deviation threshold. Under the assumptions of the simulation, UAS were therefore prevented from entering the area in which exposure to the protected bird population was represented. On this basis, success criterion CRT-SOL0520-TRL2-ERP-009.003 was assessed as OK.

The Shannon result demonstrates the effectiveness of a geographical-zone-based strategic mitigation for avoiding operations in a designated fauna-sensitive area. However, it does not constitute a direct quantitative assessment of the probability or severity of a UAS–fauna encounter. Fauna movements, population density, seasonal behaviour and bird–UAS collision dynamics were not represented by a dedicated fauna-risk model [11]. The zero-infringement result should therefore be interpreted as evidence that the simulated UAS traffic was excluded from the designated exposure area, rather than as evidence that the residual fauna-related air risk was universally zero.

OBJ-SOL0520-ERP-009 was partially achieved. The objective was successfully evaluated only in Shannon, where the fauna-relevant Special Protection Area was represented and no UAS infringements were recorded. It could not be evaluated in Benidorm because no geographical zone was implemented, or in Manduria because the implemented zone was not documented as fauna-related. The results support geographical-zone enforcement as a potentially effective preventive

[11] This constitutes an *Assumption*, further detailed in *Appendix B.*

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barrier for protected fauna areas, while further modelling would be required to quantify fauna-related air risk outside designated zones or under dynamic ecological conditions.

4.3 Confidence in validation results

4.3.1 Limitations of validation results

The validation results should be interpreted within the scope of the assessed scenarios, traffic patterns, airspace configurations, and modelling assumptions. The analyses are representative of the Benidorm, Manduria, and Shannon–Limerick environments and are based on realistic trajectories, stochastic navigation errors, environmental disturbances, modelled human behaviour, and probabilistic fault events. Several services were evaluated under conditional or scenario-specific assumptions, including pairwise encounters, predefined trajectory sets, simplified pilot response models, and limited traffic configurations. Consequently, the results should not be interpreted as direct estimates of operational encounter frequencies, authorisation approval rates, or maximum achievable airspace capacities. Quantitative outputs remain sensitive to assumptions regarding sensor performance, wind effects, simulation time step, excursion rate, loss-of-control behaviour, and response delays. In addition, rare-event estimation is inherently constrained by finite simulated exposure, meaning that zero observed collision events do not imply zero underlying risk. Nevertheless, although absolute risk and capacity values may vary under different assumptions, the key behavioural trends and relative effectiveness of the assessed U-space services were consistently observed across three independently validated simulators, providing confidence that the main insights are transferable to a wider range of operational environments.

4.3.1.1 Quality of validation results

Quality of the consolidated results is assessed here in terms of the accuracy of, and confidence in, the reported KPIs, with specific attention to the quantitative divergences between platforms. These divergences are not stochastic noise: they are systematic, reproducible, and traceable to five identified differences in the modelling mechanisms of the three simulators. Making these mechanisms explicit is essential both to establish the confidence that can be placed in each platform's figures and to interpret the consolidated ranges correctly.

The CRA implementation of the flight-authorisation conflict check evaluates distances between discrete points along the interpolated flight plans at a 1-second resolution; it does not test for intersections between the line segments joining consecutive points. Conflict geometries in which two trajectories cross between sampling instants can therefore escape detection at authorisation time, and reducing the interpolation interval has been verified to lower the residual risk at the price of computational cost. In addition, the CRA trajectory model applies a deliberately conservative disturbance model yielding an excursion rate of approximately 27%, driven by sensor noise, wind effects and a 5% probability of loss of control (modelled as 100 s of constant velocity and heading). The combination of these two mechanisms explains why the CRA residual NMAC rate saturates towards a non-zero floor at large deviation thresholds (DT = 64–128 m) rather than decreasing to zero: however wide the strategic buffer, a fraction of vehicles leaves its authorised corridor, and a fraction of the resulting crossings occurs between discrete checking instants. The CRA figures at large DT are accordingly to be read as a conservative upper bound on the residual risk.

The UPV implementation adopts a different detection principle: rather than comparing trajectory positions point-to-point at discrete instants, it evaluates the linear region swept between the previous

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and the current time step, effectively checking each proposed segment — and the protected corridor around it — against the corresponding segments of the active traffic over their overlapping time intervals. This continuous, swept-area formulation cannot miss inter-sample crossings; a proposed flight is rejected whenever its swept path would penetrate the protected volume of an already authorised flight. Therefore, once the deviation threshold is large relative to the modelled trajectory dispersion, the UPV residual UAS–UAS conflict count decreases smoothly and reaches zero, which is the theoretically expected behaviour of an exhaustive strategic filter. UPV substantiates this behaviour analytically: for the limiting Certified_Unknown category (horizontal NMAC distance 152.4 m), the protected deconfliction distance, the TSE margins of both aircraft (14.3 m each) plus their MAC dimensions (10.0 m each) plus twice the deviation threshold, exceeds the NMAC distance for thresholds of approximately 60 m, so that the authorised spacing alone covers the NMAC scale and the NMAC frequency is expected to approach zero despite a non-zero excursion frequency. UPV appropriately cautions that a zero observed frequency in a Monte Carlo output means only that no event occurred within the simulated exposure, not that the true underlying frequency is zero; the exposure-limited capacity estimates for Shannon at DT ≥ 32 m are reported in this spirit. In the UPV framework, vehicles involved in a MAC event are additionally removed from the active traffic population, so no post-collision encounters inflate the counts.

4.3.1.2 Significance of validation results

All results derive from Monte Carlo campaigns sized to accumulate a statistically significant number of flight hours per scenario and configuration, with seeded stochastic draws ensuring exact reproducibility of every repetition for post hoc analysis and replay. For high-frequency indicators (baseline NMAC rates, risk ratios at small deviation thresholds), the dispersion across repetitions is small relative to the observed trends, and the reported density dependence is not driven by simulation variability. For rare-event indicators (residual NMAC at DT = 64–128 m, UAS–manned MAC), individual counts approach the exposure-limited resolution of the campaigns; apparent orderings at this level — such as a single residual event at DT = 128 m against none at DT = 64 m — are exposure artefacts and are not interpreted as physical differences.

Operational significance

The three scenarios are derived from real operational environments and populated with the traffic mix defined in D2.3 and with manned traffic derived from historical ADS-B data, which supports the operational realism of the density sweeps and of the service models. At the same time, the results of this section demonstrate that quantitative KPI values at TRL2 are conditioned by simulator-level design choices to a degree comparable with the effects under study at large deviation thresholds.

The cross-platform analysis leads to a clear methodological conclusion, differences in the underlying assumptions of the trajectory models and of the conflict-detection and conflict-counting algorithms directly and systematically determine the variability observed in the validation results. This variability does not undermine the solution-level conclusions, which rest on the convergent findings of three independent implementations. Still, it does bound the precision with which capacity figures can be stated at this maturity level. It demonstrates that U-space performance figures produced by any single simulator cannot be assumed transferable.

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5 Conclusions and recommendations

5.1 Conclusions

This section consolidates the conclusions derived from Validation Exercises #01 and #02. The two exercises progressively assessed the U-AGREE mitigation framework, beginning with the unmitigated baseline and the initial implementation of Flight Authorisation, Traffic Information and Conformance Monitoring, and subsequently extending the assessment to Final Flight Authorisation[12] (including Strategic Conflict Resolution, Dynamic Airspace Reconfiguration and geographical-zone management) and Tactical Conflict Prediction and Resolution.

5.1.1 Conclusions on project/ SESAR solution maturity

The validation activities confirm achievement of the targeted exploratory-research maturity for SESAR Solution 0520 (TRL2) and provide a coherent basis for subsequent R&I activities. Validation Exercise #01 established the baseline safety and capacity limitations and assessed the progressive contribution of Flight Authorisation, Traffic Information and Conformance Monitoring. Validation Exercise #02 incorporated the final risk models and extended the framework to mixed UAS-manned strategic deconfliction, geographical-zone constraints and advanced strategic and tactical functionalities, including SCR, coordinated DAR rerouting and TCP&R.

The overall validation outcome is positive at solution level. The results consistently demonstrate the need for mitigation in the assessed operational environments and confirm that the proposed service layers can provide meaningful safety and operational benefits. Confidence is high in the qualitative conclusions and in the direction of the principal effects, particularly the dominant strategic contribution of FAS, the prevention of geographical-zone infringements and the conditional benefit of tactical mitigation. Confidence is lower in exact numerical values obtained in rare-event regions, at large deviation thresholds or from configurations with very few residual events.

The results also show that the different elements of the solution have not reached the same maturity. Strategic Flight Authorisation and static geographical-zone enforcement are more clearly defined and produce the most repeatable effects. By contrast, the tactical phase remains strongly dependent on algorithmic choices, conflict definitions, manoeuvring responsibilities, CNS assumptions, response behaviour and the treatment of simultaneous conflicts. Tactical conflict management therefore requires further exploratory definition and validation before a common operational implementation or generally transferable mitigation credit can be established.

5.1.2 Conclusions on concept clarification

The validation work confirms the U-AGREE concept as a layered risk-management framework in which the different services address distinct stages in the evolution of collision and operational risk. Flight Authorisation provides the principal strategic safety gate by determining which trajectories may enter

[12] This concept is further defined in Appendix B, dedicated to exercise #02.

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the active operational environment. Batch 1 demonstrated its direct influence on UAS-UAS conflict populations, while Batch 2 extended strategic deconfliction to declared manned-aircraft trajectories and, where implemented, geographical-zone constraints.

Traffic Information and TCP&R address residual encounters during operation, but their operational roles are different. TIS provides information from which an appropriate response must subsequently be selected and executed, making its effectiveness dependent on CNS and Human Performance. TCP&R extends the tactical chain by predicting a conflict and generating a resolution manoeuvre. Its contribution nevertheless remains conditional on the resolution logic, available look-ahead time, required separation, aircraft performance, response delay and successful execution of the manoeuvre.

Conformance Monitoring primarily supports containment and the management of deviations from authorised trajectories. Without pre-alerting, corrective action begins at the outer monitoring boundary and limits the continuation of an excursion without preventing the initial TSE exceedance. With pre-alerting, recovery begins at the TSE boundary and provides an earlier containment response. When used together with TCP&R, Conformance Monitoring should not be interpreted as the primary tactical collision-resolution service; tactical conflict prevention and resolution remain the responsibility of TCP&R.

The advanced Final FAS functionalities have complementary roles. SCR supports the recovery of U-plans that would otherwise be rejected by identifying an alternative conflict-free route. Coordinated DAR rerouting manages flights already active when a portion of airspace becomes unavailable and supports their safe and orderly diversion. Geographical-zone enforcement operates as a hard authorisation constraint, preventing candidate trajectories from entering a protected volume rather than progressively reducing infringement probability through a larger deviation threshold.

The exercises also clarify the distinction between safety-based and operationally achievable capacity. A collision-frequency criterion may support a theoretical traffic level above the number of trajectories that can actually be generated, allocated and authorised within the available airspace. In these cases, safety is no longer the limiting factor; capacity is constrained by trajectory availability, the Flight Authorisation process and the Authorisation Approval Rate.

Performance cannot be inferred from traffic density or aircraft mix alone. Local spatial and temporal traffic organisation - including route concentration, vertical distribution, crossing patterns, delivery hubs, scanning operations and encounter geometries - materially affects collision frequency and service performance. Operational scenarios must therefore represent traffic patterns as well as aggregate demand. Overall, the services should be treated as successive and complementary barriers rather than interchangeable alternatives.

5.1.3 Conclusions on technical aspects

The two validation exercises confirm the technical feasibility of implementing and assessing the main U-AGREE services in fast-time simulation environments. The partner platforms represented traffic generation, trajectory propagation, strategic deconfliction, geographical-zone enforcement, conflict detection, alerting, response, recovery, route replacement and tactical manoeuvre execution. The independent implementations provide useful cross-validation and demonstrate that several technical approaches can realise the intended service functions.

Algorithmic and implementation choices nevertheless materially influence quantitative results. Relevant differences include simulation time step, interpolation and swept-path treatment, conflict-

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detection logic, protected-volume construction, rejection or replacement of U-plans, removal or retention of aircraft after a MAC, disturbance modelling, event counting and exposure normalisation. These differences become particularly important when residual events are rare or lie close to the applicable safety criterion.

TCP&R provides the clearest example of this implementation sensitivity. ENGage applies an RRT-based trajectory-resolution process, CRA uses a differential-geometry approach and UPV applies a CPA/velocity-obstacle heading search within a paired encounter model. The implementations also differ in conflict construction, processing of simultaneous encounters, look-ahead time, separation factors, priority rules, response assumptions and return-to-track behaviour. These differences demonstrate the feasibility of multiple algorithms but prevent direct transfer of a single numerical mitigation credit across platforms.

TCP&R performance is affected by look-ahead time, protection volume or separation factor, CNS performance, response delay, aircraft responsibilities and the residual encounter population. UAS-UAS and UAS-manned encounters require separate models and interpretation. In the mixed encounter, only the UAS manoeuvres, while the larger manned-aircraft NMAC dimensions may require a clearance that cannot always be achieved within the available detection and response time.

SCR and DAR were also shown to be technically feasible, although their effectiveness depends on route availability. SCR depends on free cells and on the possibility of preserving mandatory operator-defined waypoints. The ML route search and A*[13] fallback can identify a feasible route when one exists but cannot resolve an operation for which the constraints leave no compatible alternative. DAR coordinated rerouting similarly depends on the distribution of affected flights, predefined safe-landing locations and available routing space.

Static geographical-zone enforcement was successfully incorporated into FAS. However, conditional and time-activated geographical zones were not represented. The validation therefore demonstrates static enforcement but does not establish the technical and coordination requirements for dynamic activation, deactivation or permission-based access to particular geofenced areas.

The principal technical limitation at the current maturity level is not the absence of feasible algorithms, but the lack of sufficiently detailed and harmonised service specifications to support tighter quantitative convergence. Further specification is required for strategic deconfliction, tactical conflict management, containment functions, event accounting and the interaction between mitigation layers.

5.1.4 Conclusions on performance assessments

Safety

Across both validation exercises, the unmitigated baseline results consistently show that collision-related frequencies increase with traffic density and that the assessed environments provide negligible or very limited concurrent capacity against the applicable safety criteria. Although absolute frequencies and capacity estimates differ between platforms and scenario configurations, the common

[13] As defined in *paragraph B.4*.

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conclusion from both batches is that scalable UAS operations require the introduction of strategic and tactical U-space mitigation services.

Validation Exercise #01 demonstrated that FAS provides the dominant and most repeatable strategic safety contribution for UAS-UAS encounters. Residual MAC and NMAC frequencies generally decrease as the deviation threshold increases, with the largest thresholds producing very low or zero observed events in several configurations. The improvement is scenario-dependent, and a substantial relative reduction does not necessarily imply compliance where the applicable safety criterion remains particularly stringent.

Batch 1 also showed that the providence associated with progression from NMAC to MAC changes substantially after strategic deconfliction. In the unmitigated baseline, estimated providence ranges from approximately 20% to 60%, depending on the scenario, whereas it decreases to below 1% in the FAS-mitigated configurations. Nevertheless, the NMAC safety criterion is derived from the MAC criterion using a fixed providence assumption of 10%. This assumption overestimates progression to MAC after FAS is applied and produces a conservative NMAC criterion for the mitigated configurations. Consequently, compliance is generally achieved only at the larger deviation thresholds, despite the substantially lower progression observed after strategic deconfliction. Further statistical evidence would be required before the observed mitigated providence values could be used to revise the criterion.

The Batch 1 TIS assessment provides evidence of conditional tactical risk reduction, with Risk Ratios below one for the assessed UAS-UAS and UAS-manned encounters. However, TIS only provides information: the benefit depends on accurate and timely information being correctly interpreted and followed by a suitable manoeuvre that is successfully executed within the available encounter time. Its operational mitigation credit therefore remains conditional on the CNS and Human Performance levels that can be assured. The available results demonstrate sensitivity to response-time distributions, manoeuvre strategies and encounter family rather than an empirically validated pilot-performance model.

Batch 1 further showed that Conformance Monitoring provides a targeted containment and residual-safety contribution. Its effect is clearer for limiting the duration or magnitude of deviations and, in some cases, preventing progression towards MAC than for producing a uniform NMAC reduction. Without pre-alerting, recovery begins at the outer monitoring boundary after the initial TSE exceedance; with pre-alerting, recovery begins at the TSE boundary and provides an earlier containment response. The incremental benefit remains dependent on communication and reaction delays, recovery logic, deviation geometry and the residual event population.

Validation Exercise #02 extended the strategic safety assessment by including declared manned-aircraft trajectories in Final FAS. Final FAS therefore directly reduces both UAS-UAS and UAS-manned collision frequencies, rather than affecting mixed encounters only indirectly through redistribution of UAS traffic. For UAS-manned encounters, smaller deviation thresholds may be sufficient to prevent progression to MAC while residual NMAC remains possible. A stronger NMAC reduction is obtained when the complete protected distance reaches the applicable UAS-manned NMAC separation scale. The UAS-manned criterion consequently remains the limiting criterion in several configurations.

The Batch 2 TCP&R assessment provides additional evidence on tactical mitigation. UPV and CRA demonstrate substantial potential reductions for UAS-UAS encounters when sufficient detection and manoeuvring space is available. By contrast, the UAS-manned benefit is more limited and less monotonic because only the UAS manoeuvres and the larger manned-aircraft NMAC dimensions may

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require a clearance that cannot be achieved within the available detection and response time. ENGage obtained tactical results comparable to FAS alone within simulation variability where strategic deconfliction had already reduced residual events to the detection floor. The consolidated conclusion is that TCP&R can reduce residual risk, particularly for UAS-UAS encounters, but no common quantitative mitigation credit can yet be generalised across algorithms, scenarios and operating conditions.

Batch 2 also provides complementary functional safety evidence. SCR preserves strategic separation by accepting an alternative route only when a compatible conflict-free solution is identified. Coordinated DAR rerouting improved conflict-free diversions from 1/5 to 5/5, from 2/10 to 10/10 and from 0/20 to 19/20 in the assessed Shannon-Limerick configurations, showing that coordination prevents simultaneous contingency diversions from creating additional conflicts.

Overall, the two batches establish a consistent safety hierarchy. FAS provides the clearest and most robust strategic reduction; TIS and TCP&R address residual tactical encounters under explicit CNS, response and manoeuvre assumptions; and Conformance Monitoring limits the consequences of deviations from authorised trajectories. Their contributions are complementary, but their mitigation credits must remain specific to the validated scenario, encounter family, implementation and statistical exposure.

Capacity

Across both exercises, the unmitigated baseline provides negligible or very limited capacity in the assessed operational environments. FAS produces the clearest direct capacity contribution because it changes the set of trajectories admitted before operation. Capacity increases only when residual collision frequency falls below the applicable safety criterion, and the resulting value remains strongly dependent on scenario, deviation threshold, encounter family, local traffic organisation and modelling approach.

In Validation Exercise #01, Benidorm generally showed limited capacity improvement at smaller deviation thresholds and a more pronounced increase once a sufficiently large threshold was applied. Manduria required comparatively large thresholds before the risk reduction translated into demonstrable compliance, while Shannon-Limerick generally supported larger capacity increments. These differences confirm that no single deviation threshold can be assumed to provide equivalent capacity performance in every operational environment.

Batch 1 also demonstrated that safety-based capacity may exceed the traffic that can be operationally accommodated. Where the theoretical value is higher than the number of trajectories that can be generated, allocated and authorised, trajectory availability and FAS performance become the limiting factors. The result must therefore be identified as safety-based capacity rather than as an achievable operational traffic level.

Validation Exercise #02 retained this distinction and added the effect of UAS-manned strategic deconfliction. The UPV assessment demonstrates potentially substantial safety-based capacity increments once the protected distance reaches the UAS-manned NMAC separation scale. At smaller thresholds, the UAS-manned criterion remains limiting despite larger UAS-UAS estimates. ENGage reports no robust capacity increment where measurable residual frequencies remain incompatible with the stringent criterion or where an apparent increment is supported by only one or very few events. These results are complementary rather than directly contradictory: they reflect different exposure, modelling and extrapolation conditions and reinforce the need for cautious interpretation of low-frequency capacity estimates.

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The Batch 1 Conformance Monitoring results did not demonstrate a uniform capacity increment. Some configurations produced a higher estimate than FAS alone, while others showed no improvement or a statistically indistinguishable result. Conformance Monitoring should therefore be credited primarily as a containment and residual-safety barrier unless an additional capacity benefit is demonstrated with sufficient scenario-specific statistical confidence.

In Batch 2, SCR provides a complementary operational-capacity benefit by recovering U-plans that would otherwise be rejected. Across the four predefined Benidorm configurations, initial acceptance rates of 84%, 92%, 86.7% and 79% increased to 92%, 98%, 96% and 91% with 2D SCR and to 88%, 96%, 94.7% and 86% with the more conservative 3D implementation. These values demonstrate functional improvement for the selected trajectory sets but do not constitute statistically representative resolution probabilities or estimates of maximum airspace capacity.

Capacity conclusions from both batches must therefore be accompanied by the applicable safety criterion, simulated exposure, residual event count, trajectory availability, average number of authorised U-plans and Authorisation Approval Rate. Zero observed events and estimates exceeding the available trajectory population should not be interpreted as directly achievable operational traffic levels.

Security and Environment

Security and Environment were assessed principally in Validation Exercise #02 through geographical-zone management. Final FAS completely prevented geographical-zone infringements in the Manduria and Shannon-Limerick configurations assessed by ENGage. The unmitigated rates of 0.803 infringements/FH in Manduria and an average of 0.911 infringements/FH in Shannon-Limerick were reduced to zero at every tested deviation threshold. The threshold-independent result confirms that geographical-zone enforcement operates as a hard authorisation constraint rather than as a progressive separation-buffer effect.

Conformance Monitoring provided no additional measurable reduction in these configurations because FAS had already prevented authorised trajectories from entering the restricted zones. This does not imply that Conformance Monitoring is unnecessary for geographical-zone protection in general. Its incremental value should be assessed in configurations where the authorised trajectory remains outside the zone but the actual trajectory can deviate into it.

In Shannon-Limerick, geographical-zone enforcement also provides simplified fauna-risk mitigation because the restricted volume corresponds to the River Shannon and River Fergus Estuaries Special Protection Area. However, the simulation does not represent species, seasonality, time of day, altitude or moving bird corridors. No equivalent fauna-related conclusion can be drawn for the archaeological geozone in Manduria or for Benidorm, where no geozones was implemented in the relevant assessment.

Access and Equity

The two validation exercises show a consistent trade-off between strategic protection and access to airspace. Batch 1 demonstrated that the Authorisation Approval Rate decreases as traffic demand and deviation threshold increase because larger protected volumes reduce the number of compatible trajectories. The magnitude of this effect depends on scenario geometry, available airspace, local traffic patterns and vertical distribution.

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Batch 2 introduced additional manned-aircraft and geographical-zone constraints. Relative to the less constrained Batch 1 implementation, the combined consideration of manned-aircraft corridors and geographical zones reduced the Authorisation Approval Rate by approximately 10-13 percentage points in Manduria and Shannon-Limerick. This reduction represents the operational cost of requiring candidate trajectories to remain compatible with a broader set of safety, security and environmental constraints.

SCR can partially compensate for this restriction by proposing an alternative conflict-free route rather than directly rejecting an incompatible request. Its effectiveness depends on route availability, mandatory waypoints, authorisation order and occupancy created by previously accepted trajectories. The descriptive acceptance percentages obtained in the predefined Benidorm cases should not be generalised as a scenario-wide Authorisation Approval Rate.

TIS, TCP&R, DAR and Conformance Monitoring do not directly change the initial Authorisation Approval Rate in the assessed architectures because they act after authorisation or during operation. Their contributions concern residual-risk management, containment and contingency response rather than initial access to the airspace. Selection of an operational configuration must therefore balance safety improvement, compliant capacity, trajectory availability and equitable access rather than maximising the deviation threshold alone.

Overall performance conclusion

Taken together, Validation Exercises #01 and #02 confirm that Safety, Capacity, Security, Environment and Access and Equity cannot be assessed independently. Batch 1 established the baseline limitations and the layered contribution of FAS, TIS and Conformance Monitoring. Batch 2 extended the concept to direct UAS-manned strategic deconfliction, TCP&R, SCR, DAR and geographical-zone enforcement. The consolidated evidence supports the layered concept while showing that each barrier acts on a different stage of risk and should receive only the mitigation credit demonstrated under its validated conditions.

Strategic restrictions can reduce collision and infringement risk and support higher safety-based capacity while simultaneously reducing the set of trajectories that can be authorised. Tactical and containment services can reduce residual risk without directly increasing trajectory-allocation capability. Conversely, alternative-route generation can improve operational accommodation without independently demonstrating compliance with collision-frequency criteria.

The preferred operational configuration should therefore be selected through a balanced assessment of collision frequency, providence, safety-based capacity, simulated exposure, trajectory availability, Authorisation Approval Rate, geographical-zone protection, containment performance and reliability of the tactical response chain. No single KPI, service or maximum parameter value is sufficient to characterise overall solution performance.

5.1.5 Conclusions on human performance

The central Human Performance conclusion is that the Batch 1 TIS assessment provides an exploratory sensitivity model, not an empirically validated representation of remote-pilot performance. No representative human-in-the-loop experiment, operational dataset or validated workforce distribution was available to calibrate the pilot categories, response-time distributions, manoeuvre choices or compliance probabilities. This is particularly important for TIS because the service provides information but does not itself complete the avoidance action: its safety contribution depends on the information

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being received and understood and on a suitable manoeuvre being selected, commanded and successfully executed within the available encounter time.

The common assessment represented expert, intermediate and novice response through shifted-Gamma distributions with a five-second minimum delay and mean response times of approximately 20, 40 and 60 seconds. The UPV campaign retained the full set of ordered pilot-pair combinations and used the prescribed uniform population as the common reporting reference. These profiles also apply different manoeuvre strategies and return-to-track behaviour. They must therefore be understood as combined assumptions about timing, decision logic and manoeuvre execution, rather than as measured pilot populations or as a pure comparison of reaction time or expertise.

UPV simulation results confirm that these assumptions materially affect the TIS outcome. The official scenario results report residual Risk Ratios below one for the assessed UAS–UAS and UAS–manned encounters, supporting the potential of TIS to reduce conditional collision risk. However, the pilot-population sensitivities change both Risk Ratio and Loss-of-separation Ratio, and the direction and magnitude of the change differ between encounter families because response time and manoeuvre strategy vary together. CRA likewise found that the modelled benefit decreased substantially when a longer assumed human response was introduced. The consistent conclusion across the available evidence is therefore that the time and quality of the response are dominant sensitivities; the different numerical results do not validate any one Human Performance assumption.

Systems Performance and Human Performance must remain separate. CNS delay, packet loss, surveillance error, processing and display updates determine when and how accurately the information becomes available. Human monitoring, comprehension, decision-making, manoeuvre selection and command entry occur after that point, while aircraft dynamics determine when the manoeuvre becomes effective. Combining these stages into a single delay would conceal the cause of an unsuccessful outcome and prevent meaningful performance requirements from being assigned.

Human Performance is intrinsically difficult to reproduce in a fast-time pairwise encounter model because operational response depends on interface design, alert salience, information quality, encounter geometry, workload, fatigue, training, trust, competing tasks, procedures and organisational responsibilities. The assessed models cannot represent human prioritisation in case of multiple simultaneous alerts, interruption, supervision of several UAS, team coordination or mode confusion. Their results may therefore underrepresent both response variability and the probability of an inappropriate, delayed or incomplete action.

The evidence consequently supports a conditional conclusion: TIS can contribute to safety when accurate and timely information is followed by a correct and successfully executed response, but its operational mitigation credit cannot be guaranteed from the current pilot assumptions alone. The principal achievement of the Batch 1 Human Performance work is to expose this dependency, quantify its sensitivity under controlled assumptions and identify the stages that require separate requirements. Until the assumed distributions and behaviours are calibrated through representative human-in-the-loop trials using the intended interface, traffic, procedures and workload, TIS safety and capacity conclusions must remain conditional on an unverified Human Performance level.

5.1.6 Conclusions on automation level

The UPV TCP&R campaign assessed two automation-response families under exactly matched encounter and system configurations. The Autonomous case uses a Gamma response distribution with a mean of 3 seconds, while the RPAS case uses a shifted-Gamma distribution with a three-second

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minimum and a mean of 7 seconds to represent a slower human-mediated response. Communication and surveillance latency remain separate model stages. The comparison therefore isolates the executed response-time assumption; it does not compare different aircraft or provide an empirically calibrated model of every automated system or remote pilot.

For UAS–UAS encounters, the shorter Autonomous response provides the strongest and most consistent temporal margin. Across the 4,480 matched configurations, the RPAS assumption produces a higher Loss-of-separation Ratio in every case and a higher Risk Ratio in 4,364 cases (97.41%). At the reporting baseline and 45-second look-ahead, raw RR increases from 0.015927 for Autonomous to 0.020111 for RPAS, while raw LR increases from 0.204563 to 0.220903. The difference is much larger at short look-ahead and generally narrows as more response time becomes available, confirming that earlier detection can partly compensate for a slower response.

The UAS–manned results do not support the same universal ordering. The RPAS assumption produces the higher Loss-of-separation Ratio in 4,257 of the 4,480 matched cases (95.02%), but the Risk Ratio is almost evenly divided: RPAS is higher in 2,184 cases and Autonomous in 2,296, with a small negative median difference. At the 45-second reporting baseline the two raw RR values are also close, while LR remains higher for RPAS. The larger manned-aircraft encounter dimensions, the non-manoeuvring role assigned to the manned participant and the interactions with look-ahead, separation and CNS assumptions can reverse the small RR difference. UAS–UAS and UAS–manned results must therefore remain separate.

Overall, the comparison shows that reducing the response delay through automation can improve the tactical opportunity, most clearly for UAS–UAS encounters, and that a slower human-mediated chain can erode the benefit of an otherwise correct detection and resolution. However, response time is only one element of the end-to-end chain. Surveillance, communication and processing determine when usable data are available; human acceptance and command entry depend on the automation mode; and vehicle dynamics and manoeuvre success determine when the resolution becomes effective.

Automation does not eliminate Human Performance considerations. It changes the human role from direct command execution towards configuration, supervision, override, exception management and recovery. The appropriate automation level therefore cannot be selected solely by choosing the shortest mean response. It must also consider authority, workload, situation awareness, trust, the consequences of an incorrect automated manoeuvre, assurance of the resolution logic, failure detection and safe fallback.

The response distributions are modelling assumptions and the pairwise campaign does not include representative human-in-the-loop trials, multiple simultaneous alerts, operator workload, prioritisation or multi-USSP coordination. The principal conclusion is that increased automation offers a credible way to preserve tactical time margin, but its safety credit remains conditional on validation of both the automated function and the people, interfaces and procedures that govern its use.

5.2 Recommendations

This section contains recommendations for the next research and innovation (R&I) activities.

5.2.1 Recommendations for next R&I phase

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The next R&I phase should prioritize incremental progression from TRL2 toward higher maturity through a harmonized multi-platform validation programme. Validation specifications should be tightened at implementation level, with explicit alignment of conflict-detection logic, trajectory/interpolation treatment, event counting, exposure management and barrier activation assumptions, in order to reduce systematic dispersion and improve quantitative comparability.

Future validation activities should preserve the three reference scenarios and extend the assessed conditions with targeted additional cases that stress local traffic organization, trajectory-pattern effects and service-parameter sensitivity. Barrier performance should continue to be assessed both individually and in layered combinations, with case-by-case analysis of mitigation efficacy and explicit handling of residual-risk floors in rare-event conditions.

Concept and procedure refinements should focus on clearer operational definition of strategic, monitoring and tactical interfaces, including activation conditions, monitoring boundaries, recovery logic and coordination constraints. Functional requirements should be updated accordingly where validation has identified ambiguity or sensitivity with direct effect on performance interpretation.

In line with the WP5 workshop outcomes, future simulations should also extend the Flight Authorisation Service scope to include explicit requests for permission to operate in specific geofenced areas, together with dynamic geozones activation/deactivation logic. This extension is particularly relevant for operational conditions linked to temporary constraints such as bird activity and should be assessed as part of the strategic-mitigation workflow.

Human-performance aspects should be treated as a dedicated validation stream in the next phase, including broader response-behaviour assumptions, non-response effects, and evaluation of procedural/interface support and training implications for operational reliability. This work is necessary to consolidate confidence in services that depend on timely and consistent human reaction.

The continuation strategy should remain conservative and evidence-driven: first consolidate cross-platform reproducibility under harmonized assumptions, then progressively increase realism and scope as a controlled path to higher TRLs and broader SESAR integration.

The tactical phase requires particular attention. TCP&R is technically feasible, but conflict definitions, prioritisation rules, manoeuvring responsibilities, separation requirements and failure behaviour are not yet sufficiently harmonised to support a generally applicable mitigation credit. Future research should define how simultaneous and interacting conflicts are resolved, which participant manoeuvres in UAS-UAS and UAS-manned encounters, how secondary conflicts are managed, what occurs when no valid resolution is found or executed, and how consistency is ensured between different USSPs.

The complete detection-resolution-execution-return-to-track chain should be validated under common encounter geometries, CNS conditions, response-time assumptions and event-accounting rules. Future campaigns should include multiple simultaneous conflicts and assess whether resolving one encounter modifies or creates another.

The complete service chain should also be assessed in integrated configurations. Manned-aware FAS, geographical-zone enforcement, Conformance Monitoring and TCP&R have so far been evaluated individually or in partial combinations. Future campaigns should verify that tactical manoeuvres remain compatible with strategic authorisations, geographical-zone constraints, active DAR measures and decisions generated by other USSPs.

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Future capacity assessments should explicitly report statistical uncertainty, simulated exposure, residual event counts, trajectory availability and authorisation performance. Zero observed events should not be interpreted as zero underlying risk, and capacities derived from one or very few residual events should remain indicative until confirmed through additional repetitions, extended exposure or suitable rare-event methods.

Soft FAS deconfliction based on stochastic approaches and combined with highly automated TCP&R could not be assessed because the available information was insufficient to define and implement the concept consistently. Additional exploratory research at TRL2 is required to specify the interaction between probabilistic strategic decisions and automated tactical resolution, including the corresponding safety conditions and fallback mechanisms, before progression to a higher TRL can be considered.

5.2.2 Recommendations for future R&I activities

Beyond the immediate next phase, future R&I should address advanced collision-risk modelling and mitigation assessment methods able to better represent complex multi-aircraft interactions, richer operational perturbations and broader uncertainty structures while maintaining transparent traceability of assumptions.

Additional research should investigate new validation approaches for rare-event robustness, including methods that strengthen quantitative confidence in very low-frequency regions and improve interpretation of finite-exposure zero-event outcomes. These approaches are relevant to long-term safety-envelope definition for high-density operations.

Future research should also revisit the safety-criteria assumptions adopted in batch 2, where the conservative worst-case treatment assumed hull loss in case of MAC. Dedicated simulation campaigns and, when available, operational test evidence should be used to derive better-grounded severity estimates; this may support a refinement of the applicable safety criteria and associated performance targets.

Future activities should also explore extended operational concepts that integrate strategic and tactical services under more demanding coordination environments, including broader multi-provider interaction patterns and progressively realistic communication and surveillance conditions.

Human-performance research should continue beyond project scope with dedicated studies on response variability, non-response phenomena, training impact and human-machine interaction design, to support long-term operationalization of information-driven and tactical mitigation services.

For long-term SESAR opportunities, the solution evolution should follow a staged pathway from exploratory evidence to transferable industrial envelopes, combining conservative performance interpretation, progressively richer operational realism and systematic cross-platform benchmarking as foundations for future deployment-oriented research.

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6 References

6.1 Applicable documents

This ERR complies with the requirements set out in the following documents:

Content development

[1] DES HE requirements and validation & demonstration guidelines (1_0)

Performance management

[2] PJ19_04_D4_7 DES Performance Framework U-space Companion Document v00_01_02 (1_0)

Programme management

[3] 101167187 U-AGREE Grant Agreement, 25/06/2024

[4] SESAR 3 JU Project Handbook – Programme Execution Framework, 11/04/2022, Ed. 01.00

6.2 Reference documents

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[6] U-AGREE Consortium, D2.1 Operational Service and Environment Version 1 (OSED), 2025.

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Appendix A Validation exercise #01 report

A.1 Summary of the validation exercise #01 plan

Validation exercise #01 has been conducted in accordance with the activities planned for SESAR Solution SOL0520.

The *Human Performance Modelling* was introduced as a modelling refinement within the validation exercise to enhance the representation of operator behaviour. More information on this is provided in following paragraphs.

A.1.1 Validation exercise description and scope

The validation exercise description and scope are fully aligned with those defined in the ERP for SESAR Solution SOL0520.

Exercise #01 focuses on the assessment of the impact of I-space basic services (Flight Authorisation, Traffic Information and Conformance Monitoring) defined in Regulation 2021/664 [7] as mitigation barriers in the three scenarios chosen for the project.

Fast-time simulations, based on Monte-Carlo technique, have been conducted to generate statistically significant results and to calculate relevant KPIs, addressing the **Safety**, **Capacity** and **Access & Equity** Key Performance Areas, as defined in the ERP.

A.1.2 Summary of validation exercise #01 validation objectives and success criteria

The validation objectives and associated success criteria for validation exercise #01 reflect those of the ERP and have been enriched by the addition of new KPI (illustrated in paragraph 3.3 *Deviations*).

The exercise addresses the identification of baseline capacity and the **quantification of capacity increments** resulting from the progressive introduction of U-space services, while ensuring that the **safety levels** identified for each scenario are **not degraded**, in line with the ERP objectives.

A.1.3 Summary of validation exercise #01 validation scenarios

Validation scenarios for exercise #01 are fully aligned with those defined in the EPP. No changes have been introduced.

The exercise includes one reference scenario and three solution scenarios (Figure 2).

The reference scenario considers operations without U-space services, in which UAS operate in shared airspace without mitigation mechanisms. Risk estimation is conducted using the initial U-AGREE risk models under a no-mitigation assumption.

The solution scenarios introduce U-space services acting as mitigation barriers, with a progressive implementation of:

- Flight Authorisation Service and Traffic Information Service (Solution Scenario 1),
- Flight Authorisation, Traffic Information and Conformance Monitoring services without pre-alerting (Solution Scenario 2),

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- Flight Authorisation, Traffic Information and Conformance Monitoring services with pre-alerting (Solution Scenario 3).

These validation scenarios are evaluated in the three sub-operating environments defined in the ERP, namely Benidorm, Manduria and Shannon, described also in paragraph 3.2.1 and Annex A.

A.1.4 Summary of validation exercise #01 validation assumptions

In addition to the assumptions defined at ERP level, which apply to both exercises, the following assumptions are specifically introduced for Exercise #01.

Assumptions 10 through 13 represent a deviation with respect to the ERP and have been added after the implementation of key elements (e.g. human performance modelling) and a better understanding of exercise #01 implementation.

Assumption ID	Assumption title	Assumption description	Justification	Impact assessment
Assumption 09	Dynamic Airspace Reconfiguration	DAR is not considered in U-AGREE exercise #01.	The implementation of DAR is beyond the scope of exercise.	The absence of DAR may limit the representativeness of highly dynamic or demand-driven U-space environments.
Assumption 10	Human Performance Modelling	Human performance is represented through three pilot categories (expert, intermediate, novice) with Gamma-distributed reaction times and differentiated conflict resolution behaviours ranging from rule-based to random manoeuvres[14].	The approach enables the representation of heterogeneous human response behaviours in conflict detection and resolution processes.	The simplification may affect the fidelity of human behaviour representation and conflict resolution outcomes.
Assumption 11	Flight Authorisation Service – conflict resolution mechanism	FAS is applied in exercise #01 without a conflict resolution mechanism: conflicting U-plans are directly rejected. Manned aircraft are not deconflicted by GAS.	Simplifies strategic deconfliction logic for evaluation.	May over-constrain operational capacity.
Assumption 12	Traffic Information Service –	Only conflicts between two UAS at the time are	Reduces complexity of multi-agent	Does not capture multi-UAS or

[14] More information is defined in paragraph A.2.

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	pairwise conflict handling	considered for resolution in TIS.	conflict resolution modelling.	cascading conflict effects.
Assumption 13	Traffic information service – Rule-based conflict resolution logic	Conflict resolution within the TIS is based on the Rules of the air [20]. Alternative conflict resolution strategies may exist, particularly for simultaneous multi-UAS conflicts or different pilot behaviours.	A rule-based approach provides a simple conflict resolution mechanism for simulation purposes.	Results may differ under alternative conflict resolution strategies or more advanced coordination approaches.

Table 8: validation exercise #01 assumptions overview

A.2 Deviation from the planned activities

Some deviations from the ERP have been introduced:

1. Human Performance Modelling

In exercise #01, the *Human Performance Modelling* was introduced as a modelling refinement within the validation exercise. This enhancement was introduced to improve the realism and behavioural fidelity of the simulated human responses to tactical information, ensuring a more accurate representation of operator decision-making processes under realistic operational conditions.

To approach human performance, U-AGREE has adopted the existence of three possible human actors:

1. Expert pilot
2. Intermediate pilot
3. Novice pilot

The reaction time of each pilot has been adopted as a Gamma distribution, presented in the following figure:

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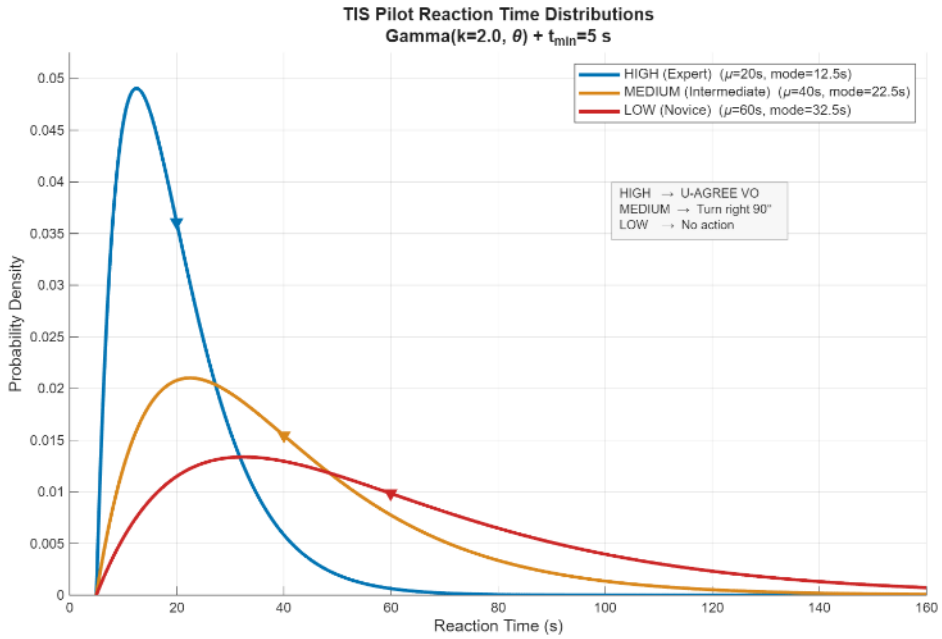


Figure 5: Distribution of the reaction time for the Human Performance

The parameters for each distribution are:

Pilot	κ	θ	t_min [s]	Mean [s]	Mode [s]
Expert	2.0	7.5	5	20	12.5
Intermediate	2.0	17.5	5	40	22.5
Novice	2.0	27.5	5	60	32.5

Table 9: Distribution of the reaction time for the Human Performance parameters

Each of these pilots, will implement different maneuvers to avoid the conflict:

Expert pilot maneuver:

This pilot, will perform an adapted version of the Rules of Air, defined in ICAO ANNEX II [20], originally defined for manned aircraft:

- *Approaching head-on:* When two aircraft are approaching head-on or approximately so and there is danger of collision, each shall alter its heading to the right.
- *Converging:* When two aircraft are converging at approximately the same level, the aircraft that has the other on its right shall give way.
- *Overtaking:* An overtaking aircraft is an aircraft that approaches another from the rear on a line forming an angle of less than 70 degrees with the plane of symmetry of the latter […]. An aircraft that is being overtaken has the right-of-way and the overtaking aircraft, whether climbing, descending or in horizontal flight, shall keep out of the way of the other aircraft by altering its heading to the right, and no subsequent change in the relative positions of the two

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aircraft shall absolve the overtaking aircraft from this obligation until it is entirely past and clear.

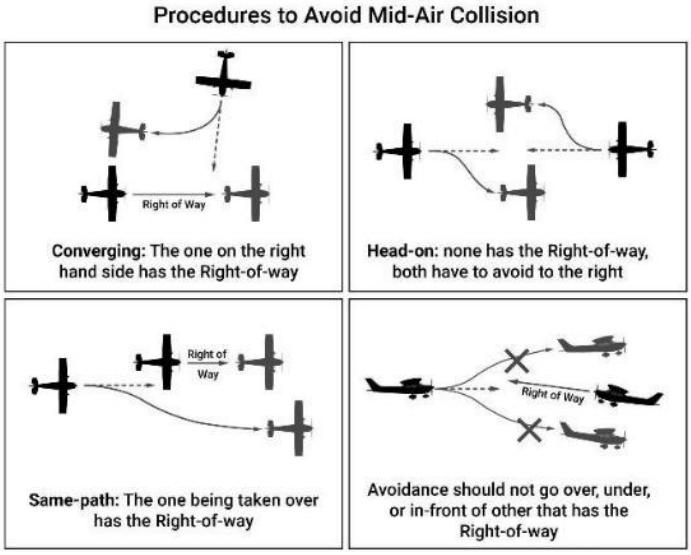


Figure 6: Rules of Air

Intermediate pilot maneuver:

This pilot will execute the rules of the air with a 50% likelihood, and in the remaining 50%, it will perform a random right or left turn.

Novice pilot maneuver:

This pilot, as he will be a novice, is not trained to perform the rules of the air maneuver; as a result, he will just turn right or left randomly.

2. New KPA

Other deviations in exercise #01 are the introduction of the new KPA of Access & Equity and related KPI. The reasoning behind this decision is illustrated in paragraph 3.3 *Deviations*.

3. Validation assumptions

Additional assumptions have been introduced and are shown in paragraph A.1.4 *Summary of validation exercise #01 validation assumptions* .

4. Exercise conducted

As anticipated in paragraph 3.3.2 not all the simulation scenarios originally planned for ENGage could be completed. During the execution of the validation campaign, some scenarios produced results that could not be considered sufficiently reliable for analysis due to limitations affecting the confidence of the outputs and the maturity of the corresponding implementations. As a result, these scenarios were excluded from the final assessment to preserve the robustness of the validation results.

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A.3 Validation exercise #01 results - ENGage

A.3.1 Summary of validation exercise #01 results

This sub-section summarises the results of validation exercise #01 from the ENGage simulator. Table 10: validation exercise #01 results - ENGag presents the summary of results compared to the success criteria identified within the ERP per validation objective. The analysis covers the validation objectives embedded in the validation exercise as per the corresponding ERP.

Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
OBJ-SOL0520-ERP-001[15]	Identification of the baseline capacity (N_0).	CRT-SOL0520-TRL2-ERP-001.001	The MAC frequency between UAS shall not exceed 4.35×10^{-5} per flight-hour in Scenario 1, for exercise #01.	Scenario 1: The city of Benidorm (non U-space sub-OE)	The number of concurrent UAS compatible with the required TLS has been calculated. At any tested density, including the minimum simulated concurrency (N = 2). This underlines the necessity to include U-space services in this scenario to obtain the required TLS.	OK
		CRT-SOL0520-TRL2-ERP-001.002	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 1, for exercise #01 and #02.			OK

[15] Only success criteria related to exercise 1 are illustrated here.

Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
		CRT-SOL0520-TRL2-ERP-001.003	The MAC frequency between UAS shall not exceed $1{,}5 \times 10^{-4}$ per flight-hour in Scenario 2, for exercise #01.	Scenario 2: The city of Manduria (non U-space sub-OE)	The number of concurrent UAS compatible with the required TLS has been calculated. At any tested density, including the minimum simulated concurrency (N = 2). This underlines the necessity to include U-space services in this scenario to obtain the required TLS.	OK
		CRT-SOL0520-TRL2-ERP-001.004	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 2, for exercise #01 and #02.			OK
		CRT-SOL0520-TRL2-ERP-001.005	The MAC frequency between UAS shall not exceed $1{,}7 \times 10^{-2}$ per flight hour in Scenario 3, for exercise #01.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	The number of concurrent UAS compatible with the required TLS has been calculated. At any tested density, including the minimum simulated concurrency (N = 2). This underlines the necessity to include U-space services in this scenario	OK
		CRT-SOL0520-TRL2-ERP-001.006	The MAC frequency between UAS and manned aircraft in uncontrolled airspace shall not exceed 10^{-7} per flight-hour in Scenario 3, for exercise #01 and #02.			OK

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
		CRT-SOL0520-TRL2-ERP-001.007	The MAC frequency between UAS and manned aircraft in controlled airspace shall not exceed 10^{-9} per flight-hour in Scenario 3, for exercise #01 and #02.		to obtain the required TLS.	OK
OBJ-SOL0520-ERP-002	Quantification of capacity increment (ΔN_1) because of the introduction of mitigation measures based on Flight Authorisation and Traffic Information services.	CRT-SOL0520-TRL2-ERP-002.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 1: The city of Benidorm (non U-space sub-OE)	Only the Flight Authorisation Service is included for this run. The Traffic Information Service is excluded, as its modelling is not yet validated to a reliable level. Under the same target level of safety, FAS *increases the maximum number of simultaneous UAS with respect to the unmitigated baseline:* **ΔN_1 = 0 for DT ≤ 32 meters and ΔN_1 = 0.7 at DT64.**	Partially OK

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
		CRT-SOL0520-TRL2-ERP-002.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 2: The city of Manduria (non U-space sub-OE)	Only the Flight Authorisation Service is included for this run. The Traffic Information Service is excluded, as its modelling is not yet validated to a reliable level. Under the same target level of safety, FAS *increases the maximum number of simultaneous UAS with respect to the unmitigated baseline:* **ΔN_1 = 0 for DT ≤ 16 meters and ΔN_1 = +25 at DT64 and ΔN_1 =+16 at DT128.**	Partially OK

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
		CRT-SOL0520-TRL2-ERP-002.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	Only the Flight Authorisation Service is included for this run. The Traffic Information Service is excluded, as its modelling is not yet validated to a reliable level. Under the same target level of safety, FAS *increases the maximum number of simultaneous UAS with respect to the unmitigated baseline:* **ΔN_1 = 6 for DT=4 meters, ΔN_1 = 10 at DT16, ΔN_1= 26 at DT64 and 128 meters.**	Partially OK

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
OBJ-SOL0520-ERP-003	Quantification of capacity increment (ΔN_2) because of the introduction of mitigation measures based on Flight Authorisation, Traffic Information, and Conformance Monitoring (without pre-alerting) services.	CRT-SOL0520-TRL2-ERP-003.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 1: The city of Benidorm (non U-space sub-OE)	For both DT, there is no capacity increase with respect to the one provided by FAS alone, so $\boldsymbol{\Delta N_2 = \Delta N_1}$. On the other hand, CM helps address a high number of non-conforming events, preventing them from escalating into NMACs. TIS is not included in simulations.	Partially OK
		CRT-SOL0520-TRL2-ERP-003.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 2: The city of Manduria (non U-space sub-OE)	No capacity increment obtained beyond those provided by FAS at DT16, so $\boldsymbol{\Delta N_2 = \Delta N_1}$. For DT64, the capacity increment of FAS+CM with respect to baseline is of $\boldsymbol{\Delta N_2}$**=15.** TIS is not included in simulations.	Partially OK

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
		CRT-SOL0520-TRL2-ERP-003.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	At DT16, the capacity increment with respect to baseline provided by FAS+CM is of $\boldsymbol{\Delta N_2}$**=11.** No capacity increment obtained beyond those provided by FAS For DT64 so $\boldsymbol{\Delta N_2 = \Delta N_1}$. TIS is not included in simulations.	Partially OK
OBJ-SOL0520-ERP-004	Quantification of the capacity increment (ΔN_3) because of the introduction of mitigation measures based on Flight Authorisation, Traffic Information, and Conformance Monitoring (with pre-alerting) services.	CRT-SOL0520-TRL2-ERP-004.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 1: The city of Benidorm (non U-space sub-OE)	For both DT, there is no capacity increase with respect to the one provided by FAS alone, so $\boldsymbol{\Delta N_2 = \Delta N_1}$. On the other hand, CM helps address a high number of non-conforming events, preventing them from escalating into NMACs TIS is not included in simulations.	Partially OK

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
		CRT-SOL0520-TRL2-ERP-004.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 2: The city of Manduria (non U-space sub-OE)	For both DT16 and DT64, no capacity increment with respect to those provided by FAS has been observed, so $\Delta N_3 = \Delta N_2 = \Delta N_1$. TIS is not included in simulations.	Partially OK

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
		CRT-SOL0520-TRL2-ERP-004.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	For DT16, the number of simultaneous UAS flying compatibly with TLS is of 9, so there is an increase in capacity with respect to the baseline levels of $\boldsymbol{\Delta N_3 = 8.}$ For DT64, no capacity increment with respect to those provided by FAS has been observed, so with respect to the baseline $\boldsymbol{\Delta N_3 = \Delta N_2 = \Delta N_1.}$ TIS is not included in simulations.	Partially OK

Table 10: validation exercise #01 results - ENGage

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A.3.2 Analysis of validation exercise #01 results per validation objective

The ENGage estimation uses a fast time simulation (FTS) engine based on five main pillars:

1. **Navigation error modelling**

Every simulated vehicle follows its nominal 4D trajectory perturbed by the *Ornstein-Uhlenbeck disturbance model*, a mean-reverting stochastic process applied independently to the cross-track and vertical axes (there is no along-track component), with a reversion rate of 0.05 s^{-1} on both axes. The process is constrained by a shared kinematic controller (maximum 50 m/s^2 acceleration, 50 m/s speed). The stationary deviation of the process is set to half of the vehicle's category-specific Total System Error (TSE) per axis, so the declared TSE corresponds to roughly 95% containment, and the process is initialised directly from its stationary distribution to avoid a warm-up transient.

At the start of each repetition, a seeded random draw assigns each vehicle an "excursion" behaviour, routing it to the hybrid model rather than the default Ornstein-Uhlenbeck model. The probability of this assignment decreases with the vehicle's operational assurance level, consistent with Regulation (EU) 2021/664: 10^{-2} for Open category, 10^{-3} for PDRA/STS and Specific SAIL I–III, 10^{-4} for Specific SAIL IV–V, Certified and manned VFR traffic. All stochastic draws are seeded, so every repetition, including its conflicts and near-conflicts, is exactly reproducible for post-hoc analysis and replay.

2. **Flight Authorisation Service and conflict detection**

The Flight Authorisation Service (FAS) works with nominal 4D trajectories. Flight requests are processed on a first-come, first-served basis: each candidate trajectory is checked only against those that have already been authorised, without re-ordering or optimizing the overall traffic set. This approach keeps the authorisation process deterministic and computationally efficient, although it does not guarantee a globally optimal allocation. By default, manned traffic is always accepted and added to the authorised traffic set.

To each trajectory is assigned a protection margin, defined as the sum of its Trajectory Specification Error (TSE), Mid-Air Collision (MAC) dimension, and Deviation Threshold (DT). When two trajectories are compared, their protection margins are combined, and the separation check can be performed either in full 3D or in horizontal-only (2D) mode, depending on the required level of conservatism.

Conflict detection is carried out using a hierarchical filtering process that progressively eliminates trajectory pairs that are clearly well separated, while applying more detailed geometric checks only to those that may conflict. This ensures high detection accuracy while keeping the computational cost of large-scale simulations manageable.

Collision and encounter events are classified according to a fixed hierarchy (MAC $\subseteq$ NMAC $\subseteq$ tactical conflict $\subseteq$ encounter), with predefined horizontal and vertical separation thresholds used consistently throughout the simulations.

In exercise 1, Flight Authorisation Service is compliant with Regulation (EU) 2021/664: it deconflicts UAS against other UAS only and does not act on manned traffic (manned aircraft fly their planned route). This changes in exercise 2, where manned aircraft are considered in the deconfliction process.

3. **Traffic generation and timeline construction**

For each traffic density N, the total flight-hour budget is kept constant by distributing it across N parallel *traffic lanes*. As the number of simultaneous flights increases, the duration of each lane decreases accordingly, ensuring that all density levels are compared over the same overall traffic exposure. Traffic in each lane is generated by randomly sampling trajectories from the scenario trajectory pool using a fixed random seed, ensuring that simulations are fully reproducible. To avoid an unrealistic concentration of departures at the beginning of the simulation, the first flight in each lane is randomly shifted in time so that the simulation starts from a steady-state traffic condition rather than from a transient start-up phase.

In the FAS simulations, lane generation and flight authorisation are performed simultaneously. For each traffic slot, multiple candidate trajectories are sampled, and the first one satisfying both the no-fly-zone constraint and the strategic conflict check against previously authorised traffic is accepted. If no candidate is accepted, a strategic replanning algorithm based on Rapidly exploring Random Trees (RRT) attempts to generate an alternative conflict-free trajectory while respecting operational constraints. Only trajectories that successfully pass the subsequent validation checks are authorised; otherwise, the slot remains empty. This retry-and-replanning strategy prevents the effective traffic density from being unintentionally reduced because of FAS rejections, ensuring a fair comparison with the baseline case.

Baseline simulations use the same traffic-generation procedure but omit the flight-authorisation step. Consequently, the only difference between the baseline and FAS scenarios is the application of the authorisation process itself, while all other simulation conditions remain unchanged. For computational efficiency, long simulations are divided into independent windows of up to 30 simulated minutes, with the results subsequently aggregated across all windows and Monte Carlo repetitions.

4. Parallel execution and adaptive time sampling

Each scenario variant (baseline or FAS with a given deviation threshold) is executed through a parallel simulation framework that distributes independent repetitions across multiple workers. Since repetitions are mutually independent, they can be processed concurrently, substantially reducing the overall execution time of the large Monte Carlo sensitivity campaigns while ensuring reproducible results.

To further improve computational efficiency, the simulation uses adaptive time sampling rather than a fixed 1 Hz time step. The timeline is refined around events where interactions between aircraft are more likely, such as trajectory waypoints and predicted closest approaches, while larger time steps are used during long periods of stable flight. Significant instants are always included in the simulation timeline, ensuring that potential conflicts are evaluated at the required temporal resolution.

This adaptive strategy provides sub-second resolution where it is most needed while avoiding unnecessary computations during conflict-free flight segments. As a result, the number of simulation steps is substantially reduced without affecting conflict-detection fidelity, making the large-scale density and deviation-threshold sensitivity analyses computationally feasible. When required, the adaptive sampling scheme can be replaced by a conventional fixed 1 Hz time step for validation purposes.

5. MAC detection and removal

The ENGage simulator differs from the other simulation frameworks in the treatment of vehicles involved in a MAC event. In ENGage, a UAS involved in a MAC is **not terminated** and removed from

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the active traffic set; instead, it remains in the simulation and continues to follow its trajectory. Therefore, subsequent encounters involving the same vehicle can still be counted as additional MAC/NMAC events. This modelling choice leads to **higher conflict counts compared with UPV/CRA** simulators where collided vehicles are removed after the first event.

A.3.2.1. OBJ-SOL0520-ERP-001 Results

Results for this validation objective in all scenarios are obtained from fast-time simulations, run without U-space services only **below-VLL**. Between 2 and 30 simultaneous vehicles[16] are present in each scenario, with a fixed exposure of 200 flight-hours simulated at every density level.

In this exercise Flight Authorisation Service deconflicts UAS against other UAS only and does not act on manned traffic (manned aircraft fly their planned route). Therefore, NMAC values between UAS and manned aircraft do not change when applying basic U-space services according to Regulation (EU) 2021/664 and related graphs are displayed only for OBJ-001 (baseline scenario), that will be a reference for exercise 2.

Scenario 1 (Benidorm, non-U-space sub-OE)

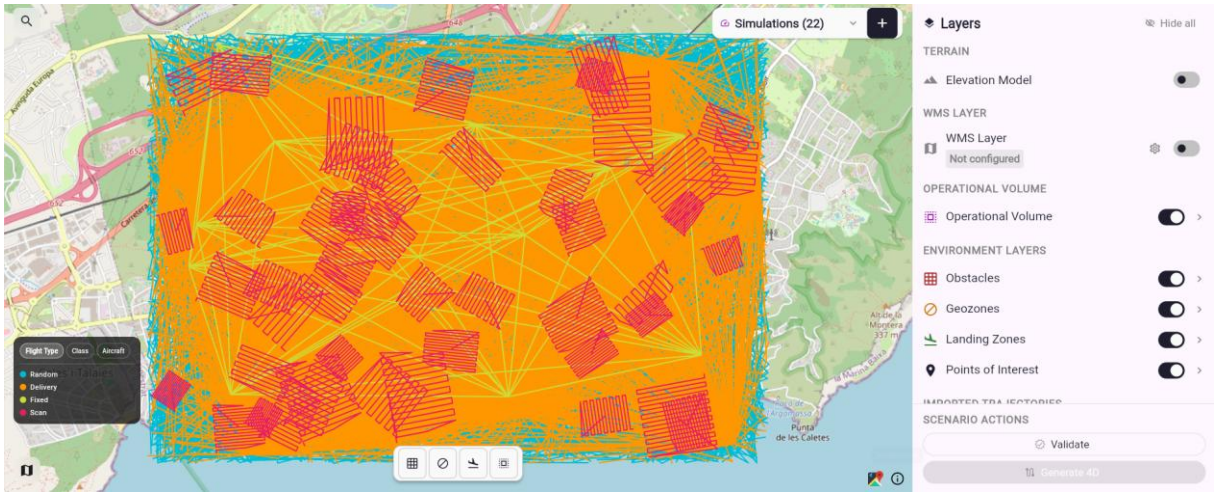


Figure 7: Imported trajectories in Benidorm scenario - ENGage simulator

Figure 8 shows the baseline NMAC and MAC frequencies as a function of simultaneous vehicles for UAS-UAS and UAS-manned pairs[17]. Both series *grow approximately linearly with density*: UAS–UAS NMAC climbs essentially linearly from ≈0.1 events/fh at the first density to ≈2.0/fh at 26 simultaneous vehicles, for a run-wide rate of 1.079 NMAC/fh. UAS–UAS MAC sits below it by a factor ≈2.4. The UAS–manned pair follows the same linear-in-density law lower down. A linear function is fitted to each, anchored at N = 1 with NMAC = 0, since a single vehicle cannot generate an NMAC event.

[16] Simultaneous vehicles" indicates the total number of UAS + manned aircraft present in the scenario.

[17] Manned-manned related values have been calculated for the sake of completeness, but they are not displayed since out of the scope of U-AGREE project.

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The safety targets against which capacity is assessed are 4.35×10^{-5}MAC/fh for UAS-UAS and 1×10^{-7} MAC/fh for UAS-manned but NMAC, rather than MAC, is used as the primary indicator for baseline capacity. MAC frequency has high variance relative to its magnitude, making it an **unstable** basis for capacity estimation; NMAC behaves more consistently across densities and, since MAC is always contained within NMAC, using NMAC yields a conservative estimate that still ensures the target level of safety is met.

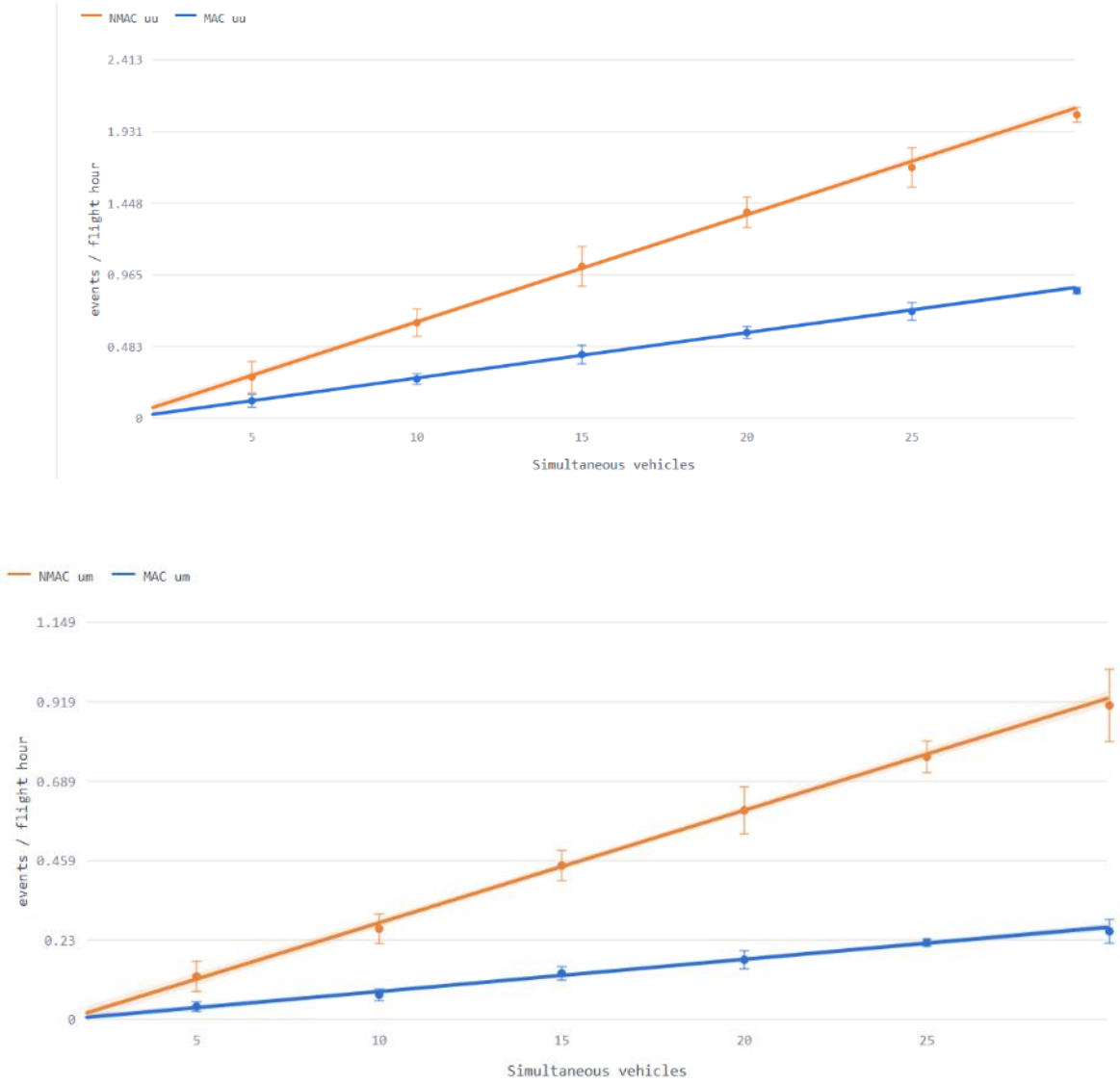


Figure 8: Baseline NMAC values for Benidorm

Based on the fitted functions, even the lowest tested density (N = 2) *already exceeds both targets*. The resulting baseline capacity is $N_0 \approx 1$ for both pair types, meaning **the unmitigated baseline cannot sustain any meaningful concurrent traffic without exceeding the target level of safety**. These results confirm the need for **at least one U-space service in this scenario**.

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KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	Values are shown in Figure 8 and depend on the value of simultaneous vehicles: UAS–UAS: NMAC/fh grow almost linearly with density and it exceeds the TLS already at 2 vehicles. UAS–manned: follows the same law.
Capacity	U-AGREE-KPI-03 **Area drone density**	The capacity is bound to $\mathbf{N_o \approx 1}$ UAS over the scenario area. ≈ 0.047 UAS/km²

Table 11: KPIs for OBJ-SOL0520-ERP-001 Benidorm, exercise 1

Scenario 2: The city of Manduria (non U-space sub-OE)

For Manduria, the unmitigated baseline shows a rapid degradation of safety performance as UAS density increases. The UAS–UAS NMAC rate grows approximately linearly with the number of simultaneous operations, reaching values already orders of magnitude **above the TLS at the lowest tested density**. This indicates that the uncontrolled airspace has practically no sustainable capacity: even the minimum number of concurrent UAS operations exceeds the acceptable safety threshold.

For UAS–manned, the baseline exposure remains approximately constant across the density range, as the manned traffic demand is fixed while only the UAS population varies. However, the resulting risk remains far above the target level, showing that **coexistence with manned aviation cannot be considered acceptable without additional mitigation measures**.

Overall, the Manduria baseline highlights that the airspace **cannot support scalable UAS operations without the introduction of U-space services.**

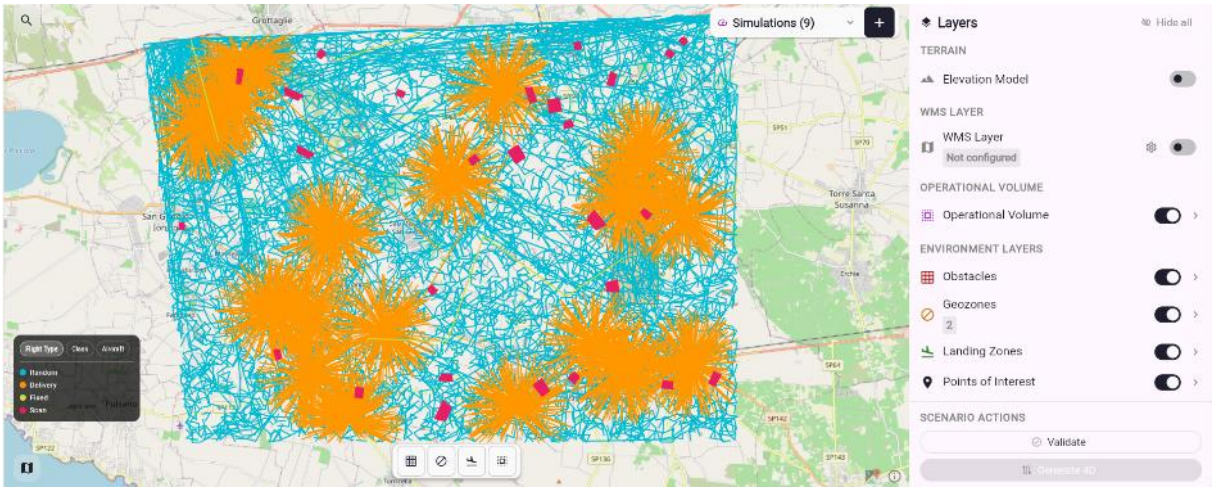


Figure 9: Imported trajectories in Manduria scenario - ENGage simulator

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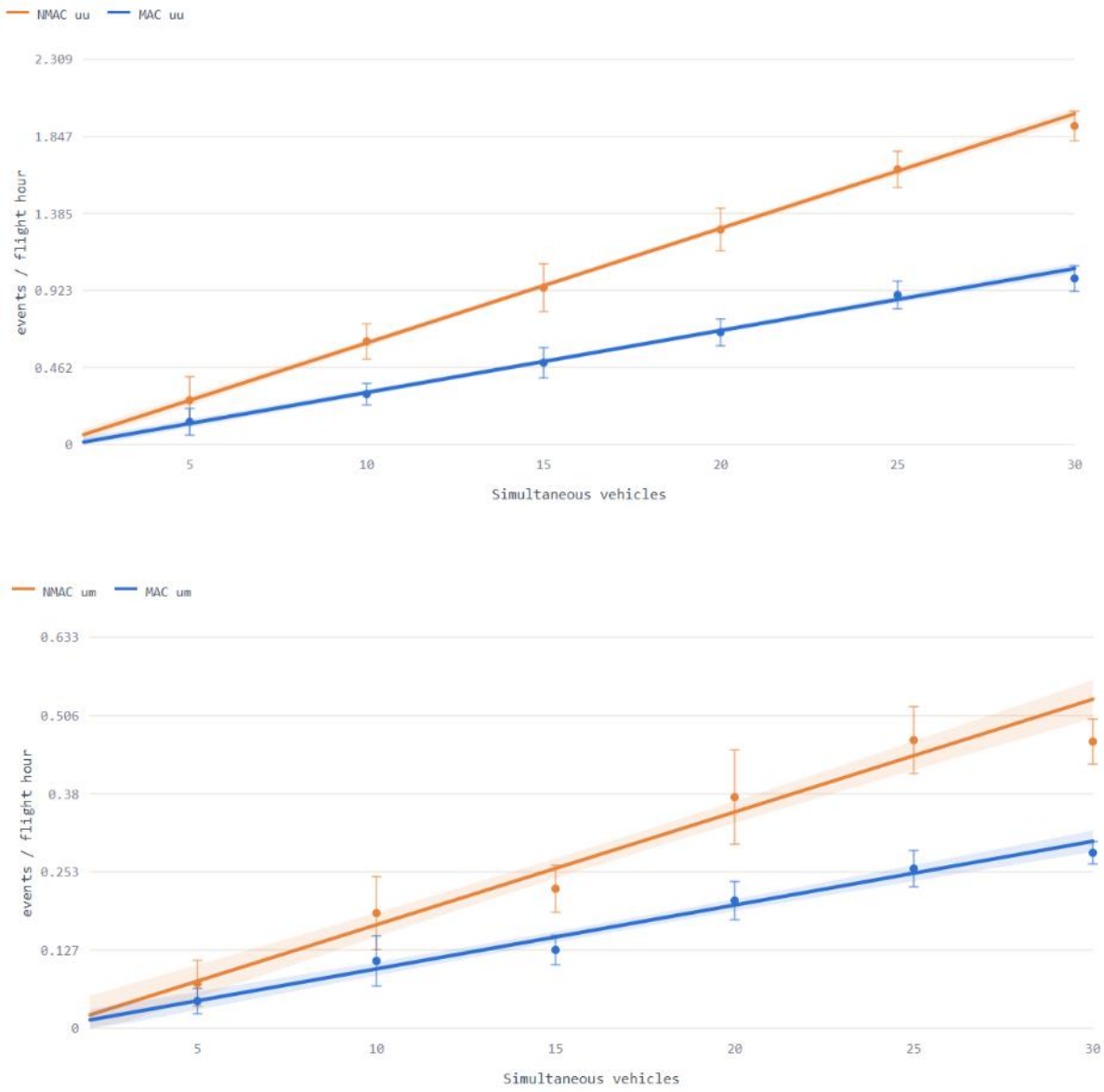


Figure 10: Baseline NMAC values for Manduria

KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	Values are shown in Figure 10: Baseline NMAC values for Manduria and depend on the value of simultaneous vehicles. UAS–UAS NMAC/fh grow almost linearly with density and it exceeds the TLS already at 2 vehicles. UAS–manned follows the same law.
Capacity	U-AGREE-KPI-03 **Area drone density**	The capacity is bound to $\mathbf{N_0 \approx 1}$ UAS over the scenario area. ≈ 0.002 UAS/km²

Table 12: KPIs for OBJ-SOL0520-ERP-001 Manduria, exercise 1

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Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)

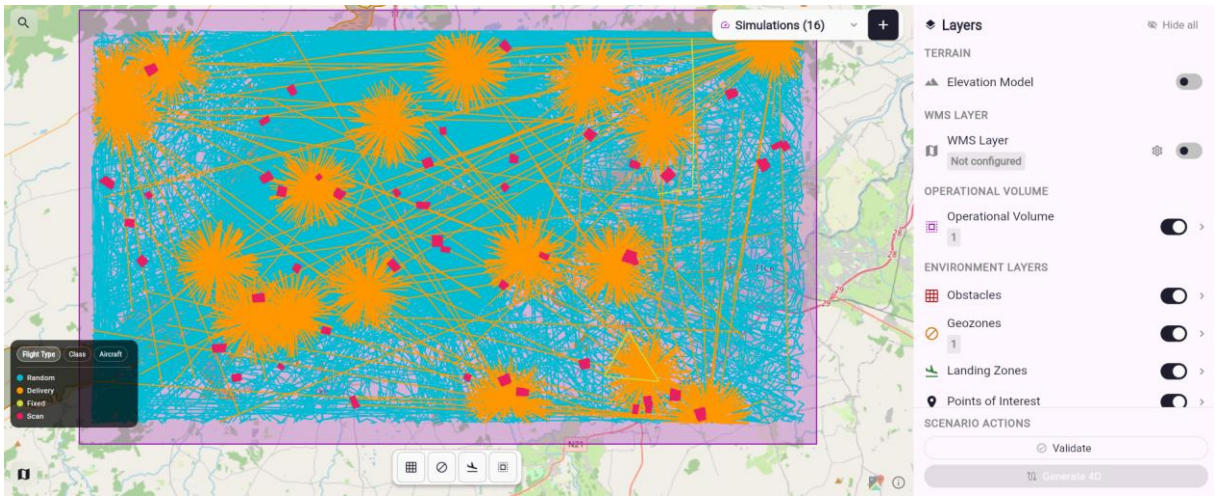
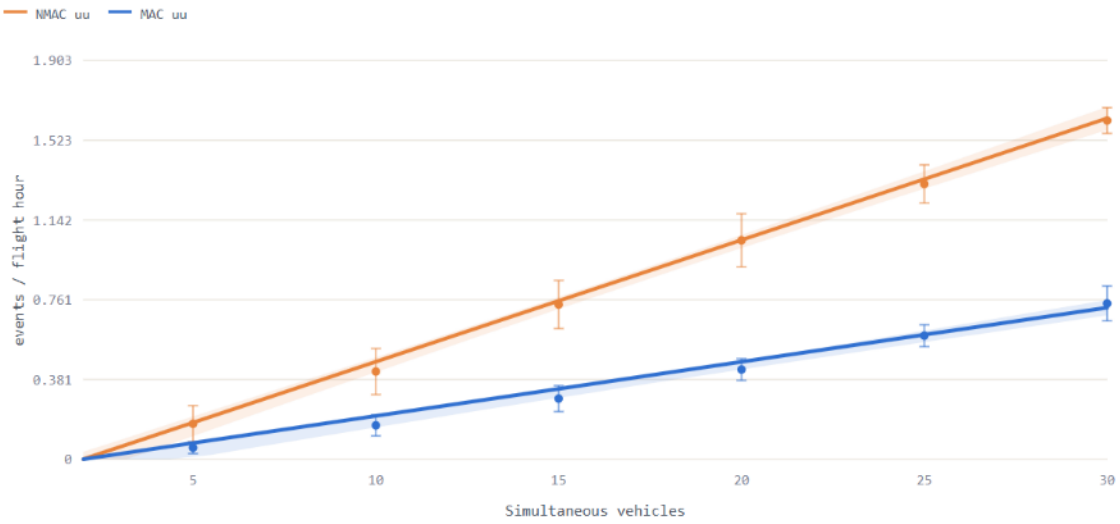


Figure 11: Imported trajectories for Shannon-Limerick scenario - ENGage simulator



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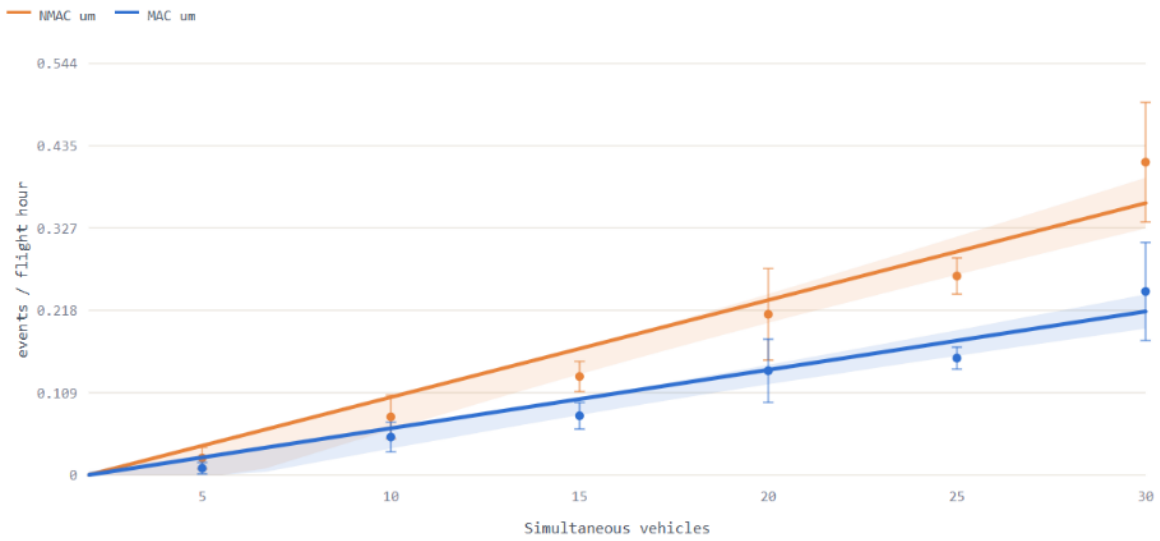


Figure 12: Baseline NMAC values for Shannon-Limerick

The unmitigated baseline shows a clear degradation of safety performance with increasing UAS density. The UAS–UAS NMAC rate increases approximately linearly with the number of simultaneous vehicles, reflecting the growth in potential pairwise interactions as more vehicles operate simultaneously within the same airspace volume. The trend is consistent across the density range, and the limited dispersion (shadowed in the graphs) confirms that the observed increase is not driven by simulation variability.

The baseline already exceeds the applicable TLS at the minimum tested traffic level. The safety threshold is therefore not reached at any density window, resulting in a baseline capacity below the minimum tested concurrency ($N_0 < 2$). This indicates that **the Shannon–Limerick airspace, in its unmitigated configuration, cannot support meaningful concurrent UAS operations while satisfying the required safety target.**

UAS–manned NMACs show the same trend, remaining well above the required target level.

Overall, the baseline assessment confirms that **U-space based mitigation is necessary before scalable UAS operations can be introduced in the Shannon–Limerick scenario**.

KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	Values are shown in Figure 12 and depend on the value of simultaneous vehicles. UAS–UAS NMAC/fh grow almost linearly with density and it exceeds the TLS already at 2 vehicles. UAS–manned follows the same law.
Capacity	U-AGREE-KPI-03 **Area drone density**	The capacity is bound to $\mathbf{N_0 \approx 1}$ UAS over the scenario area. ≈ 0.002 UAS/km²

Table 13: KPIs for OBJ-SOL0520-ERP-001 Shannon-Limerick, exercise 1

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A.3.2.2. OBJ-SOL0520-ERP-002 Results

The second objective is related to the quantification of capacity increment because of the introduction of mitigation measures based on Flight Authorisation and Traffic Information services.

In ENGage, the Traffic Information Service is available in the simulator but is not included in this simulation campaign (for both exercise 1 and 2), as its components have not yet been validated to a level sufficient to ensure statistically robust and reliable results. This constitutes a deviation from the ERP (explained in paragraph 3.3.2 *Deviations with respect to the exploratory research plan (ERP)*).

Instead, the flight Authorisation Service is implemented with a parametric approach: for each Monte-Carlo run, a particular value of the deviation threshold is selected from the set {0, 0.5, 1, 2, 4, 8, 16, 32, 64,128} meters. This enables a systematic assessment of the impact of different DT values, identifying the threshold that provides the best **trade-off** between **safety requirements** and the **maximum achievable airspace capacity for each operational scenario.**

The Flight Authorisation Service implements a Medium-Term Conflict Detection-based approach, checking each proposed trajectory segment against currently authorised traffic in both space and time before granting authorisation; U-plans that would breach the deviation threshold are rejected, and a retry-pick immediately re-fills the slot with a different, deconflicted trajectory. **In exercise 1, Flight Authorisation Service is compliant with Regulation (EU) 2021/664: it deconflicts UAS against other UAS only and does not act on manned traffic (manned aircraft fly their planned route). This changes in exercise 2, where manned aircraft are considered in the deconfliction process.**

200 flight hours have been chosen for simulations in this objective. Results show that the **FAS is fundamental to reduce risk in this scenario.**

Scenario 1 (Benidorm, non-U-space sub-OE)

As shown in Figure 13, even with DT = 0 m, the least restrictive setting, the rate of NMAC events drops by a large margin with respect to the baseline. This confirms the expected safety benefit of introducing strategic separation between authorised trajectories. Increasing the deviation threshold further reduces the NMAC rate, but in Benidorm this reduction is not uniform. Between DT = 0 m and DT = 8 m the rate decreases only slightly from one setting to the next, because the below-VLL traffic geometry in this scenario is already loose at small thresholds — conflicting trajectory pairs are spread across many crossing angles and distances rather than clustered at one scale, so the first few metres of separation already remove most of the avoidable NMAC and each further increment only catches a few additional pairs. From DT = 16 m onward the benefit becomes more pronounced, and at DT = 64 m the NMAC rate collapses almost to zero. This behaviour — a gradual plateau between DT = 0 m and DT = 32 m followed by a sharp drop at DT = 64 m — is the defining feature of the Benidorm scenario, and it directly determines the capacity results.

The capacity result is read against NMAC, using the conservative criterion adopted throughout this report. The residual NMAC value stays above the safety target $\lambda = 4.35 \times 10^{-5}$ /fh for every threshold up to DT = 32 m, so the NMAC-constrained capacity remains stuck at the baseline value along the whole plateau and only clears the target at DT = 64 m, **where a modest capacity increase is obtained**.

Nonetheless, this stays below the threshold for a second simultaneous UAS: the fitted crossing does not reach 2, so in operational terms the near-miss criterion continues to cap the scenario at **a single UAS even at DT = 64.**

The reason capacity behaves as a step function while the risk falls continuously is definitional. The safety-constrained capacity is the largest traffic density whose residual event rate still stays below the

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safety target, so it only moves when that rate crosses the target. The continuous NMAC reduction reported under KPI-01 therefore does not translate into a proportional capacity gain: *the capacity increases only when the residual risk finally falls below the TLS*, which — given Benidorm's plateau-then-cliff profile — happens at DT = 64 m.

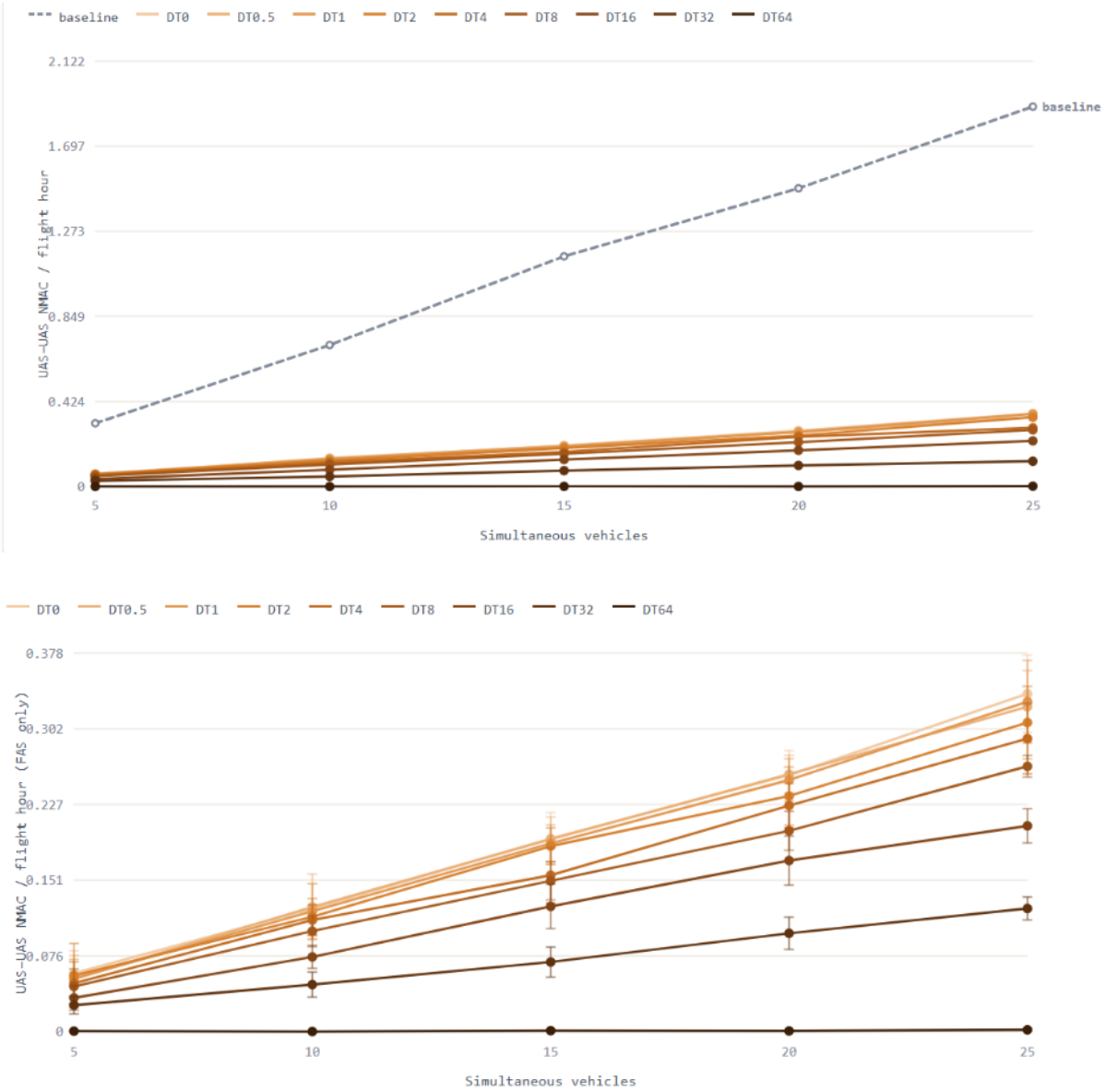


Figure 13: UAS-UAS NMAC Values for Benidorm with FAS

The improvement in NMAC values obtained with FAS comes with an operational cost: larger DT values make the authorisation process more restrictive per each run, as each authorised trajectory requires a larger protected volume around it. This effect is reflected in the number of accepted U-plans (Figure 14: Authorisation approval rate in Benidorm). The proportion of authorised U-plans decreases sharply between DT = 0 m and DT = 64 m.

This behaviour is expected, as larger DT values require greater separation between authorised trajectories, effectively enlarging the protected volume around each authorised flight and reducing the available airspace for additional flight authorisations. Consequently, the safety gains achieved through

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larger DT values are accompanied by a corresponding reduction in the percentage of authorized U-plans. This effect is particularly relevant in Benidorm scenario, whose airspace extension is much smaller than in other scenarios.

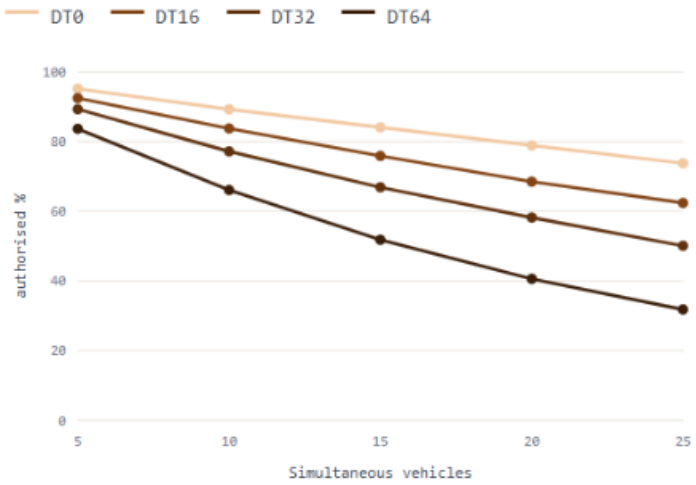


Figure 14: Authorisation approval rate in Benidorm

The following table provides the calculated risk ratios (RR) for different numbers of simultaneous vehicles (sv) (RR = variant NMAC/fh ÷ baseline NMAC/fh at matched density).

Variant	RR for sv=5	RR for sv=10	RR for sv=15	RR for sv=20	RR for sv=25	Mean RR
DT 0	0.201	0.195	0.178	0.188	0.192	0.191
DT 0.5	0.189	0.201	0.177	0.182	0.183	0.186
DT 1	0.185	0.193	0.173	0.183	0.191	0.185
DT 2	0.197	0.182	0.167	0.171	0.182	0.180
DT 4	0.176	0.170	0.151	0.167	0.155	0.164
DT 8	0.165	0.155	0.142	0.149	0.149	0.152
DT 16	0.120	0.118	0.117	0.121	0.120	0.119
DT 32	0.088	0.071	0.069	0.071	0.067	0.073
DT 64	0.001	0.000	0.001	0.000	0.001	0.001

Table 14: Risk Ratios for FAS - Benidorm

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Risk ratios confirm that the **FAS is worth deploying at every tested DT**, and that its protection is stable across traffic density. Even at DT = 0 m, the least restrictive setting, the FAS removes roughly 81% of the baseline NMAC risk (mean RR= 0.19). Risk ratios decrease as expected by increasing DT, highlighting the effectiveness of DT64.

KPIs calculated for this objective are:

KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	Decreases monotonically with DT, reaching TLS by DT 64 m.
Capacity	U-AGREE-KPI-03 **Area drone density**	Using NMAC against the TLS: DT ≤ 32 m capacity is unchanged at $\mathbf{N_0 \approx 1}$, For DT64 a capacity increase of $\mathbf{\Delta N_1 = 0.7}$ is obtained. Compatibly, we have: ≈ 0.047 UAS/km² for DT0 ≈ 0.047 UAS/km² for DT4 ≈ 0.047 UAS/km² for DT8 ≈ 0.047 UAS/km² for DT16 ≈ 0.047 UAS/km² for DT32 ≈ 0.079 UAS/km² for DT64.
	U-AGREE-KPI-04 **Average number of authorised U-plans**	1 for DT ≤ 32 m, rising to 1.7 at DT64 — the NMAC-constrained capacity point.
Access & Equity	U-AGREE-KPI-07 **Authorisation approval rate**	It decreases with increasing DT: 82.5% for DT0, 80.5% for DT4, 78.3% for DT8 45.1% for DT64

Table 15: KPIs for OBJ-SOL0520-ERP-002 Benidorm

FAS results have provided evidence that this service **contributes to progressively reduces NMAC as the deviation threshold increases**. However, the NMAC reduction achieved for DT ≤ 32 m is not sufficient to satisfy the TLS for this scenario. Consequently, even the lowest tested traffic density exceeds the target, and the corresponding safety-constrained capacity remains limited to the minimum value (just 1 vehicle present in the scenario). Only at DT = 64 m does the NMAC rate decrease below the required threshold, but only **a capacity increase of $\Delta N_1 = 0.7$ UAS is gained. Therefore, the required number of flying UAS compliant with the TLS in this scenario is 1.**

Since the Traffic Information Service could not be included, the objective is assessed as Partially OK.

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Scenario 2: The city of Manduria (non U-space sub-OE)

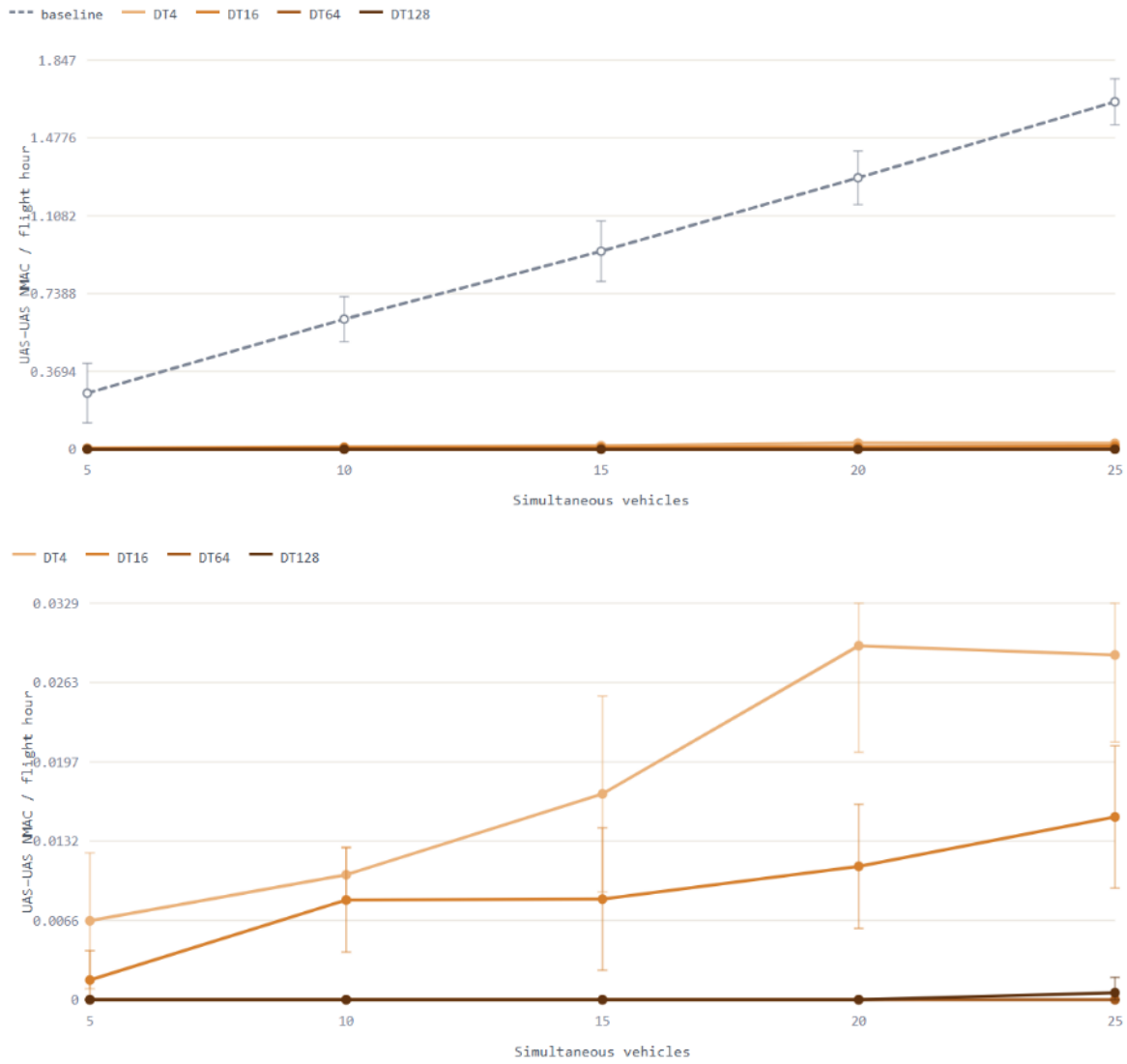


Figure 15: UAS-UAS NMAC Values for Manduria with FAS

The FAS deviation-threshold analysis shows a clear separation between moderate and large deviation buffers. All FAS configurations substantially reduce UAS–UAS risk compared with the unmitigated baseline, with the improvement increasing as the authorised deviation threshold becomes wider. DT4 and DT16 reduce the baseline NMAC rate by approximately two orders of magnitude, maintaining a stable relative risk reduction across the density range and demonstrating that FAS protection scales with increasing traffic density.

No UAS–UAS NMACs are observed for DT64, while DT128 produces only a single residual event over the entire simulation run. These results indicate that the remaining risk is below the measurable resolution of the simulation rather than providing evidence of a meaningful difference between the two configurations. The apparent DT128/DT64 ordering is therefore considered an exposure artefact.

The impact on capacity reflects this distinction. DT4 and DT16 significantly mitigate the baseline risk but remain above the TLS and do not achieve a compliant capacity within the tested density range.

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Conversely, For DT64, the demonstrated operational capacity **increases from 1 baseline case to 26** compliant cases with TLS, while for DT128 it increases from **1 baseline case to 17** compliant cases with TLS.

These results confirm that, for Manduria, strong risk reduction alone is not sufficient: **the strict TLS requires very large deviation margins to translate mitigation into demonstrable operational capacity increase**.

Overall, the Manduria results demonstrate that FAS provides a strong mitigation effect, removing approximately 98–100% of the baseline UAS–UAS risk. However, due to the stringent safety target and the high initial baseline exposure, only the largest deviation thresholds achieve demonstrable TLS compliance within the simulated density range.

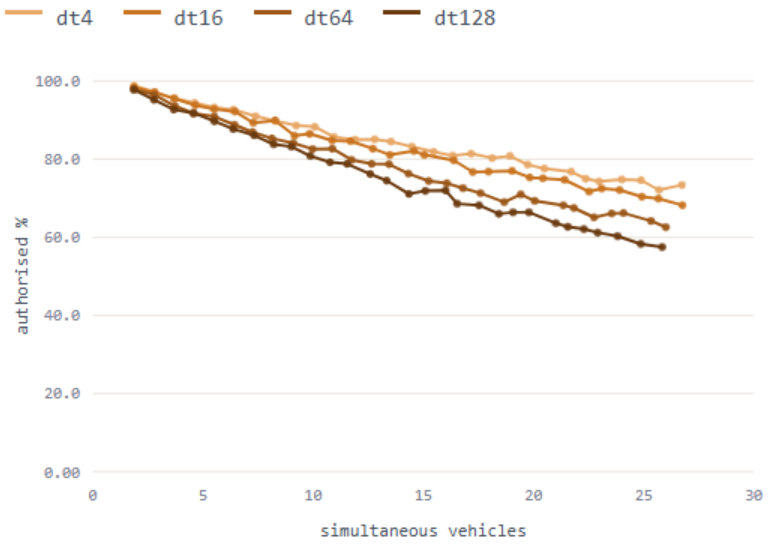


Figure 16: Authorisation approval rate in Manduria

As expected, the authorisation approval rate decreases by increasing the number of simultaneous vehicles and deviation thresholds width.

Accordingly, risk Ratios (RR = variant NMAC/fh ÷ baseline NMAC/fh at matched density) calculated are:

Variant	RR for sv=5	RR for sv=10	RR for sv=15	RR for sv=20	RR for sv=25	Mean RR
DT 4	0.023	0.015	0.021	0.022	0.022	0.020
DT 16	0.012	0.013	0.0091	0.0072	0.0095	0.010
DT 64	0	0	0	0	0	0
DT128	0	0	0	0.0003	0	0.0001

Table 16: Risk Ratios for FAS - Manduria

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Risk ratios drop consistently as the deviation threshold increases. This pattern holds across all tested traffic densities (sv=5–25), confirming the mitigation's effect is consistent rather than density-dependent. The tiny non-zero value at DT128/sv20 (0.0003) reflects a single isolated event, not a real difference from DT64.

The success criterion is partially achieved by FAS alone, as capacity improvements with respect to the unmitigated baseline are demonstrated only for the widest deviation thresholds. On the conservative NMAC basis, DT4 and DT16 do not increase the operational capacity, as their residual rates remain **above** the TLS despite the substantial risk reduction. Conversely, **DT64 achieves a capacity increase of at least ΔN_1 = 25 vehicles, while DT128 provides a ΔN_1=16 increase, limited by the occurrence of a single residual event.**

Among the tested configurations, DT64 represents the most relevant operating point, achieving zero observed UAS–UAS NMACs over the total flight-hours while maintaining a high authorisation acceptance rate. However, since the Traffic Information Service could not be integrated in this campaign, the combined FAS+TI objective cannot be fully assessed. The overall status is therefore classified as Partially OK.

KPIs calculated are:

KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	Decreases monotonically with DT, DT64/DT128 provide NMAC< 10^{-4}/fh.
Capacity	U-AGREE-KPI-03 **Area drone density**	Using NMAC against the TLS: DT4 and DT16 provide no capacity increase ($N_0 \approx 1$), DT64 provides a capacity increase of at least **ΔN_1 = 25** DT128 provides a capacity increase of **ΔN_1=16**. Compatibly, we have: ≈ 0.002 UAS/km² for DT4 ≈ 0.002 UAS/km² for DT16 ≈ 0.056 UAS/km² for DT64 ≈ 0.036 UAS/km² for DT128.
	U-AGREE-KPI-04 **Average number of authorised U-plans**	1 for DT4 and DT16 where the target is already exceeded — rising to 26 for DT64 and 17 for DT128.
Access & Equity	U-AGREE-KPI-07 **Authorisation approval rate**	It decreases with increasing DT: from 84% (DT 4 m) to 75% (DT 128 m).

Table 17: KPIs for OBJ-SOL0520-ERP-002 Manduria

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Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)

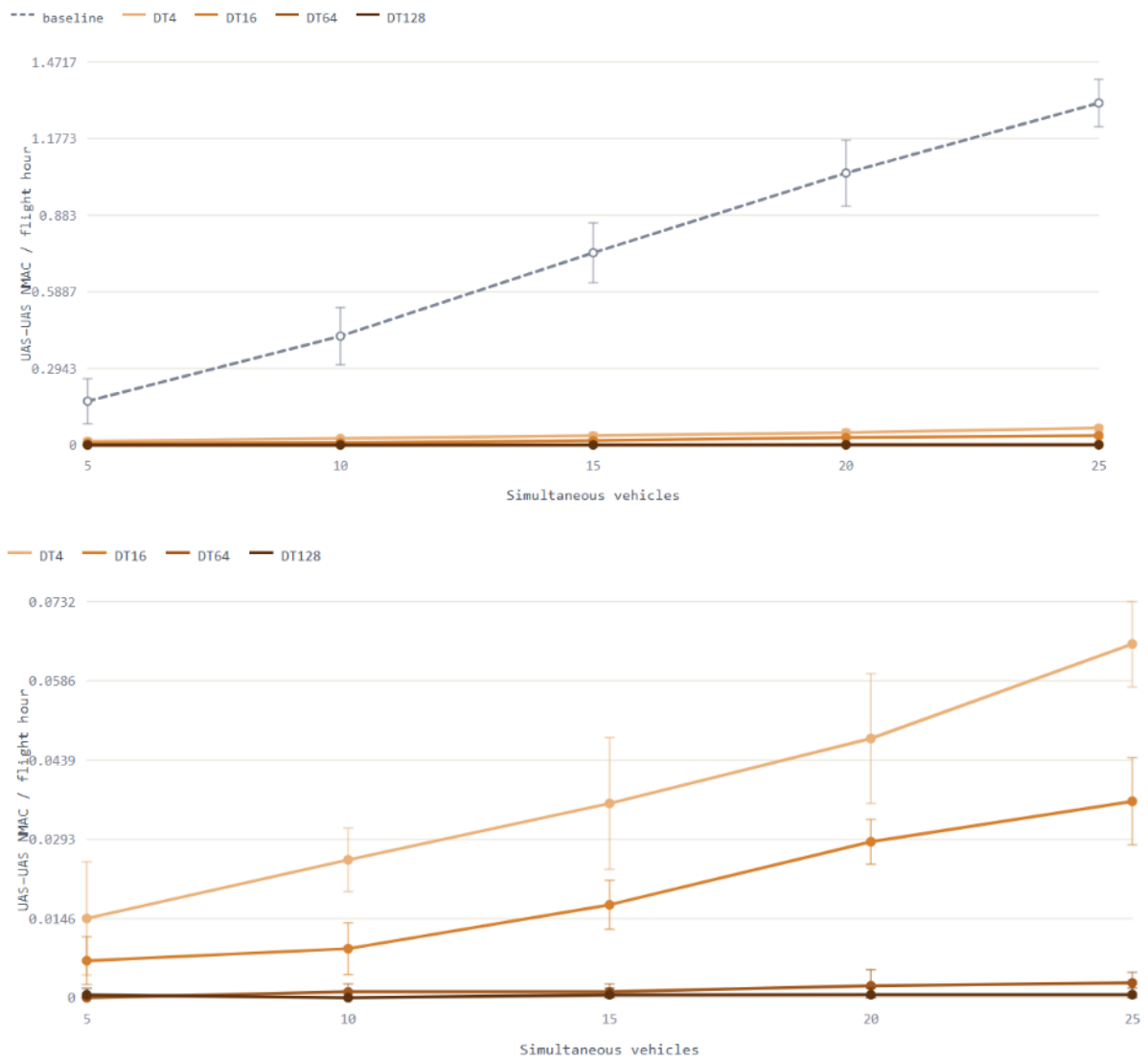


Figure 17: UAS-UAS NMAC Values for Shannon Limerick with FAS

The deviation-threshold analysis shows a clear reduction of residual UAS–UAS risk as the authorised deviation threshold increases. All FAS configurations remain well below the unmitigated baseline across the entire density range. Increasing the deviation threshold progressively reduces residual UAS–UAS conflicts, confirming that larger deviation margins provide stronger mitigation. DT4 and DT16 achieve significant risk reduction but support only limited increases in operational capacity, whereas DT64 and DT128 maintain compliance across the full tested density range. The observed ladder confirms that wider deviation margins enable higher traffic levels to be safely accommodated without reducing the simulated traffic demand.

The capacity assessment highlights the operational impact of this risk reduction. DT4 and DT16 improve safety performance but achieve compliance only up to limited traffic densities, resulting in capacity gains of approximately **+6** and **+11** vehicles respectively compared with the unmitigated baseline. Conversely, DT64 and DT128 maintain compliance over the full tested density range, corresponding to a demonstrated capacity increase of at least **+26** vehicles.

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Overall, the results demonstrate that increasing the deviation threshold provides progressively stronger mitigation and enables higher operational capacity while maintaining the same traffic generation and authorisation framework.

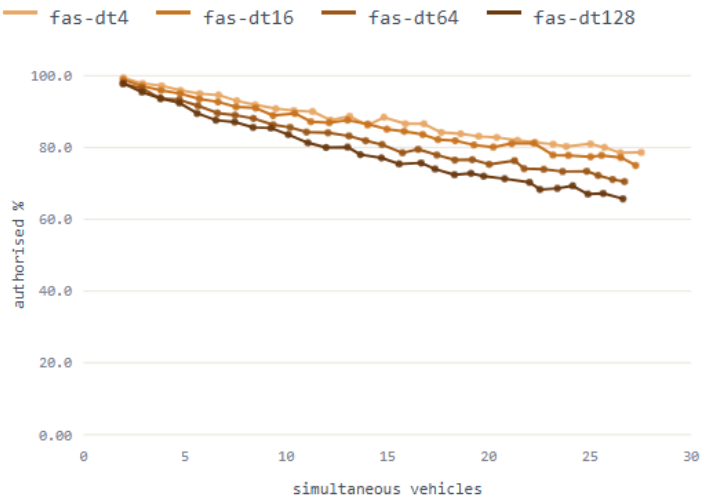


Figure 18: Authorisation approval rate in Shannon-Limerick

The operational cost of FAS is reflected in the increased number of rejected authorisation requests required to achieve greater separation margins. The approval rate decreases progressively with the deviation threshold, as wider deviation thresholds increase the protected volume around each authorised trajectory and reduce the available space for additional operations. The same trend is observed within each density window, with acceptance decreasing as traffic congestion increases.

Calculated risk ratios are:

Variant	RR for sv=5	RR for sv=10	RR for sv=15	RR for sv=20	RR for sv=25	Mean RR
DT 4	0.087	0.065	0.040	0.052	0.044	0.057
DT 16	0.041	0.020	0.026	0.030	0.026	0.029
DT 64	0	0.0024	0.0023	0.0020	0.0026	0.0018
DT128	0.0026	0	0.0006	0.0010	0	0.0008

Table 18: Risk Ratios for FAS - Shannon Limerick

The risk ratio analysis confirms that FAS provides a consistent relative reduction of UAS–UAS risk across the full density range. DT4 and DT16 reduce the baseline risk by approximately 94% and 97%, respectively, while the larger thresholds achieve near-complete risk suppression, with DT64 and DT128 removing more than 99.8% of the baseline risk within the simulated exposure.

KPIs calculated are:

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KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	Decreases monotonically with DT.
Capacity	U-AGREE-KPI-03 **Area drone density**	Using NMAC against the TLS: DT4 provides a capacity increase of **ΔN_1=6** DT16, with a capacity increase of **ΔN_1=11** DT64 and DT128 provide a capacity increase of **ΔN_1=26.** Compatibly, we have: ≈ 0.008 UAS/km² for DT4 ≈ 0.014 UAS/km² for DT16 ≈ 0.032 UAS/km² for DT64 ≈ 0.032 UAS/km² for DT128.
	U-AGREE-KPI-04 **Average number of authorised U-plans**	It increases with DT: 7 for DT4 → 27 for DT128.
Access & Equity	U-AGREE-KPI-07 **Authorisation approval rate**	It decreases with increasing DT: from 87% (DT4), 86% (DT16), 82% (DT64), 79% (DT128).

Table 19: KPIs for OBJ-SOL0520-ERP-002 Shannon Limerick

The success criterion (capacity increase with respect to the unmitigated baseline at the same TLS) is met by FAS alone for all tested thresholds. The achieved capacity gain ranges from **ΔN_1 = +6 vehicles for DT4 to ΔN_1= +26 vehicles for DT64 and DT128**.

Since the Traffic Information Service could not be included in this campaign, the overall objective is assessed as Partially OK: the FAS contribution to the criterion is demonstrated, whereas the TI contribution remains unevaluated.

A.3.2.3. OBJ-SOL0520-ERP-003 Results

The objective aim is to quantify the capacity increment (ΔN_2) because of the introduction of mitigation measures based on Flight Authorisation, Traffic Information, and Conformance Monitoring (without pre-alerting) services. While the FAS provides the strategic layer of conflict prevention by filtering trajectories before authorisation, CM adds a tactical layer by continuously monitoring the execution of authorised flights and detecting deviations from the planned trajectory. In this variant only the alert is active: it triggers once the UAS has breached both the deviation threshold and the TSE corridor, and the UAS is then overridden back onto its authorised corridor after a sampled pilot-reaction delay. A 200 flight-hour Monte Carlo campaign evaluates the combined implementation of Conformance Monitoring (CM) on top of the Flight Authorisation Service (FAS) with a Deviation Threshold of 16 and 64 meters. As previously justified, TIS is not included in ENGage simulations.

Scenario 1 (Benidorm, non-U-space sub-OE)

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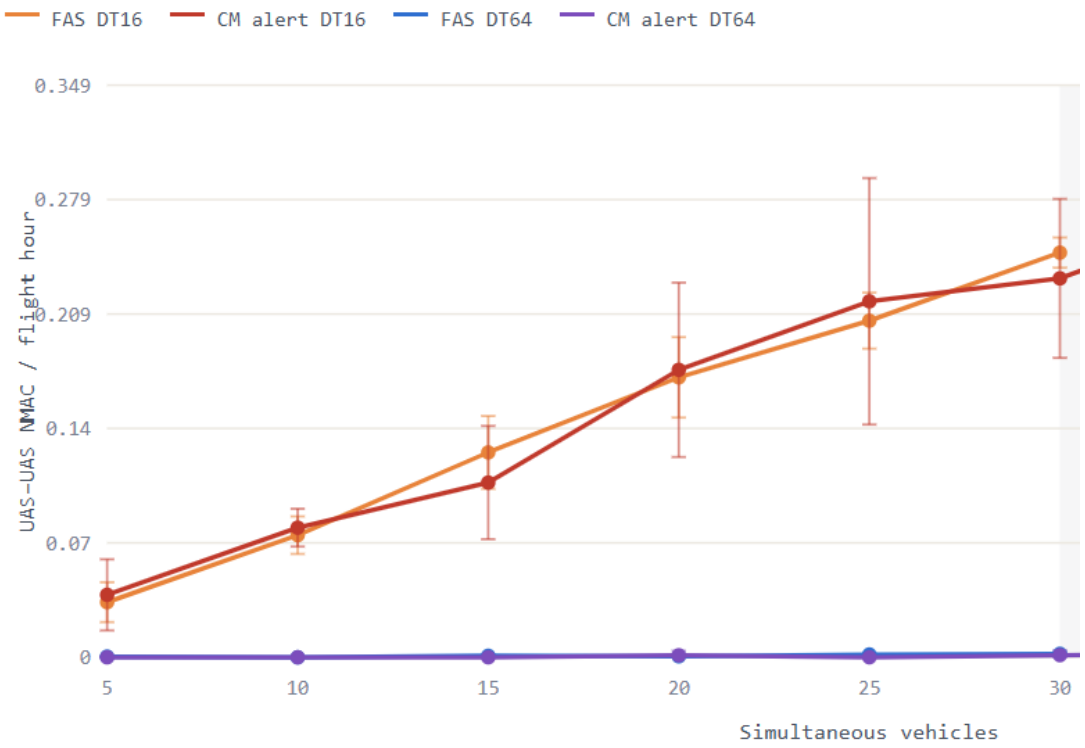


Figure 19: NMAC vs simultaneous vehicles in Benidorm - FAS + CM (without pre-alerting)

For the number of NMAC/fh between UAS, the comparison between FAS and CM alert configurations shows no measurable improvement from conformance monitoring on top of FAS under the tested conditions. At DT16, both configurations increase approximately with traffic density, with small differences between the two curves remaining within the variability range (indicated by the error bars). No configuration consistently outperforms the other, indicating that the **residual UAS–UAS NMAC level is mainly driven by the deviation threshold rather than by the monitoring layer**.

The same behaviour is observed, even more clearly, at DT64. Across the full density range investigated both FAS DT64 and CM alert DT64 remain at essentially zero UAS–UAS NMAC/fh, with no observable increase as traffic density grows. The two configurations are therefore indistinguishable within the simulation resolution, showing that once DT64 has reduced the residual conflict rate to the detection floor, the addition of conformance monitoring **does not** provide further measurable benefit.

Overall, **the deviation threshold is the dominant factor controlling residual UAS–UAS risk**. Under the exercise 1 conditions, **no additional reduction in residual NMAC rates can be attributed to CM alert**, although CM does not negatively affect the achieved safety performance.

This is also reflected in the calculated risk ratios (RR = variant NMAC/fh ÷ baseline NMAC/fh at matched density). Comparing these values with the risk ratios calculated for OBJ-002, where only FAS is implemented, shows that they are of the same order of magnitude. This indicates that the introduction of Conformance Monitoring does not provide any additional risk mitigation beyond that already achieved by FAS.

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Variant	RR for sv=5	RR for sv=10	RR for sv=15	RR for sv=20	RR for sv=25	Mean RR
CM without pre-alert DT16	0.137	0.123	0.104	0.126	0.129	0.124
CM without pre-alert DT64	0.000	0.000	0.000	0.001	0.000	0.000

Table 20: Risk Ratios for CM (without pre-alerting) for Benidorm

To assess capacity, the NMAC/fh values for each drone density are assessed against the TLS, and under this criterion the introduction of Conformance Monitoring does not produce a reliable capacity gain at either threshold. Overall, **no capacity increment beyond that already provided by FAS can be reliably attributed to CM at either DT16 or DT64**, consistent with the risk-ratio analysis, which **found CM statistically indistinguishable from plain FAS** at both deviation thresholds. KPIs calculated for this objective are:

KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	At DT16, CM alert provides no measurable improvement over plain FAS, with both configurations showing equivalent UAS–UAS safety performance; at DT64, both configurations achieve near-zero residual risk, with no additional benefit from conformance monitoring once the deviation threshold has reduced conflicts to the detection floor; no collisions are observed in either configuration.
	U-AGREE-KPI-02 **Number of non-conformance events/FH**	With DT16, 65.1 events have been solved with the support of CM without pre-alerting, for DT64 the number the number of non-conformance events is 54.4.
Capacity	U-AGREE-KPI-03 **Area drone density**	Using NMAC against the TLS: For both, there is no capacity increase with respect to the one provided by FAS alone, so $\Delta N_2 = \Delta N_1$. Compatibly, we have: ≈ 0.047 UAS/km² for DT16 ≈ 0.079 UAS/km² for DT64.

Table 21: KPIs for OBJ-SOL0520-ERP-003 Benidorm

Scenario 2: The city of Manduria (non U-space sub-OE)

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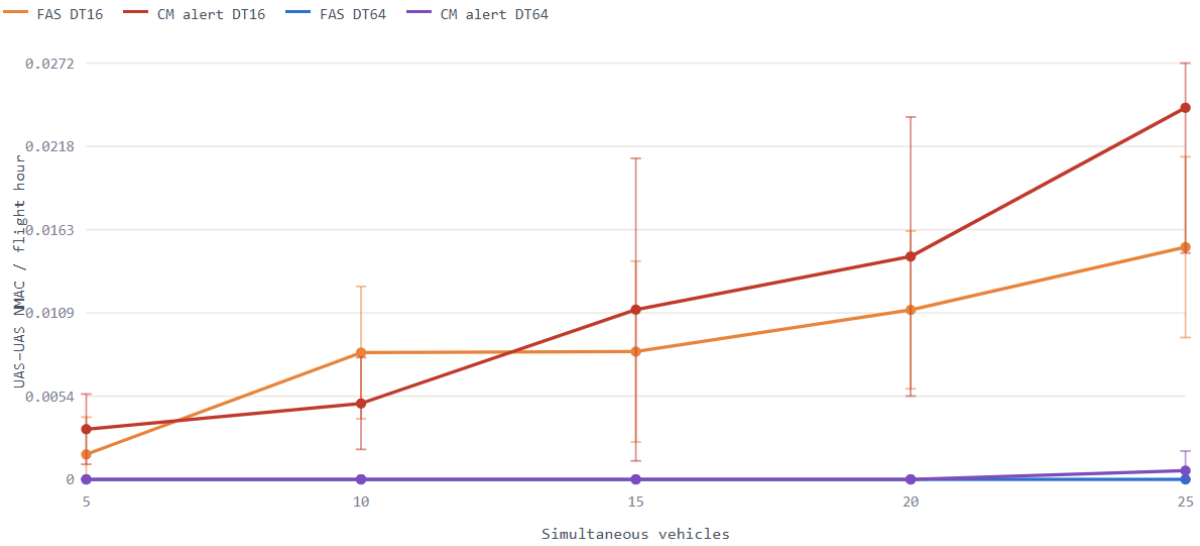


Figure 20: NMAC vs simultaneous vehicles in Manduria - FAS + CM (without pre-alerting)

At DT16, the two configurations shown — plain FAS and CM alert — exhibit a crossing trend rather than a consistent separation: CM alert starts marginally above FAS at low density, FAS becomes slightly lower at intermediate density, and CM alert remains above FAS at the highest tested density. No configuration consistently outperforms the other, **indicating that CM does not provide a measurable reduction of residual UAS–UAS near-miss risk when the deviation threshold is unchanged**.

At DT64, both FAS and CM alert operate close to the detection floor across the tested density range, with only minor residual variations and no statistically meaningful separation between the two configurations. This confirms that also in this scenario, **once a sufficiently large deviation threshold is applied, the residual UAS–UAS risk is primarily determined by the deviation threshold itself rather than by the additional monitoring layer.**

The limited observable contribution of CM is consistent with the role of the deviation buffer: the strategic separation margin already prevents trajectory deviations from developing into conflicts with other authorised corridors. Accordingly, CM does not produce a measurable improvement in UAS–UAS safety performance, while UAS–manned exposure remains unchanged, as expected for a service focused on monitoring UAS conformance.

For a deviation threshold of 16 meters, conformance monitoring without pre-alerting has not provided any capacity increment. At 64 meters instead, capacity has **increased of 15 UAS** with respect to the baseline.

The apparent reduction in TLS compatible capacity under CM alert (ΔN_3**=15**) relative to plain FAS (ΔN_1 **=26**) at DT64 is not evidence that conformance monitoring degrades safety. The FAS DT64 value is right-censored, as no NMAC events were observed across the tested simultaneous vehicles range. The CM values are based on a single observed NMAC event and should therefore be considered indicative only. At this exposure level, observing zero or one event is statistically plausible. Therefore, small differences between runs may be due to statistical variability rather than a real difference in capacity. The FAS DT64 bound should therefore be considered the more robust reference at this threshold, while the CM DT64 values should be treated with caution until additional replicates or higher exposure are available.

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Consequently, risk ratios for this exercise are:

Variant	RR for sv=5	RR for sv=10	RR for sv=15	RR for sv=20	RR for sv=25	Mean RR
CM without pre-alert DT16	0.014	0.0075	0.011	0.014	0.013	0.012
CM without pre-alert DT64	0	0	0	0	0	0

Table 22: Risk Ratios for CM (without pre-alerting) for Manduria

KPIs calculated for this objective are:

KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	At DT16, CM alert provides no measurable change compared with plain FAS, as the differences remain within the simulation variability. At DT64, FAS and CM alert are indistinguishable within the simulation resolution, as both configurations reduce the residual UAS–UAS risk to the detection floor and no additional benefit from CM can be identified.
	U-AGREE-KPI-02 **Number of non-conformance events/FH**	With DT16, 39 events have been solved with the support of CM without pre-alerting, for DT64 the number of non-conformance events is 2.4.
Capacity	U-AGREE-KPI-03 **Area drone density**	No capacity increment obtained beyond those provided by FAS at DT16, so $\boldsymbol{\Delta N_2 = \Delta N_1}$. For DT64, the capacity increment of FAS+CM with respect to baseline is of $\boldsymbol{\Delta N_2}$**=15.** Compatibly, we have: ≈ 0.002 UAS/km² for DT16 ≈ 0.033 UAS/km² for DT64.

Table 23: KPIs for OBJ-SOL0520-ERP-003 Manduria

Overall, the success criterion is partially achieved at the wide deviation threshold, with the demonstrated capacity increase attributable to FAS. No additional measurable contribution can be attributed to CM under the exercise conditions, and the Traffic Information Service component remains unevaluated. The objective is therefore classified as Partially OK.

Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)

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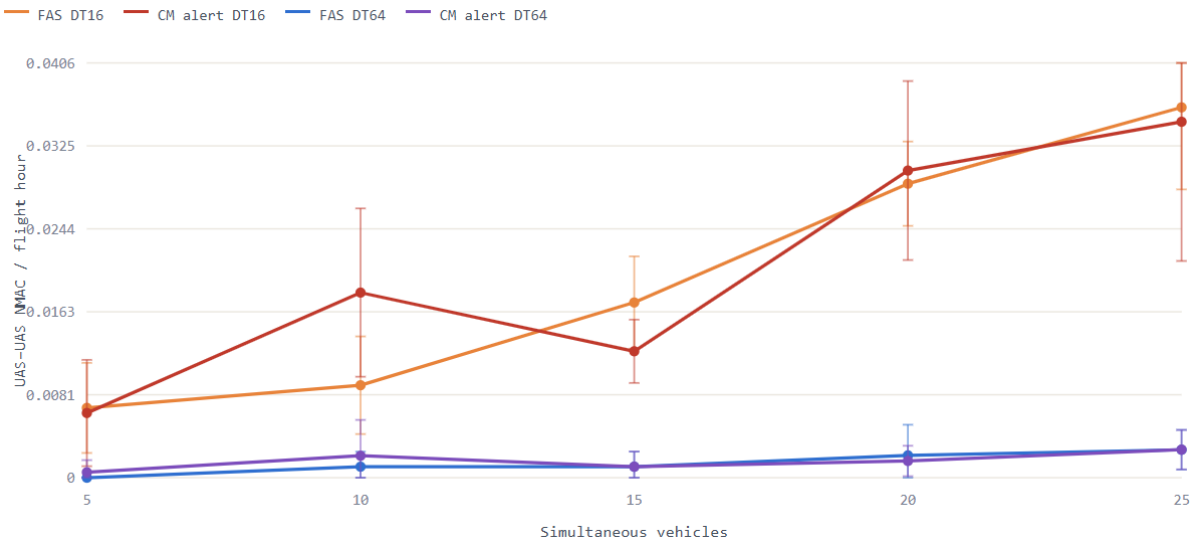


Figure 21: NMAC vs simultaneous vehicles in Shannon-Limerick - FAS + CM (without pre-alerting)

At DT16, FAS and CM show comparable residual UAS–UAS NMAC rates across the tested density range, with no configuration consistently outperforming the other. The observed differences remain within the variability of the simulation (errors range are indicated by vertical bars), indicating that they are driven by cycle-to-cycle fluctuations rather than by a measurable CM contribution.

The same behaviour is observed at DT64, where residual event counts are extremely low and the comparison is limited by the detection floor of the simulation. The configurations remain statistically indistinguishable, confirming that once the deviation threshold provides sufficient separation margin, the residual NMAC level is determined primarily by DT rather than by the additional monitoring layer.

Consequently, risk ratios calculated with respect to baseline scenario for this exercise are:

Variant	RR for sv=5	RR for sv=10	RR for sv=15	RR for sv=20	RR for sv=25	Mean RR
CM without pre-alert DT16	0.038	0.037	0.020	0.026	0.025	0.029
CM without pre-alert DT64	0.0053	0.0047	0.0011	0.0017	0.0034	0.0032

Table 24: Risk Ratios for CM (without pre-alerting) for Shannon-Limerick

Comparing these values with the risk ratios calculated for OBJ-002, where only FAS is implemented, shows that they are of the same order of magnitude. This indicates that the introduction of Conformance Monitoring does not provide any additional risk mitigation beyond that already achieved by FAS.KPIs calculated for this objective are:

For a deviation threshold of 64 meters, conformance monitoring without pre-alerting has not provided any capacity increment. At 16 meters instead, capacity has increased of 1 UAS with respect to FAS, so of 11 with respect to baseline levels.

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KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	CM alert remains within cycle variability of plain FAS at both thresholds: at DT16, the run-wide residual NMAC rates differ only within the expected simulation dispersion, while at DT64 the two configurations interleave across the full density range with no measurable separation.
	U-AGREE-KPI-02 **Number of non-conformance events/FH**	With DT16, 47 events have been solved with the support of CM without pre-alerting.
Capacity	U-AGREE-KPI-03 **Area drone density**	At DT16, the capacity increment with respect to baseline provided by FAS+CM is of $\boldsymbol{\Delta N_2}$**=11.** No capacity increment obtained beyond those provided by FAS For DT64 so $\boldsymbol{\Delta N_2 = \Delta N_1}$. Compatibly, we have: ≈ 0.015 UAS/km² for DT16 ≈ 0.033 UAS/km² for DT64.

Table 25: KPIs for OBJ-SOL0520-ERP-003 Shannon-Limerick

Overall, the capacity increment is achieved only through the increased deviation threshold, while no additional measurable contribution can be attributed to the monitoring layer under exercise #01 conditions. Furthermore, since the Traffic Information Service component remains unevaluated, the objective is classified as Partially OK.

A.3.2.4. OBJ-SOL0520-ERP-004 Results

In this objective, pre-alerting is included in the Conformance Monitoring.

Scenario 1 (Benidorm, non-U-space sub-OE)

At DT16, CM pre-alert remains within the variability of plain FAS across the shared density range. The two curves interleave, with two points where pre-alert shows a lower residual rate (sv=20); however, this difference is not maintained at neighbouring densities. Under these conditions, CM pre-alert **does not** demonstrate a measurable safety improvement over plain FAS at DT16, and the achievable capacity remains limited by the same TLS constraint.

At DT64, the difference between configurations is further reduced by the very low residual event rate. The deviation threshold alone reduces the NMAC rate to the detection floor, and CM pre-alert remains at the same level, with **no measurable additional risk reduction compared with plain FAS**. The addition of monitoring does not modify the achieved safety performance, while preserving the operational throughput of the authorisation process.

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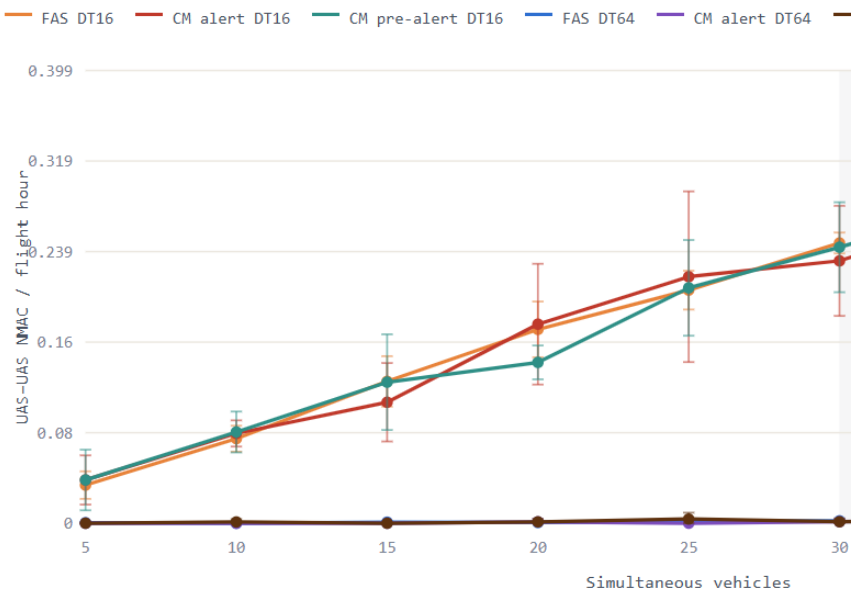


Figure 22: NMAC vs simultaneous vehicles in Benidorm - FAS + CM (with pre-alerting)

Therefore, risk ratios for this exercise are therefore negligible:

Variant	RR for sv=5	RR for sv=10	RR for sv=15	RR for sv=20	RR for sv=25	Mean RR
CM with pre-alert DT16	0.137	0.125	0.122	0.102	0.123	0.122
CM with pre-alert DT64	0.000	0.002	0.000	0.001	0.002	0.001

Table 26: Risk Ratios for CM (with pre-alerting) for Benidorm

Once again, comparing these values with those obtained for FAS alone confirms that the reduction in residual risk is primarily driven by the deviation threshold. DT64 reduces the NMAC risk to its floor, while the addition of the monitoring layer does not provide any measurable further risk reduction. **Neither alerting nor pre-alerting therefore offers additional mitigation beyond plain FAS once the DT64 threshold is applied.**

Regarding capacity, at both DT no capacity increment with respect to the one provided by FAS alone was detected, so $\boldsymbol{\Delta N_2 = \Delta N_1}$ is observed.

KPIs calculated for this objective are:

KPA	KPI	Value obtained
	U-AGREE-KPI-01 **Number of NMAC/FH**	CM pre-alert shows no measurable difference with respect to both plain FAS or CM alert at DT16 and DT64.

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Safety	U-AGREE-KPI-02 **Number of non-conformance events/FH**	With DT16 60.3 events have been solved with the support of CM with pre-alerting, for DT64 the number is 54.8.
Capacity	U-AGREE-KPI-03 **Area drone density**	At both DT no capacity increment with respect to the one provided by FAS alone was detected, so $\Delta N_3 = \Delta N_2 = \Delta N_1$ is observed. Compatibly, we have: ≈ 0.047 UAS/km² for DT16 ≈ 0.079 UAS/km² for DT64.

Table 27: KPIs for OBJ-SOL0520-ERP-004 Benidorm

Since the Traffic Information Service component is not included in this configuration, it remains unevaluated. The objective is therefore classified as Partially OK.

Scenario 2: The city of Manduria (non U-space sub-OE)

At DT16, CM pre-alert interleaves with the other configurations across the tested density range, being lowest at some densities and highest at others, with no consistent ordering. The run-wide residual rate remains comparable to CM alert and within the variability range of plain FAS, indicating **no measurable safety improvement from the earlier trigger mechanism.**

At DT64, all configurations operate at the detection floor. The difference between isolated residual events and zero events does not provide statistical evidence of a performance difference, and the alert and pre-alert configurations remain indistinguishable within the available simulation exposure. This confirms the Manduria results and supports the interpretation that the previously observed pre-alert benefit in Benidorm was not representative of a systematic mechanism.

For both DT16 and DT64, No capacity increment with respect to those provided by FAS has been observed, so $\Delta N_3 = \Delta N_2 = \Delta N_1$.

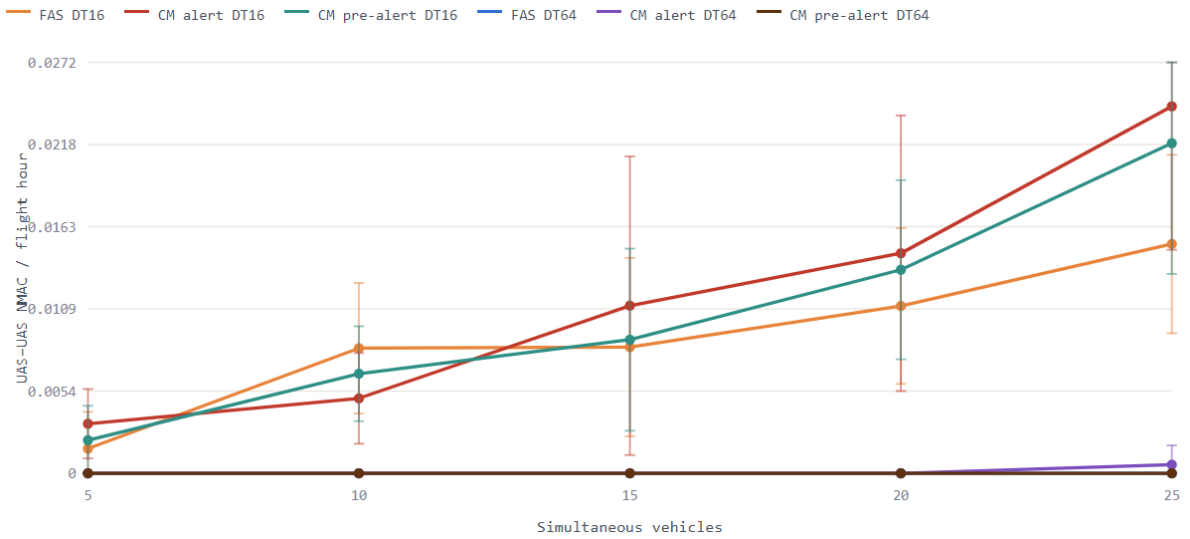


Figure 23: NMAC vs simultaneous vehicles in Manduria - FAS + CM (with pre-alerting)

Consequently, risk ratios for this exercise are:

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Variant	RR for sv=5	RR for sv=10	RR for sv=15	RR for sv=20	RR for sv=25	Mean RR
CM with pre-alert DT16	0.0090	0.0099	0.011	0.011	0.017	0.011
CM with pre-alert DT64	0	0	0	0	0.0003	0.0001

Table 28: Risk Ratios for CM (with pre-alerting) for Manduria

KPIs calculated for this objective are:

KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	CM pre-alert remains within the simulation variability of plain FAS and CM alert at both thresholds: at DT16, the run-wide residual NMAC rates are comparable across configurations, while at DT64 the comparison is limited by the detection floor, with only isolated residual events observed. Alert and pre-alert dispersion ranges overlap across the tested densities, indicating no measurable safety benefit from the earlier trigger.
	U-AGREE-KPI-02 **Number of non-conformance events/FH**	With DT16, 39.6 events have been solved with the support of CM with pre-alerting, for DT64 the number of non-conformance events is 2.7.
Capacity	U-AGREE-KPI-03 **Area drone density**	For both DT16 and DT64, no capacity increment with respect to those provided by FAS has been observed, so $\Delta N_3 = \Delta N_2 = \Delta N_1$. Compatibly, we have: ≈ 0.002 UAS/km² for DT16 ≈ 0.031 UAS/km² for DT64.

Table 29: KPIs for OBJ-SOL0520-ERP-004 Manduria

Overall, the success criterion is achieved through the increased deviation threshold at DT64, while no additional measurable contribution can be attributed to CM pre-alerting beyond plain FAS. Under the tested Manduria conditions, conformance monitoring alone — with or without pre-alerting — is not sufficient to satisfy the strict TLS at lower deviation thresholds. Since the Traffic Information Service is not evaluated, the objective is classified as Partially OK.

Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)

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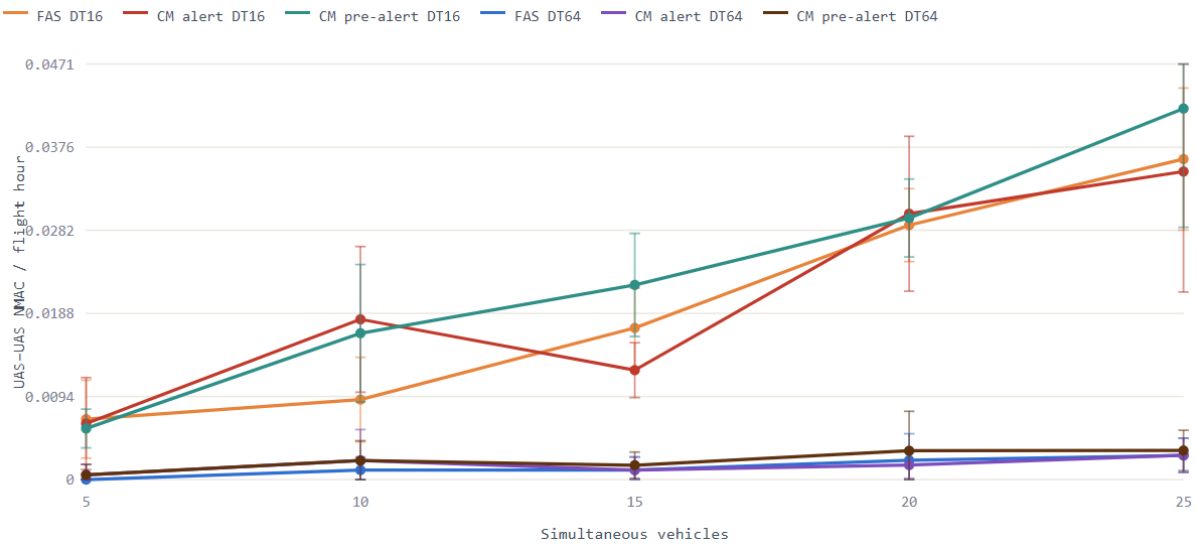


Figure 24: NMAC vs simultaneous vehicles in Shannon- Limerick - FAS + CM (with pre-alerting)

The comparison between pre-alert, alert and plain FAS confirms that the monitoring mode does not determine the residual UAS–UAS risk when the deviation threshold is unchanged. At DT16, CM pre-alert interleaves with the other configurations across the tested density range, being marginally lower at low density, comparable at intermediate densities, and slightly higher at the highest tested density. No consistent ordering is observed, and the run-wide residual rate remains within the range of the other configurations. In the smoothed per-density results, alert and pre-alert dispersion ranges overlap at all densities, indicating no measurable safety benefit from the earlier trigger mechanism. The anomalous pre-alert behaviour previously observed in Benidorm is not reproduced in Shannon, supporting its interpretation as a statistical effect rather than a systematic mechanism.

At DT64, the same behaviour is observed at a lower residual risk level, where individual events dominate the comparison. The three configurations remain indistinguishable within the available simulation resolution, **confirming that once the deviation threshold has reduced the residual conflict rate to the detection floor, the monitoring mode provides no additional measurable benefit.**

For DT16, the number of simultaneous UAS flying compatibly with TLS is 9, so there is an increase in capacity with respect to the baseline levels of $\boldsymbol{\Delta N_3 = 8}$.

For DT64, no capacity increment with respect to those provided by FAS has been observed, so with respect to the baseline $\boldsymbol{\Delta N_3 = \Delta N_2 = \Delta N_1}$.

Consequently, Risk ratios for this exercise are marginal:

Variant	RR for sv=5	RR for sv=10	RR for sv=15	RR for sv=20	RR for sv=25	Mean RR
CM with pre-alert DT16	0.034	0.041	0.028	0.027	0.036	0.033
CM with pre-alert DT64	0.0026	0.0047	0.0020	0.0029	0.0029	0.0030

Table 30: Risk Ratios for CM (with pre-alerting) for Shannon-Limerick

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KPIs calculated for this objective are:

KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	CM pre-alert remains within the simulation variability of plain FAS and CM alert at both thresholds.
	U-AGREE-KPI-02 **Number of non-conformance events/FH**	With DT16, 47 events have been solved with the support of CM with pre-alerting.
Capacity	U-AGREE-KPI-03 **Area drone density**	For DT16, the number of simultaneous UAS flying compatibly with TLS is of 9, so there is an increase in capacity with respect to the baseline levels of $\Delta N_3 = 8$. For DT64, no capacity increment with respect to those provided by FAS has been observed, so with respect to the baseline $\Delta N_3 = \Delta N_2 = \Delta N_1$. Compatibly, we have: ≈ 0.012 UAS/km² for DT16 ≈ 0.033 UAS/km² for DT64.

Table 31: KPIs for OBJ-SOL0520-ERP-004 Shannon-Limerick

Overall, the success criterion is achieved through the increased deviation threshold, while no additional measurable contribution can be attributed to the pre-alerting layer beyond plain FAS. Under the tested conditions, **conformance monitoring does not replace the need for larger deviation margins to achieve the strict safety target**. Since the Traffic Information Service is not evaluated, the objective is classified as Partially OK.

A.3.3 Unexpected behaviours/results

The following unexpected results were identified during the execution and analysis of validation exercise #01:

- **Manduria scenario — DT128/DT64 capacity inversion.** No UAS–UAS NMACs were observed for DT64, while DT128 produced a single residual event over the entire simulation run. Since DT128 uses a wider deviation margin than DT64, this would nominally suggest DT128 is less safe — a result with no physical justification. The analysis concluded that the remaining risk in both configurations is below the measurable resolution of the simulation, and that the apparent DT128/DT64 ordering is an exposure artefact rather than evidence of a real difference between the two configurations.
- **Benidorm — localized CM pre-alert anomaly at 20 simultaneous vehicles (sv).** At DT16, CM pre-alert showed a lower residual NMAC rate than FAS, specifically at sv=20, suggesting an apparent safety benefit from the earlier trigger mechanism. This difference was not maintained at neighbouring densities and was not reproduced in Manduria or Shannon-Limerick, where CM pre-alert showed no comparable isolated advantage at any density. This confirmed that the Benidorm sv=20 result was a statistical effect confined to that single density point, not a systematic mechanism.

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- **Traffic Information Service not included.** Although available in the ENGage simulator, TIS was not included in the simulation campaign for either Exercise #01 or Exercise #02, as its components had not yet been validated to a level sufficient to ensure statistically robust and reliable results. This is documented as a deviation from the ERP and affects every objective from ERP-002 onward: only the FAS/CM contribution to capacity could be isolated and assessed in all three scenarios, while the TI contribution remains unevaluated.

A.3.4 Confidence in results of validation exercise #01

A.3.4.1. Level of significance/limitations of validation exercise results

Results for OBJ-SOL0520-ERP-001 through -004 were obtained via Monte Carlo simulation, with flight plans drawn at random to sustain a target number of simultaneous vehicles (2 to 30) and a fixed exposure of 200 flight-hours simulated at every density level for each configuration. The representativeness of these results for the corresponding sub-operating environments is subject to the following limitations:

- The Traffic Information Service deviation means that the FAS+TI capacity increment specified by the ERP could not be evaluated as such in any scenario: results for ERP-002, ERP-003, and ERP-004 reflect the FAS/CM-only contribution, not the fully mitigated configuration the ERP objectives describe.
- Capacity behaviour is strongly scenario-dependent: Benidorm shows a plateau between DT=0m and DT=32m followed by a sharp drop at DT=64m, while Manduria requires very large deviation margins (DT64/DT128) to translate risk reduction into demonstrable compliance, given its stricter TLS. Extrapolation of a given DT/CM configuration's performance from one scenario to another is therefore not directly supported by these results without accounting for **each scenario's specific traffic geometry and safety target**.

A.3.4.2. Quality of validation exercises results

NMAC, rather than MAC, was adopted as the primary indicator for capacity assessment throughout, because MAC frequency has high variance relative to its magnitude, making it an unstable basis for capacity estimation; since MAC is always contained within NMAC, using NMAC provides a conservative estimate that still ensures the target level of safety is met where achieved.

Several results at the higher deviation thresholds (DT64/DT128) are constrained by very low residual event counts — down to zero events or a single event over the full simulated run. This affects the reliability of specific figures: the Manduria DT128/DT64 capacity ordering and the CM alert/pre-alert comparisons at DT64 in all three scenarios (where alert and pre-alert configurations were found statistically indistinguishable within the available exposure).

The exclusion of the Traffic Information Service is a documented deviation from the ERP, and every OBJ-SOL0520-ERP-002/003/004 result is consequently classified as "Partially OK": the FAS/CM contribution to the success criterion is demonstrated where achieved, but the TI contribution to the combined objective remains unevaluated in all scenarios.

A.3.4.3. Significance of validation exercises results

The interpretation of the results should consider both statistical and operational aspects. From a statistical perspective, each DT/CM configuration was simulated for 200 flight-hours at each density level across the 2–30 simultaneous-vehicle sweep, providing sufficient exposure to identify clear and

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repeatable trends in the effect of the FAS deviation threshold. In all three sub-operating environments, residual risk decreases consistently as DT increases. By contrast, the number of simulated flight-hours is generally insufficient to distinguish the different Conformance Monitoring configurations from FAS alone with statistical confidence: at DT16, and especially at DT64 where residual events become extremely rare, the observed differences between FAS, CM alert and CM pre-alert remain within the simulation variability.

From an operational perspective, the simulations were designed to compare mitigation strategies under controlled conditions rather than to reproduce a specific traffic demand. Flight plans were generated randomly to maintain the target number of simultaneous vehicles, and the Flight Authorisation Service was evaluated over a predefined set of deviation thresholds (0–128 m) instead of a single operationally optimised value. Consequently, while the study provides robust comparative evidence on the relative effectiveness of the mitigation strategies, the absolute numerical results should be interpreted in the **context of these modelling assumptions** and of **the specific characteristics of the three considered sub-operating environments** (Benidorm, Manduria and Shannon-Limerick).

A.4 Validation exercise #01 results - UPV

A.4.1 Summary of validation exercise #01 results

This sub-section summarises the results of validation exercise #01 from the UPV simulator. The Table 32 presents the summary of results compared to the success criteria identified within the ERP per validation objective. The analysis covers the validation objectives embedded in the validation exercise as per the corresponding ERP.

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
OBJ-SOL0520-ERP-001OF[18]	Identification of the baseline capacity (N_0).	CRT-SOL0520-TRL2-ERP-001.001	The MAC frequency between UAS shall not exceed 4.35×10^{-5} per flight-hour in Scenario 1, for exercise #01.	Scenario 1: The city of Benidorm (non U-space sub-OE)	The baseline capacity N_0 was successfully identified for each scenario and altitude configuration. For Benidorm and Manduria, the capacity obtained from the UAS–UAS and both UAS–manned criteria is 1 simultaneous UAS, below and above VLL. For Shannon, the UAS–UAS capacity is 1 simultaneous UAS below VLL and 5 simultaneous UAS above VLL; however, both UAS–manned criteria give a capacity of 1 simultaneous UAS. Therefore, when all applicable safety criteria are considered together,	OK
		CRT-SOL0520-TRL2-ERP-001.002	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 1, for exercise #01 and #02.			
		CRT-SOL0520-TRL2-ERP-001.003	The MAC frequency between UAS shall not exceed $1{,}5 \times 10^{-4}$ per flight-hour in Scenario 2, for exercise #01.	Scenario 2: The city of Manduria (non U-space sub-OE)		
		CRT-SOL0520-TRL2-ERP-001.004	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 2, for exercise #01 and #02.			

[18] Only success criteria related to exercise 1 are illustrated here.

Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
		CRT-SOL0520-TRL2-ERP-001.005	The MAC frequency between UAS shall not exceed $1{,}7 \times 10^{-2}$ per flight hour in Scenario 3, for exercise #01.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	the limiting baseline capacity is 1 simultaneous UAS in every assessed scenario and altitude configuration. These results establish the baseline reference required for the subsequent mitigation comparisons.	
		CRT-SOL0520-TRL2-ERP-001.006	The MAC frequency between UAS and manned aircraft in uncontrolled airspace shall not exceed 10^{-7} per flight-hour in Scenario 3, for exercise #01 and #02.			
		CRT-SOL0520-TRL2-ERP-001.007	The MAC frequency between UAS and manned aircraft in controlled airspace shall not exceed 10^{-9} per flight-hour in Scenario 3, for exercise #01 and #02.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	For Shannon, the UAS–UAS capacity is 1 simultaneous UAS below VLL and 5 simultaneous UAS above VLL; however, both UAS–manned criteria give a capacity of 1 simultaneous UAS.	OK

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
OBJ-SOL0520-ERP-002	Quantification of capacity increment (ΔN_1) because of the introduction of mitigation measures based on Flight Authorisation and Traffic Information services.	CRT-SOL0520-TRL2-ERP-002.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 1: The city of Benidorm (non U-space sub-OE)	The capacity increment associated with FAS+TIS was successfully quantified and depends strongly on the deviation threshold and scenario configuration. At deviation thresholds of 4, 32 and 64 m, the UAS–UAS capacities are respectively 1, 1 and 20 UAS for Benidorm below VLL; 1, 2 and 141 UAS for Benidorm above VLL; 1, 1 and 52 UAS for Manduria below VLL; and 1, 2 and	Partially OK
		CRT-SOL0520-TRL2-ERP-002.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 2: The city of Manduria (non U-space sub-OE)		

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		CRT-SOL0520-TRL2-ERP-002.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	87 UAS for Manduria above VLL. For Shannon, the resulting UAS–UAS safety-based capacities are substantially higher: 526, 1181 and 925 UAS below VLL, and 2316, 932 and 583 UAS above VLL for deviation thresholds of 4, 32 and 64 m, respectively. Where the safety-based capacity exceeds the traffic that FAS can allocate within the available airspace, operational capacity is limited by trajectory availability rather than safety. The UAS–manned capacity remains 1 UAS for all scenarios because manned aircraft are not directly included in FAS strategic deconfliction. The Authorisation Approval Rate decreases as traffic demand and deviation threshold increase, capturing the trade-off between strategic separation and access to the airspace.	

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
OBJ-SOL0520-ERP-003	Quantification of capacity increment (ΔN_2) because of the introduction of mitigation measures based on Flight Authorisation, Traffic Information, and Conformance Monitoring (without pre-alerting) services.	CRT-SOL0520-TRL2-ERP-003.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 1: The city of Benidorm (non U-space sub-OE)	The additional effect of Conformance Monitoring without pre-alerting was successfully quantified relative to FAS+TIS. The UAS–UAS MAC Risk Ratio is below 1 for most assessed configurations, demonstrating an additional reduction in MAC risk, although the magnitude is dispersed across traffic levels, deviation thresholds and scenarios.	Partially OK
		CRT-SOL0520-TRL2-ERP-003.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 2: The city of Manduria (non U-space sub-OE)		

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		CRT-SOL0520-TRL2-ERP-003.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	By contrast, the UAS–UAS NMAC Risk Ratio remains approximately equal to 1, and UAS–manned frequencies remain broadly unchanged. Deviation-boundary non-conformance decreases rapidly as the deviation threshold increases. At a deviation threshold of 4 m, Conformance Monitoring reduces the frequency from approximately 6E-2 to 5E-2 events/FH, corresponding to an additional reduction of about 17%. TSE non-conformance is less affected because recovery starts only after the outer monitoring boundary is reached. Consequently, CM may increase the capacity derived from the UAS–UAS MAC criterion where RR < 1, but the overall capacity remains equal to the FAS+TIS value while the UAS–manned criterion or FAS trajectory-allocation	

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
					capability remains limiting. Authorised U-plans and the Authorisation Approval Rate are unchanged because CM is applied after Flight Authorisation.	
OBJ-SOL0520-ERP-004	Quantification of the capacity increment (ΔN_3) because of the introduction of mitigation measures based on Flight Authorisation, Traffic Information, and Conformance Monitoring (with pre-alerting) services.	CRT-SOL0520-TRL2-ERP-004.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 1: The city of Benidorm (non U-space sub-OE)	The additional effect of Conformance Monitoring with pre-alerting was successfully quantified relative to FAS+TIS and to CM without pre-alerting. Earlier recovery at the TSE boundary generally provides an additional UAS–UAS MAC safety benefit, with MAC Risk Ratios below 1 for most assessed configurations. The NMAC Risk Ratio remains close to 1 in several configurations,	Partially OK
		CRT-SOL0520-TRL2-ERP-004.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 2: The city of Manduria (non U-space sub-OE)		

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		CRT-SOL0520-TRL2-ERP-004.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	although reductions are observed for some larger deviation thresholds, while UAS–manned frequencies remain broadly unchanged. Pre-alerting improves TSE containment because recovery begins before the UAS reaches the outer monitoring boundary; the containment level increases from approximately 93.2% under FAS to approximately 94.0% with pre-alerting and remains broadly independent of the deviation threshold. The resulting UAS–UAS capacity benefit is configuration-dependent and must be calculated using the applicable RR, whereas the overall capacity remains equal to FAS+TIS where the UAS–manned criterion or FAS trajectory-allocation capability is limiting. Authorised U-plans and the Authorisation	

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
					Approval Rate remain unchanged because pre-alerting is applied after Flight Authorisation.	

Table 32: validation exercise #01 results - UPV

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A.4.2 Analysis of validation exercise #01 results per validation objective

The UPV assessment uses fast-time Monte Carlo simulation to estimate the frequency of collision-related events under sustained traffic conditions. Each simulation run represents a scenario in which a target number of aircraft is kept airborne at the same time. Aircraft are introduced into the scenario, propagated along their trajectories with the selected navigation-error model, monitored for conformance, checked for conflicts, and removed when they complete their route. If an aircraft is involved in a MAC event, it is also removed from the active traffic population. Whenever the number of active aircraft falls below the target concurrent traffic level, a new aircraft may be introduced. The simulated traffic level therefore represents a sustained density condition, not a finite list of pre-defined flights.

This replacement mechanism is important for interpreting the validation objectives. A case with 5, 10, 15 or 20 concurrent aircraft should be read as a scenario in which that traffic level is maintained over the simulated exposure, subject to the availability of acceptable trajectories. The metric is therefore not the number of scheduled operations completed in a fixed scenario duration, but the frequency of conflict events observed while the scenario is operated at a defined concurrent traffic level.

Exposure is normalised in flight hours. The simulated scenario time is derived from a fixed target exposure and from the selected number of concurrent aircraft. This avoids the bias that would occur if all traffic-density cases were simulated for the same scenario time: in that case, higher concurrent traffic would automatically accumulate more flight hours, increase computational cost, and make frequencies harder time is to compare. Instead, the scenario shortened as concurrent traffic increases, so that cases are interpreted under comparable flight-hour exposure. Conflict frequencies are then read as event counts per unit exposure, with the relevant denominator being the accumulated flight hours of the aircraft population represented in the case.

The traffic model uses realistic trajectories and a stochastic Total System Error (TSE) model. TSE is represented probabilistically: a stated containment level does not mean that aircraft never leave the declared corridor. It means that, under the assumed navigation-error process, aircraft are expected to remain within the TSE corridor for a corresponding proportion of flight time. The default model used in this validation context provides approximately 95% containment within the declared TSE volume. The remaining flight time is still relevant for safety, because excursions beyond the nominal corridor can erode the margins assumed during strategic deconfliction.

Conflict monitoring is based on the movement of aircraft between consecutive propagated positions. The conflict check considers the segment travelled during the time step rather than relying only on the sampled position at the end of the step. This reduces the risk of overlooking close approaches that occur between two sampled instants, especially when aircraft pass each other quickly or when the adaptive time step is larger in non-critical conditions. The same principle is used when the Flight Authorisation Service assesses whether a proposed trajectory conflicts with trajectories that are already active: overlapping trajectory segments are compared in both space and time.

The simulation records conflict events by severity and by aircraft-pair type. The relevant severity levels include MAC and NMAC, as well as less severe proximity states used for monitoring and time-step control. The pair categories are UAS-UAS, UAS-manned and manned-manned. Directional UAS-manned and manned-UAS records should be consolidated when a non-directional UAS-manned indicator is required. This separation is necessary because the mitigation mechanisms do not affect all pair types in the same way.

The Flight Authorisation Service primarily affects UAS-UAS conflicts. When a new unmanned trajectory is proposed, it is compared with already active unmanned trajectories and may be rejected if the protected volumes would overlap. The deconfliction distance combines the TSE margins, the relevant MAC dimensions and the selected deviation threshold. UAS-manned and manned-manned conflicts are still detected and reported, but they are not mitigated by the same UAS-UAS strategic deconfliction mechanism. For this reason, the safety effect of Flight Authorisation should mainly be interpreted through UAS-UAS MAC and UAS-UAS NMAC indicators. UAS-manned and manned-manned events remain useful as complementary scenario indicators, but they should not be treated as direct evidence of the UAS-UAS deconfliction effect.

The deviation threshold is an additional margin around the deconflicted trajectory corridor. Increasing the deviation threshold increases the distance that must be preserved between authorised unmanned trajectories. Even small buffer values can reduce both MAC and NMAC opportunities, because any additional spacing moves authorised trajectories farther apart. However, the effect is much faster for MAC because the buffer scale is initially much closer to the MAC distance scale than to the NMAC distance scale. A small buffer can therefore make MAC events fall very rapidly, while NMAC events may remain possible because the NMAC volume is much larger.

This scale difference can be illustrated with the largest horizontal UAS thresholds used by the deconfliction-relevant category set. The Certified_Unknown category has a horizontal MAC distance of 10.0 m and a horizontal NMAC distance of 152.4 m. For two aircraft of this category, the horizontal deconfliction distance includes the TSE margins of both aircraft, the MAC distances of both aircraft and the deviation threshold on both sides. With TSE margins of 14.3 m per aircraft, the protected horizontal distance is therefore 14.3 m + 14.3 m + 10.0 m + 10.0 m + 2 x deviation threshold. A deviation threshold around 60 m gives a protected distance of approximately 168.6 m, which is already above the 152.4 m horizontal NMAC distance. At that point, the same strategic spacing that prevents MAC is large enough to cover the NMAC scale for this limiting UAS category, so NMAC frequency is expected to approach zero despite the presence of a non-zero excursion frequency (rare events). This means that the authorised spacing has become large enough that aircraft no longer intersect inside the NMAC threshold.

Conformance monitoring modifies how TSE excursions are handled during flight. It compares the actual aircraft position with the nominal trajectory and the monitored TSE or TSE-plus-buffer limits. When an excursion is detected and the monitoring chain is successful, recovery behaviour is initiated after the modelled communication and reaction delays. This increases effective containment because aircraft that would otherwise continue outside the monitored corridor are detected and managed. However, the benefit is probabilistic and delay-dependent; conformance monitoring reduces the time and distance spent outside the corridor, but it does not guarantee that every excursion is prevented immediately.

The effect of conformance monitoring is expected to be most visible for MAC at small protection-buffer values. In those cases, small departures from the deconflicted corridor can be sufficient to erode the MAC-scale safety margin, so reducing excursion duration can reduce the probability of a MAC event. The effect on NMAC may be less visible, because NMAC thresholds are much larger than MAC thresholds. Unless the deviation threshold and the monitored corridor are large enough to act at the NMAC scale, improved TSE containment may reduce MAC without producing an equally clear reduction in NMAC. The UAS non-conformance is calculated as the UAS time in non-conformance per flight hour for the UPV's results.

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The excursion-frequency assumptions differ by aircraft category and represent the expected rate at which non-nominal deviations are introduced into the traffic population. Open-category UAS are assigned an excursion frequency of 0.01 per flight hour, Specific-category UAS are assigned 0.001 per flight hour, and Certified-category UAS are assigned 0.0001 per flight hour. These values reflect progressively lower expected excursion rates for categories with higher operational assurance. They also affect the interpretation of the mitigation barriers: categories with more frequent excursions create more opportunities for TSE loss and for erosion of the deconflicted margins, while lower excursion frequencies reduce, but do not eliminate, the need to interpret results probabilistically.

Finally, zero observed frequencies in Monte Carlo outputs require careful interpretation. A zero frequency means that no event of that type was observed during the simulated exposure. It does not prove that the true underlying frequency is mathematically zero. When events are rare, the probability of observing them depends strongly on the amount of simulated exposure. Estimating very small frequencies with confidence would require substantially larger numbers of simulated flight hours and correspondingly greater computational effort. This distinction applies especially to MAC, which is rarer than NMAC and therefore more sensitive to finite-exposure effects.

The encounter model is a conditional, conflict-rich assessment used to compare each barrier against a paired unmitigated branch under the same sampled geometry and traffic-class combination. It uses synthetic traffic, pairwise encounters and rectilinear, level reference trajectories to isolate the effect of TIS. These assumptions support reproducible barrier comparisons but do not represent the complete frequency or complexity of operational traffic. For that reason, the consortium-agreed final reporting convention multiplies each aggregated RR by 2 after scenario weighting. The values transferred to the final tables already contain this conservative margin; it is applied once and is not repeated in downstream calculations.

A.4.2.1. OBJ-SOL0520-ERP-001 Results

This objective identifies the baseline capacity and provides the reference condition for later mitigation comparisons. In the baseline interpretation, the scenario is operated at a fixed concurrent traffic level without Flight Authorisation deconfliction. Aircraft are introduced until the target number is active, propagated along their trajectories, removed after route completion or MAC, and replaced when the active population falls below the target level. The baseline therefore represents sustained exposure at a given traffic density rather than the outcome of a finite set of scheduled flights.

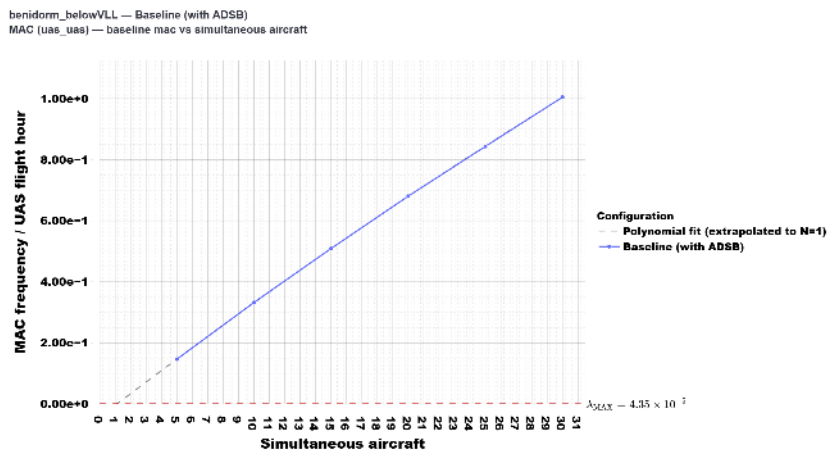
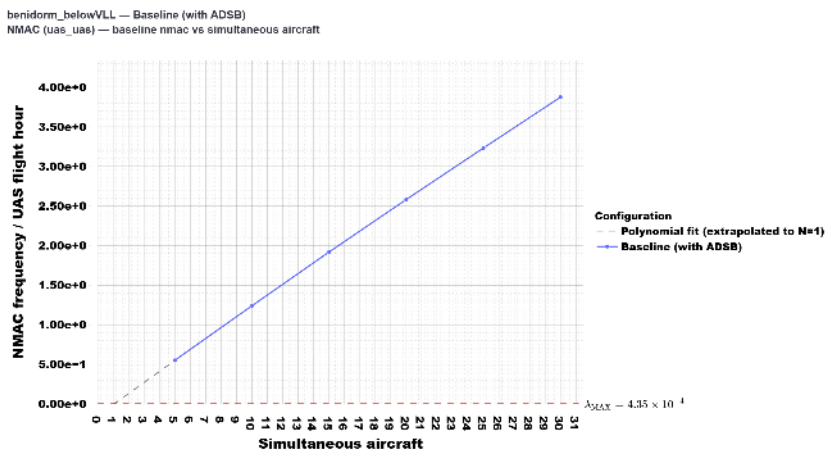
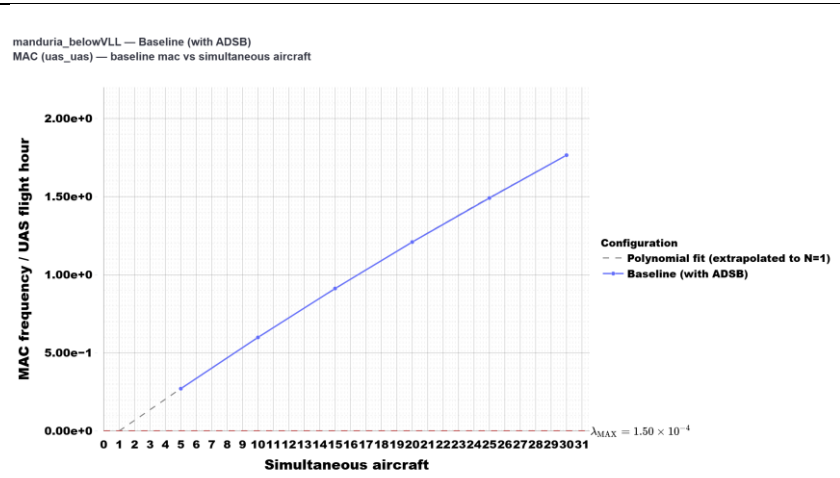
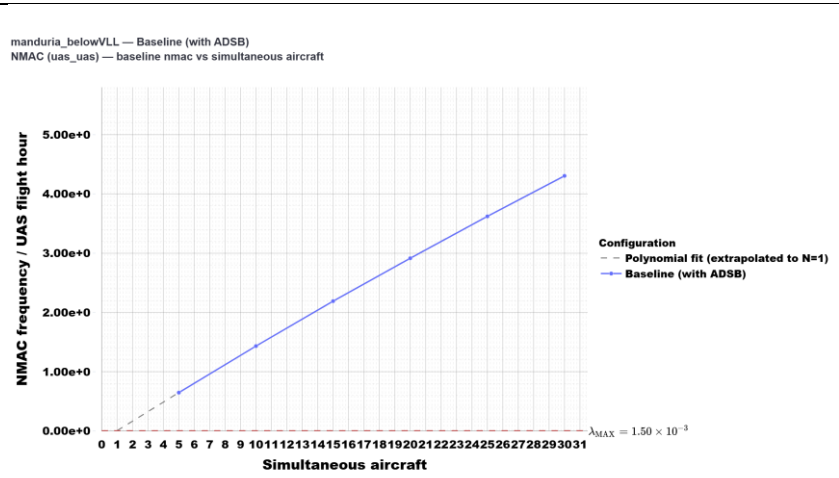
The main assumption for this objective is that conflict frequency is interpreted per unit flight-hour exposure. Because the scenario time is derived from the target exposure and the concurrent traffic level, cases with different traffic densities can be compared without automatically giving higher-density cases a larger exposure. The relevant baseline indicators are UAS-UAS MAC, UAS-manned MAC and the corresponding NMAC indicators, with manned-manned events reported for completeness where applicable.

MAC remains the primary safety event for the target level of safety, but NMAC is also necessary for interpretation. NMAC events are more frequent and occur at larger distances, so they provide a useful proximity indicator when MAC counts are sparse. A baseline case with no observed MAC events must not be interpreted as risk-free. It means only that no MAC was observed within the simulated exposure for that traffic level and scenario. The associated NMAC frequency and the total exposure should be used to understand whether the absence of MAC is likely to reflect a robust margin or a finite-sampling limitation.

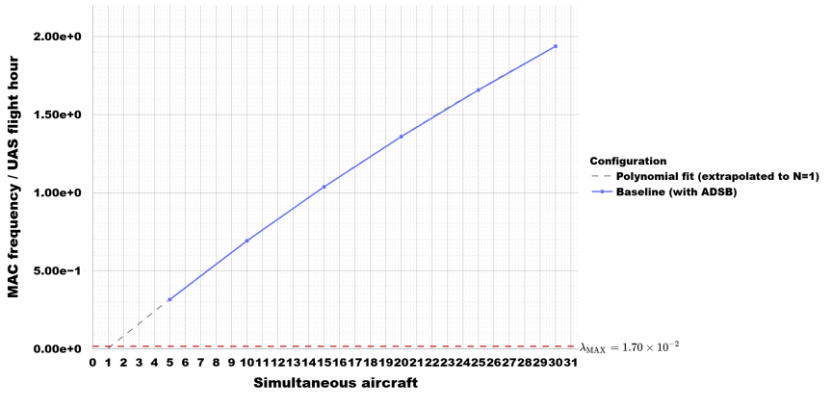
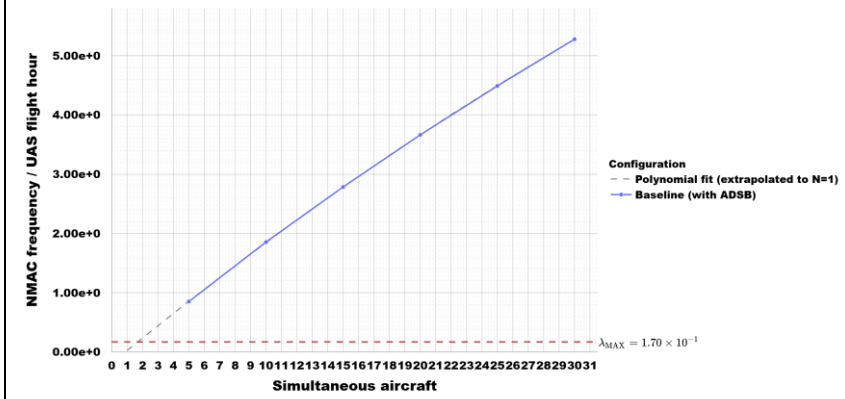
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Co-funded by the European Union

Figure 25: UPV - Baseline below VLL UAS-UAS frequency

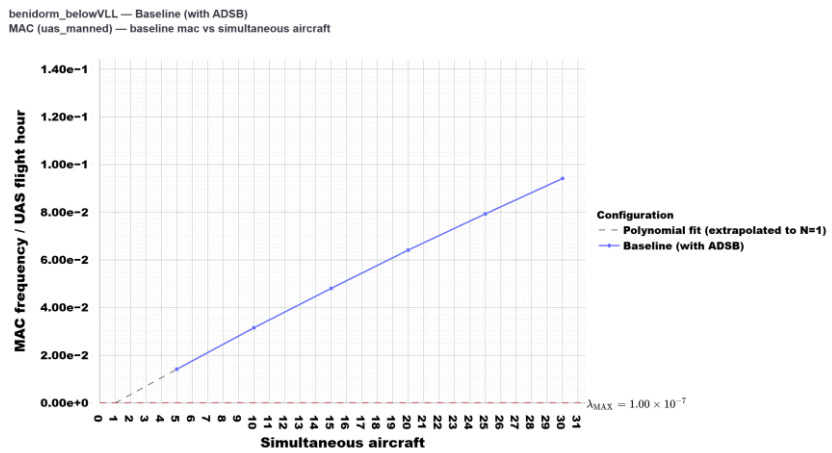
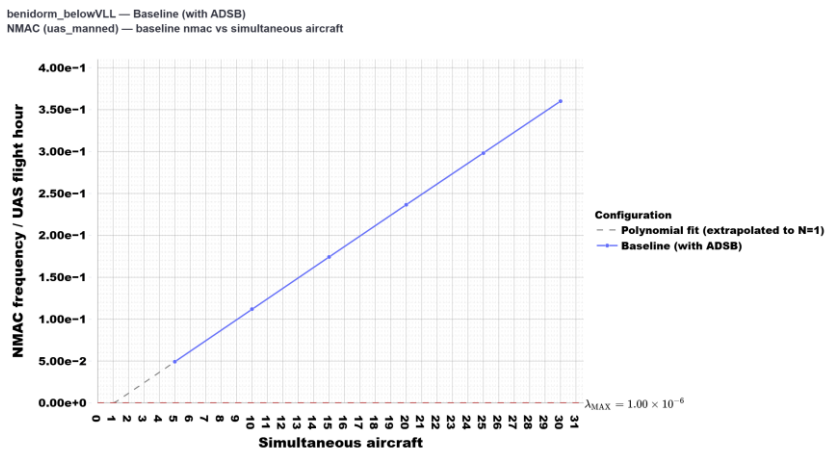
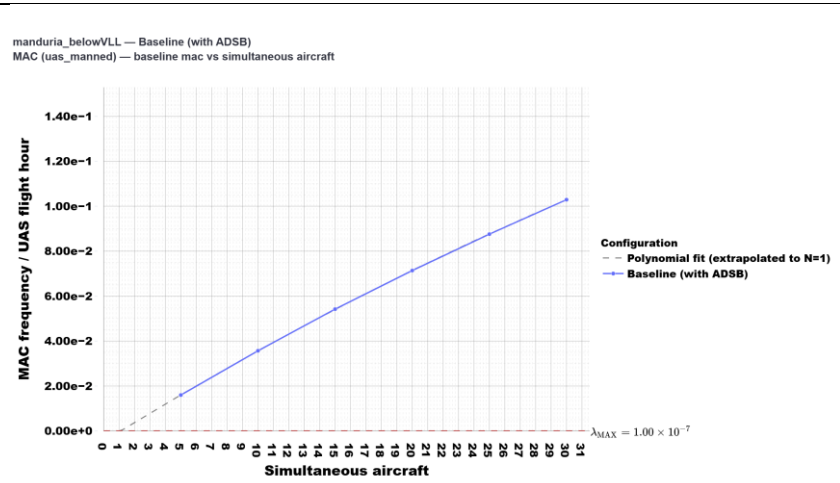
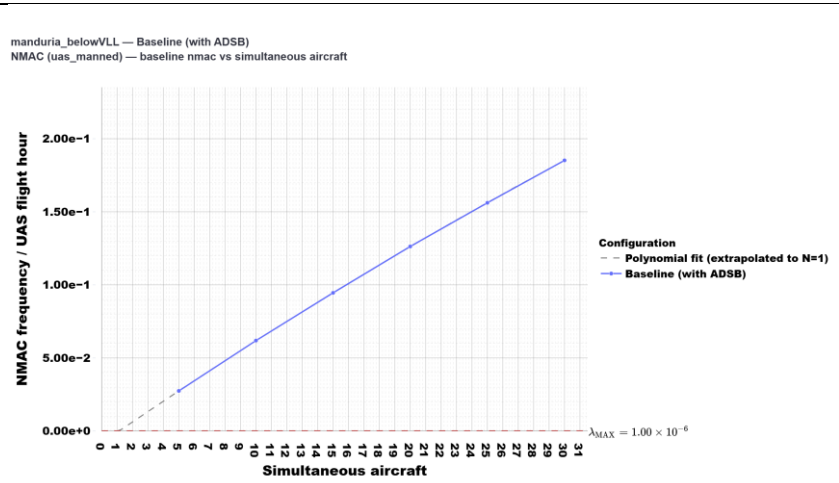
	MAC	NMAC
Benidorm below VLL		
Manduria below VLL		

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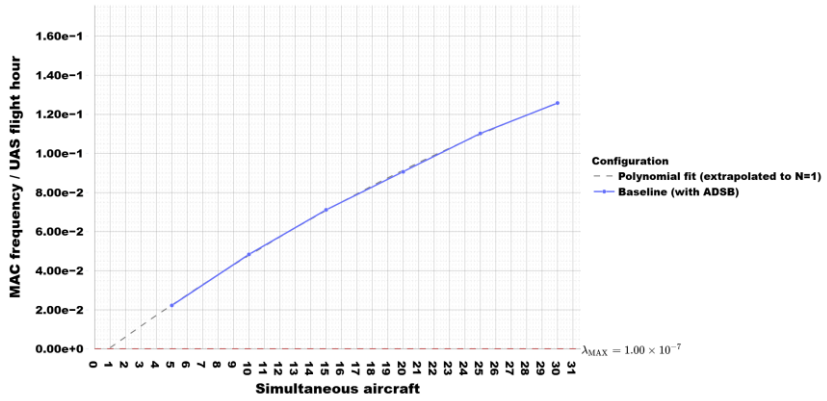
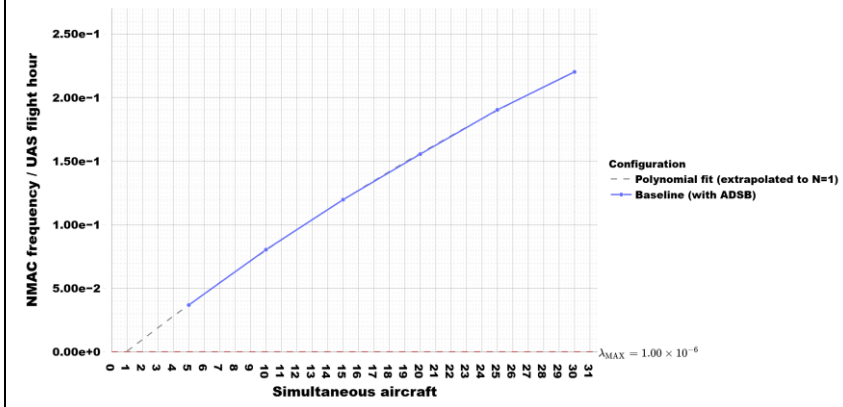
Shannon below VLL		

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Figure 26: UPV - Baseline below VLL UAS-manned frequency in UAS flight hours

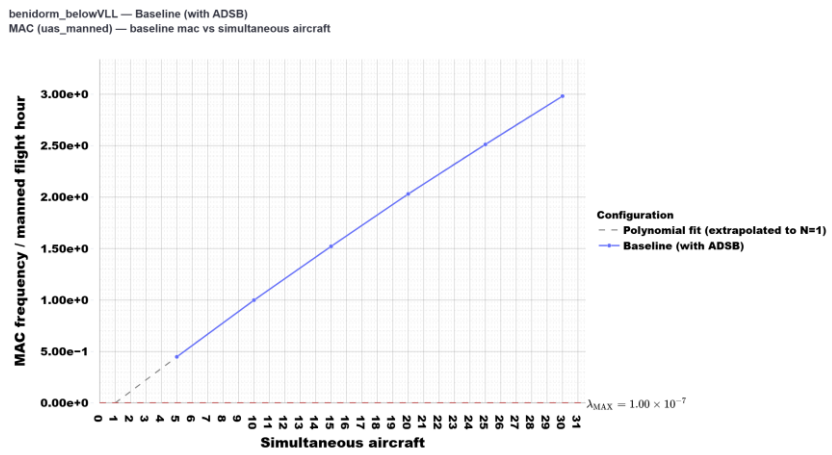
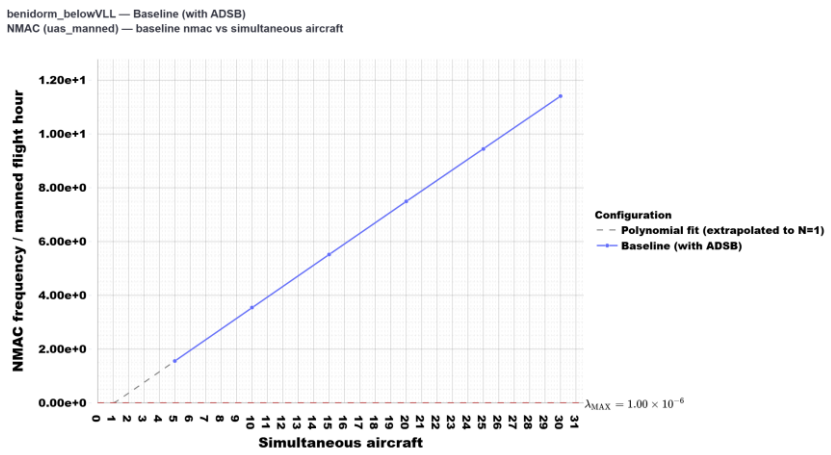
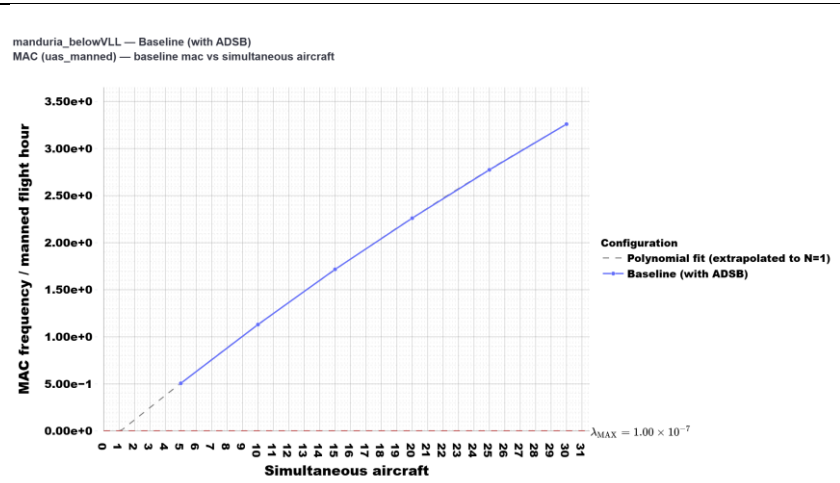
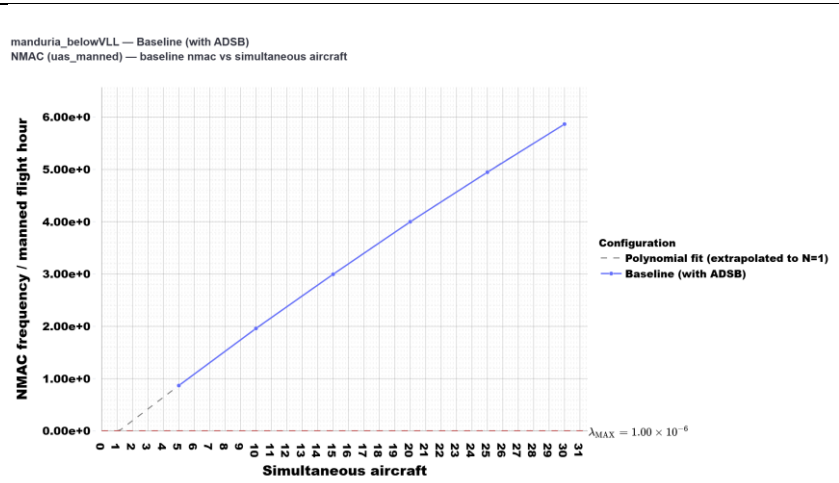
	MAC	NMAC
Benidorm below VLL		
Manduria below VLL		

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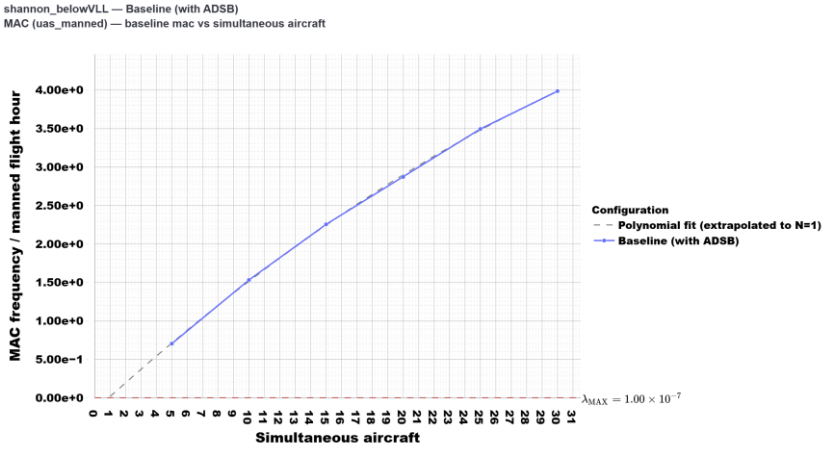
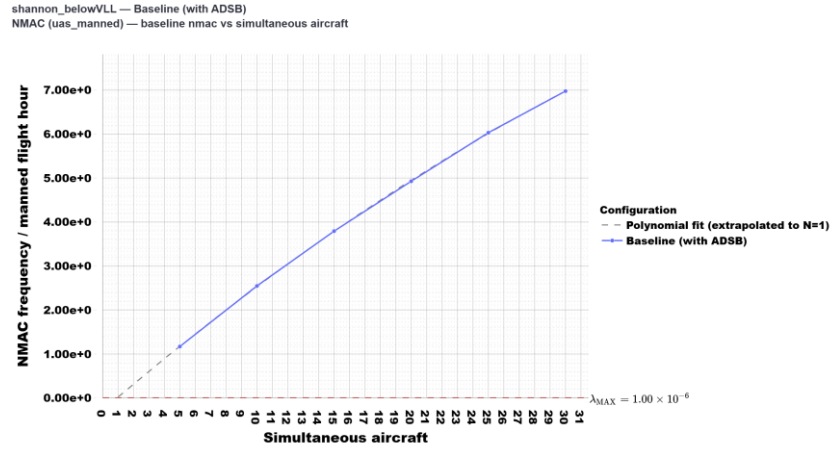
Shannon below VLL		

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Figure 27: UPV - Baseline below VLL UAS-manned frequency in manned flight hours

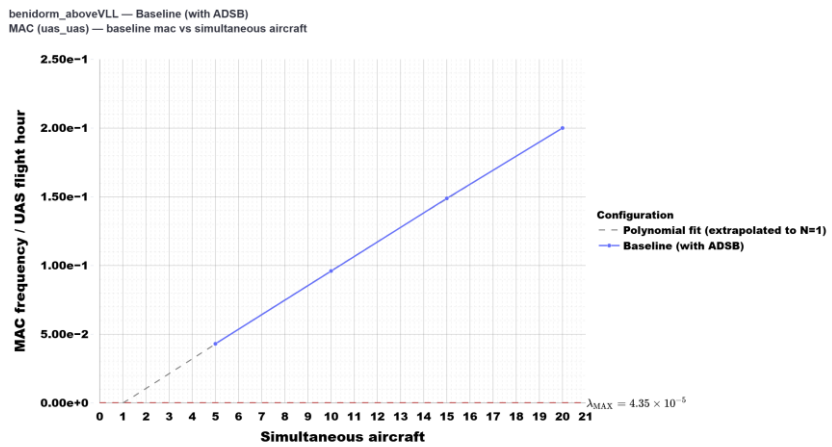
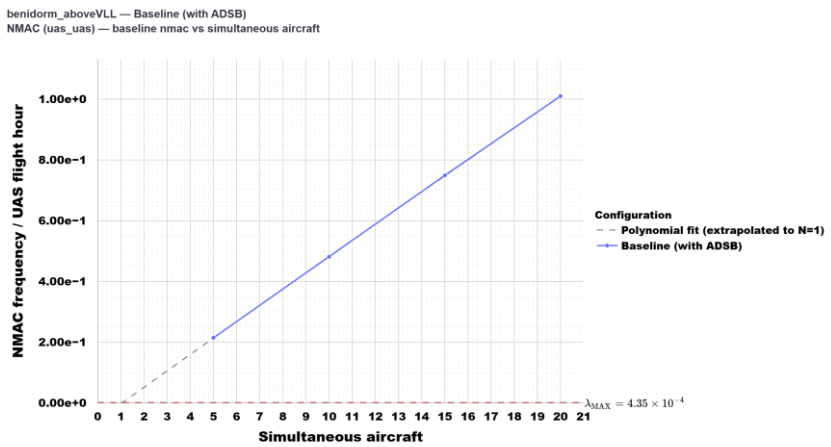
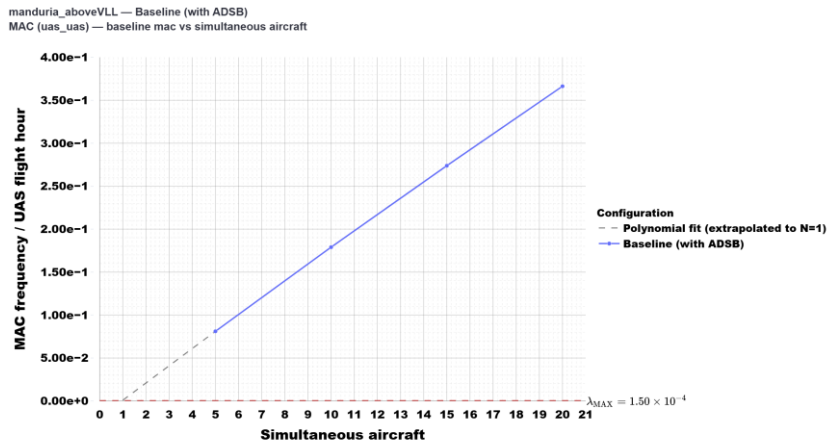
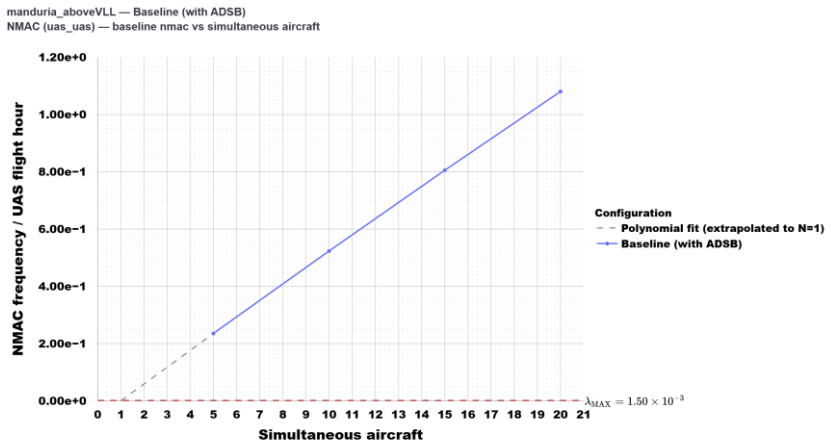
	MAC	NMAC
Benidorm below VLL		
Manduria below VLL		

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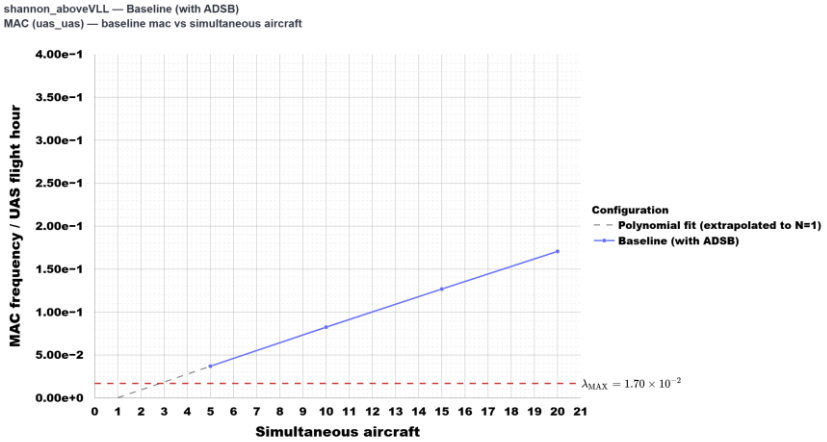
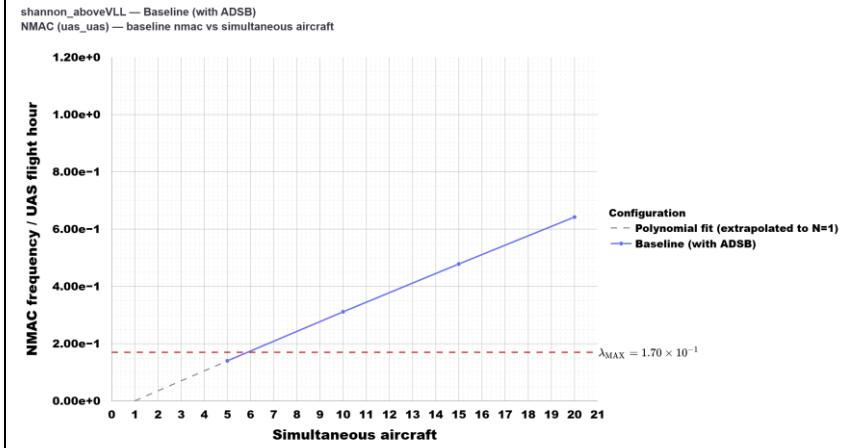
Shannon below VLL		

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Figure 28: UPV - Baseline above VLL UAS-UAS frequency

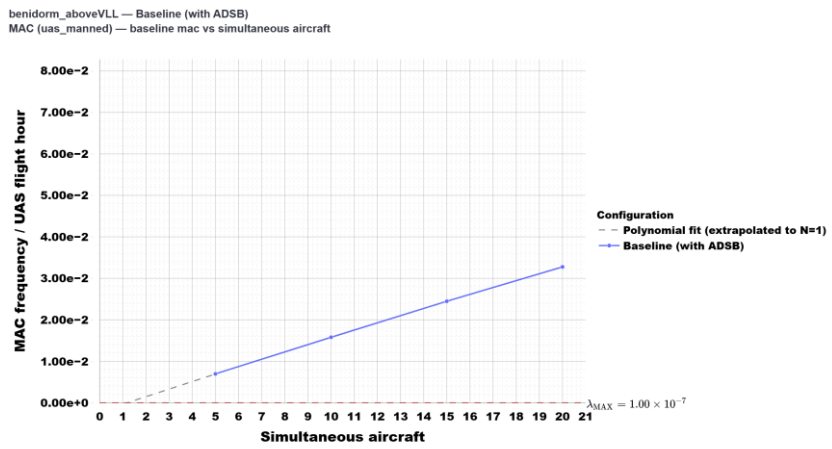
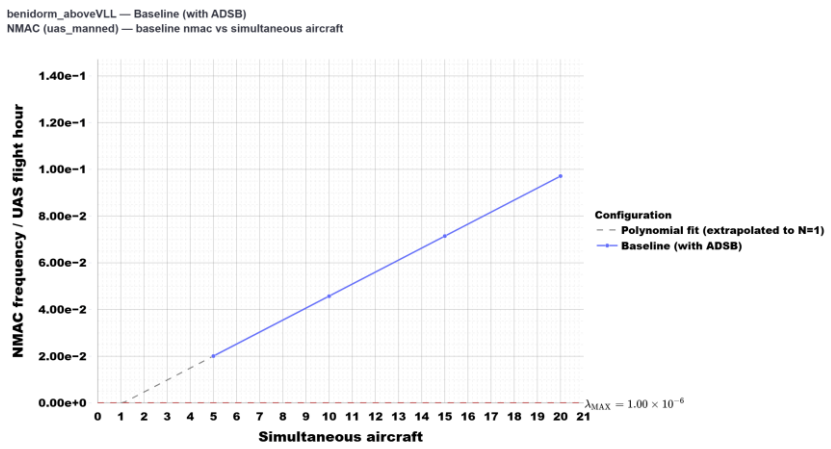
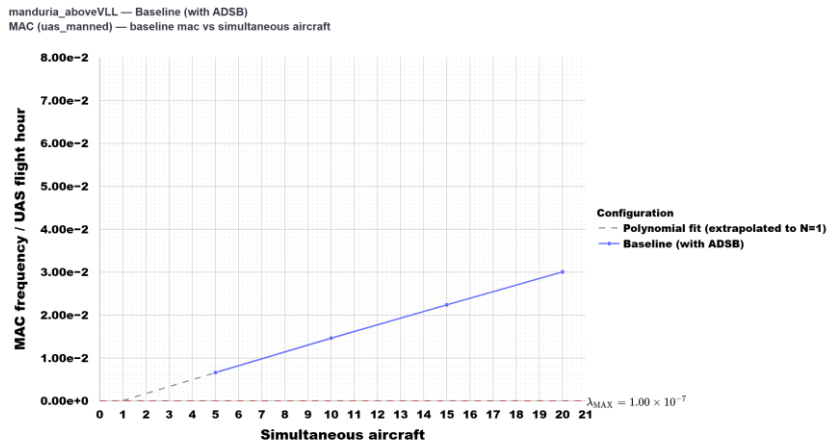
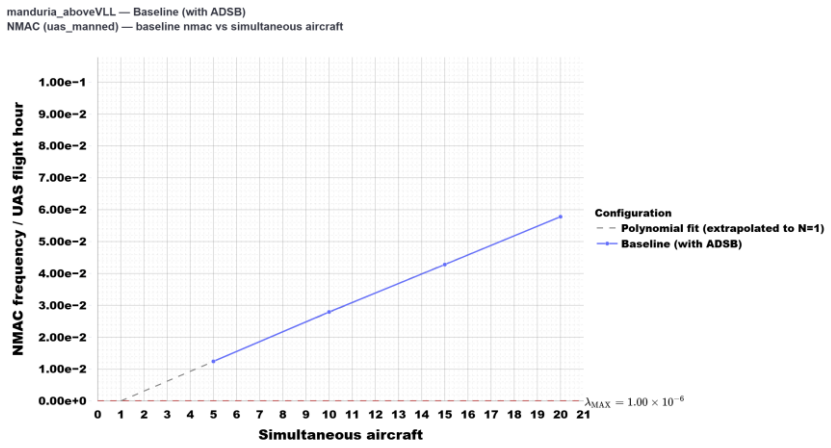
	MAC	NMAC
Benidorm above VLL		
Manduria above VLL		

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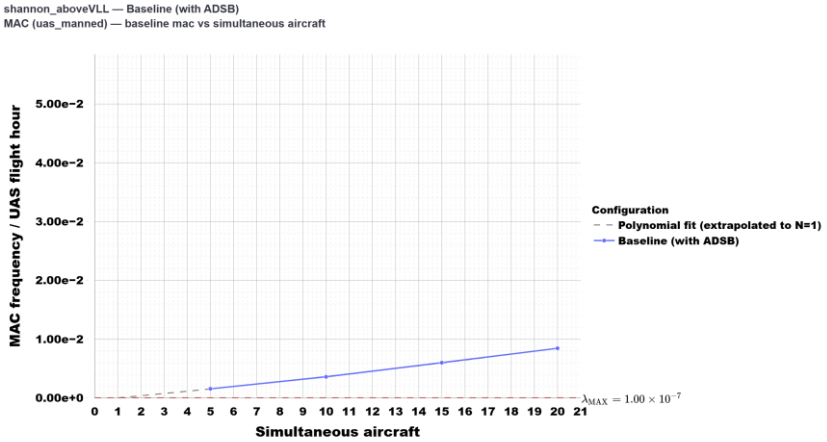
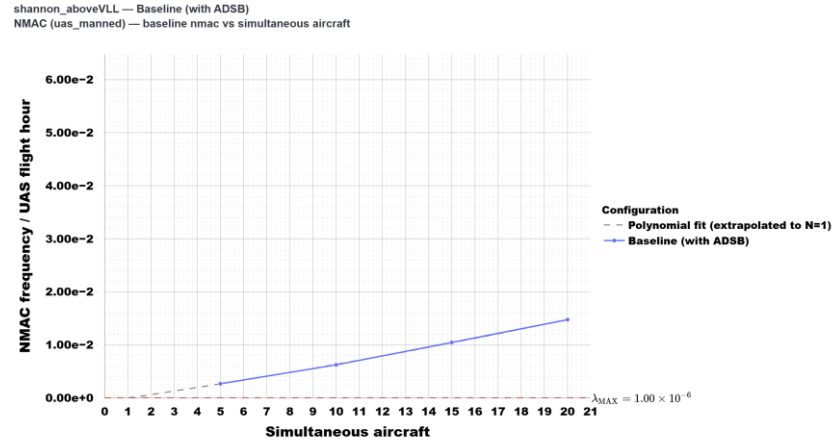
Shannon above VLL		

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Figure 29: UPV - Baseline above VLL UAS-manned frequency in UAS flight hours

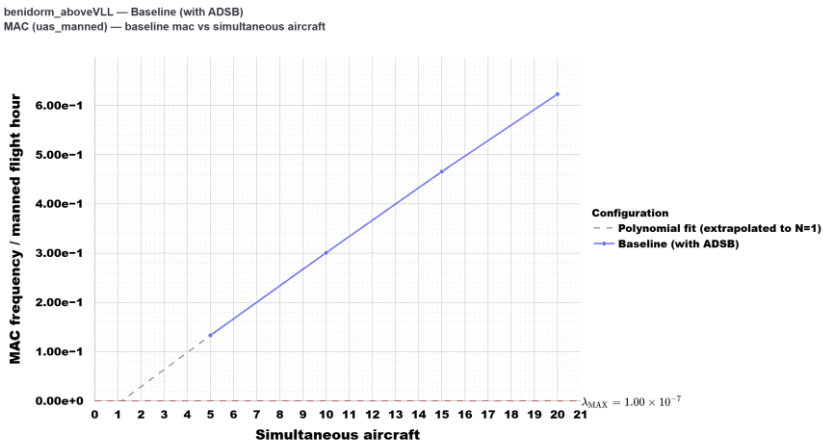
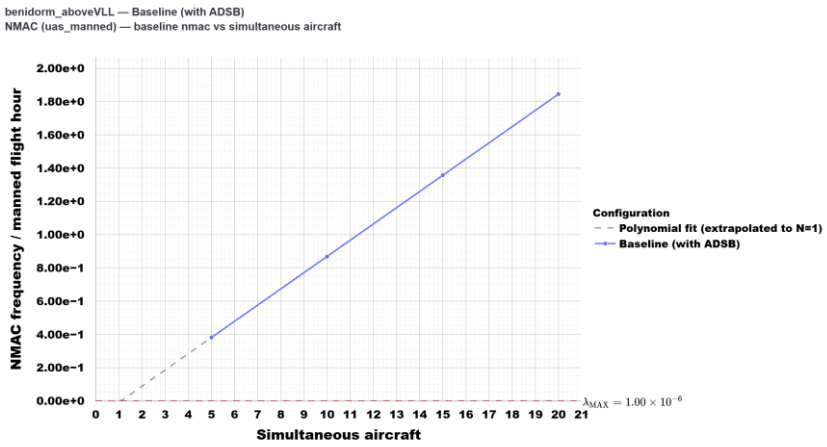
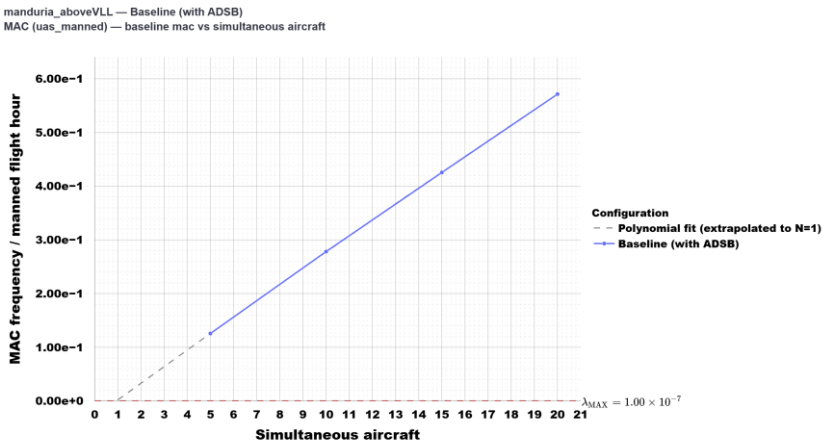
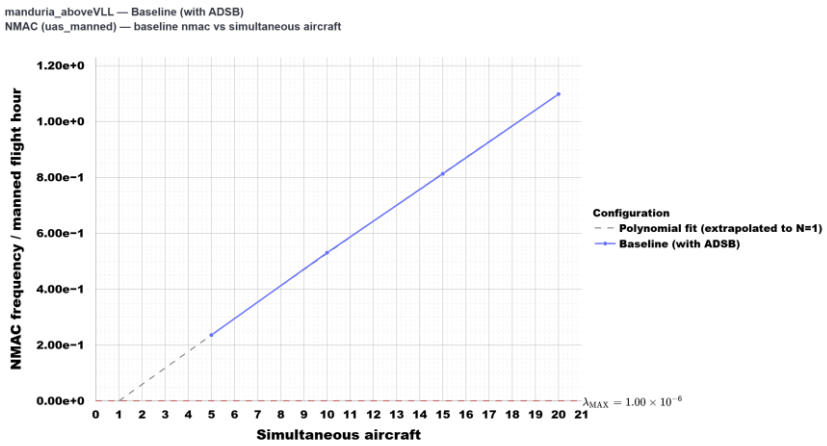
	MAC	NMAC
Benidorm above VLL		
Manduria above VLL		

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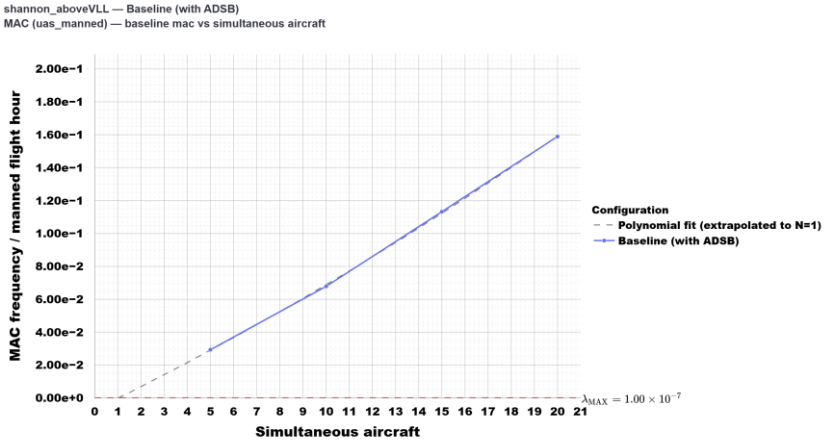
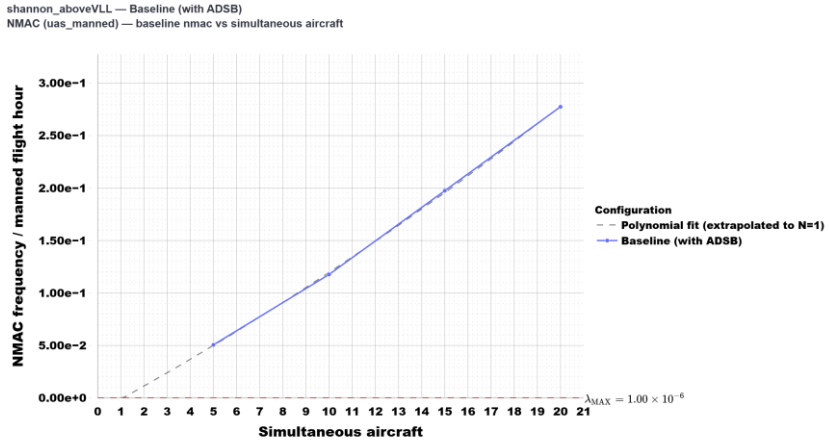
Shannon above VLL		

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Figure 30: UPV - Baseline above VLL UAS-manned frequency in manned flight hours

	MAC	NMAC
Benidorm above VLL		
Manduria above VLL		

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Shannon above VLL		

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The baseline results show that collision frequency increases with the number of simultaneous aircraft in all three scenarios. A comparison between the below VLL and above VLL configurations also shows consistently lower MAC and NMAC frequencies above VLL. This reduction can be attributed to the wider vertical distribution of UAS trajectories above VLL, which decreases the probability that two aircraft simultaneously converge within the horizontal and vertical dimensions defining a MAC or NMAC. The effect is visible for both UAS–UAS and UAS–manned encounters, although its magnitude depends on the scenario, traffic mix and encounter type.

The UAS–UAS and UAS–manned results should be interpreted separately, as they represent different encounter populations and operational exposure conditions. The differences observed among Benidorm, Manduria and Shannon are influenced by the scenario-specific traffic composition, the spatial and vertical distribution of trajectories, and the resulting encounter geometries. Therefore, the results do not support a single general ranking of the three scenarios that applies to every encounter category. For UAS–manned encounters, the interpretation also depends on whether the frequency is normalised by UAS or manned-aircraft flight hours. In all configurations, NMAC events are more frequent than MAC events because the NMAC thresholds define a substantially larger proximity volume. NMAC therefore provides a broader indicator of encounter exposure, whereas MAC represents the less frequent but more safety-critical outcome.

The frequency results also provide the basis for estimating the baseline capacity N_0, presented in Table 33. The horizontal axis represents the number of simultaneous aircraft, while the maximum admissible MAC frequency defines the applicable safety limit. The intersection between the fitted frequency curve and this limit determines the estimated capacity for each scenario. The results generally indicate baseline capacities close to one simultaneous aircraft, showing that only a very limited traffic level can be accommodated in the absence of mitigation measures while satisfying the applicable safety criteria.

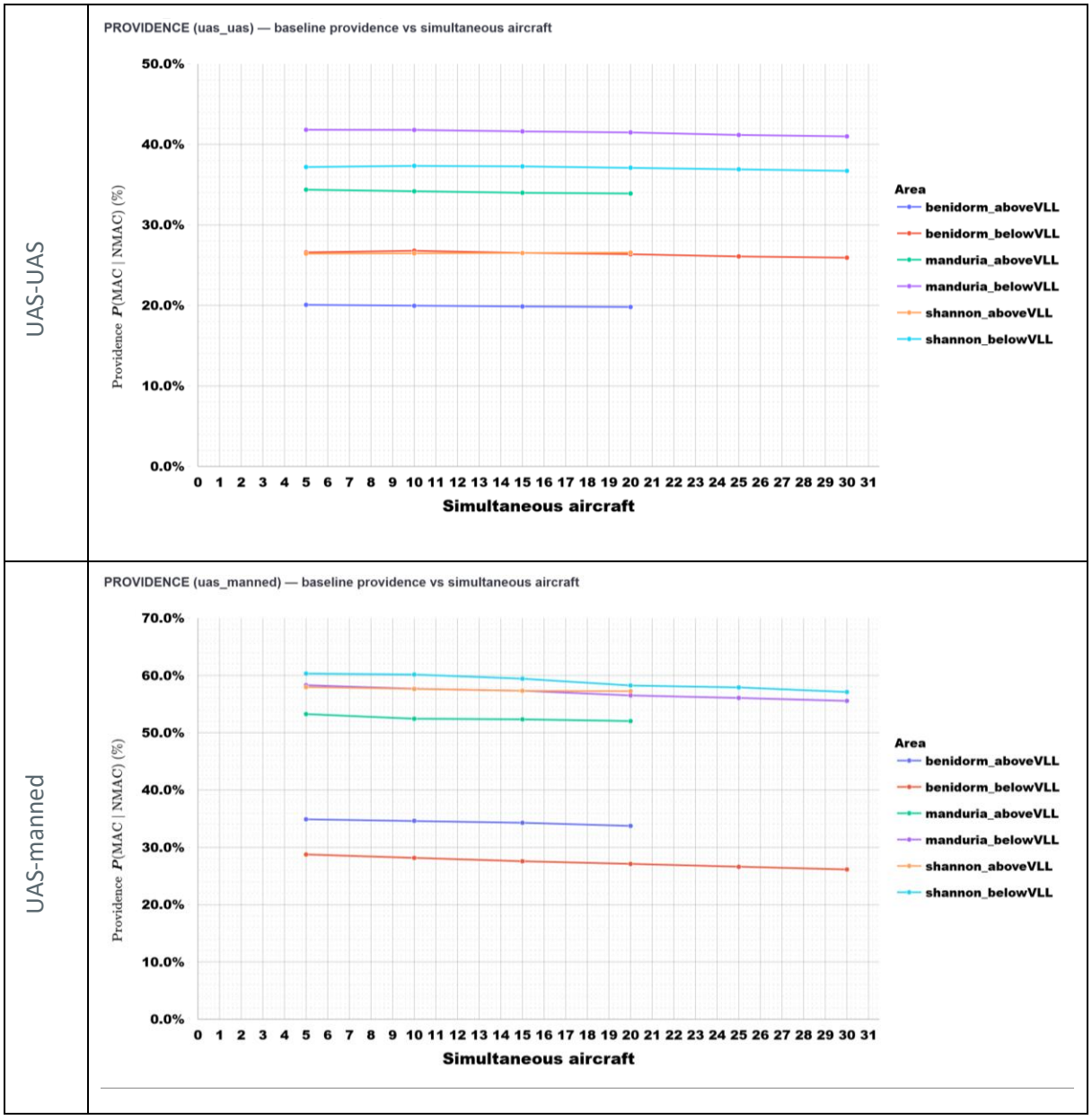
Scenario	UAS–UAS capacity	UAS–manned capacity per UAS FH	UAS–manned capacity per manned FH
Benidorm below VLL	1	1	1
Benidorm above VLL	1	1	1
Manduria below VLL	1	1	1
Manduria above VLL	1	1	1
Shannon below VLL	1	1	1
Shannon above VLL	5	1	1

Table 33: UPV - Baseline capacity results for batch 1

To complement the previous MAC and NMAC frequency results, providence is evaluated as the conditional probability of a MAC given an NMAC, $P(\mathrm{MAC} \mid \mathrm{NMAC})$. This indicator summarises the

relationship between the two types of events and facilitates comparison across scenarios. Since the progression from NMAC to MAC depends on the characteristics of each operational environment, providence may differ among Benidorm, Manduria and Shannon, as well as between below-VLL and above-VLL operations.

Figure 31: UPV - Baseline providence



The providence results confirm that the probability of an NMAC progressing into a MAC is not constant across the analysed operational environments. A value of 10% has historically been used in collision-risk modelling as a conservative reference or upper bound, corresponding to the assumption of approximately one MAC for every ten NMACs. However, this value should not be interpreted as a universal probability that must necessarily be reproduced in every scenario.

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In the present assessment, the providence values differ among Benidorm, Manduria and Shannon because each scenario generates a different population of encounters. The probability that an NMAC progresses into a MAC is influenced by the scenario-specific traffic mix, aircraft dimensions, operational-area size, traffic patterns, altitude distribution and conflict geometry. The differences observed between below VLL and above VLL operations are also consistent with the different vertical distribution of traffic in these configurations. Moreover, providence differs between UAS–UAS and UAS–manned encounters because the two encounter families involve different aircraft populations, physical dimensions and MAC and NMAC thresholds.

Consequently, a single providence value should not be applied uniformly across all scenarios and encounter types. Instead, scenario and encounter-specific providence values should be considered when interpreting the relationship between the MAC and NMAC frequencies presented above

The results obtained for the KPIs associated with this validation objective are summarised in the following Table 34. The values are presented separately for each operational scenario and for below-VLL and above-VLL operations, allowing the influence of the scenario and traffic configuration on the assessed safety and capacity indicators to be examined.

Scenario	KPA	KPI	Value obtained
Benidorm below VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS–UAS** ≈ 5E-1 NMAC/UAS FH for 5 simultaneous vehicles–3.9 NMAC/UAS FH for 30 simultaneous vehicles **UAS–manned per UAS flight hours** ≈ 5E-2 NMAC/UAS FH for 5 simultaneous vehicles–3.6E-1 NMAC/UAS FH for 30 simultaneous vehicles **UAS–manned per manned flight hours** ≈ 1.6 NMAC/manned FH for 5 simultaneous vehicles–11.5 NMAC/manned FH for 30 simultaneous vehicles
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS–UAS** ≈ 0.0469 UAS/km² **UAS–manned per UAS flight hours** ≈ 0.0469 UAS/km² **UAS–manned per manned flight hours** ≈ 0.0469 UAS/km²
Benidorm above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS–UAS** ≈ 2E-1 NMAC/UAS FH for 5 simultaneous vehicles–1 NMAC/UAS FH for 30 simultaneous vehicles **UAS–manned per UAS flight hours** ≈ 2E-2 NMAC/UAS FH for 5 simultaneous vehicles–1E-1 NMAC/UAS FH for 30 simultaneous vehicles **UAS–manned per manned flight hours** ≈ 4E-1 NMAC/manned FH for 5 simultaneous vehicles–1.85 NMAC/manned FH for 30 simultaneous vehicles

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	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS–UAS** ≈ 0.0469 UAS/km² **UAS–manned per UAS flight hours** ≈ 0.0469 UAS/km² **UAS–manned per manned flight hours** ≈ 0.0469 UAS/km²
Manduria below VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS–UAS** ≈ 6E-1 NMAC/UAS FH for 5 simultaneous vehicles–4.4 NMAC/UAS FH for 30 simultaneous vehicles **UAS–manned per UAS flight hours** ≈ 2.5E-2 NMAC/UAS FH for 5 simultaneous vehicles–1.9E-1 NMAC/UAS FH for 30 simultaneous vehicles **UAS–manned per manned flight hours** ≈ 9E-1 NMAC/manned FH for 5 simultaneous vehicles–6 NMAC/manned FH for 30 simultaneous vehicles
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS–UAS** ≈ 0.0022 UAS/km² **UAS–manned per UAS flight hours** ≈ 0.0022 UAS/km² **UAS–manned per manned flight hours** ≈ 0.0022 UAS/km²
Manduria above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS–UAS** ≈ 2E-1 NMAC/UAS FH for 5 simultaneous vehicles– 1.1NMAC/UAS FH for 30 simultaneous vehicles **UAS–manned per UAS flight hours** ≈ 1E-2 NMAC/UAS FH for 5 simultaneous vehicles–6E-2 NMAC/UAS FH for 30 simultaneous vehicles **UAS–manned per manned flight hours** ≈ 2.25E-1 NMAC/manned FH for 5 simultaneous vehicles–1.1 NMAC/manned FH for 30 simultaneous vehicles
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS–UAS** ≈ 0.0022 UAS/km² **UAS–manned per UAS flight hours** ≈ 0.0022 UAS/km² **UAS–manned per manned flight hours** ≈ 0.0022 UAS/km²
Shannon below VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS–UAS** ≈ 9E-1 NMAC/UAS FH for 5 simultaneous vehicles–5.3 NMAC/UAS FH for 30 simultaneous vehicles **UAS–manned per UAS flight hours** ≈ 4E-2 NMAC/UAS FH for 5 simultaneous vehicles–2.25E-1 NMAC/UAS FH for 30 simultaneous vehicles **UAS–manned per manned flight hours** ≈ 1.2 NMAC/manned FH for 5 simultaneous

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			vehicles–7 NMAC/manned FH for 30 simultaneous vehicles
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS–UAS** ≈ 0.0012 UAS/km² **UAS–manned per UAS flight hours** ≈ 0.0012 UAS/km² **UAS–manned per manned flight hours** ≈ 0.0012 UAS/km²
Shannon above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS–UAS** ≈ 1.5E-1 NMAC/UAS FH for 5 simultaneous vehicles–6.2E-1 NMAC/UAS FH for 30 simultaneous vehicles **UAS–manned per UAS flight hours** ≈ 5E-3 NMAC/UAS FH for 5 simultaneous vehicles–1.5E-2 NMAC/UAS FH for 30 simultaneous vehicles **UAS–manned per manned flight hours** ≈ 2.1E-1 NMAC/manned FH for 5 simultaneous vehicles–1.1 NMAC/manned FH for 30 simultaneous vehicles
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS–UAS** ≈ 0.0059 UAS/km² **UAS–manned per UAS flight hours** ≈ 0.0012 UAS/km² **UAS–manned per manned flight hours** ≈ 0.0012 UAS/km²

Table 34: UPV - KPIs for OBJ-SOL0520-ERP-001 (Baseline)

A.4.2.2. OBJ-SOL0520-ERP-002 Results

This objective evaluates the capacity increment associated with the Flight Authorisation Service and Traffic Information Service.

Flight Authorisation Service

The Flight Authorisation mechanism acts before a new UAS is introduced into the active traffic population. A proposed unmanned trajectory is checked against active unmanned trajectories over their overlapping time intervals. The comparison considers the segments between consecutive trajectory points, so a proposed flight can be rejected when its swept path would penetrate the protected volume of an already active unmanned flight.

The key assumption is that the Flight Authorisation Service modifies the UAS-UAS conflict population directly. The deconfliction distance includes the relevant TSE margins, the MAC dimensions of the aircraft categories and the selected deviation threshold. Larger deviation thresholds increase the separation required at authorisation time and should reduce the opportunity for UAS-UAS MAC events. They may also reduce UAS-UAS NMAC events, but this effect depends on the size of the buffer relative to the NMAC threshold. A buffer that is small compared with the 152.4 m horizontal NMAC distance used by the Certified_Unknown category can prevent MAC without eliminating NMAC.

UAS-manned conflicts should be interpreted separately for this objective. They are detected and reported, but they are not the main indicator of the Flight Authorisation effect if they are not deconflicted by the same UAS-UAS mechanism. Their value is complementary: they show whether the

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scenario contains relevant exposure to other airspace users, but they should not be used alone to judge the effectiveness of the UAS-UAS authorisation barrier.

The deviation threshold also affects operational acceptance. A larger buffer can reduce conflicts after authorisation, but it also makes trajectory acceptance more restrictive. The capacity interpretation should therefore consider both safety indicators and rejected or non-accepted authorisations. The expected trade-off is that stronger strategic separation may reduce conflict frequency while also reducing the number of trajectories that can be accepted at high traffic density.

Traffic Information Service: encounter-model assumptions and definitive reporting baseline

The TIS assessment uses a paired encounter design. Each sampled geometry is evaluated once without the TIS manoeuvre and once with the TIS manoeuvre, using the same aircraft-type pair and stochastic sample. This paired unmitigated branch is the baseline used in the RR denominator and avoids comparing unrelated encounter populations. UAS–UAS and UAS–manned encounters are aggregated separately before applying the traffic mix of each validation scenario.

Human response is represented by the three shifted-Gamma families shown in **Figure 5**: expert, intermediate and novice pilots have mean reaction times of 20 s, 40 s and 60 s, respectively, with a common 5 s minimum shift. The definitive baseline weights the three families equally; these are modelling assumptions used consistently in the mitigated and unmitigated branches.

The definitive TIS result uses separation factor 1. This preserves the complete type-specific U-AGREE separation minima and prevents the reported mitigation credit from being improved by reducing the protected volume. In a UAS–manned encounter, the UAS is the manoeuvring participant, and the manned trajectory is retained as the reference path; manoeuvre execution is assumed to be correct for this assessment.

The definitive TIS result uses separation factor 1. This preserves the complete type-specific U-AGREE separation minima and prevents the reported mitigation credit from being improved by reducing the protected volume. In a UAS–manned encounter, the UAS is the manoeuvring participant, and the manned trajectory is retained as the reference path; manoeuvre execution is assumed to be correct for this assessment.

RR is the ratio P (NMAC | TIS mitigated) / P (NMAC | unmitigated). The scenario value is obtained as the ratio of the traffic-weighted probabilities, rather than as an arithmetic average of type-pair ratios. RR therefore expresses the fraction of the unmitigated conditional NMAC risk that remains after the TIS barrier.

The RR values reported in Table 2 already include the consortium-agreed conservative transfer factor of 2. The factor is applied once, after encounter-model aggregation, because the campaign uses synthetic traffic, rectilinear and level reference trajectories, and pairwise planar conflict geometries. These controlled conditions are appropriate for isolating barrier performance but do not reproduce every interaction that can occur in operational traffic. Doubling the residual RR reduces the mitigation credit carried into the final risk calculations and provides a conservative margin for those idealisations; it is not an additional simulation and must not be applied a second time downstream.

Complete UPV TIS encounter-model method and assumptions

The TIS model is a conditional, conflict-rich encounter model designed to measure how much residual NMAC and separation-loss risk remains when a traffic-information alert is followed by a pilot response. It does not estimate how often operational traffic generates an encounter. That exposure belongs to

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the surrounding risk model. The simulator instead holds the encounter population under control so that the mitigated branch can be compared with a like-for-like unmitigated branch.

An ordered aircraft-type pair is sampled from the eleven UAS classes plus Manned VFR. Start time, relative geometry and altitude offset define the encounter; optional random turns and climb/descent events are campaign dimensions rather than part of the nominal baseline. The same sampled encounter is propagated twice: once with no TIS avoidance manoeuvre and once with the TIS response active. Pairing controls geometry and stochastic exposure in the numerator and denominator and is therefore the fundamental baseline construction.

The service is issued when the pair first crosses inward through a symmetric encounter bubble. The radius is 1 NM (1,852 m) for the UAS-scale NMAC case and 2 NM (3,704 m) whenever the pair requires the manned/certified-scale volume. Both participants share that crossing instant but draw their response delay independently. The pilots are not assumed to know a time of closest approach or a tactical look-ahead horizon. Accordingly, the fixed LA = 1 field retained in the campaign filenames is an identifier/fixed campaign dimension, not a one-second TIS look-ahead assumption.

GNSS error is applied to the delayed tracker position used by the response logic. A per-pair communication latency is drawn from the configured half-normal model, and packet loss is applied at each one-second tracker update; on a lost packet the tracker predicts rather than receiving a fresh observation. These perturbations affect what the TIS participant can infer, while final NMAC and separation-loss scoring uses the ground-truth trajectories. Reaction time, communication latency and surveillance error are therefore separate stages and must not be collapsed into one response-delay parameter.

The campaign retains all nine ordered pilot-pair matrices HH, HM, HL, MH, MM, ML, LH, LM and LL. Postprocessing evaluates the five configured population profiles—All HIGH, All MEDIUM, All LOW, Uniform (1/3) and Expert-heavy—exactly as defined for the simulation campaign; Uniform (1/3) is the selected reference profile for baseline and one-at-a-time sensitivity results. The shifted-Gamma response families have k = 2 and a common 5 s minimum shift; scale values 7.5 s, 17.5 s and 27.5 s give means of 20 s, 40 s and 60 s. The archetypes also differ in manoeuvre strategy: HIGH uses a CPA/velocity-obstacle heading and may return to track when safe; MEDIUM uses the geometric SPATIO heading and continues that avoidance heading; LOW uses a right-only clockwise solution. An invalid solution falls back to a 90° clockwise heading. Pilot-profile comparisons therefore change behaviour as well as delay.

In UAS–UAS encounters both participants can react after their independent delays. In UAS–manned encounters the manned aircraft is forced to retain its reference trajectory, so the UAS carries the active avoidance role. Ground-truth NMAC and separation loss require simultaneous horizontal and vertical infringement at a simulation step. The mitigated and unmitigated branches are scanned over the full encounter rather than scoring only the nominal closest-approach instant.

Definitive TIS reporting baseline

The definitive UPV TIS reporting baseline is defined as one exact campaign configuration, not as an average of degraded or sensitivity settings. The TIS model is a conditional, conflict-rich encounter model: it measures the residual NMAC and separation-loss risk that remains when a traffic-information alert is followed by a pilot response. It does not estimate how frequently operational traffic generates encounters. For that reason, the encounter population is kept under control, and each geometry is

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propagated in paired mitigated and unmitigated branches, allowing the TIS effect to be evaluated on a like-for-like basis.

Results are reported separately for UAS–UAS and UAS–manned encounters. In each case, the 12×12 aircraft-type matrix is masked to the selected encounter family, and the corresponding traffic weights are renormalised before the scenario-weighted metrics are computed. This avoids blending branches with different separation volumes and different manoeuvring responsibilities. In UAS–UAS encounters, both participants may react after their independently sampled response delays. In UAS–manned encounters, the manned aircraft retains its reference trajectory and the UAS carries the active avoidance role.

The TIS alert is issued at the first inward crossing of the symmetric encounter bubble. The trigger radius is 1 NM for UAS-scale pairs and 2 NM whenever the pair requires the manned/certified-scale volume. This trigger starts an independent pilot-response delay for each participant. The fixed LA = 1 field retained in the campaign filenames is therefore treated as a fixed campaign identifier, not as a one-second tactical look-ahead assumption.

The final pilot population assumes independent assignment of HIGH, MEDIUM and LOW pilot archetypes with probability 1/3 each. Consequently, all nine ordered pilot-pair matrices (HH, HM, HL, MH, MM, ML, LH, LM and LL) enter the final mixture with product weight 1/9. The response-time families are shifted-Gamma distributions with k = 2 and a common 5 s minimum shift, giving mean response times of 20 s, 40 s and 60 s for the three archetypes. These profiles differ not only in reaction time but also in manoeuvre logic: HIGH uses a CPA / velocity-obstacle heading and may return to track when safe; MEDIUM uses the geometric SPATIO heading and continues that avoidance heading; and LOW uses a clockwise/right-only solution. Invalid solutions fall back to a 90° clockwise heading. Therefore, pilot-profile comparisons should not be interpreted as pure reaction-time experiments.

The nominal CNS baseline corresponds to GNSS 1.87 m / 3.16 m, latency 1.1 s / 1.1 s, and packet loss 2% / 2%. GNSS error perturbs the delayed tracker position used by the response logic, latency is applied through the configured communication-delay model, and packet loss causes prediction-only tracker updates when a packet is lost. The response is therefore driven by perturbed observations, while final NMAC and separation-loss scoring is performed on the ground-truth trajectories.

The reporting baseline retains the complete U-AGREE protected volume by setting SFH = 1 and SFV = 1. It also uses MF = 0, RT = [0, 0] and CP = [0, 0], so that there is no manoeuvre failure, no random turn perturbation and no climb/descent perturbation in the reference case. Degraded CNS cases, manoeuvre failure, trajectory perturbations and alternative traffic configurations are treated as controlled sensitivity evidence rather than being mixed into the final quoted RR.

Traffic aggregation is performed using the Benidorm, Manduria and Shannon validation mixes, each in BVLL and AVLL form. Scenario percentages are converted into ordered-pair weights after the encounter-family masking step. The RR is then formed only after applying both the traffic weights and the pilot-pair weights; it is not obtained by averaging cell-level ratios. For each branch and scenario, the mitigated aggregate probability is divided by the paired unmitigated aggregate probability, using the same sampled encounter geometry in numerator and denominator.

The final reporting convention makes the reported RR equals to two times the RR obtained via simulation. This factor of 2 is applied once, after aggregation, as a conservative transfer from the conditional encounter model to the integrated assessment. It is not a confidence interval and must not

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be applied again downstream. The final TIS RR values reported in Table 2 are therefore already doubled and should be used directly in the final calculations.

The TIS simulation sweep contains 1,296 parameter cases: 3 manoeuvre-failure levels × 3 random-turn vectors × 6 horizontal separation factors × 3 climb/descent vectors × 8 CNS configurations; SFV and the filename LA field remain fixed at 1.

Calculation from pilot-pair matrices to the reported RR

Let q_a denote the configured coefficient of pilot class a in the selected postprocessor profile. For branch E and traffic scenario s, the ordered type-pair weights $w_{ij,s}$ are first masked to E and renormalised so that their sum is one. For outcome x (mitigated or unmitigated), the aggregate probability is $P_s^x = \sum_{ij \in E} w_{ij,s} \times \sum_{a,b \in \{H,M,L\}} q_a q_b P_{ij,ab}^x$. The products $q_a\, q_b$ combine the nine ordered pilot-pair matrices before the ratios are formed. For the baseline-selection figures, q is taken from the campaign's Uniform (1/3) profile. $RR_{raw,s} = P_{mit,s} \,/\, P_{unmit,s}$ is formed only after both sums. LR uses the analogous separation-loss probabilities; $P_{fa} = 1 - P_{unmit,NMAC} \,/\, P_{unmit,SL}$; and alert probability is the traffic- and pilot-weighted conflict probability.

The conservative transfer is then $RR_{reported,s} = 2 \times RR_{raw,s}$, once and only once. A transparent reverse check can be made from the controlled values already present in Table 2: Benidorm below VLL has reported RR 0.166222608 for UAS–UAS, corresponding to raw aggregate RR 0.083111304, and reported RR 0.579837374 for UAS–manned, corresponding to raw aggregate RR 0.289918687. This arithmetic check explains the baseline calculation without altering any partner-controlled RR cell.

Executed TIS campaign and result aggregation

The archived TIS sweep contains 1,296 parameter cases: 3 manoeuvre-failure levels × 3 random-turn vectors × 6 horizontal separation factors × 3 climb/descent vectors × 8 CNS configurations; SFV and the filename LA field remain fixed at 1. Each final NDJSON snapshot contains 12×12 matrices for five metrics and all nine ordered pilot pairs. Applying the five original postprocessor profiles produces 90,720 checked result rows across two encounter branches and seven traffic mixes, with no missing RR, LR, Pfa or alert-probability values. This complete aggregation is the numerical basis of the ten baseline-selection figures below.

Evidence boundary. Table 36 remains the controlled consortium reporting record and is not overwritten. The figures below provide reproducible campaign evidence for the selection of baseline parameters and are shown as raw values before the factor of two. With the selected Uniform (1/3) profile, baseline RR spans 0.025350–0.055637 for UAS–UAS and 0.205399–0.213944 for UAS–manned across the six validation traffic mixes. The scenario spread, sensitivity sweeps and profile comparison together demonstrate how the chosen baseline behaves before its transfer to the reported risk ratios.

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TIS baseline selection by validation scenario

The scenario comparison preserves the selected Uniform (1/3) postprocessing profile and changes only the traffic weights within each branch. UAS–UAS raw RR is lowest for Shannon (about 0.02535) and highest for the Manduria/CORUS mix (about 0.05564); UAS–manned raw RR is less scenario-sensitive (about 0.20540–0.21394). LR changes more strongly with aircraft composition in the UAS–UAS branch, from about 0.377 to 0.525. Pfa and alert probability remain high because the campaign deliberately samples conflict-rich encounters; they are conditional model outputs, not airspace-wide false-alarm or alert frequencies. The bounded UAS–manned spread and traceable UAS–UAS scenario dependence support use of a single baseline configuration with scenario-specific traffic aggregation.

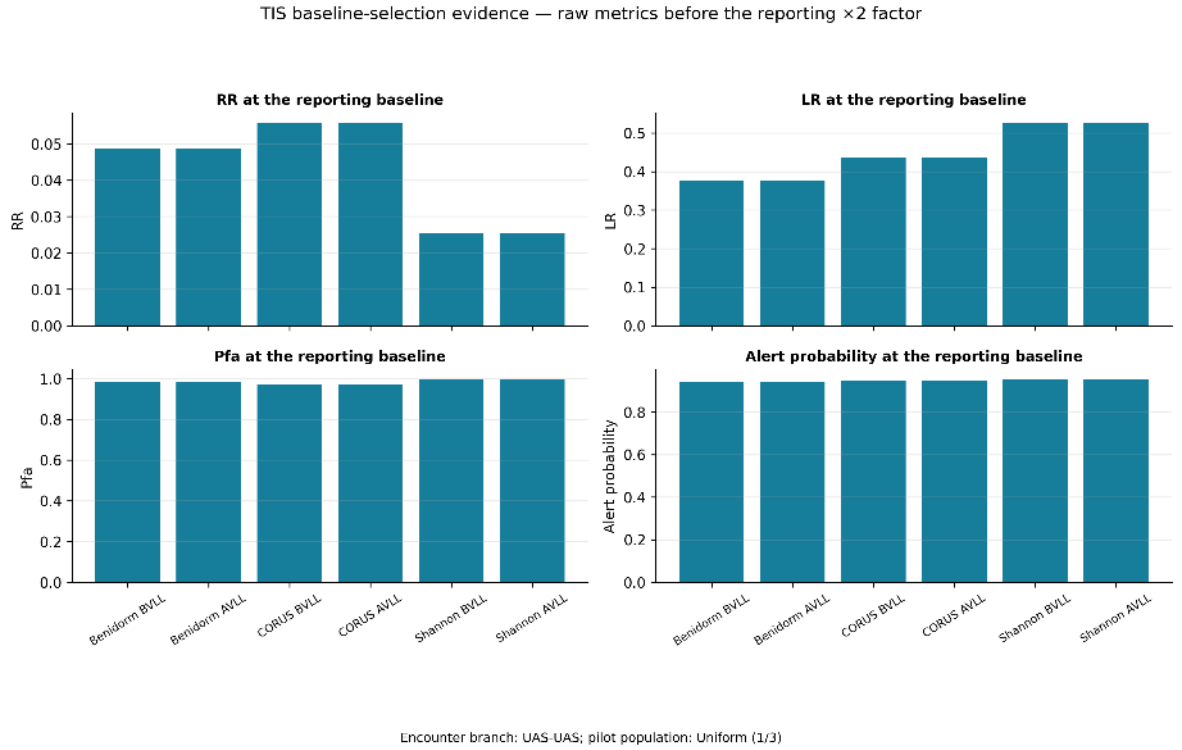


Figure 32: TIS baseline-selection metrics by validation traffic mix for UAS–UAS encounters, using the selected Uniform (1/3) reporting profile. Raw ratios are shown before the separate reporting factor of two.

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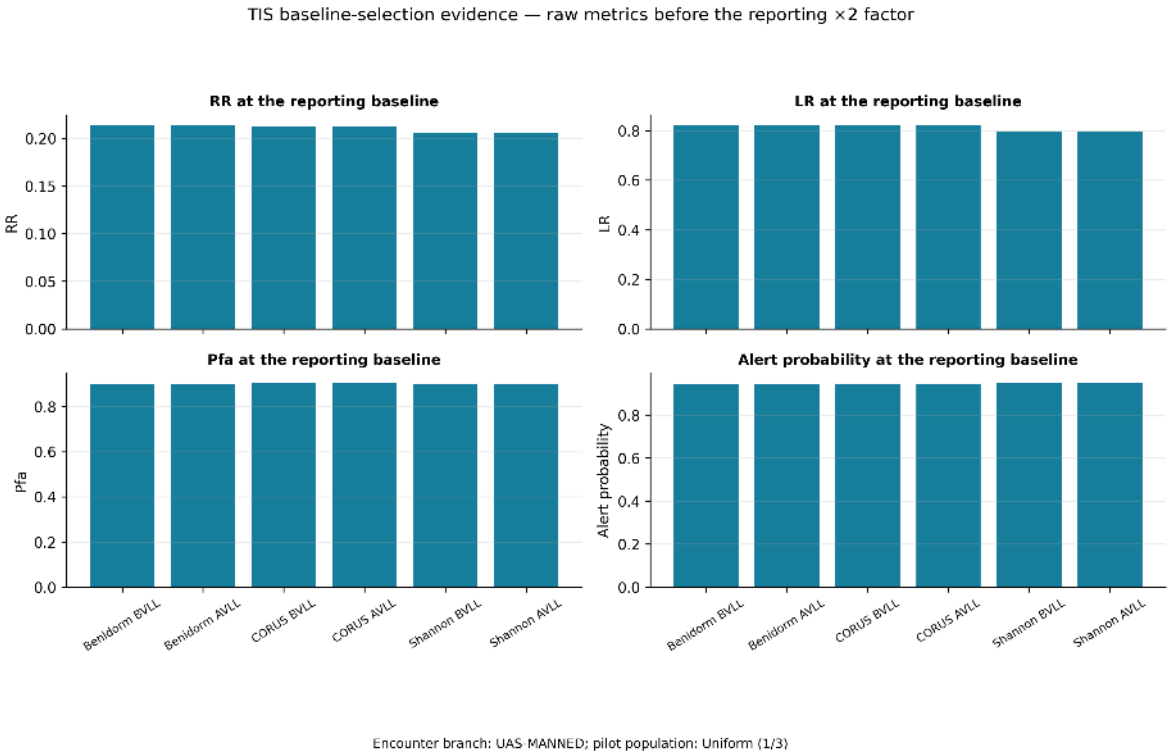


Figure 33: TIS baseline-selection metrics by validation traffic mix for UAS–manned encounters, using the selected Uniform (1/3) reporting profile. Raw ratios are shown before the separate reporting factor of two.

Horizontal-separation sensitivity

SFH is the dominant protected-volume sensitivity. In equal-weight UAS–UAS traffic, raw RR falls from 0.0851 at SFH ≈ 0.10 to a minimum of about 0.0353 at SFH = 0.5625, then reaches 0.0508 at the full-volume baseline; LR increases from 0.1199 to 0.4922 as more separation-loss exposure is counted. In UAS–manned traffic, RR falls from 0.6829 to 0.2140 as SFH reaches 1, while LR finishes at 0.8210. SFH = 1 is retained for reporting because it represents the complete protected volume and yields the most conservative, operationally meaningful assessment boundary rather than selecting a reduced volume solely for a lower ratio.

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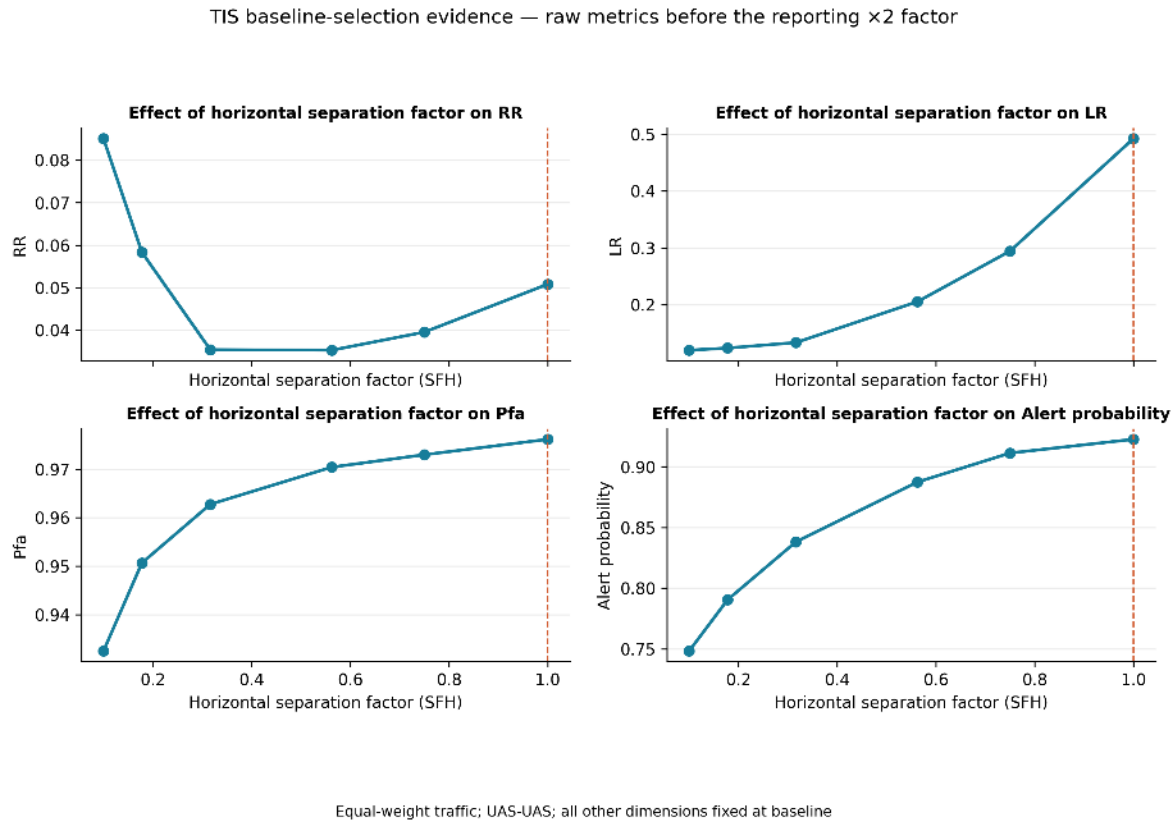


Figure 34: TIS UAS–UAS sensitivity to the horizontal separation factor, with all other dimensions fixed at the nominal baseline and equal-weight traffic used to isolate the parameter effect.

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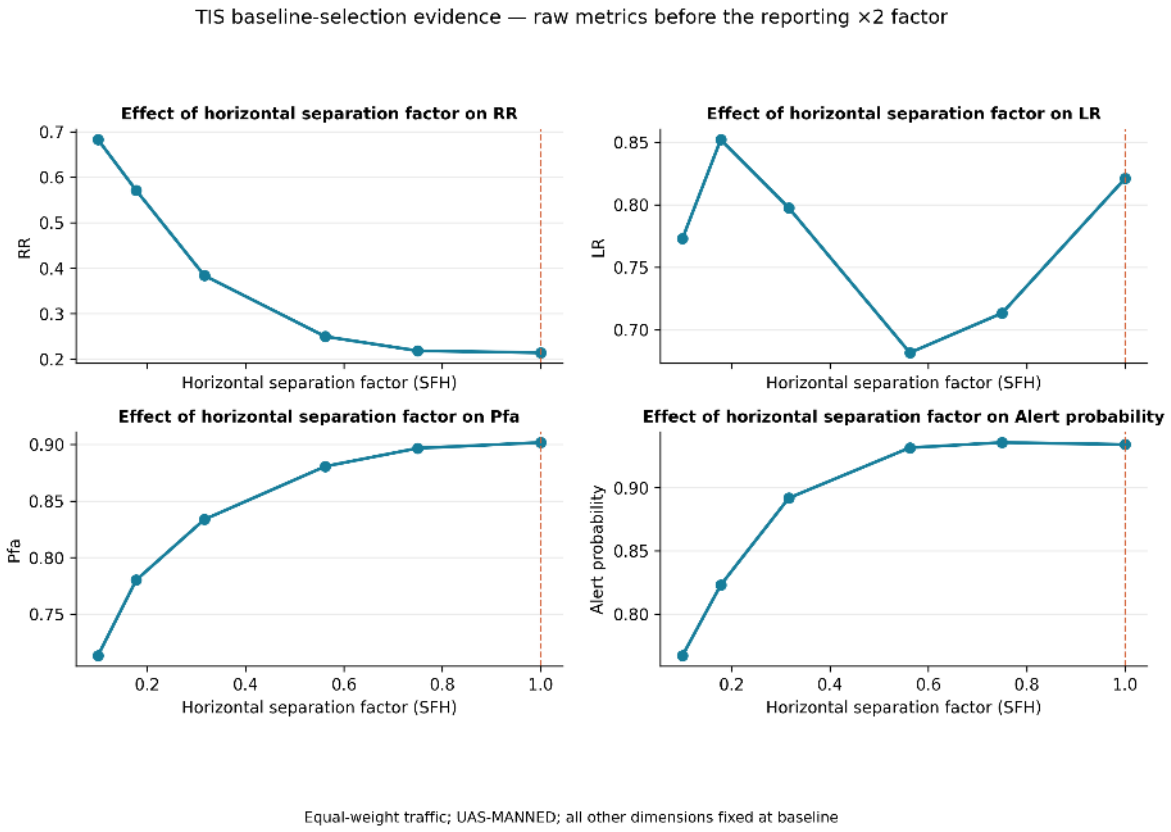


Figure 35: TIS UAS–manned sensitivity to the horizontal separation factor, with all other dimensions fixed at the nominal baseline and equal-weight traffic used to isolate the parameter effect.

Operational-perturbation sensitivity

Manoeuvre failure has the clearest adverse operational effect: as MF rises from 0 to 0.2, raw RR increases from 0.0508 to 0.1264 for UAS–UAS and from 0.2140 to 0.3841 for UAS–manned, while LR also increases. Random turns produce a modest RR increase in UAS–UAS (0.0508 to 0.0538) and a small decrease in the UAS–manned branch (0.2140 to 0.2051); climb/descent perturbations reduce RR slightly while LR remains almost flat. These one-at-a-time degradations confirm MF = 0, RT = [0, 0] and CP = [0, 0] as the clean baseline needed to isolate nominal TIS performance; degraded values are retained as robustness cases rather than blended into the baseline.

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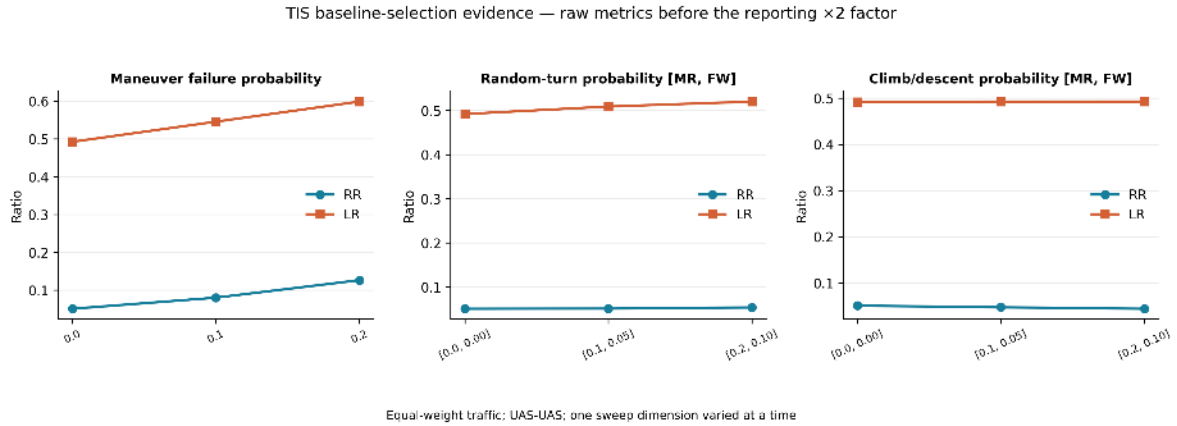


Figure 36: TIS UAS–UAS robustness to manoeuvre failure, random turns and climb/descent perturbations. Each sweep changes one dimension from the baseline.

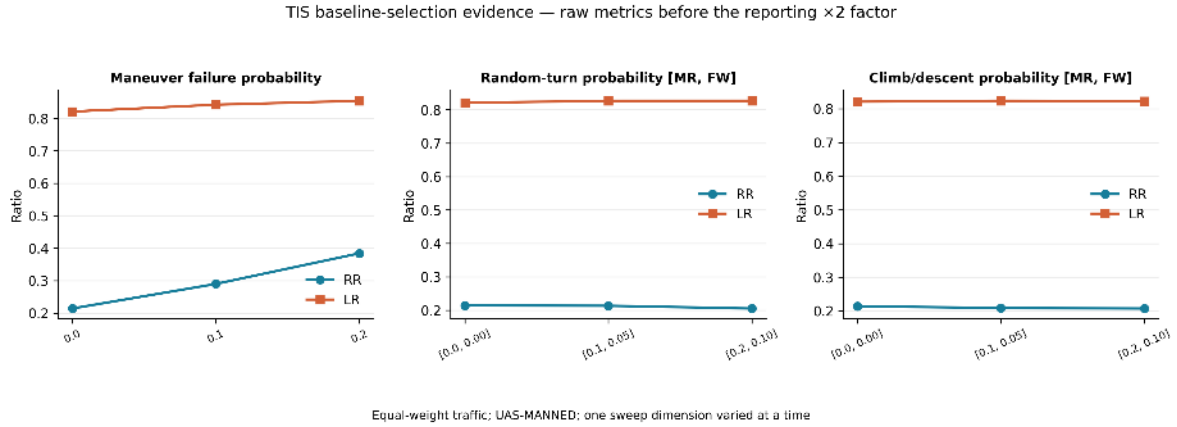


Figure 37: TIS UAS–manned robustness to manoeuvre failure, random turns and climb/descent perturbations. Each sweep changes one dimension from the baseline.

CNS-chain sensitivity

Across the eight GNSS/latency/packet-loss combinations, the campaign is comparatively stable in RR and LR: raw RR ranges 0.0432–0.0508 for UAS–UAS and 0.2075–0.2224 for UAS–manned; LR ranges 0.4922–0.4940 and 0.8167–0.8249, respectively. Alert probability shows the clearest response, ranging up to approximately 0.941 for UAS–UAS and 0.953 for UAS–manned. This limited ratio spread supports the nominal GNSS 1.87 m/3.16 m, symmetric 1.1 s latency and symmetric 2% packet loss as a reproducible reference point, while the remaining seven combinations demonstrate robustness to degraded and asymmetric CNS conditions.

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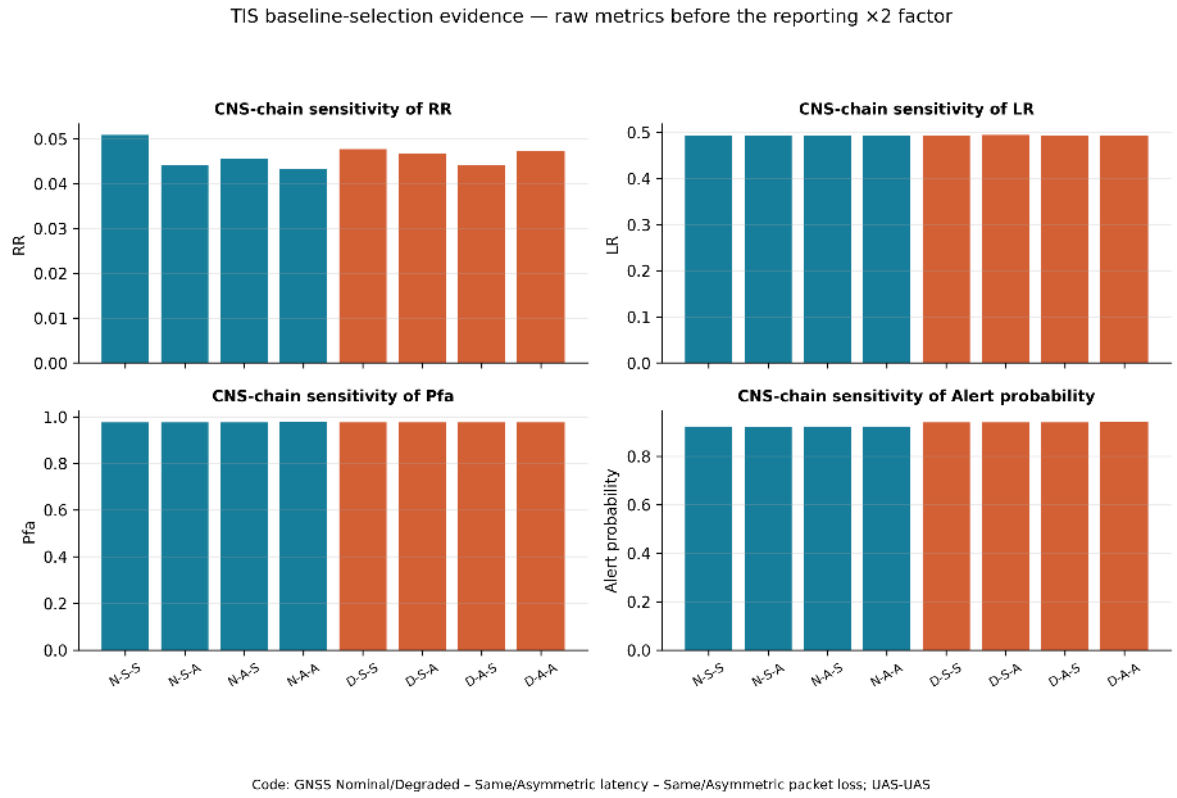


Figure 38: TIS UAS–UAS sensitivity to nominal/degraded GNSS and same/asymmetric latency and packet-loss configurations.

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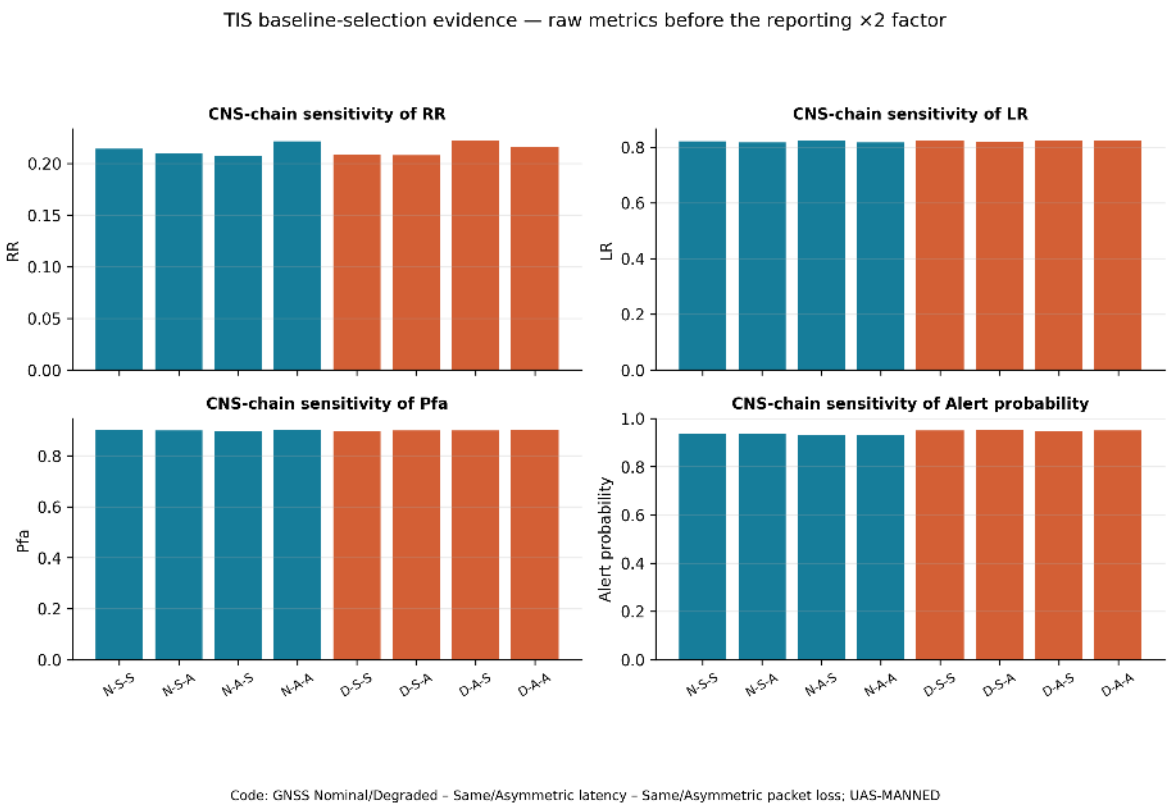


Figure 39: TIS UAS–manned sensitivity to nominal/degraded GNSS and same/asymmetric latency and packet-loss configurations.

Pilot-population sensitivity and selected reference profile

The five configured profiles show that pilot-population assumptions materially affect both RR and LR because the archetypes combine different response-time distributions and manoeuvre strategies. For UAS–UAS, raw RR is 0.0641 for All HIGH, 0.0559 for All MEDIUM, 0.0402 for All LOW, 0.0508 for Uniform (1/3) and 0.0559 for Expert-heavy. For UAS–manned, the corresponding values are 0.1653, 0.1955, 0.2543, 0.2140 and 0.1955. Uniform (1/3) lies within the profile envelope in both branches and is therefore retained as the common reference for parameter selection; it is a prescribed representative campaign profile, not a value fitted to minimise RR. All MEDIUM and Expert-heavy produce the same aggregate values under the configured campaign profiles, as shown directly in the figures.

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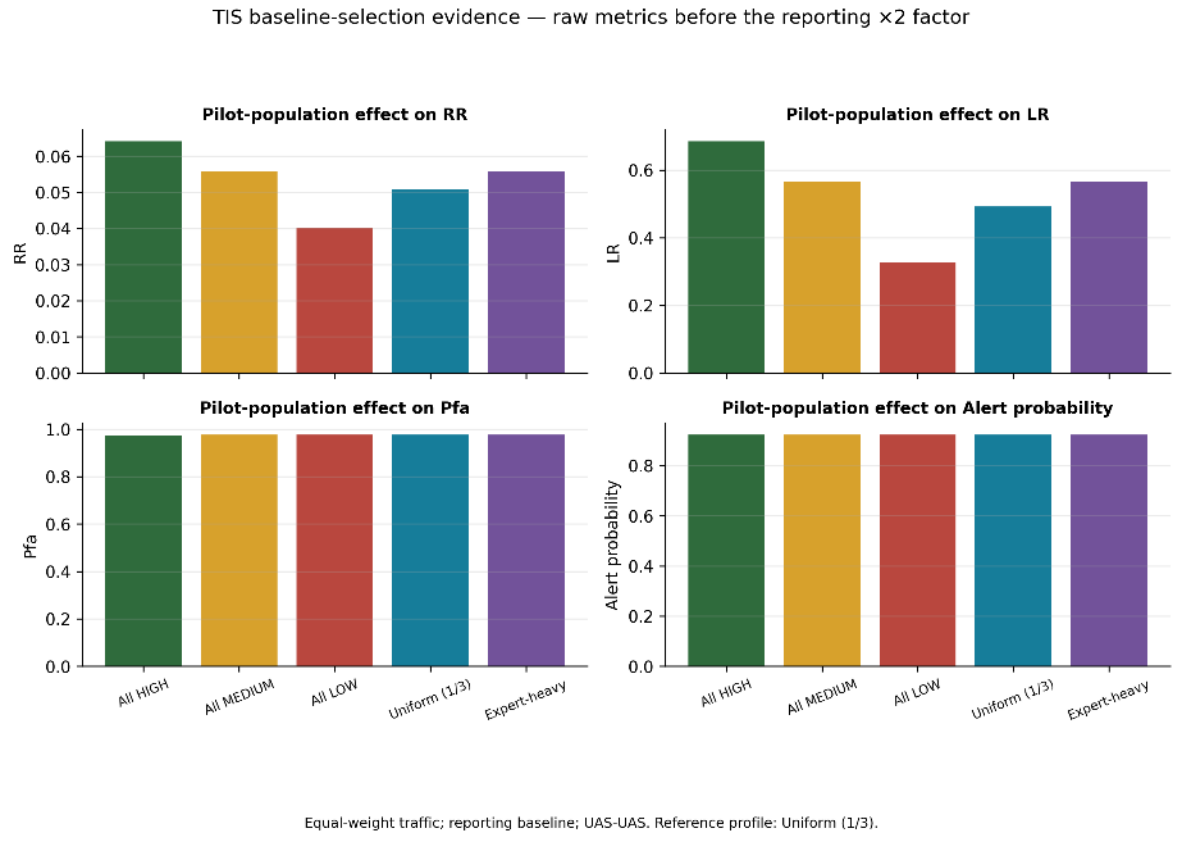


Figure 40: TIS UAS–UAS comparison across the five original postprocessor profiles; Uniform (1/3) is the baseline reference.

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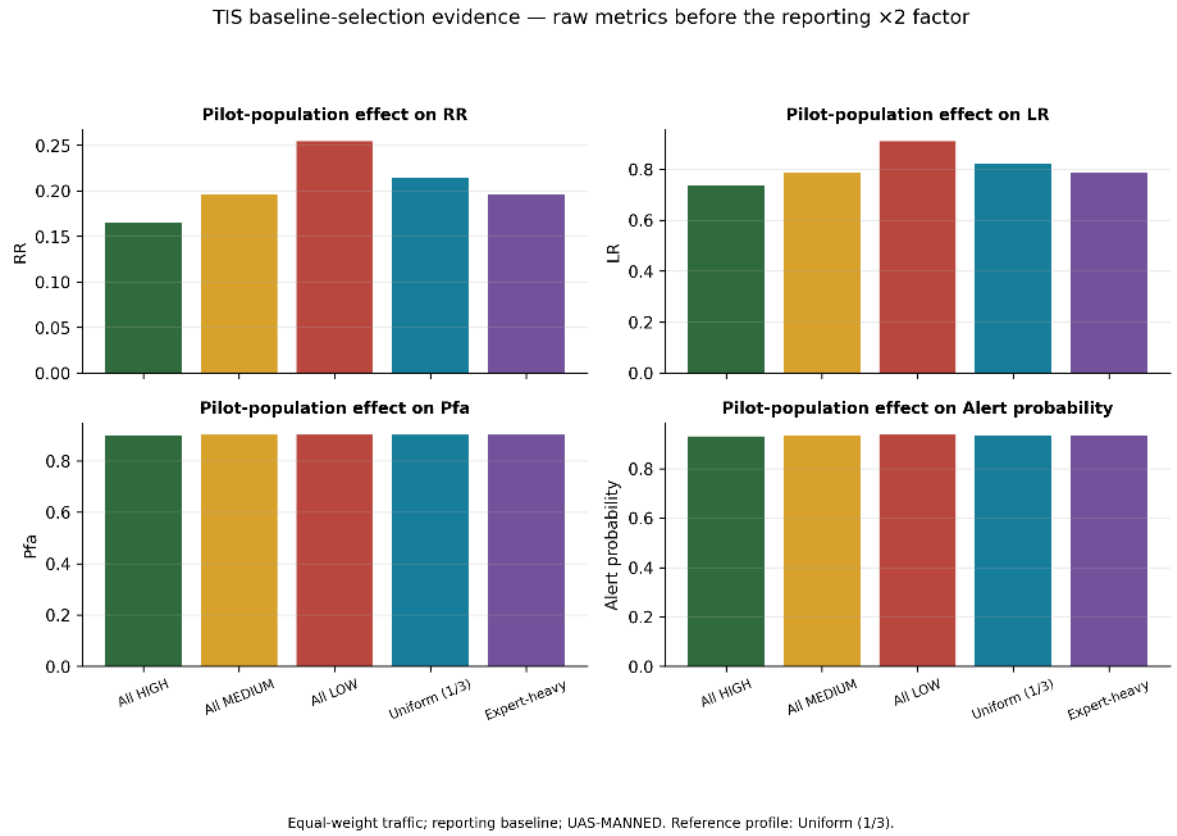


Figure 41: TIS UAS–manned comparison across the five original postprocessor profiles; Uniform (1/3) is the baseline reference.

TIS limitations

Model limitations. The simulator is pairwise, conditional and predominantly planar, with rectilinear/level nominal trajectories and one-second state updates. It does not model multi-aircraft coordination, network demand, strategic deconfliction, pilot workload, alert comprehension, learning, weather, terrain or a cooperative manned avoidance response. The pilot families are behavioural archetypes, and the selected Uniform (1/3) profile is a campaign assumption rather than a measured workforce forecast. These boundaries make the simulator suitable for controlled relative-risk and sensitivity assessment, while operational encounter frequency remains outside the TIS pair model.

Statistical limitations. The final snapshots provide accumulated matrices and pairs-so-far counts but not the underlying trial histories, random-number streams, confidence intervals for every aggregate or a common convergence certificate for all 1,296 cases. Rare-cell Monte Carlo noise can therefore produce local diagnostic RR values near or slightly above one in degraded/profile extremes. The factor of two is a conservative reporting convention for model transfer; it is not a substitute for a statistical confidence bound.

Results for FAS+TIS

For including the Encounter results into the CRM, we selected the separation factor of 1, representing the most conservative separation minima distance. The three levels of pilots are assumed to be equally distributed in performing the manoeuvre during the UAS-UAS conflict, and when a UAS-manned

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conflict occurs, the UAS performs the manoeuvres. In this assessment, we assume the manoeuvres are correctly performed.

The baseline-selection figures explain model response, justify the chosen reference parameters and demonstrate robustness across the prescribed sensitivities; they are deliberately labelled as raw values. They shall not be copied into the final risk tables or doubled again without a documented, partner-approved provenance decision.

With these assumptions in mind, the risk ratios obtained for the TIS are presented in Table 35. The tabulated values are the conservative, already doubled values used in the final calculations.

		$RR_{UAS-UAS}$	$RR_{UAS-manned}$
Benidorm	Below VLL	0.166	0.580
Benidorm	Above VLL	0.166	0.580
Manduria	Below VLL	0.170	0.603
Manduria	Above VLL	0.170	0.603
Shannon	Below VLL	0.129	0.590
Shannon	Above VLL	0.129	0.590

Table 35: UPV - TIS Risk Ratio for the different scenarios.

The RR values reported in Table 35 already include the consortium-agreed conservative transfer factor of 2. The factor is applied once, after encounter-model aggregation, because the campaign uses synthetic traffic, rectilinear and level reference trajectories, and pairwise planar conflict geometries. These controlled conditions are appropriate for isolating barrier performance but do not reproduce every interaction that can occur in operational traffic. Doubling the residual RR reduces the mitigation credit carried into the final risk calculations and provides a conservative margin for those idealisations; it is not an additional simulation and must not be applied a second time downstream.

This RR is the residual fraction of the unmitigated conditional risk remaining after application of the TIS barrier. Applying the final, already doubled RR to the maximum allowable frequency provides the updated success criterion with the inclusion of the TIS for each scenario presented in Table 36.

		$\lambda_{MAX\ UAS-UAS}$	$\lambda_{MAX\ UAS-manned}$
Benidorm	Below VLL	2.62E-04	1.72E-07
Benidorm	Above VLL	2.62E-04	1.72E-07
Manduria	Below VLL	8.82E-04	1.66E-07
Manduria	Above VLL	8.82E-04	1.66E-07
Shannon	Below VLL	1.31E-01	1.70E-07
Shannon	Above VLL	1.31E-01	1.70E-07

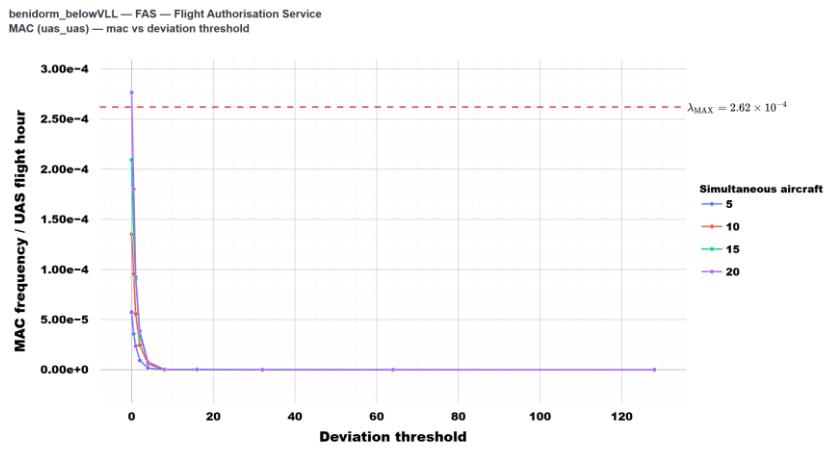
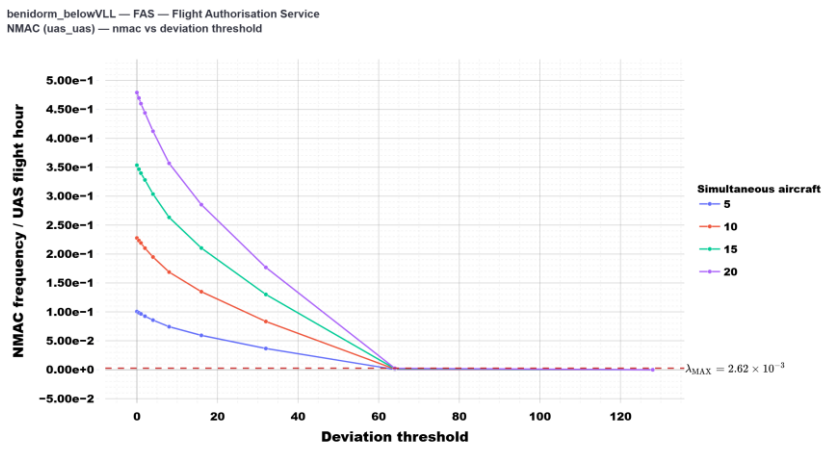
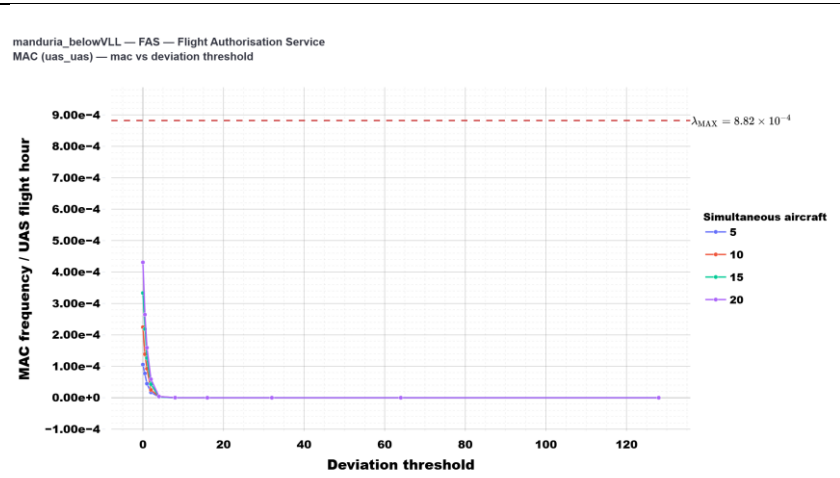
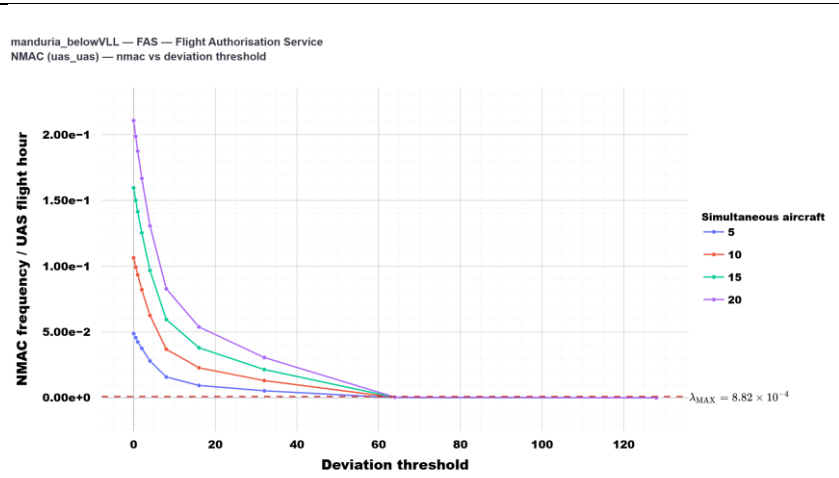
Table 36: UPV – FAS updated success criterion when applying TIS

The frequency of MAC and NMAC is presented in the following figures:

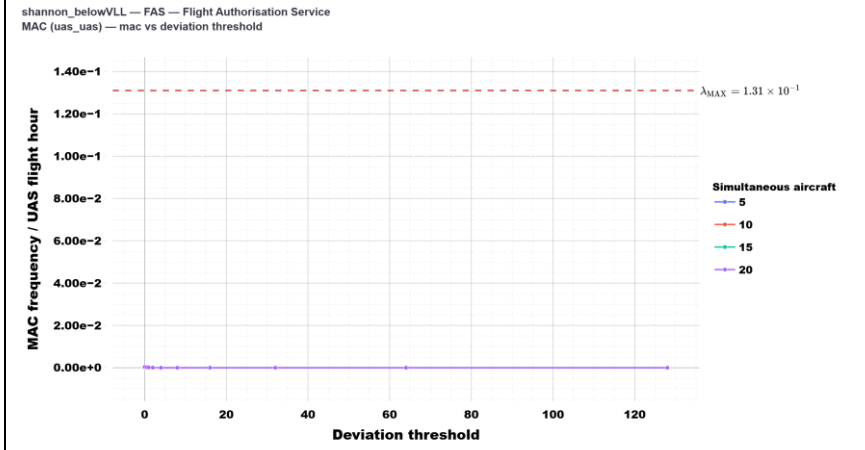
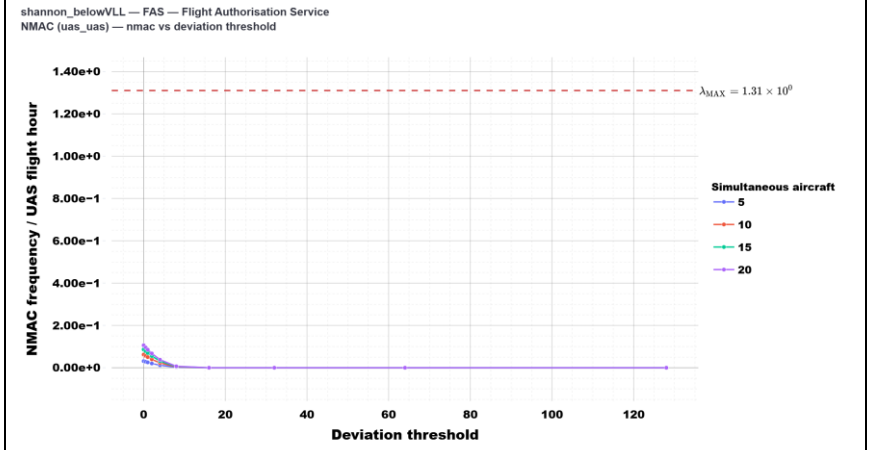
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Figure 42: UPV - FAS+TIS below VLL UAS-UAS frequency

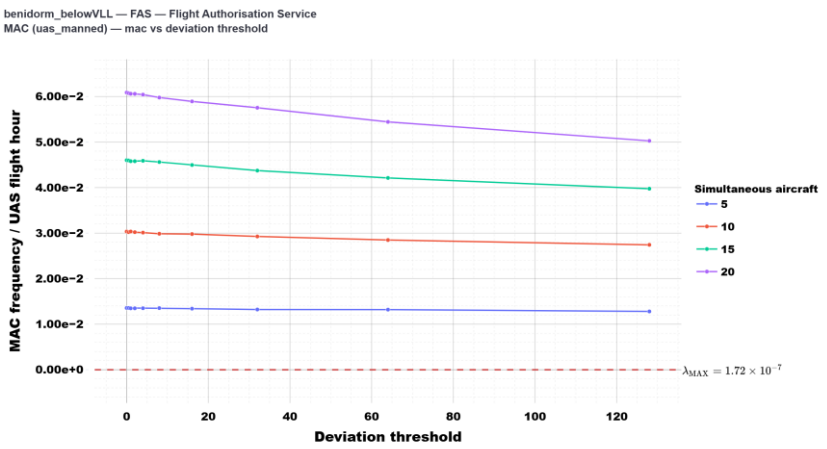
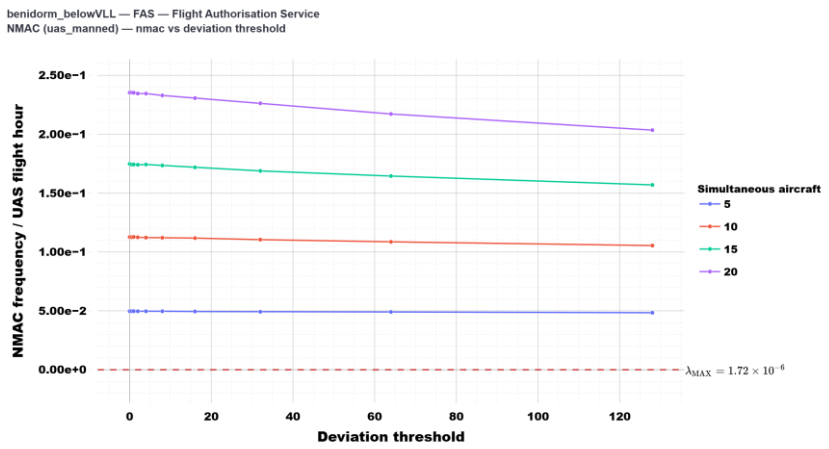
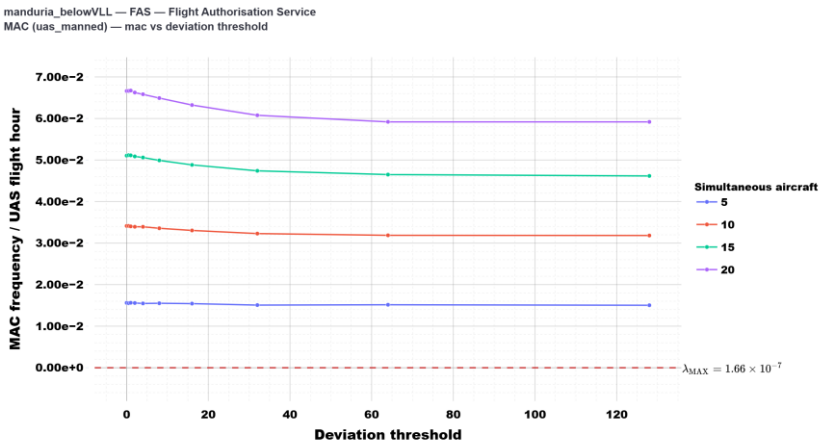
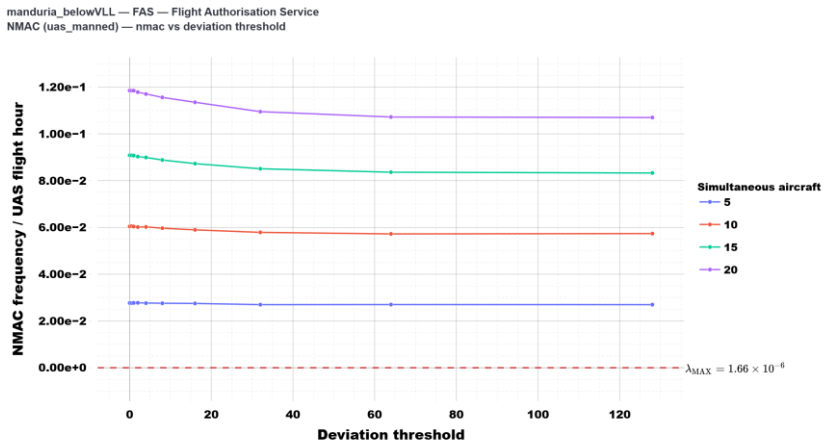
	MAC	NMAC
Benidorm below VLL		
Manduria below VLL		

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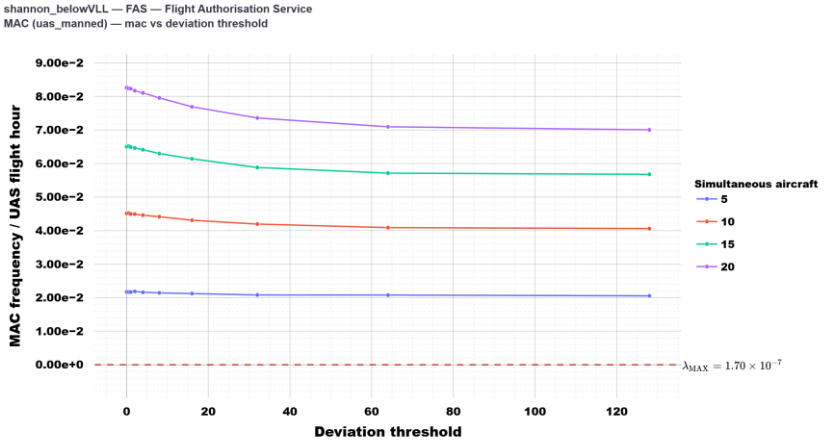
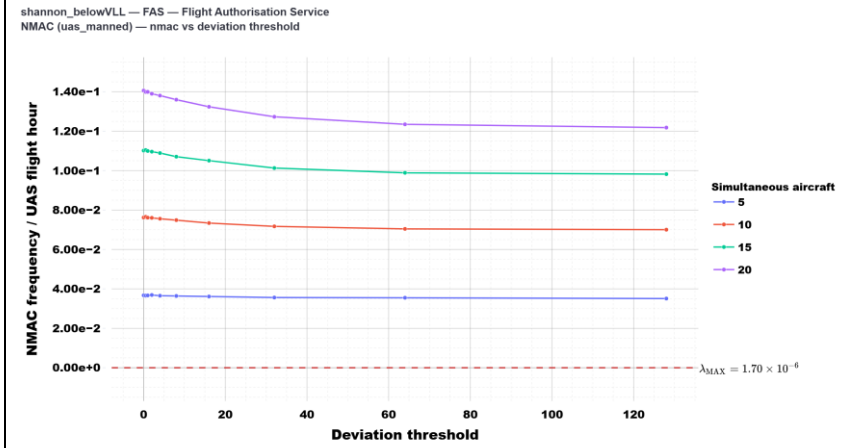
Shannon below VLL		

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Figure 43: UPV - FAS+TIS below VLL UAS-manned frequency in UAS flight hours

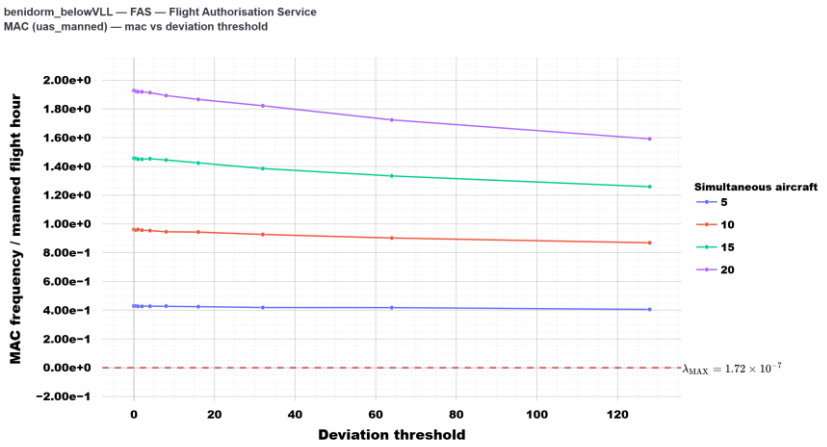
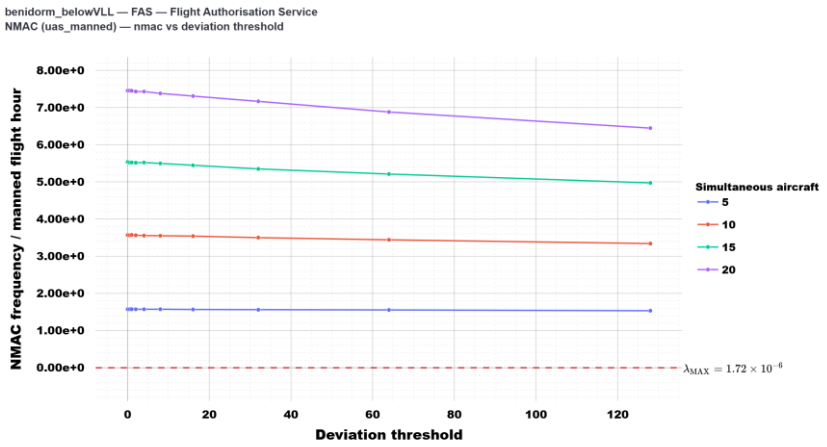
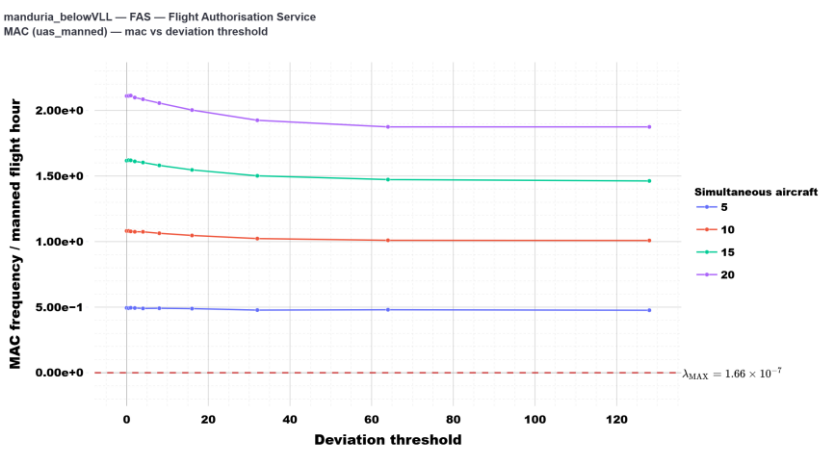
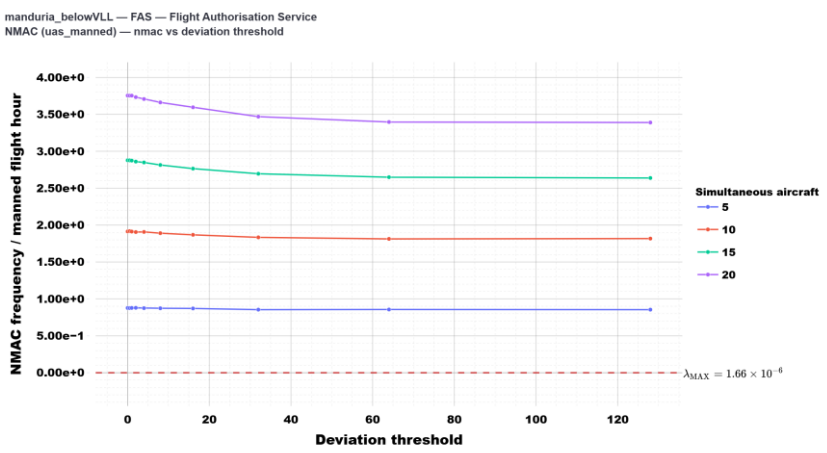
	MAC	NMAC
Benidorm below VLL		
Manduria below VLL		

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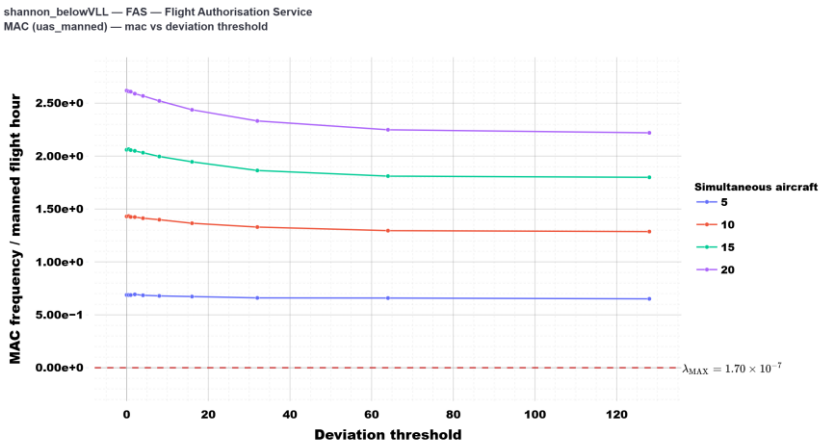
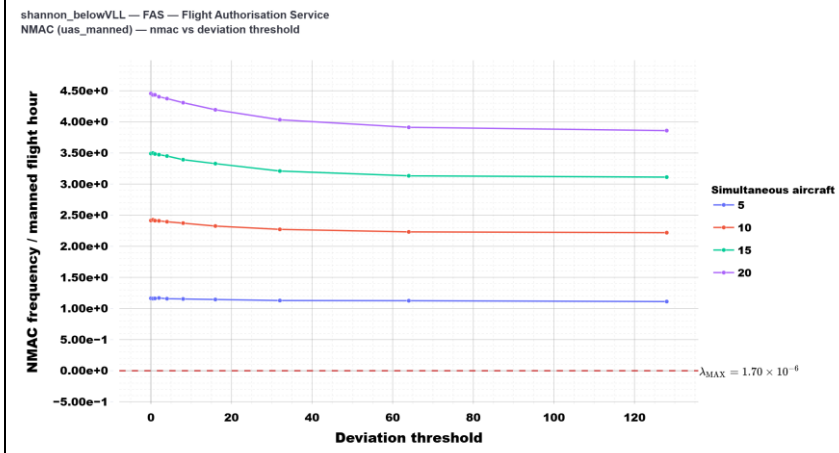
Shannon below VLL		

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Figure 44: UPV - FAS+TIS below VLL UAS-manned frequency in manned flight hours

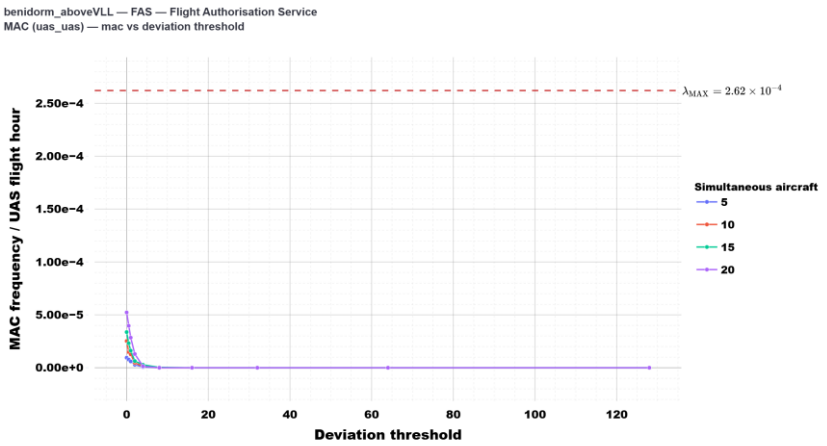
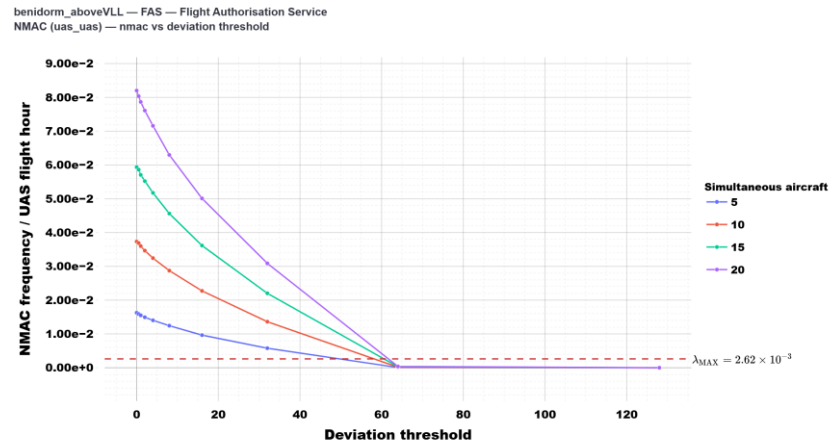
	MAC	NMAC
Benidorm below VLL		
Manduria below VLL		

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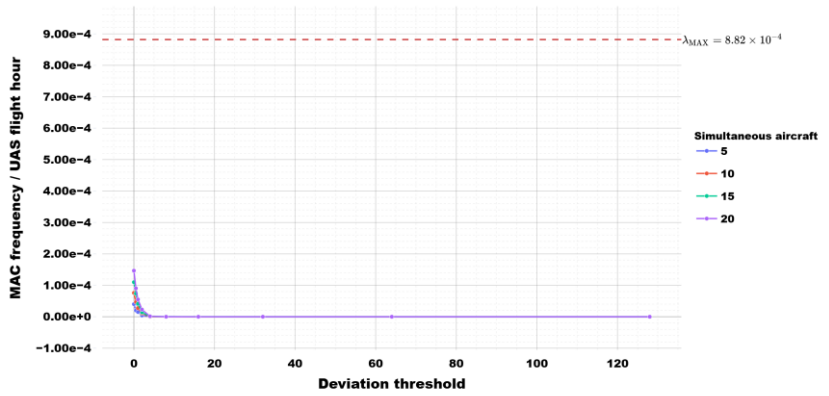
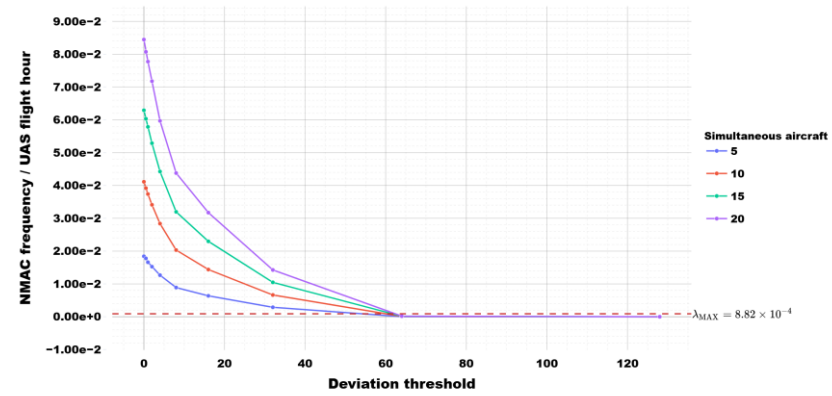
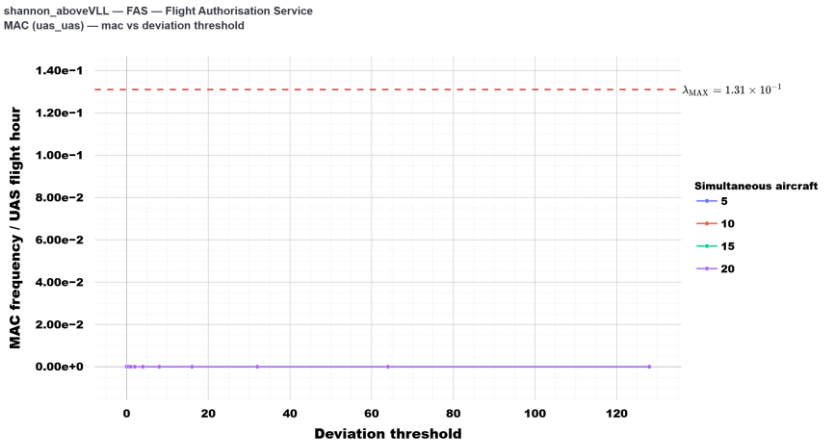
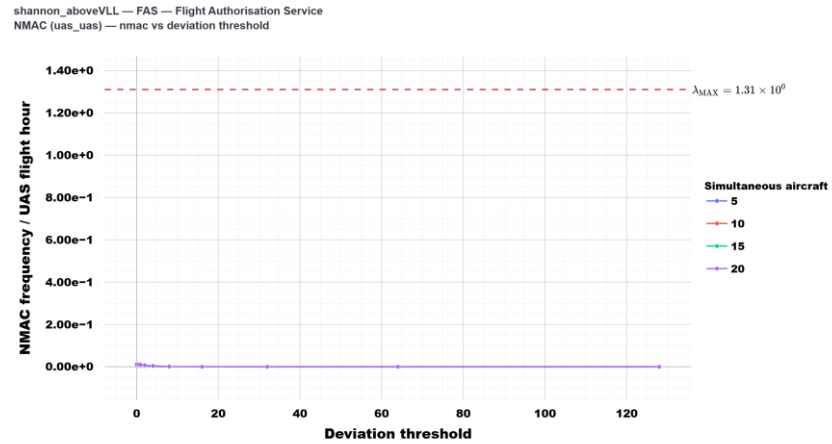
Shannon below VLL		

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Figure 45: UPV - FAS+TIS above VLL UAS-UAS frequency

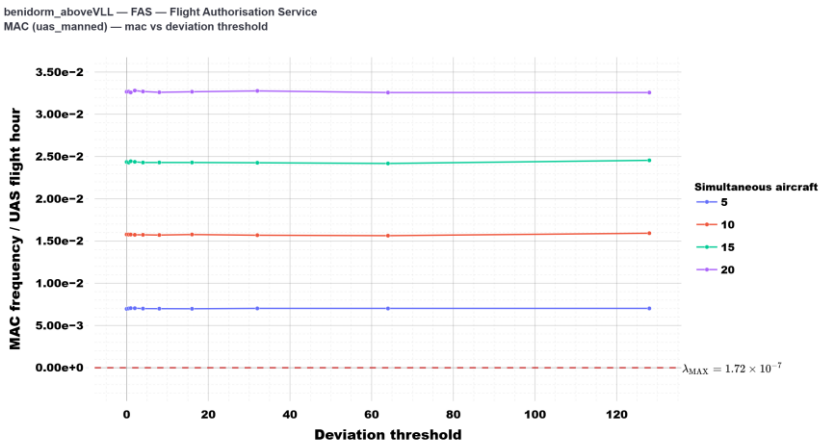
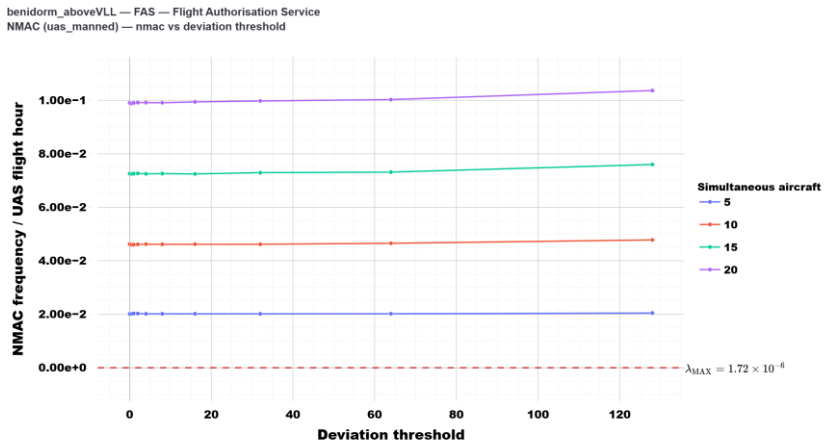
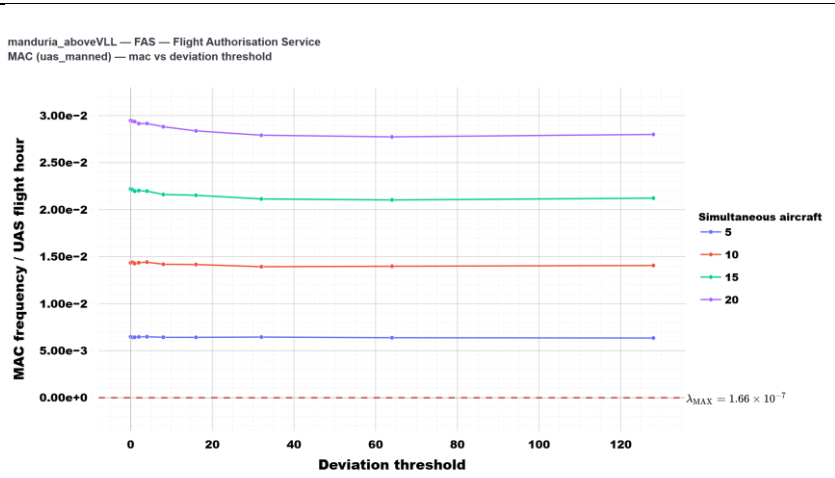
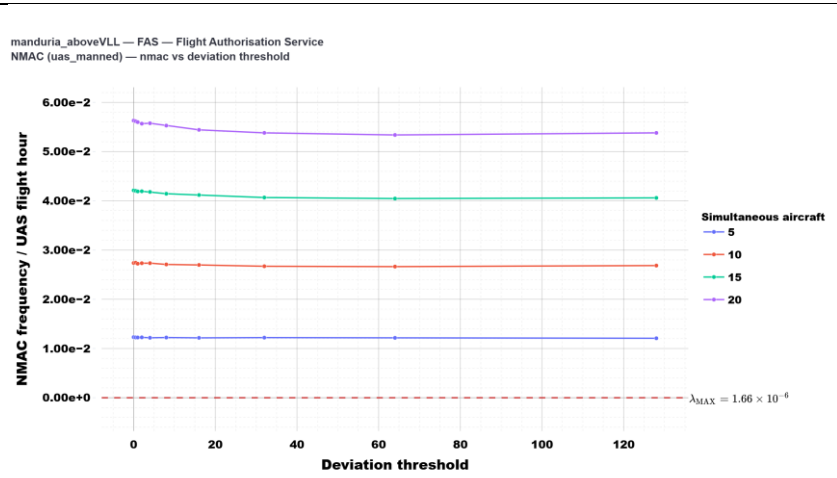
	MAC	NMAC
Benidorm above VLL		

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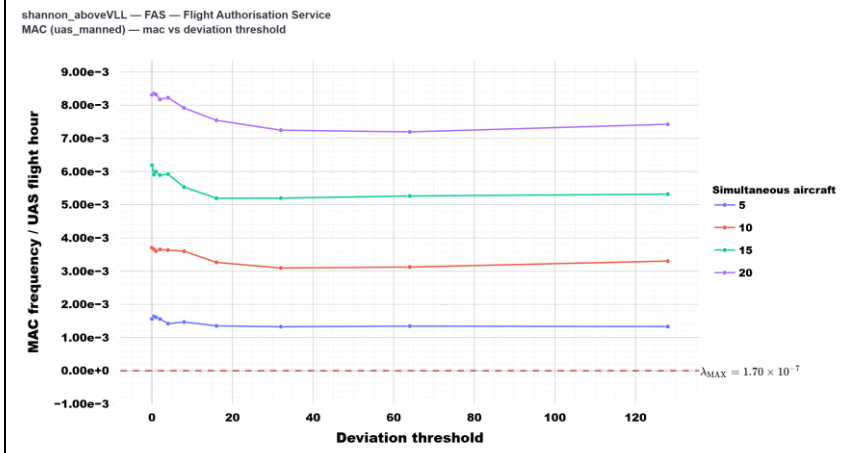
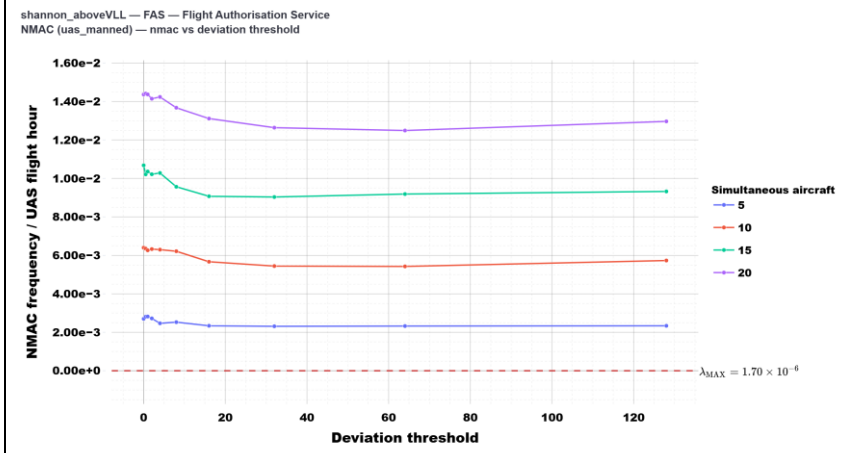
Manduria above VLL		
Shannon above VLL		

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Figure 46: UPV - FAS+TIS above VLL UAS-manned frequency in UAS flight hours

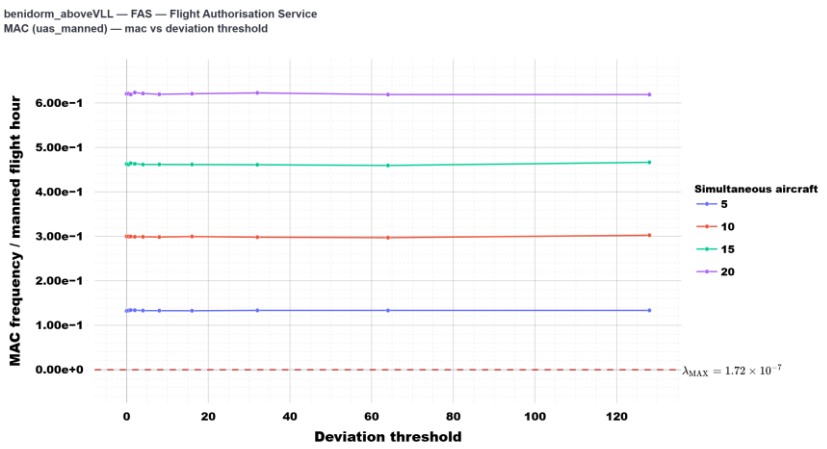
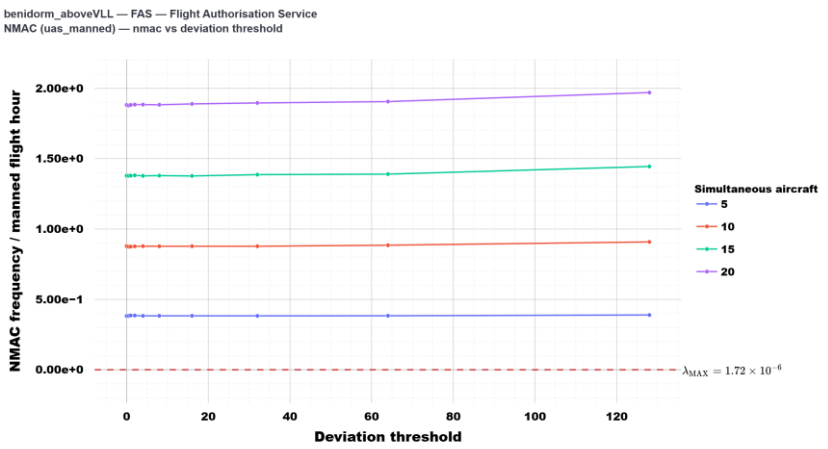
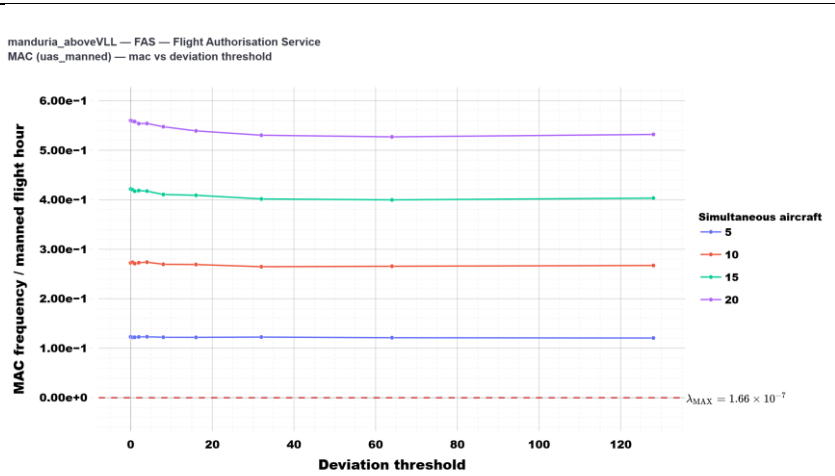
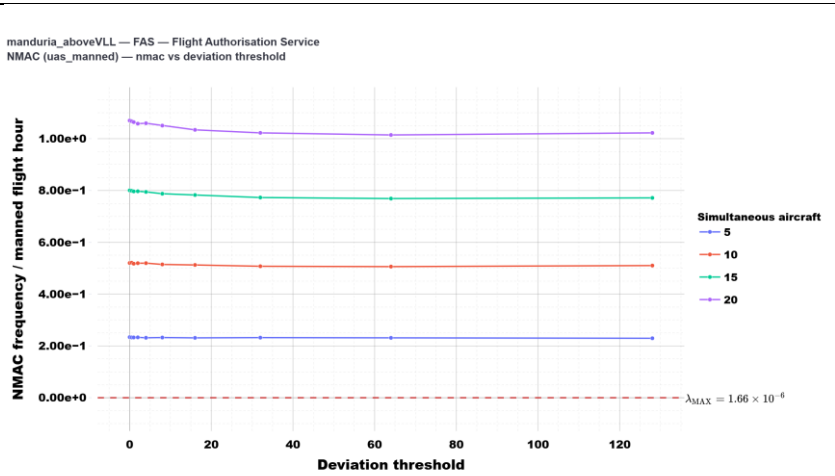
	MAC	NMAC
Benidorm above VLL		
Manduria above VLL		

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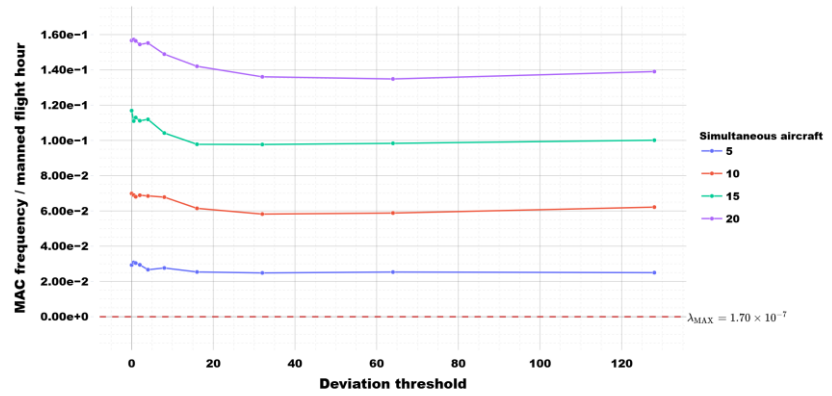
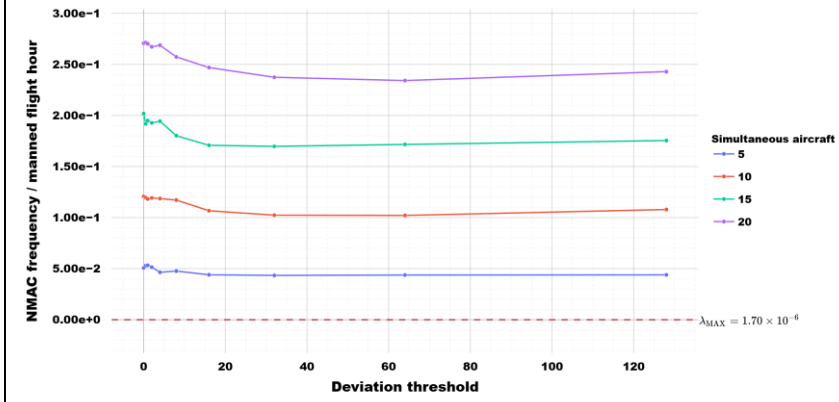
Shannon above VLL		

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Figure 47: UPV - FAS+TIS above VLL UAS-manned frequency in manned flight hours

	MAC	NMAC
Benidorm above VLL		
Manduria above VLL		

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Shannon above VLL		

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The FAS+TIS results show that MAC and NMAC frequencies generally increase with the number of simultaneous aircraft, although their magnitude varies among Benidorm, Manduria and Shannon. As in the baseline, above VLL configurations generally present lower frequencies than below VLL configurations, reflecting the greater vertical distribution of traffic. NMAC remains more frequent than MAC because it is defined by a larger separation volume.

The UAS–UAS results show a clear reduction in both MAC and NMAC frequency as the deviation threshold increases. The effect is particularly rapid for MAC, which reaches very low or zero observed frequencies at comparatively small threshold values. NMAC decreases more gradually because it is defined by a substantially larger separation volume, approaching zero only when the deviation threshold becomes sufficiently large. For a given threshold, higher traffic levels generally produce higher frequencies and may therefore require a larger protection margin to satisfy the applicable safety criterion. The specific response varies among Benidorm, Manduria and Shannon and between below VLL and above VLL operations, reflecting their different traffic distributions and encounter geometries.

Although UAS–manned encounters are not directly deconflicted by FAS, their frequencies also generally decrease as the deviation threshold increases. This can be interpreted as an indirect effect of the greater separation imposed between authorised UAS trajectories: the UAS traffic becomes more spatially dispersed and less concentrated, which may reduce the probability of UAS trajectories coinciding with those of manned aircraft. This trend should therefore be considered a secondary consequence of the reorganisation of UAS traffic rather than a direct UAS–manned deconfliction effect. TIS does not directly modify the frequencies represented by the curves; its mitigation effect is incorporated through the scenario-specific RR, which is used to derive the relaxed maximum allowable frequency shown in the plots.

The capacity obtained under the FAS+TIS configuration depends on the deviation threshold and on the applicable safety criterion. For each deviation threshold, the UAS–UAS capacity is determined as the highest assessed number of simultaneous UAS for which the UAS–UAS MAC frequency remains below the corresponding relaxed maximum allowable frequency. The UAS–manned capacity is determined independently by comparing the UAS–manned MAC frequency with its applicable relaxed criterion. The overall capacity for each scenario and below VLL or above VLL configuration is then determined by the most restrictive of these two results, since both safety criteria must be satisfied simultaneously. Consequently, increasing the deviation threshold may support a higher safety-based capacity by reducing collision frequencies, although its effect on the authorisation approval rate must also be considered because larger separation margins make the acceptance of new U-plans more restrictive.

To derive the capacity for each scenario, the parameter P_{NMAC} is obtained by normalising the NMAC frequency according to the number of potential interacting aircraft. For a traffic level of N simultaneous UAS, each aircraft may encounter the remaining $N-1$ UAS; therefore, the NMAC frequency can be expressed as $\lambda(\mathrm{NMAC}) = (N-1)P_{\mathrm{NMAC}}$. For a given deviation threshold and scenario configuration, P_{NMAC} remains approximately independent of the number of simultaneous UAS within the assessed traffic range. It can therefore be estimated from the simulated frequencies as $P_{\mathrm{NMAC}} = \lambda(\mathrm{NMAC})/(N-1)$. The theoretical capacity associated with the applicable safety criterion for NMAC (λ_{max}) is then calculated as:

$$N_{\mathrm{capacity}} = 1 + \frac{\lambda_{max}}{P_{\mathrm{NMAC}}}$$

The results for the P_{NMAC} are presented in Table 37 and Table 38:

Scenario	Deviation threshold	P_{NMAC} for UAS-UAS
Benidorm below VLL	4	2.162E-02
	32	9.260E-03
	64	1.270E-04
Benidorm above VLL	4	3.643E-03
	32	1.539E-03
	64	1.800E-05
Manduria below VLL	4	6.929E-03
	32	1.474E-03
	64	1.700E-05
Manduria above VLL	4	3.155E-03
	32	7.389E-04
	64	1.000E-05
Shannon below VLL	4	2.416E-03
	32	4.524E-09
	64	N/A[19]
Shannon above VLL	4	2.280E-04
	32	N/A
	64	N/A

Table 37: UPV – FAS independent of the number of simultaneous vehicles parameter on the UAS-UAS NMAC frequency

Scenario	P_{NMAC} UAS-manned per UAS FH	P_{NMAC} UAS-manned per manned FH
Benidorm above VLL	1.22E-02	3.87E-01
Benidorm below VLL	5.17E-03	9.82E-02
Manduria above VLL	6.44E-03	2.04E-01
Manduria below VLL	2.98E-03	5.66E-02
Shannon above VLL	7.98E-03	2.53E-01
Shannon below VLL	6.80E-04	1.28E-02

Table 38: UPV – FAS independent of the number of simultaneous vehicles parameter on the UAS-manned NMAC frequency

[19] N/A values represent frequencies of NMAC of 0 for a given deviation threshold.

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For UAS–UAS encounters, P_{NMAC} is calculated separately for each deviation threshold, since the strategic separation introduced by FAS directly modifies the probability of collision between authorised UAS trajectories. By contrast, the UAS–manned P_{NMAC} remains approximately constant across the assessed deviation thresholds, which is consistent with manned aircraft not being directly included in the FAS deconfliction process. Consequently, the resulting capacities are specific to each scenario, altitude configuration and applicable safety criterion. Increasing the deviation threshold may support a higher safety-based capacity by reducing UAS–UAS collision frequency; however, larger separation margins also make the acceptance of new U-plans more restrictive.

The capacity results are presented in Table 39:

Scenario	Deviation threshold	UAS–UAS capacity	UAS–manned capacity per UAS FH	UAS–manned capacity per manned FH
Benidorm below VLL	4	1	1	1
	32	1		
	64	20		
Benidorm above VLL	4	1	1	1
	32	2		
	64	141		
Manduria below VLL	4	1	1	1
	32	1		
	64	52		
Manduria above VLL	4	1	1	1
	32	2		
	64	87		
Shannon below VLL	4	526	1	1
	32	1181		
	64	925		
Shannon above VLL	4	2316	1	1
	32	932		
	64	583		

Table 39: UPV - Capacity results for the FAS+TIS

The grey-shaded cells in Table 39 indicate cases where the safety-based capacity exceeds the number of trajectories[20] that FAS can allocate and authorise within the available scenario airspace. In these cases, capacity is limited by the operational performance of FAS rather than by the applicable safety criterion.

[20] The trajectories are generated independently for each scenario configuration; therefore, the trajectory sets used for below-VLL and above-VLL operations may differ, even within the same scenario.

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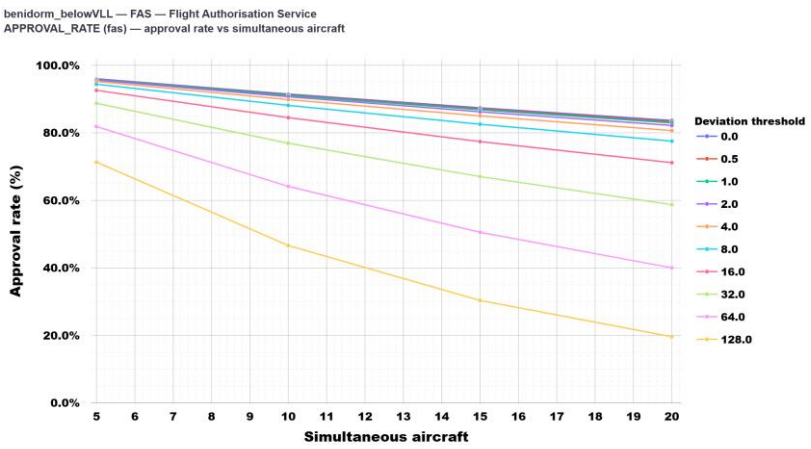
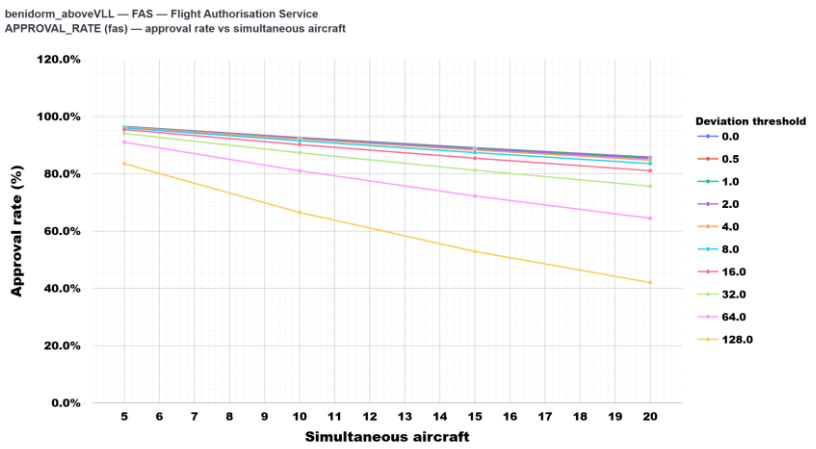
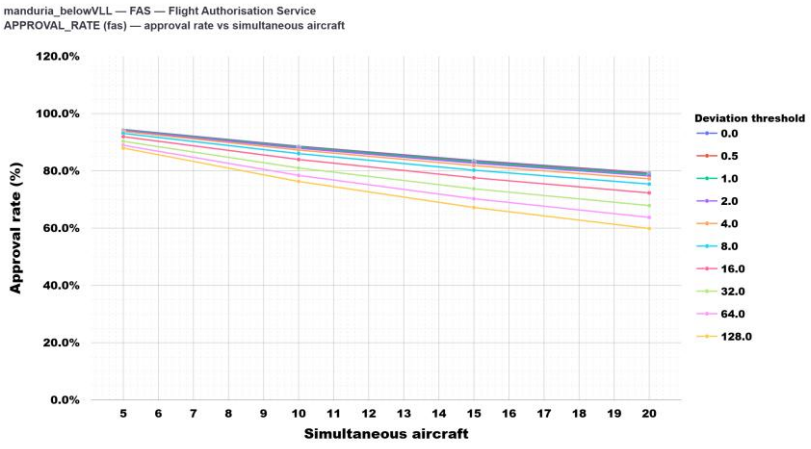
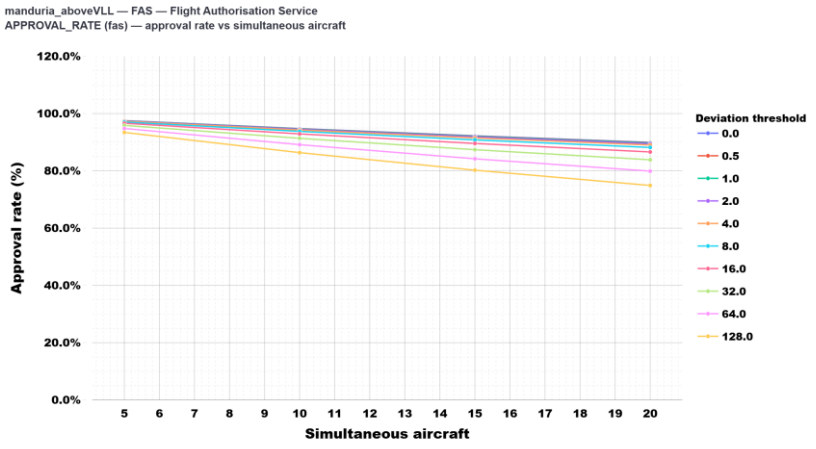
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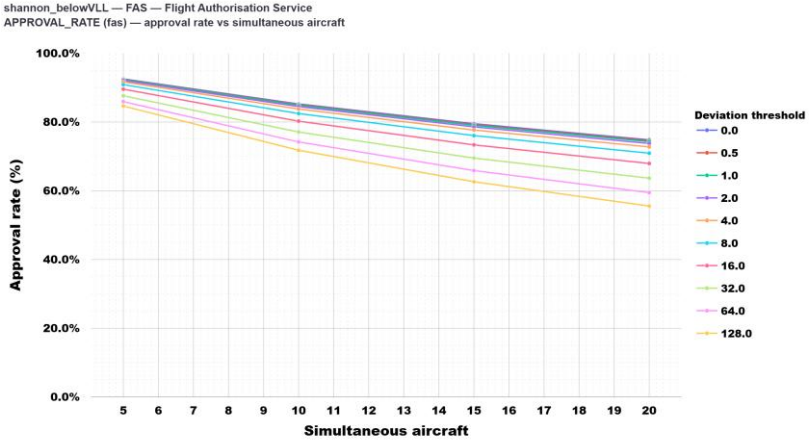
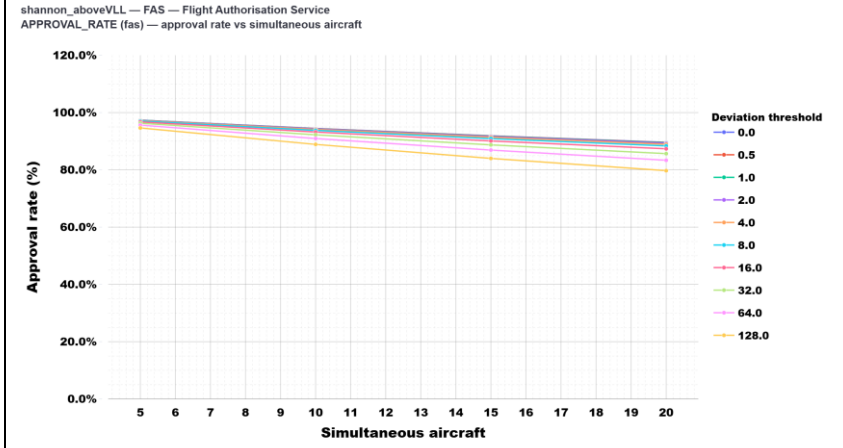
The Authorisation Approval Rate is also analysed to complement the capacity results. This indicator represents the proportion of submitted U-plans accepted by the Flight Authorisation Service and provides an operational measure of the impact of the deviation threshold. As the deviation threshold increases, the separation required between authorised UAS trajectories becomes more restrictive, which reduces the number of U-plans that can be accepted, particularly at higher traffic levels. The approval rate, therefore, supports the assessment of the trade-off between reducing collision frequencies and maintaining efficient access to the airspace. Higher approval rates are obtained for above VLL operations, where the greater vertical distribution of trajectories facilitates the identification of conflict-free U-plans at the same deviation threshold.

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Figure 48: UPV - Approval Rate of the FAS across all scenarios

	Below VLL	Above VLL
Benidorm		
Manduria		

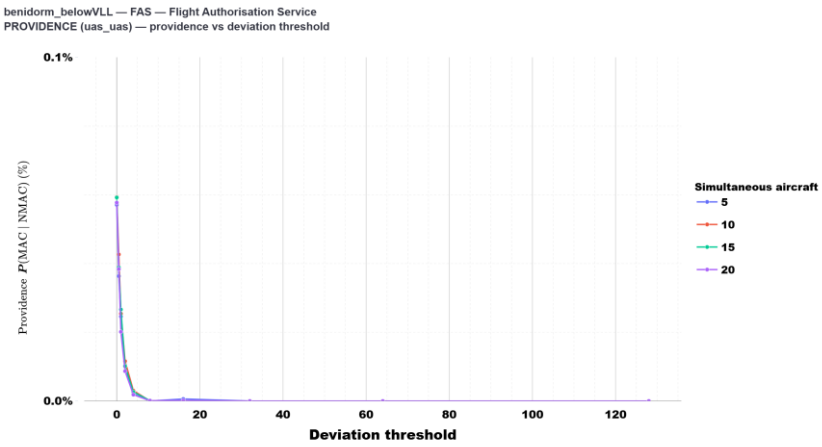
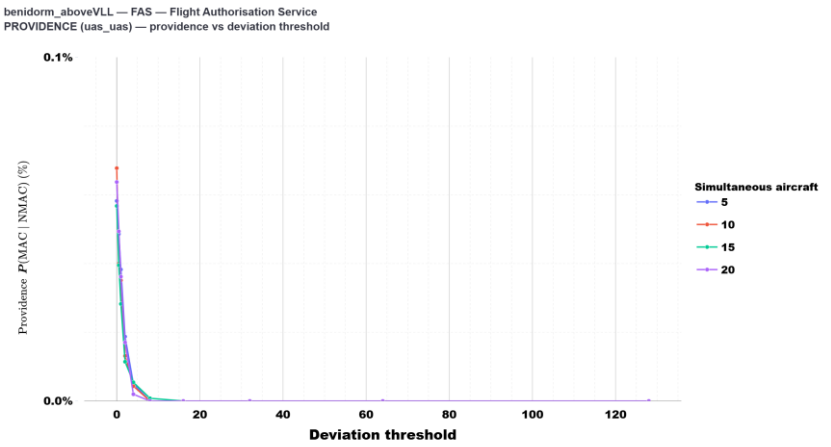
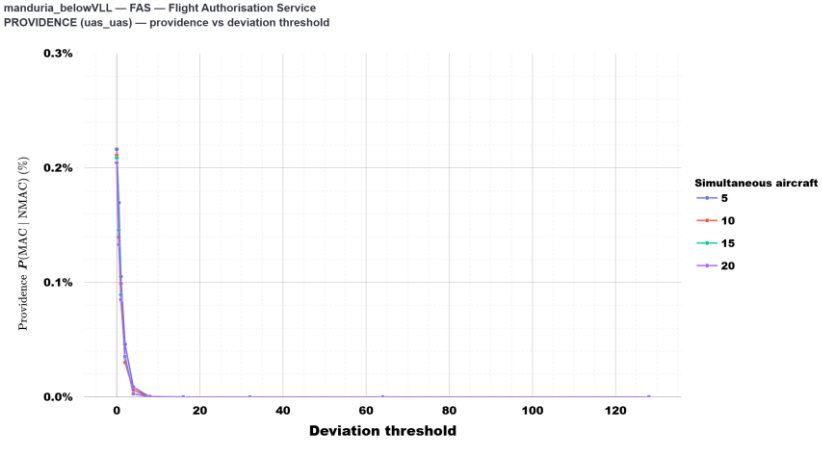
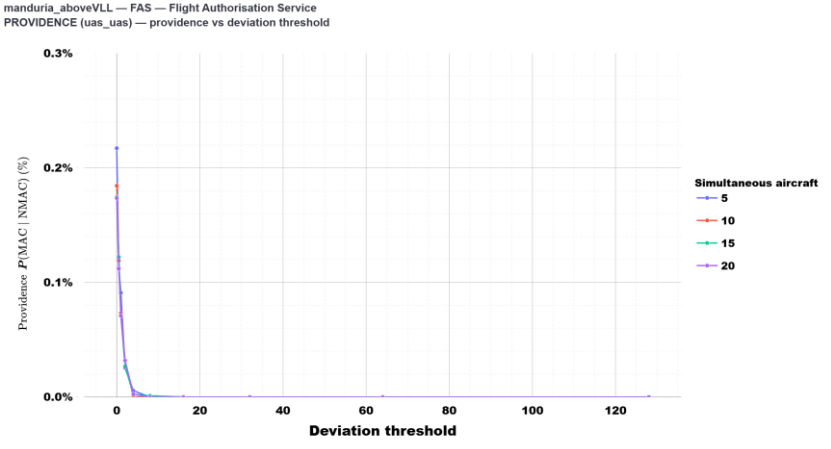
Shannon		

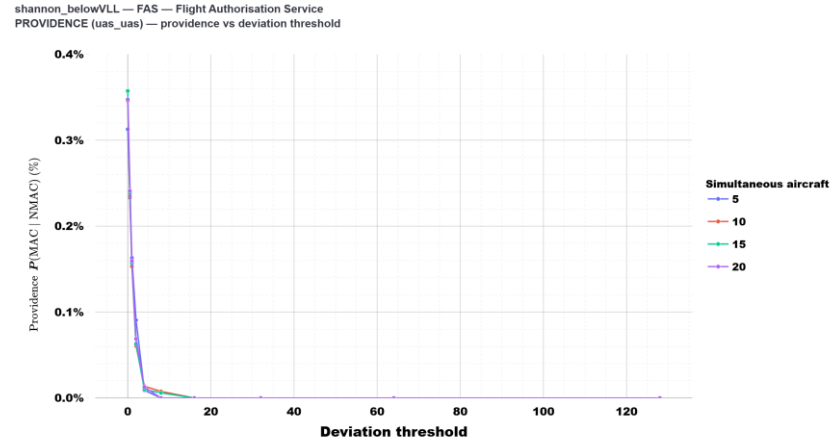
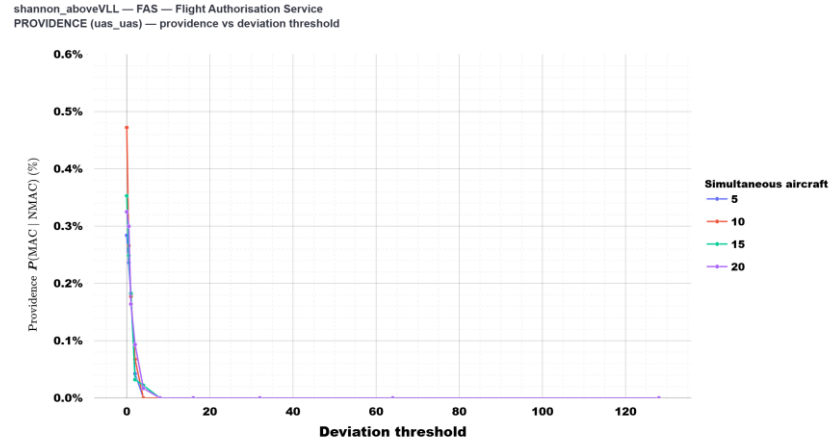
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Providence is also evaluated for the FAS configuration to examine the relationship between the resulting MAC and NMAC frequencies. For UAS–UAS encounters, while the baseline scenarios produced providence values ranging approximately from 20% to 60%, the values obtained after applying Flight Authorisation remain below 1%. This substantial reduction results from the strategic separation introduced between authorised UAS trajectories through the applicable TSE margins and deviation threshold. Consequently, the remaining NMAC events generally arise from limited deviations around already deconflicted trajectories, and only a very small proportion progresses into the more restrictive MAC volume. These results further demonstrate the effectiveness of strategic deconfliction in preventing UAS–UAS NMAC events from escalating into MAC events.

For UAS–manned encounters, providence generally remains within the same range as in the baseline configuration, which is consistent with the fact that manned aircraft are not directly considered in the FAS deconfliction process. Nevertheless, some configurations show a slight reduction as the deviation threshold increases. This behaviour may result from the indirect redistribution of UAS traffic: larger deviation thresholds impose greater separation between authorised UAS trajectories, reducing their spatial concentration and modifying the geometries of the remaining encounters with manned aircraft. Therefore, the observed variation should be interpreted as an indirect effect of UAS traffic reorganisation rather than as direct UAS–manned deconfliction.

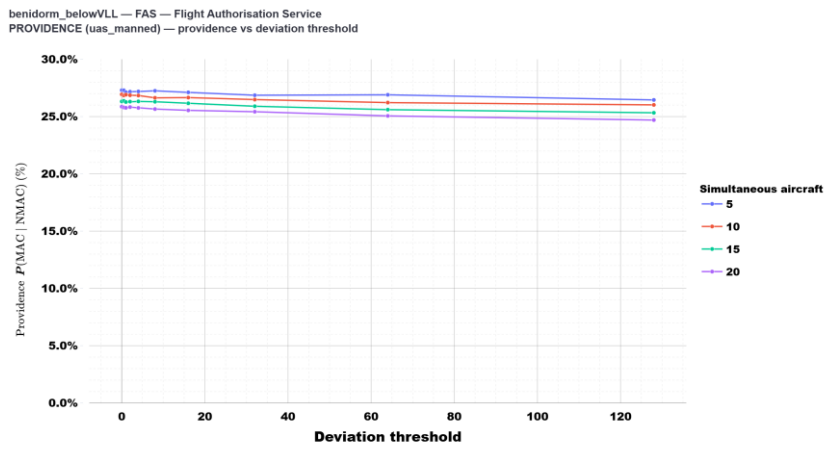
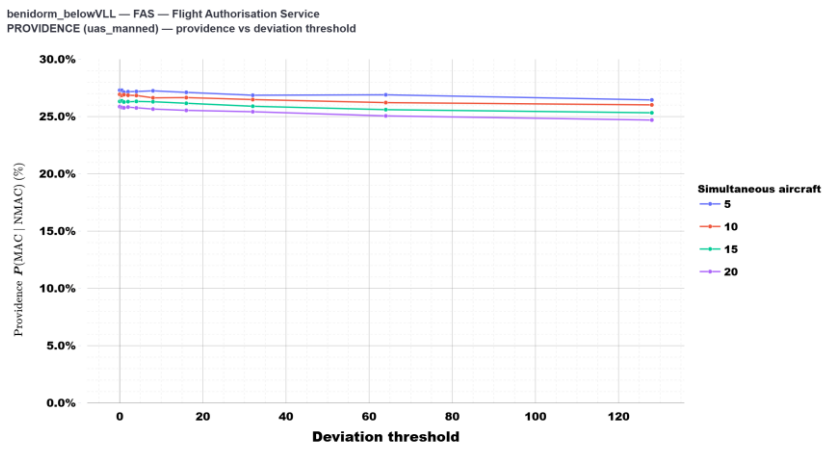
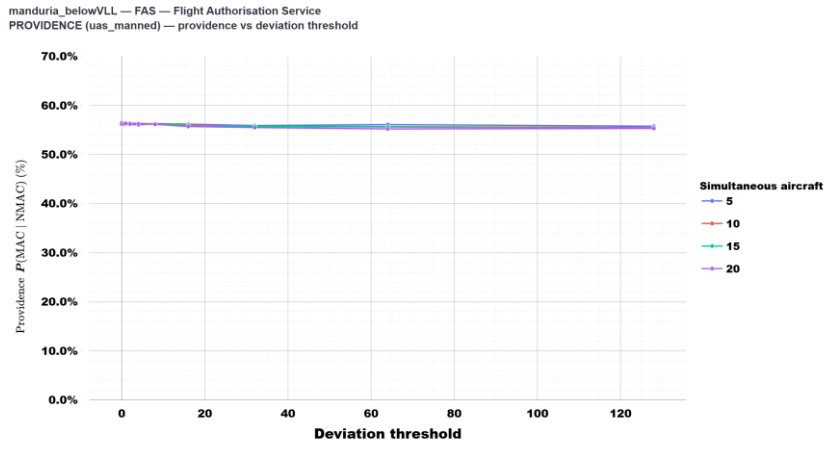
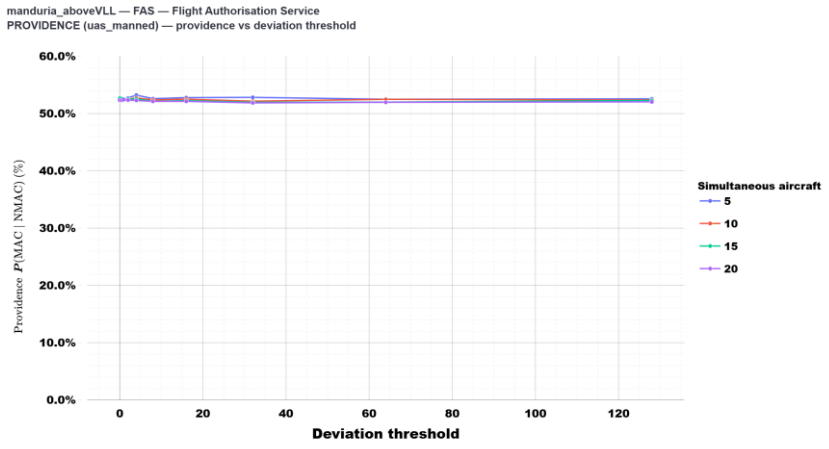
Figure 49: UPV - FAS Providence for UAS-UAS

	Below VLL	Above VLL
Benidorm		
Manduria		

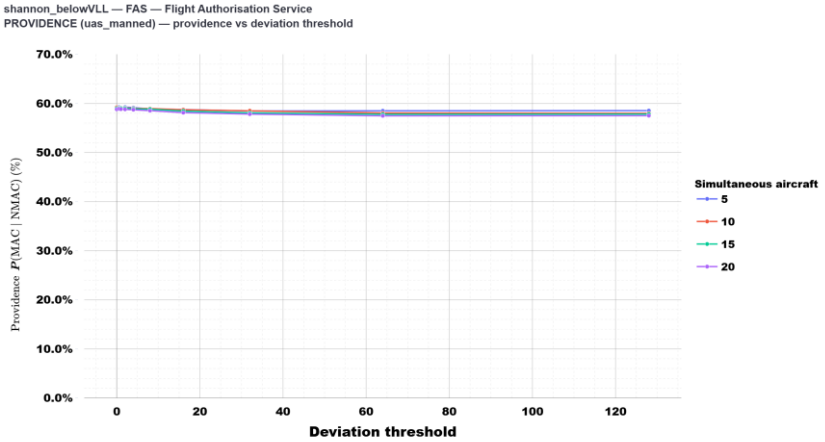
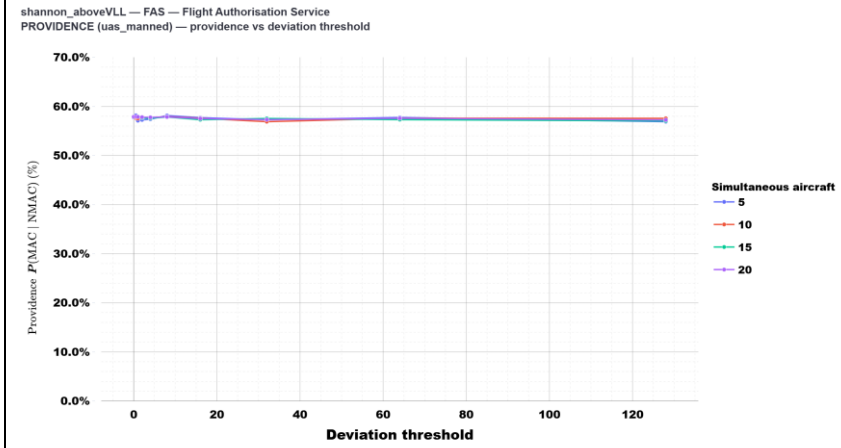
Shannon		

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Figure 50: UPV - FAS Providence for UAS-manned

	Below VLL	Above VLL
Benidorm		
Manduria		

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Shannon		

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The results obtained for the KPIs associated with this validation objective are summarised in the following table. The values are presented separately for each scenario and altitude configuration, covering the Safety, Capacity, and Access and Equity KPAs. Together, these indicators provide a consolidated view of the safety performance, the traffic levels that can be accommodated, and the operational impact of the Flight Authorisation Service and Traffic Information Service. These results have been obtained by ensuring the lower deviation threshold at which the TLS is achieved and bearing in mind the results obtained for authorisation approval rate indicate that higher deviation thresholds presented lower authorisation approval rates. This gives us a safety and capacity balance.

Scenario	KPA	KPI	Value obtained
Benidorm below VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** ≈ 1E-1 NMAC/FH for 5 simultaneous vehicles and ≈ 4.75E-1 NMAC/FH for 20 simultaneous vehicles (dt = 0) – ≈ 0.0 NMAC/FH for dt > 64 **UAS-manned per UAS flight hours** ≈ 5E-2 NMAC/FH for 5 simultaneous vehicles and ≈ 2.35E-1 NMAC/FH for 20 simultaneous vehicles (dt = 0) – ≈ 4.8E-2 NMAC/FH for 5 simultaneous vehicles and ≈ 2E-1 NMAC/FH for 20 simultaneous vehicles (dt = 128) **UAS-manned per manned flight hours** ≈ 1.57 NMAC/FH for 5 simultaneous vehicles and ≈ 7.45 NMAC/FH for 20 simultaneous vehicles (dt = 0) – ≈ 1.53 NMAC/FH for 5 simultaneous vehicles and ≈ 6.45 NMAC/FH for 20 simultaneous vehicles (dt = 128)
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** ≈ 0.0469 UAS/km² for DT of 4m ≈ 0.0469 UAS/km² for DT of 32m ≈ 0.9390 UAS/km² for DT of 64m **UAS–manned per UAS flight hours** ≈ 0.0469 UAS/km² **UAS–manned per manned flight hours** ≈ 0.0469 UAS/km²
		U-AGREE-KPI-04 **Average number of authorised U-plans**	≈ 97% of UAS and ≈ 3% of Manned aviation Therefore, 4.85 average authorised U-plans for 5 vehicles and 19.4 average authorised U-plans for 20 vehicles.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Approval rate decreases as both traffic demand and the deviation threshold increase ≈95% for 5 simultaneous vehicles and ≈83% for 20 simultaneous vehicles (dt = 0) – ≈71% for 5 simultaneous vehicles and ≈20% for 20 simultaneous vehicles (dt = 128)
Benidorm above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** ≈ 1.6E-2 NMAC/FH for 5 simultaneous vehicles and ≈ 8E-2 NMAC/FH for 20 simultaneous vehicles (dt = 0) – ≈ 0.0 NMAC/FH for dt > 64 **UAS-manned per UAS flight hours** ≈ 2E-2 NMAC/FH for 5 simultaneous vehicles and ≈ 1E-1 NMAC/FH for 20 simultaneous vehicles (∀dt > 0) **UAS-manned per manned flight hours** ≈ 3.89E-1 NMAC/FH for 5 simultaneous vehicles and ≈ 2 NMAC/FH for 20 simultaneous vehicles (∀dt > 0)

	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** ≈ 0.0469 UAS/km² for DT of 4m ≈ 0.0939 UAS/km² for DT of 32m ≈ 6.6197 UAS/km² for DT of 64m **UAS–manned per UAS flight hours** ≈ 0.0469 UAS/km² **UAS–manned per manned flight hours** ≈ 0.0469 UAS/km²
		U-AGREE-KPI-04 **Average number of authorised U-plans**	≈ 95% of UAS and ≈ 5% of Manned aviation Therefore, 4.75 average authorised U-plans for 5 vehicles and 19.0 average authorised U-plans for 20 vehicles.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Approval rate decreases as both traffic demand and the deviation threshold increase ≈96% for 5 simultaneous vehicles and ≈85% for 20 simultaneous vehicles (dt = 0) – ≈83% for 5 simultaneous vehicles and ≈42% for 20 simultaneous vehicles (dt = 128)
Manduria below VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** ≈ 4.9E-2 NMAC/FH for 5 simultaneous vehicles and ≈ 2.1E-1 NMAC/FH for 20 simultaneous vehicles (dt = 0) – ≈ 0.0 NMAC/FH for dt > 64 **UAS-manned per UAS flight hours** ≈ 2.8E-2 NMAC/FH for 5 simultaneous vehicles and ≈ 1.2E-1 NMAC/FH for 20 simultaneous vehicles (dt = 0) - ≈ 2.7E-2 NMAC/FH for 5 simultaneous vehicles and ≈ 1E-1 NMAC/FH for 20 simultaneous vehicles (dt = 128) **UAS-manned per manned flight hours** ≈ 8.8E-1 NMAC/FH for 5 simultaneous vehicles and ≈ 3.75 NMAC/FH for 20 simultaneous vehicles (dt = 0) - ≈ 8.6E-1 NMAC/FH for 5 simultaneous vehicles and ≈ 3.39 NMAC/FH for 20 simultaneous vehicles (dt = 128)
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** ≈ 0.0022 UAS/km² for DT of 4m ≈ 0.0022 UAS/km² for DT of 32m ≈ 0.1126 UAS/km² for DT of 64m **UAS–manned per UAS flight hours** ≈ 0.0022 UAS/km² **UAS–manned per manned flight hours** ≈ 0.0022 UAS/km²
		U-AGREE-KPI-04 **Average number of authorised U-plans**	≈ 97% of UAS and ≈ 3% of Manned aviation Therefore, 4.85 average authorised U-plans for 5 vehicles and 19.4 average authorised U-plans for 20 vehicles.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Approval rate decreases as both traffic demand and the deviation threshold increase ≈94% for 5 simultaneous vehicles and ≈79% for 20 simultaneous vehicles (dt = 0) – ≈88% for 5 simultaneous vehicles and ≈60% for 20 simultaneous vehicles (dt = 128)

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Manduria above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** ≈ 1.8E-2 NMAC/FH for 5 simultaneous vehicles and ≈ 8.45E-2 NMAC/FH for 20 simultaneous vehicles (dt = 0) – ≈ 0.0 NMAC/FH for dt > 64 **UAS-manned per UAS flight hours** ≈ 1.2E-2 NMAC/FH for 5 simultaneous vehicles and ≈ 5.4E-2 NMAC/FH for 20 simultaneous vehicles (∀dt > 0) **UAS-manned per manned flight hours** ≈ 2.3E-1 NMAC/FH for 5 simultaneous vehicles and ≈ 1 NMAC/FH for 20 simultaneous vehicles (∀dt > 0)
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** ≈ 0.0022 UAS/km² for DT of 4m ≈ 0.0043 UAS/km² for DT of 32m ≈ 0.1883 UAS/km² for DT of 64m **UAS–manned per UAS flight hours** ≈ 0.0022 UAS/km² **UAS–manned per manned flight hours** ≈ 0.0022 UAS/km²
		U-AGREE-KPI-04 **Average number of authorised U-plans**	≈ 95% of UAS and ≈ 5% of Manned aviation Therefore, 4.75 average authorised U-plans for 5 vehicles and 19.0 average authorised U-plans for 20 vehicles.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Approval rate decreases as both traffic demand and the deviation threshold increase ≈98% for 5 simultaneous vehicles and ≈95% for 20 simultaneous vehicles (dt = 0) – ≈89% for 5 simultaneous vehicles and ≈78% for 20 simultaneous vehicles (dt = 128)
Shannon below VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** ≈ 3.1E-2 NMAC/FH for 5 simultaneous vehicles and ≈ 1.0E-1 NMAC/FH for 20 simultaneous vehicles (dt = 0) – ≈ 0.0 MAC/FH for dt > 16 **UAS-manned per UAS flight hours** ≈ 3.7E-2 NMAC/FH for 5 simultaneous vehicles and ≈ 1.41E-1 NMAC/FH for 20 simultaneous vehicles (dt = 0) - ≈ 3.5E-2 NMAC/FH for 5 simultaneous vehicles and ≈ 1.2E-1 MAC/FH for 20 simultaneous vehicles (dt = 128) **UAS-manned per manned flight hours** ≈ 1.15 NMAC/FH for 5 simultaneous vehicles and ≈ 4.45 NMAC/FH for 20 simultaneous vehicles (dt = 0) - ≈ 1.1 NMAC/FH for 5 simultaneous vehicles and ≈ 3.86 MAC/FH for 20 simultaneous vehicles (dt = 128)
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** ≈ 0.6217 UAS/km² for DT of 4m ≈ 1.3960 UAS/km² for DT of 32m ≈ 1.0934 UAS/km² for DT of 64m **UAS–manned per UAS flight hours** ≈ 0.0012 UAS/km² **UAS–manned per manned flight hours** ≈ 0.0012 UAS/km²
		U-AGREE-KPI-04 **Average number of authorised U-plans**	≈ 97% of UAS and ≈ 3% of Manned aviation Therefore, 4.85 average authorised U-plans for 5 vehicles and 19.4 average authorised U-plans for 20 vehicles.

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	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Approval rate decreases as both traffic demand and the deviation threshold increase ≈92% for 5 simultaneous vehicles and ≈75% for 20 simultaneous vehicles (dt = 0) – ≈84% for 5 simultaneous vehicles and ≈56% for 20 simultaneous vehicles (dt = 128)
Shannon above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** ≈ 2.6E-3 NMAC/FH for 5 simultaneous vehicles and ≈ 1.1E-2 NMAC/FH for 20 simultaneous vehicles (dt = 0) – ≈ 0.0 NMAC/FH for dt > 16 **UAS-manned per UAS flight hours** ≈ 2.7E-3 NMAC/FH for 5 simultaneous vehicles and ≈ 1.4E-2 MAC/FH for 20 simultaneous vehicles (∀dt > 0) **UAS-manned per manned flight hours** ≈ 5E-2 MAC/FH for 5 simultaneous vehicles and ≈ 2.7E-1 MAC/FH for 20 simultaneous vehicles (∀dt > 0)
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** ≈ 2.7376 UAS/km² for DT of 4m ≈ 1.1017 UAS/km² for DT of 32m ≈ 0.6891 UAS/km² for DT of 64m **UAS–manned per UAS flight hours** ≈ 0.0012 UAS/km² **UAS–manned per manned flight hours** ≈ 0.0012 UAS/km²
		U-AGREE-KPI-04 **Average number of authorised U-plans**	≈ 95% of UAS and ≈ 5% of Manned aviation Therefore, 4.75 average authorised U-plans for 5 vehicles and 19.0 average authorised U-plans for 20 vehicles.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Approval rate decreases as both traffic demand and the deviation threshold increase ≈98% for 5 simultaneous vehicles and ≈97% for 20 simultaneous vehicles (dt = 0) – ≈90% for 5 simultaneous vehicles and ≈80% for 20 simultaneous vehicles (dt = 128)

Table 40: UPV - KPIs for OBJ-SOL0520-ERP-002 (FAS+TIS)

A.4.2.3. OBJ-SOL0520-ERP-003 Results

This objective evaluates the additional effect of Conformance Monitoring without pre-alerting, on top of the Flight Authorisation assumptions. In this configuration, Flight Authorisation defines the initial deconflicted corridor, while Conformance Monitoring responds after the monitored limit has been crossed. The monitoring process detects excursions, applies the configured probability of successful alerting, and initiates recovery after communication and reaction delays. The resulting effect is an increase in effective containment, not an absolute guarantee that aircraft always remain inside the corridor.

The central assumption is that the navigation-error model already provides approximately 95% TSE containment under nominal conditions. This means that a non-negligible fraction of flight time may still occur outside the declared TSE corridor. Without pre-alerting, the corrective action is triggered later than in a pre-alert configuration, so some excursion time may accumulate before recovery begins. The effect of Conformance Monitoring should therefore be interpreted through both conflict frequencies and containment-related indicators.

For MAC, Conformance Monitoring can be most influential at low protection-buffer values. At low buffer values, the protected distance is close to the MAC scale, and excursions beyond the TSE corridor

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can consume much of the available margin. Detecting and reducing those excursions can therefore have a visible effect on UAS-UAS MAC frequency. This interpretation is strongest when the simulated TSE and the TSE assumed by Flight Authorisation are consistent.

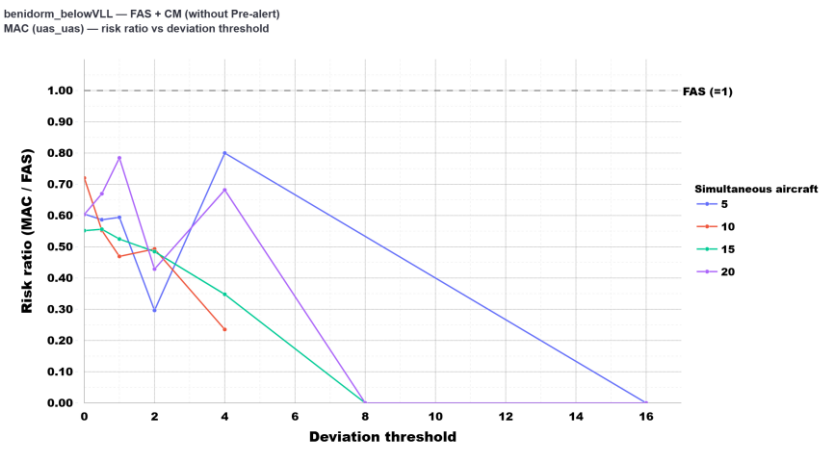
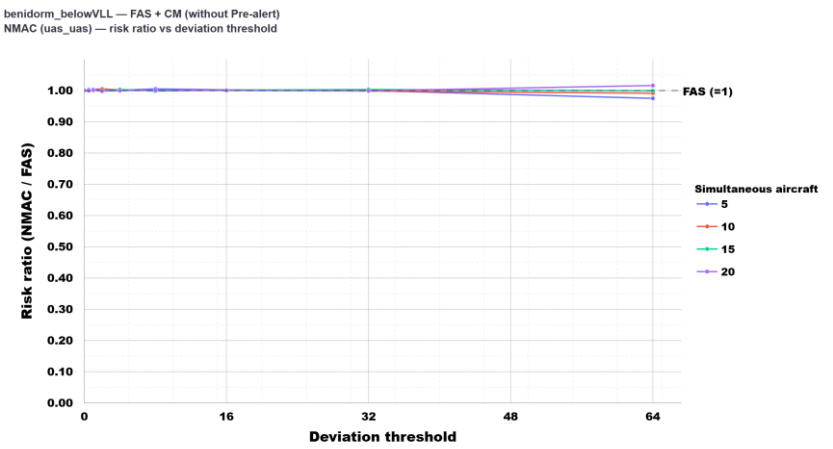
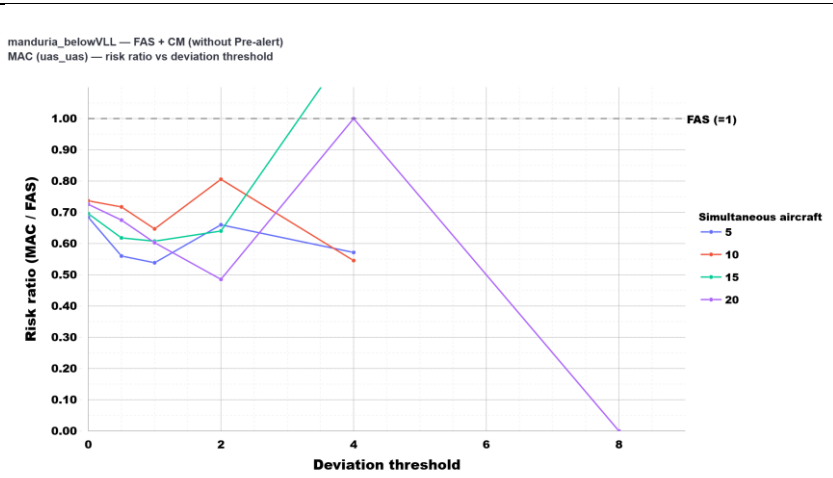
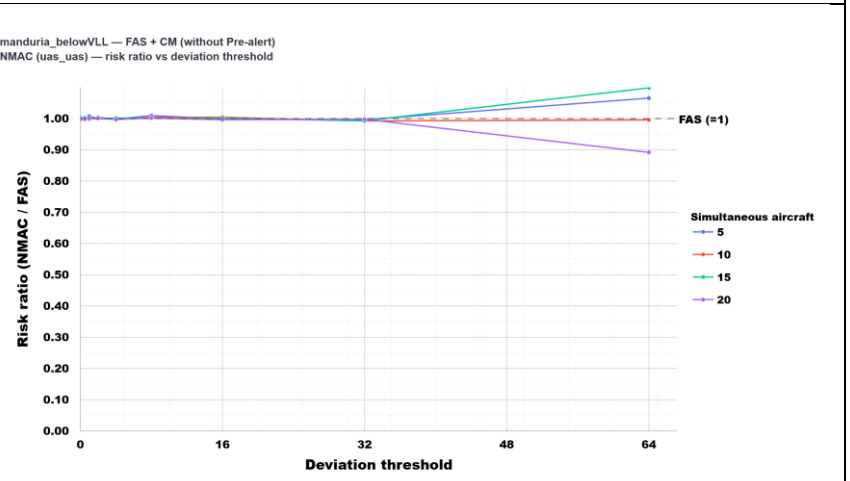
For NMAC, the interpretation is different. Because NMAC thresholds are much larger than MAC thresholds, improved containment within a MAC-scale corridor may not strongly change NMAC frequency unless the deviation threshold is also large enough to operate near the NMAC distance scale. It is therefore possible for Conformance Monitoring to improve containment and reduce MAC risk at low buffer values without producing a similarly visible reduction in NMAC. This does not necessarily indicate that monitoring is ineffective; it reflects the different spatial scales of the two indicators.

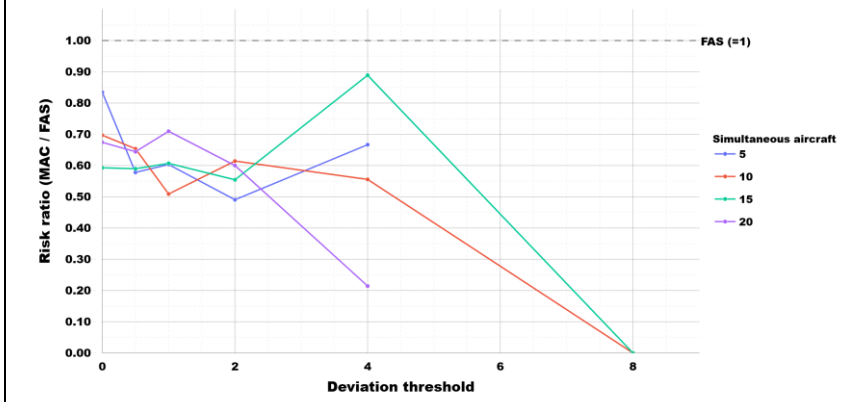
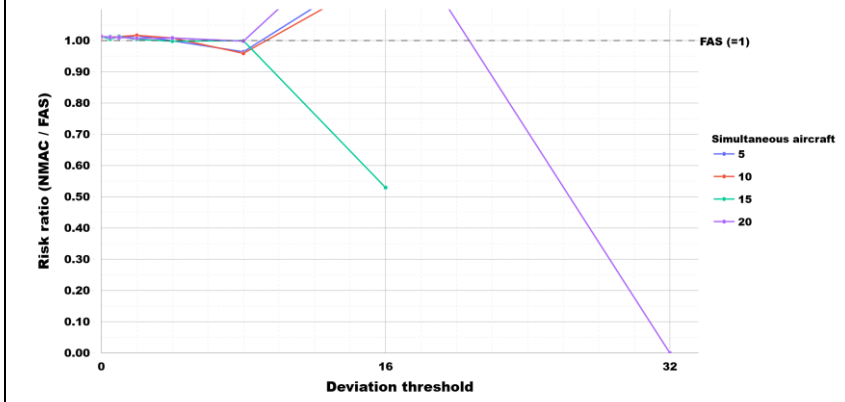
The additional effect of Conformance Monitoring without pre-alerting is assessed by comparing the MAC and NMAC frequencies obtained with FAS+CM against the corresponding FAS frequencies. TIS is subsequently considered through the scenario-specific Risk Ratio used to derive the relaxed maximum allowable frequency. The resulting Conformance Monitoring Risk Ratio therefore represents the fraction of the FAS collision frequency that remains after introducing the monitoring and recovery mechanism.

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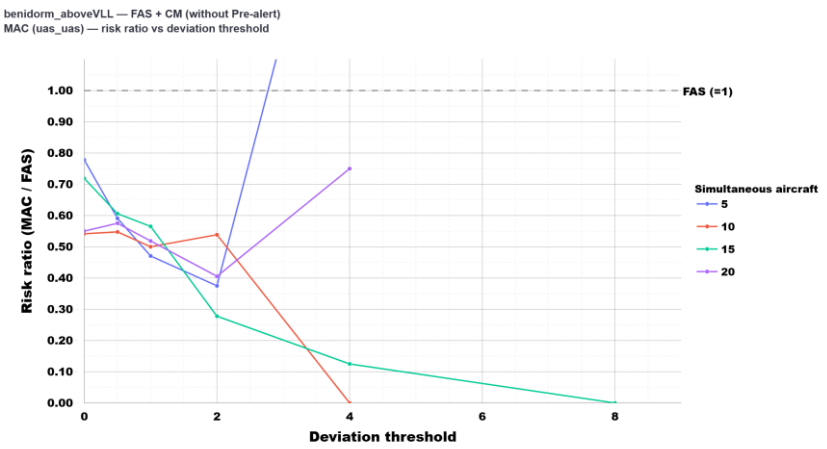
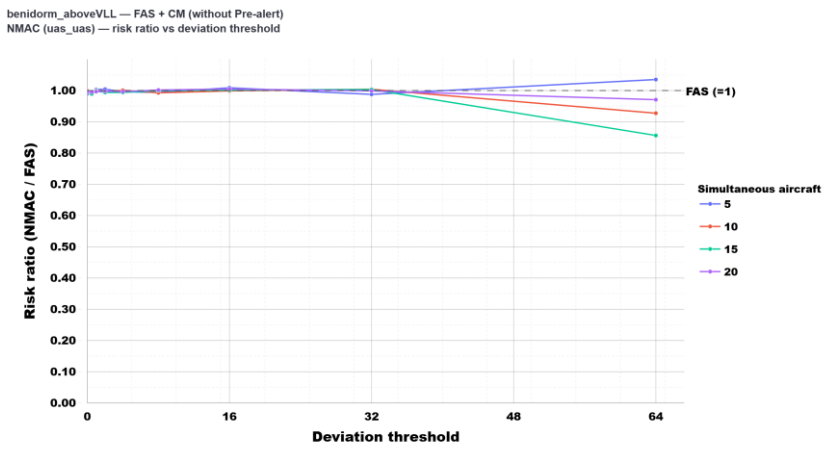
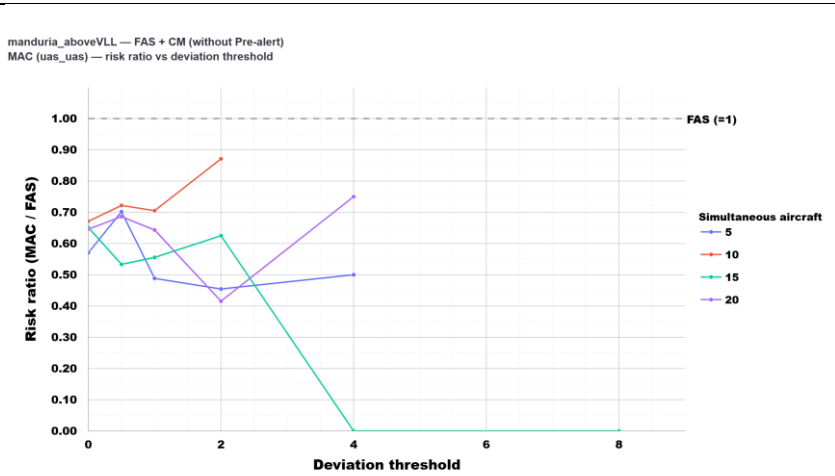
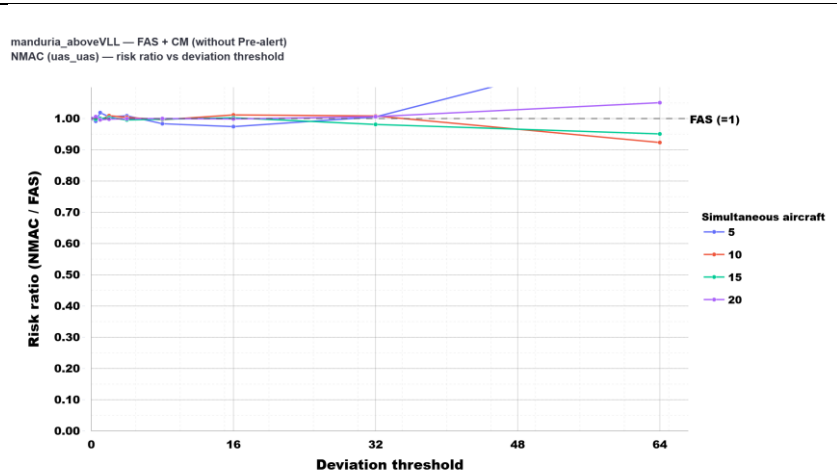
Figure 51: UPV - Risk Ratio Conformance Monitoring without pre-alert UAS-UAS below VLL

	MAC	NMAC
Benidorm below VLL		
Manduria below VLL		

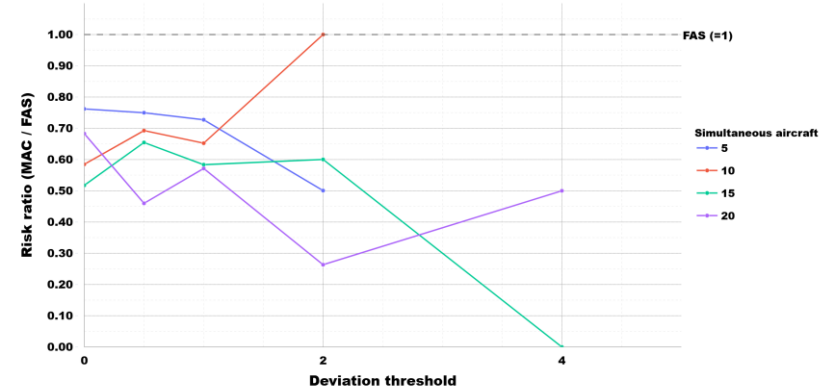
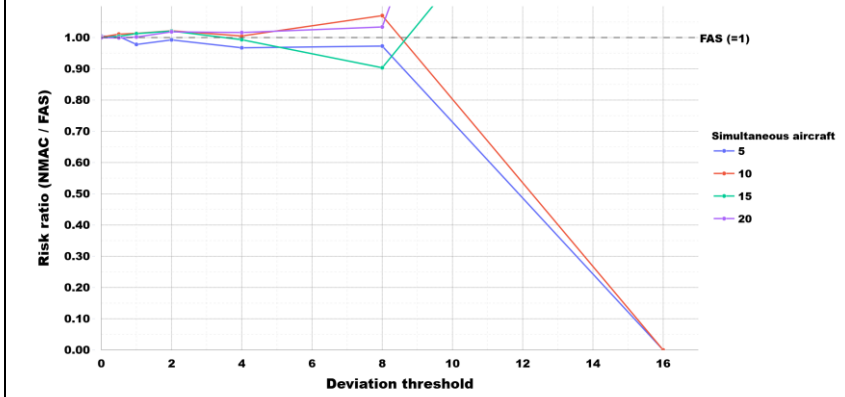
Shannon below VLL		

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Figure 52: UPV - Risk Ratio Conformance Monitoring without pre-alert UAS-UAS above VLL

	MAC	NMAC
Benidorm above VLL		
Manduria above VLL		

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Shannon above VLL		

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The MAC results generally show an additional safety benefit from Conformance Monitoring without pre-alerting, with Risk Ratios below one for most of the assessed configurations. However, the results also exhibit noticeable dispersion across traffic levels, deviation thresholds and operational scenarios, and the reduction is not always monotonic. This variability is partly associated with the low frequency of MAC events: when the FAS frequency is small, limited differences in the number of observed events can produce comparatively large variations in the resulting Risk Ratio. Despite this dispersion, the overall trend indicates that detecting excursions and initiating recovery reduces the likelihood that a deviation progresses into a MAC, particularly at smaller deviation thresholds where the available separation margin is more limited.

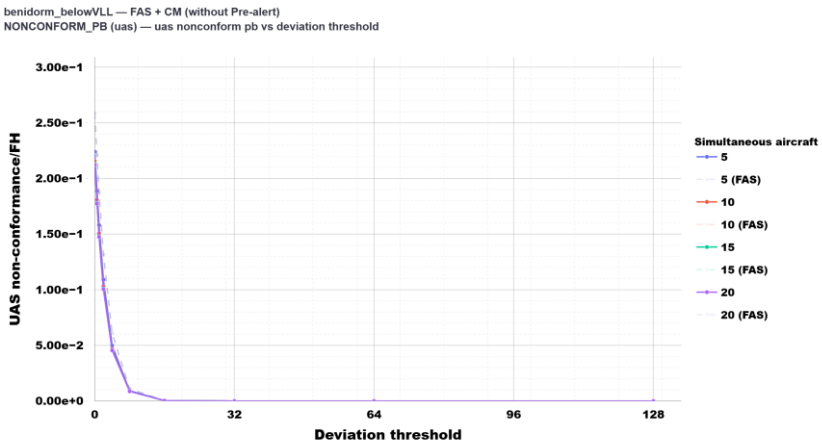
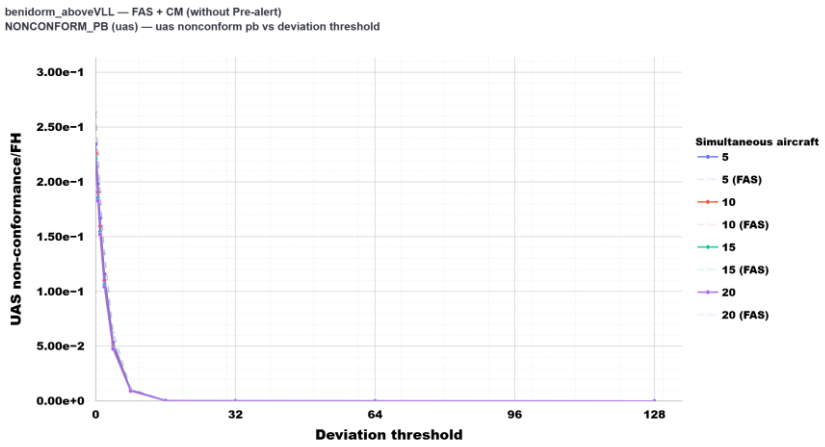
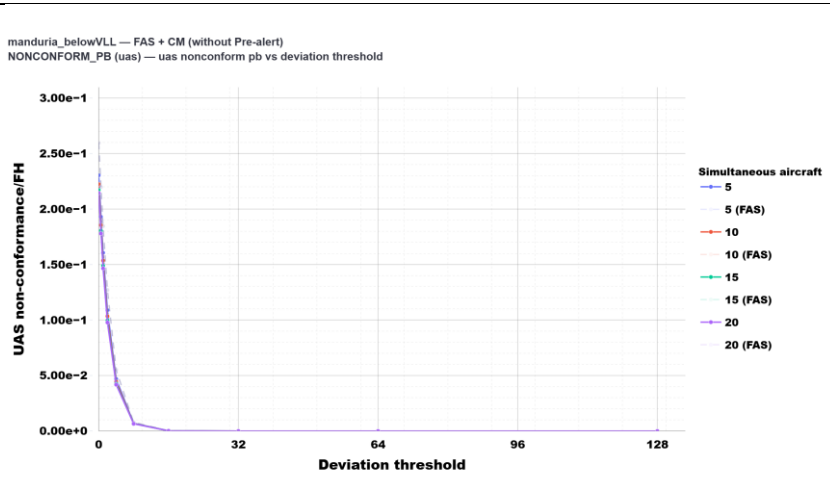
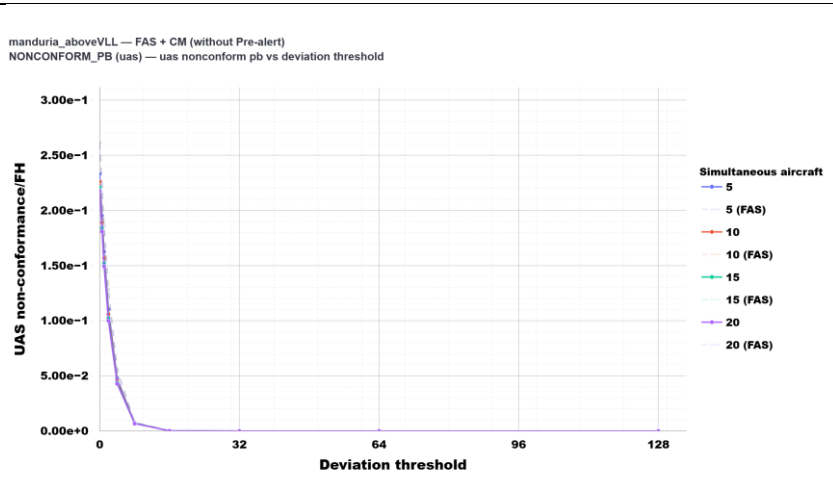
By contrast, the NMAC Risk Ratio remains approximately equal to one across the assessed deviation thresholds, traffic levels and operational scenarios. This indicates that Conformance Monitoring without pre-alerting does not provide a clear additional reduction in UAS–UAS NMAC frequency compared with FAS+TIS. This behaviour is consistent with the larger spatial scale of the NMAC volume: since recovery is initiated only after the monitored outer limit has been crossed, the aircraft may already have entered the broader NMAC volume before the corrective manoeuvre becomes effective. Conformance Monitoring without pre-alerting can therefore reduce the probability that an excursion progresses into the more restrictive MAC volume without substantially changing the number of NMAC events.

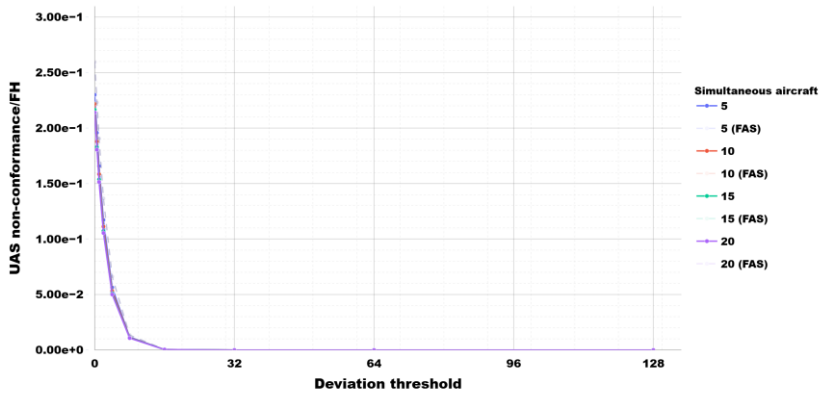
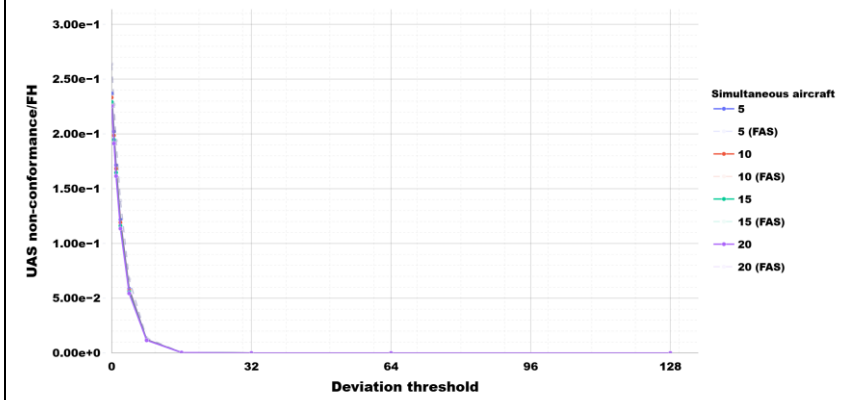
At sufficiently large deviation thresholds, the FAS+TIS and FAS+CM+TIS frequencies may both become zero within the simulated exposure. In these cases, the Risk Ratio is undefined because its calculation would require division of zero by zero, and the corresponding points are therefore omitted from the plots. Their absence indicates that no events of the corresponding type were observed in either configuration, rather than an additional reduction attributable to Conformance Monitoring.

The effect on UAS–manned encounters is limited. Conformance Monitoring acts on UAS deviations but does not directly mitigate encounters with manned aircraft. Consequently, UAS–manned frequencies remain largely determined by the scenario-specific traffic mix and encounter geometry. The results show RR values close to one across all scenarios, indicating that Conformance Monitoring does not provide a clear reduction in UAS–manned collision frequencies compared with FAS. Any variations should therefore be interpreted as limited indirect effects of returning deviating UAS towards their authorised trajectories, rather than as direct mitigation of UAS–manned encounters. Accordingly, the clearest additional safety benefit of Conformance Monitoring is observed for UAS–UAS MAC events.

In addition to the collision-frequency results, non-conformance is analysed with respect to two monitoring boundaries. Deviation-boundary non-conformance records the time per UAS flight hour of the excursions that reach the outer limit defined by the TSE and the deviation threshold, which triggers recovery in the configuration without pre-alerting. TSE non-conformance records the time per UAS flight hour of the excursions that exceed the nominal TSE boundary before reaching this outer limit. Both indicators are reported per UAS flight hour and compared with the corresponding FAS reference values.

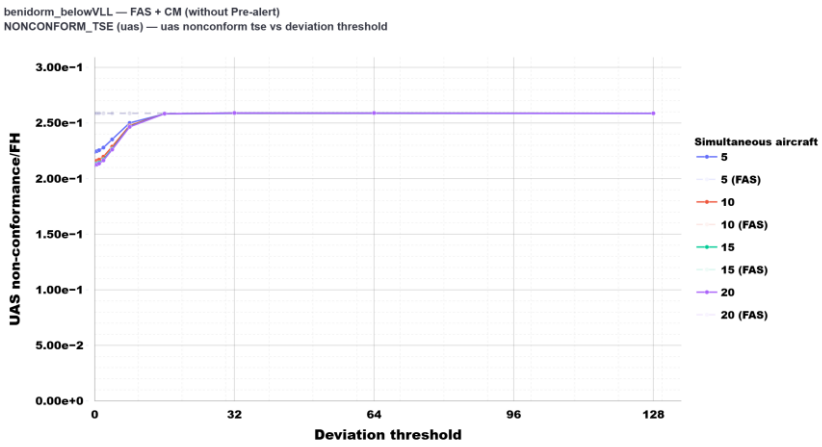
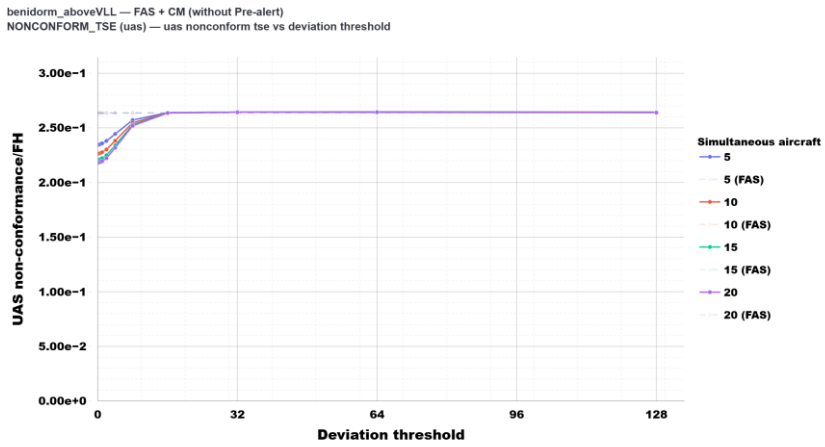
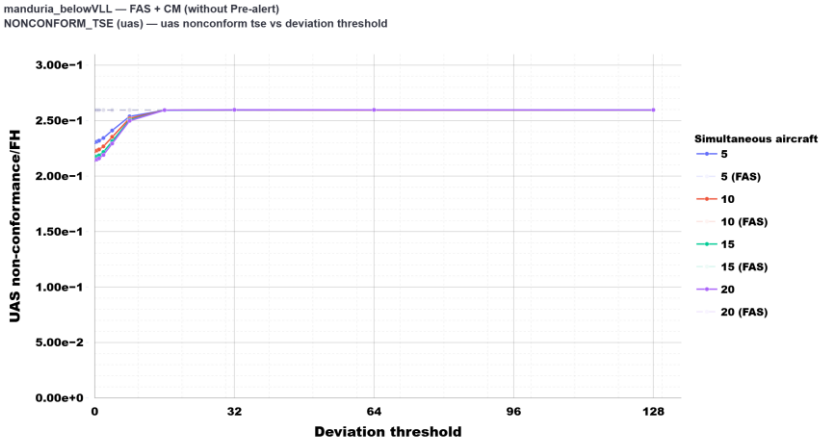
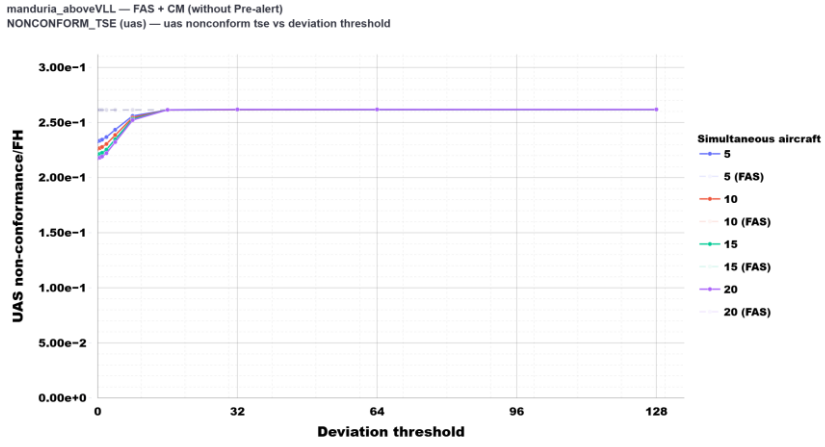
Figure 53: UPV - UAS non-conformance in deviation-boundary limit in CM without pre-alert per UAS flight hour

	Below VLL	Above VLL
Benidorm		
Manduria		

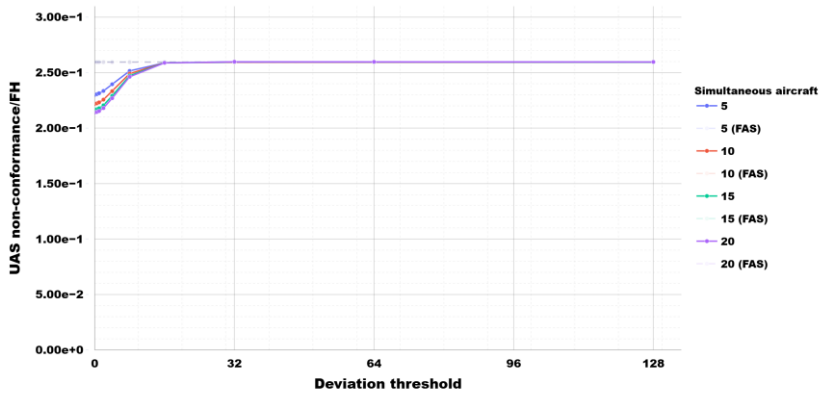
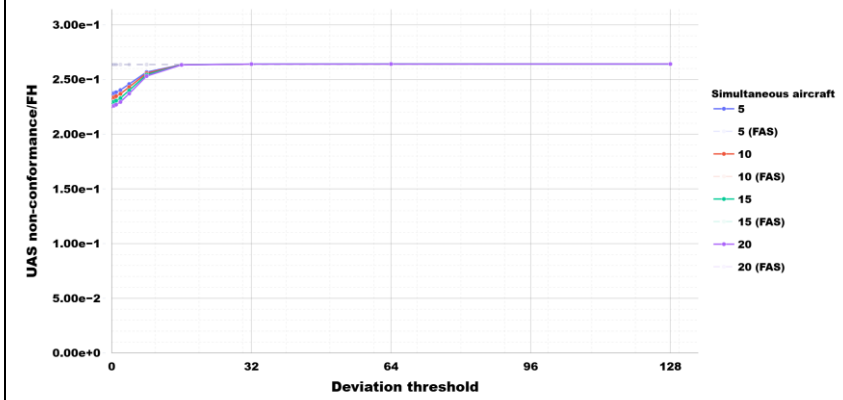
Shannon		

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Figure 54: UPV - UAS non-conformance in the TSE-boundary in CM without pre-alert per UAS flight hour

	Below VLL	Above VLL
Benidorm		
Manduria		

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Shannon		

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The deviation-boundary non-conformance frequency decreases rapidly as the deviation threshold increases, reaching values close to zero at the largest assessed thresholds. This behaviour is primarily explained by the definition of the monitored boundary: a larger deviation threshold places the outer limit farther from the nominal trajectory, making it less likely that a UAS excursion reaches it. Although the FAS+CM and FAS reference curves appear relatively close across most traffic levels, a comparison at the same deviation threshold shows a measurable additional effect from Conformance Monitoring. For example, at a deviation threshold of 4 m, the frequency decreases from approximately from 6E-2 non-conformance/FH under FAS to 5E-2 non-conformance/FH with Conformance Monitoring, corresponding to a relative reduction of approximately 17%. Therefore, while the overall decrease across the assessed thresholds is mainly driven by the outward displacement of the monitored boundary, Conformance Monitoring without pre-alerting provides an additional, although comparatively limited, reduction in deviation-boundary non-conformance. Its main contribution is to initiate recovery once the outer boundary has been crossed, limiting the continuation of the excursion and reducing the likelihood of subsequent non-conformance events.

The TSE non-conformance results characterise the containment performance achieved when Conformance Monitoring operates without pre-alerting. In this configuration, the recovery process is not initiated when the UAS first exceeds the TSE boundary, but only when it reaches the outer monitoring boundary defined by the TSE and the deviation threshold. Consequently, increasing the deviation threshold allows the UAS to travel farther outside the TSE volume before corrective action begins. This delayed intervention may increase the duration of an excursion or the likelihood of additional TSE-boundary exceedances before the aircraft is recovered, explaining the observed dependence of TSE non-conformance on the deviation threshold. Conformance Monitoring without pre-alerting can therefore limit the continuation of the excursion once the outer boundary has been reached, but it cannot prevent the initial loss of TSE containment. This explains why its effect is clearer for deviation-boundary non-conformance than for TSE non-conformance.

The additional reduction observed in UAS–UAS MAC frequency may allow higher traffic levels to satisfy the applicable safety criterion than under FAS alone. The resulting capacity increment is reported for each scenario and altitude environment in the corresponding KPI table, considering the relaxed success criterion associated with TIS.

Scenario	KPA	KPI	Value obtained
Benidorm below VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** The NMAC Risk Ratio remains approximately equal to 1; therefore, NMAC/FH remains approximately equal to the corresponding FAS+TIS result. **UAS-manned per UAS flight hours** No clear additional reduction compared with FAS+TIS. **UAS-manned per manned flight hours** No clear additional reduction compared with FAS+TIS.
		U-AGREE-KPI-02 **Number of non-conformance events/FH**	**Deviation-boundary non-conformance** The frequency decreases rapidly as the deviation threshold increases. Although this trend is mainly caused by the outer monitoring boundary moving farther from the nominal trajectory, Conformance

			Monitoring provides an additional measurable reduction. **TSE non-conformance** The effect is more limited because recovery begins only after the UAS reaches the outer monitoring boundary. Consequently, the initial TSE exceedance is not prevented, and the indicator retains some dependence on the deviation threshold.
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** Conformance Monitoring may increase the capacity derived from the UAS–UAS NMAC criterion when the applicable MAC Risk Ratio is below 1. The increase is configuration-dependent and must be calculated for each traffic level and deviation threshold. **UAS–manned per UAS flight hours** Unchanged from FAS+TIS. **UAS–manned per manned flight hours** Unchanged from FAS+TIS.
		U-AGREE-KPI-04 **Average number of authorised U-plans**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring is applied after authorisation and does not modify the number of U-plans authorised by FAS.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring does not modify the Flight Authorisation process.
Benidorm above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** The NMAC Risk Ratio remains approximately equal to 1; therefore, NMAC/FH remains approximately equal to the corresponding FAS+TIS result. **UAS-manned per UAS flight hours** No clear additional reduction compared with FAS+TIS. **UAS-manned per manned flight hours** No clear additional reduction compared with FAS+TIS.
		U-AGREE-KPI-02 **Number of non-conformance events/FH**	**Deviation-boundary non-conformance** The frequency decreases rapidly as the deviation threshold increases. Although this trend is mainly caused by the outer monitoring boundary moving farther from the nominal trajectory, Conformance Monitoring provides an additional measurable reduction. **TSE non-conformance** The effect is more limited because recovery begins only after the UAS reaches the outer monitoring boundary. Consequently, the initial TSE exceedance is not prevented, and

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			the indicator retains some dependence on the deviation threshold.
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** Conformance Monitoring may increase the capacity derived from the UAS–UAS NMAC criterion when the applicable MAC Risk Ratio is below 1. The increase is configuration-dependent and must be calculated for each traffic level and deviation threshold. **UAS–manned per UAS flight hours** Unchanged from FAS+TIS. **UAS–manned per manned flight hours** Unchanged from FAS+TIS.
		U-AGREE-KPI-04 **Average number of authorised U-plans**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring is applied after authorisation and does not modify the number of U-plans authorised by FAS.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring does not modify the Flight Authorisation process.
Manduria below VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** The NMAC Risk Ratio remains approximately equal to 1; therefore, NMAC/FH remains approximately equal to the corresponding FAS+TIS result. **UAS-manned per UAS flight hours** No clear additional reduction compared with FAS+TIS. **UAS-manned per manned flight hours** No clear additional reduction compared with FAS+TIS.
		U-AGREE-KPI-02 **Number of non-conformance events/FH**	**Deviation-boundary non-conformance** The frequency decreases rapidly as the deviation threshold increases. Although this trend is mainly caused by the outer monitoring boundary moving farther from the nominal trajectory, Conformance Monitoring provides an additional measurable reduction. **TSE non-conformance** The effect is more limited because recovery begins only after the UAS reaches the outer monitoring boundary. Consequently, the initial TSE exceedance is not prevented, and the indicator retains some dependence on the deviation threshold.
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** Conformance Monitoring may increase the capacity derived from the UAS–UAS NMAC criterion when the applicable MAC Risk Ratio is below 1. The increase is configuration-

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			dependent and must be calculated for each traffic level and deviation threshold. **UAS–manned per UAS flight hours** Unchanged from FAS+TIS. **UAS–manned per manned flight hours** Unchanged from FAS+TIS.
		U-AGREE-KPI-04 **Average number of authorised U-plans**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring is applied after authorisation and does not modify the number of U-plans authorised by FAS.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring does not modify the Flight Authorisation process.
Manduria above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** The NMAC Risk Ratio remains approximately equal to 1; therefore, NMAC/FH remains approximately equal to the corresponding FAS+TIS result. **UAS-manned per UAS flight hours** No clear additional reduction compared with FAS+TIS. **UAS-manned per manned flight hours** No clear additional reduction compared with FAS+TIS.
		U-AGREE-KPI-02 **Number of non-conformance events/FH**	**Deviation-boundary non-conformance** The frequency decreases rapidly as the deviation threshold increases. Although this trend is mainly caused by the outer monitoring boundary moving farther from the nominal trajectory, Conformance Monitoring provides an additional measurable reduction. **TSE non-conformance** The effect is more limited because recovery begins only after the UAS reaches the outer monitoring boundary. Consequently, the initial TSE exceedance is not prevented, and the indicator retains some dependence on the deviation threshold.
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** Conformance Monitoring may increase the capacity derived from the UAS–UAS NMAC criterion when the applicable MAC Risk Ratio is below 1. The increase is configuration-dependent and must be calculated for each traffic level and deviation threshold. **UAS–manned per UAS flight hours** Unchanged from FAS+TIS. **UAS–manned per manned flight hours** Unchanged from FAS+TIS.

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		U-AGREE-KPI-04 **Average number of authorised U-plans**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring is applied after authorisation and does not modify the number of U-plans authorised by FAS.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring does not modify the Flight Authorisation process.
Shannon below VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** The NMAC Risk Ratio remains generally close to 1. At the highest deviation thresholds, the ratio may be undefined when both reference and mitigated frequencies are zero. **UAS-manned per UAS flight hours** No clear additional reduction compared with FAS+TIS. **UAS-manned per manned flight hours** No clear additional reduction compared with FAS+TIS.
		U-AGREE-KPI-02 **Number of non-conformance events/FH**	**Deviation-boundary non-conformance** The frequency decreases rapidly as the deviation threshold increases. Although this trend is mainly caused by the outer monitoring boundary moving farther from the nominal trajectory, Conformance Monitoring provides an additional measurable reduction. **TSE non-conformance** The effect is more limited because recovery begins only after the UAS reaches the outer monitoring boundary. Consequently, the initial TSE exceedance is not prevented, and the indicator retains some dependence on the deviation threshold.
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** Conformance Monitoring may increase the capacity derived from the UAS–UAS NMAC criterion when the applicable MAC Risk Ratio is below 1. The increase is configuration-dependent and must be calculated for each traffic level and deviation threshold. **UAS–manned per UAS flight hours** Unchanged from FAS+TIS. **UAS–manned per manned flight hours** Unchanged from FAS+TIS.
		U-AGREE-KPI-04 **Average number of authorised U-plans**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring is applied after authorisation and does not modify the number of U-plans authorised by FAS.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring does not modify the Flight Authorisation process.

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Shannon above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** The NMAC Risk Ratio remains approximately equal to 1; therefore, NMAC/FH remains approximately equal to the corresponding FAS+TIS result. **UAS-manned per UAS flight hours** No clear additional reduction compared with FAS+TIS. **UAS-manned per manned flight hours** No clear additional reduction compared with FAS+TIS.
		U-AGREE-KPI-02 **Number of non-conformance events/FH**	**Deviation-boundary non-conformance** The frequency decreases rapidly as the deviation threshold increases. Although this trend is mainly caused by the outer monitoring boundary moving farther from the nominal trajectory, Conformance Monitoring provides an additional measurable reduction. **TSE non-conformance** The effect is more limited because recovery begins only after the UAS reaches the outer monitoring boundary. Consequently, the initial TSE exceedance is not prevented, and the indicator retains some dependence on the deviation threshold.
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** Conformance Monitoring may increase the capacity derived from the UAS–UAS NMAC criterion when the applicable MAC Risk Ratio is below 1. The increase is configuration-dependent and must be calculated for each traffic level and deviation threshold. **UAS–manned per UAS flight hours** Unchanged from FAS+TIS. **UAS–manned per manned flight hours** Unchanged from FAS+TIS.
		U-AGREE-KPI-04 **Average number of authorised U-plans**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring is applied after authorisation and does not modify the number of U-plans authorised by FAS.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring does not modify the Flight Authorisation process.

Table 41: UPV - KPIs for OBJ-SOL0520-ERP-003 (FAS+TIS+CMS without pre-alert)

A.4.2.4. OBJ-SOL0520-ERP-004 Results

This objective evaluates Conformance Monitoring with pre-alerting. The relevant assumption is that earlier detection changes the timing of recovery. Instead of waiting until the aircraft has moved farther outside the intended corridor, the monitoring logic can trigger a response closer to the TSE boundary.

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This reduces the expected time spent outside the TSE corridor and helps preserve the deconfliction margins assumed by Flight Authorisation.

Pre-alerting should therefore be interpreted primarily as a containment-improvement mechanism. If an aircraft is detected earlier, the recovery chain has more time to act before the aircraft reaches the outer protection-buffer region. This can be especially relevant for MAC at small protection-buffer values, where the residual margin between the deconflicted corridor and the MAC volume is limited. Earlier monitoring is expected to reduce the probability that a TSE excursion develops into a MAC-scale loss of separation.

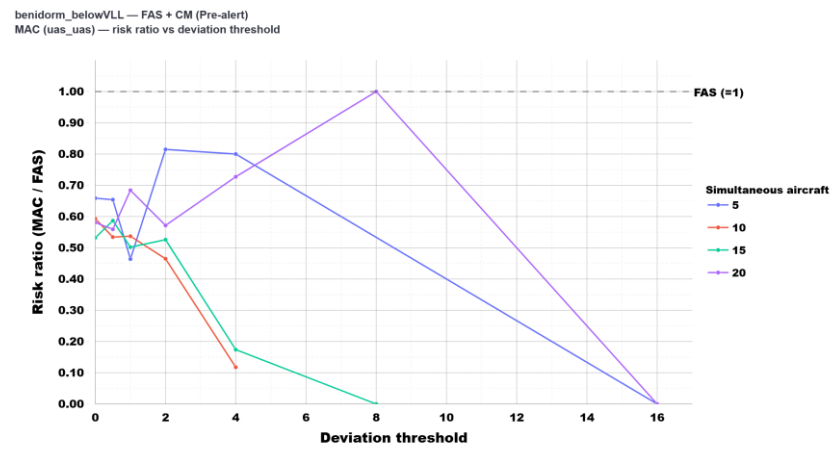
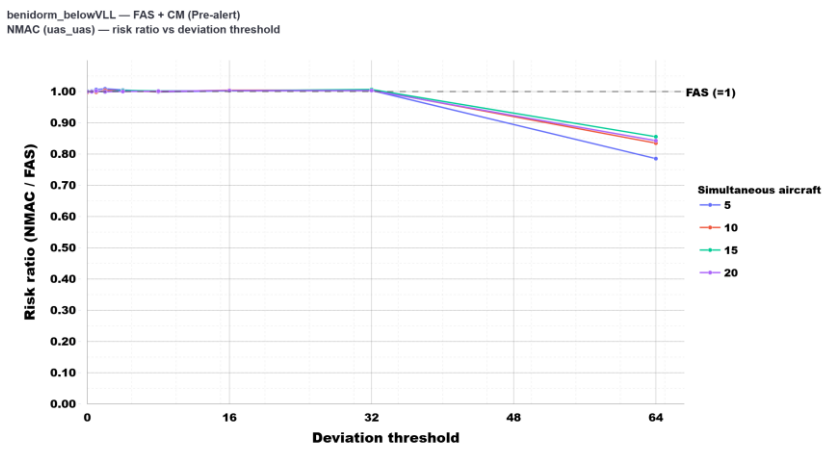
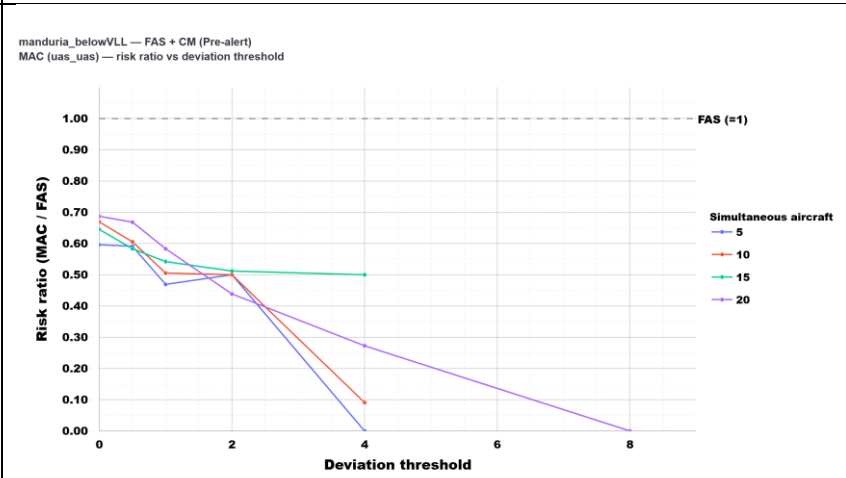
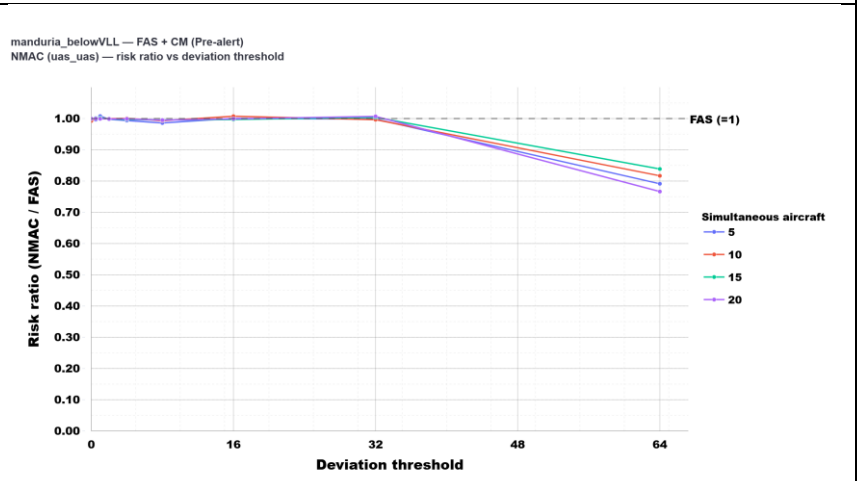
The effect on NMAC may still be less direct. NMAC is governed by larger distance thresholds, and a pre-alert response at the TSE boundary does not by itself make the authorised trajectories separated by NMAC-scale distances. NMAC reduction should therefore be interpreted together with the protection-buffer value. At small buffers, pre-alerting may improve containment and MAC behaviour while leaving NMAC less affected. At larger buffers, where strategic deconfliction is closer to the NMAC scale, the same improvement in containment is more likely to support NMAC reduction.

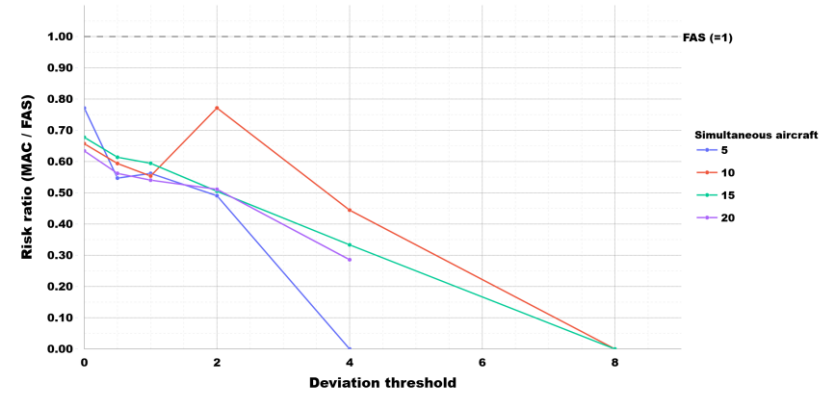
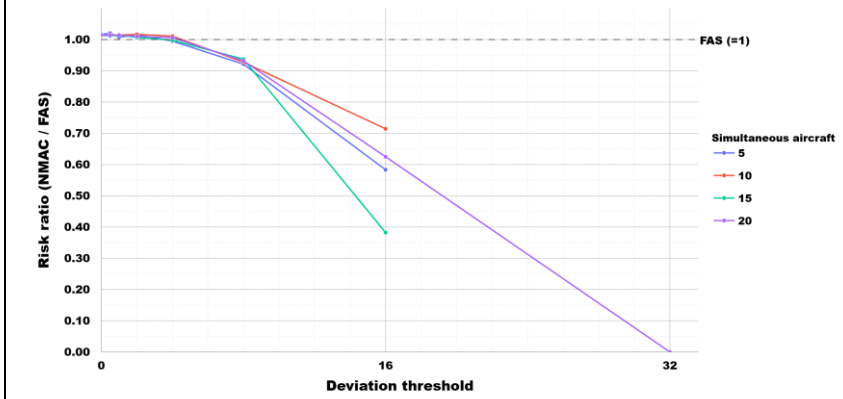
Any zero observed MAC frequency under this objective should be reported as a finite-exposure observation. It means that no MAC event was observed for the simulated traffic level, scenario and exposure. It does not prove that the true MAC frequency is zero. Demonstrating extremely small frequencies would require a much larger simulated exposure than is normally practical in this validation exercise.

The additional effect of Conformance Monitoring with pre-alerting is assessed by comparing the MAC and NMAC frequencies obtained with FAS+CM against the corresponding FAS frequencies. TIS is subsequently considered through the scenario-specific Risk Ratio used to derive the relaxed maximum allowable frequency. The resulting Conformance Monitoring Risk Ratio therefore represents the fraction of the FAS collision frequency that remains after introducing monitoring with pre-alerting. Values below one indicate an additional improvement with respect to FAS, while values close to one indicate that the resulting frequency remains similar to the reference configuration.

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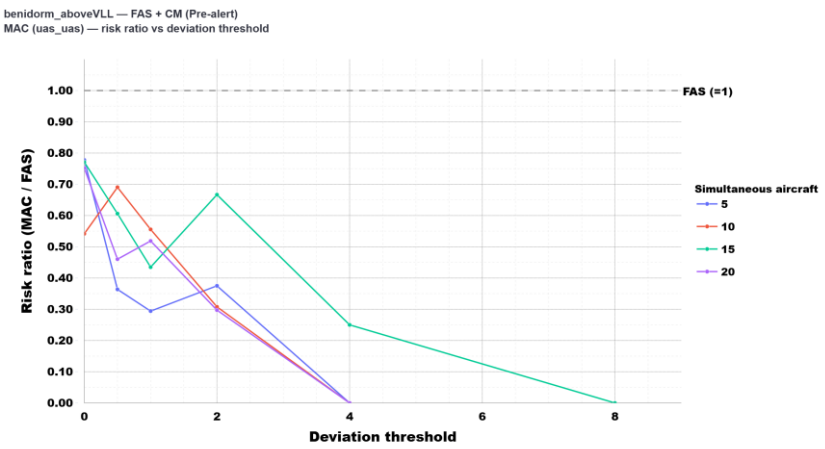
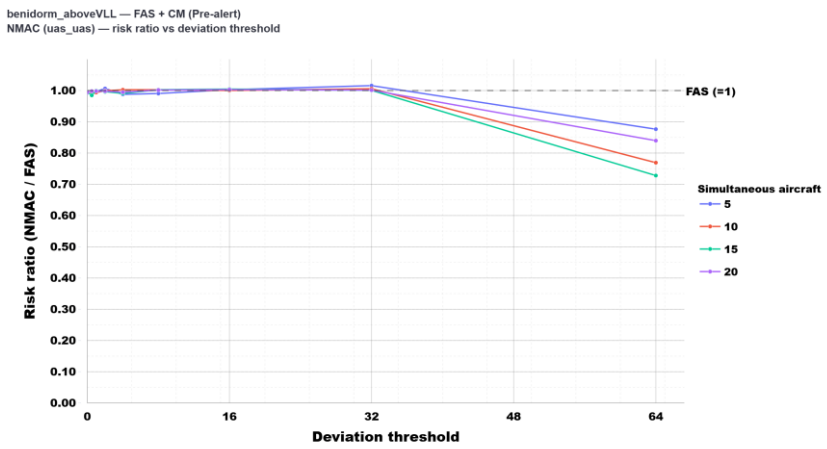
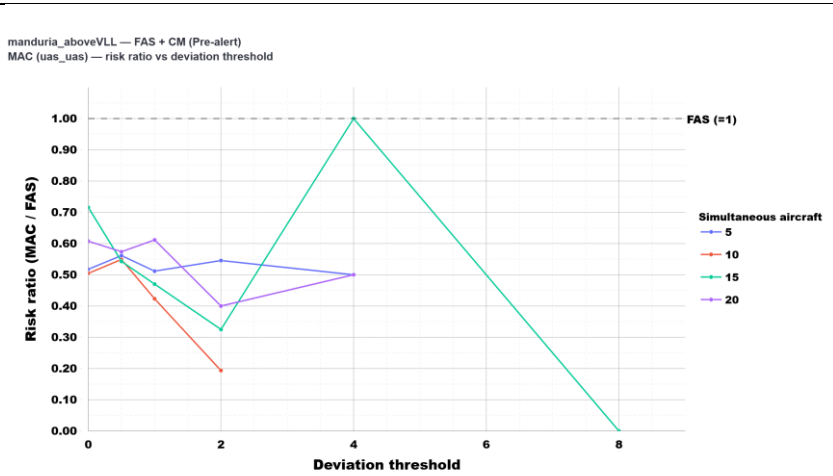
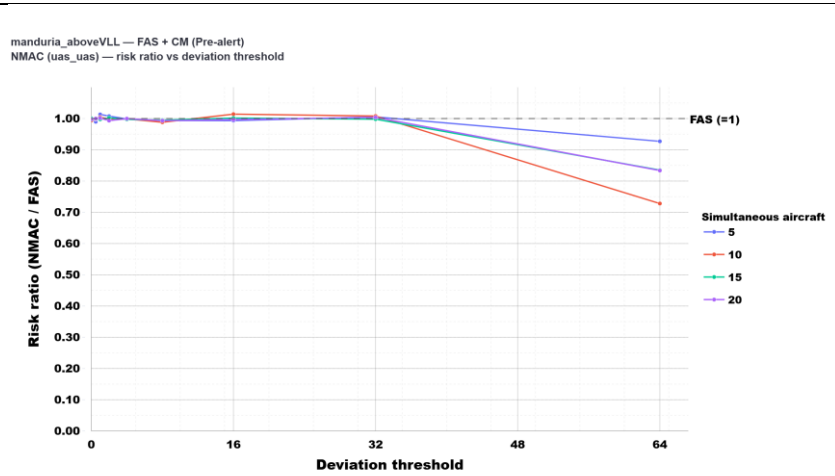
Figure 55: UPV - Risk Ratio Conformance Monitoring with pre-alert UAS-UAS below VLL

	MAC	NMAC
Benidorm below VLL		
Manduria below VLL		

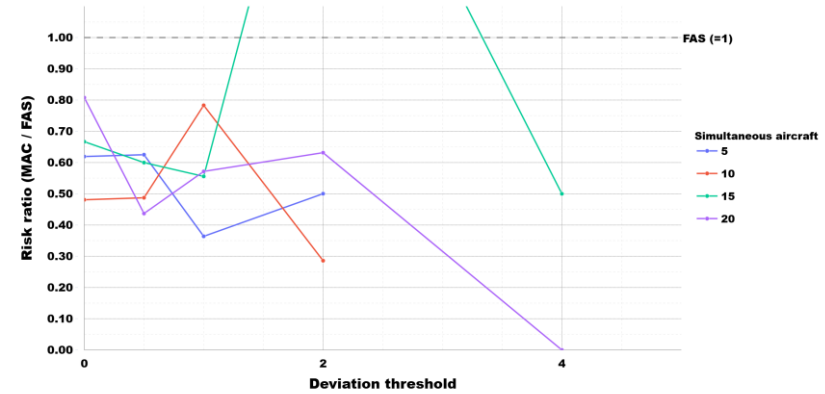
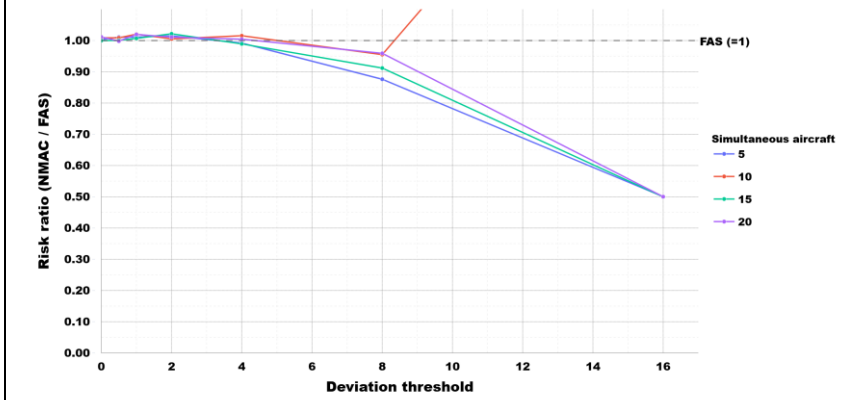
Shannon below VLL		

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Figure 56: UPV - Risk Ratio Conformance Monitoring with pre-alert UAS-UAS above VLL

	MAC	NMAC
Benidorm above VLL		
Manduria above VLL		

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Shannon above VLL		

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As observed for Conformance Monitoring without pre-alerting, the MAC results generally show an additional safety benefit, with Risk Ratios below one for most of the assessed configurations. With pre-alerting, the recovery process is initiated closer to the TSE boundary, reducing the distance travelled by the UAS before corrective action begins and helping to preserve the separation established during Flight Authorisation. However, the results continue to exhibit noticeable dispersion across traffic levels, deviation thresholds and operational scenarios, and the reduction is not always monotonic. This variability is partly associated with the low frequency of MAC events: when the FAS reference frequency is small, limited differences in the number of observed events can produce comparatively large variations in the resulting Risk Ratio. Despite this dispersion, the overall results indicate that earlier recovery reduces the likelihood that a trajectory deviation progresses into a MAC.

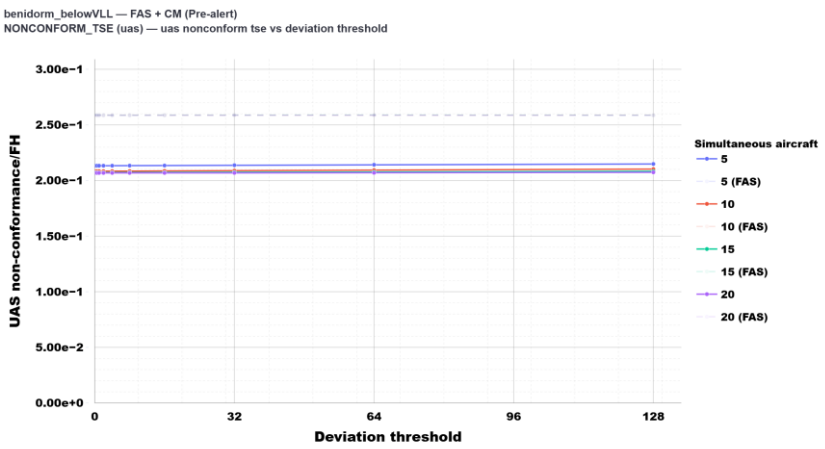
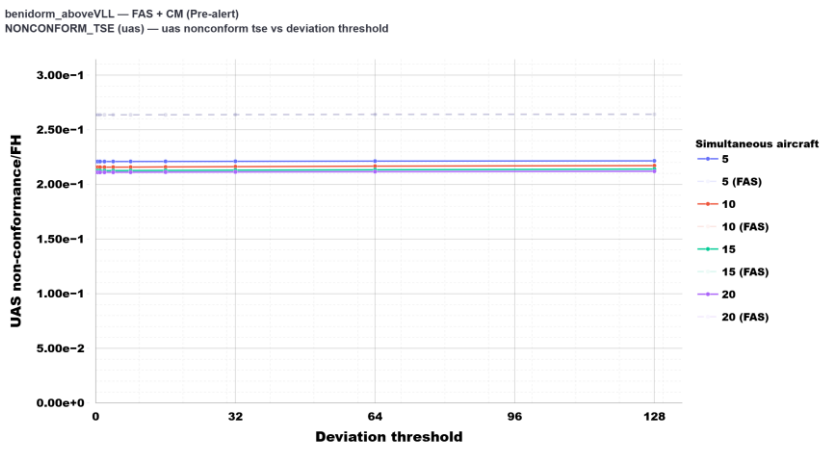
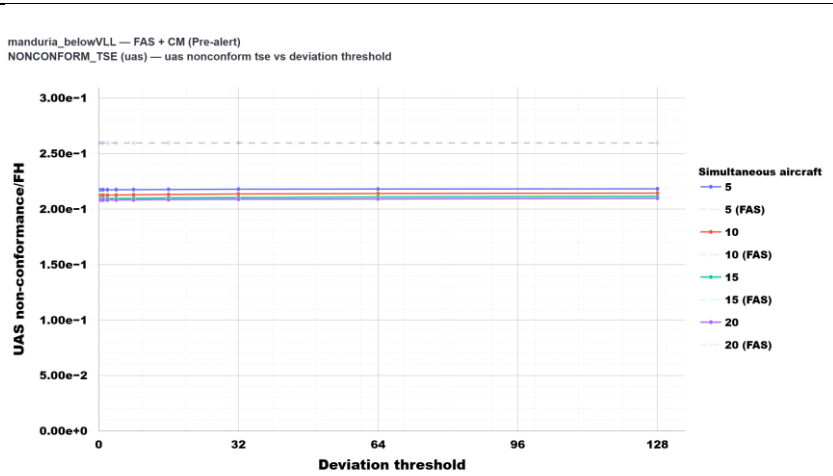
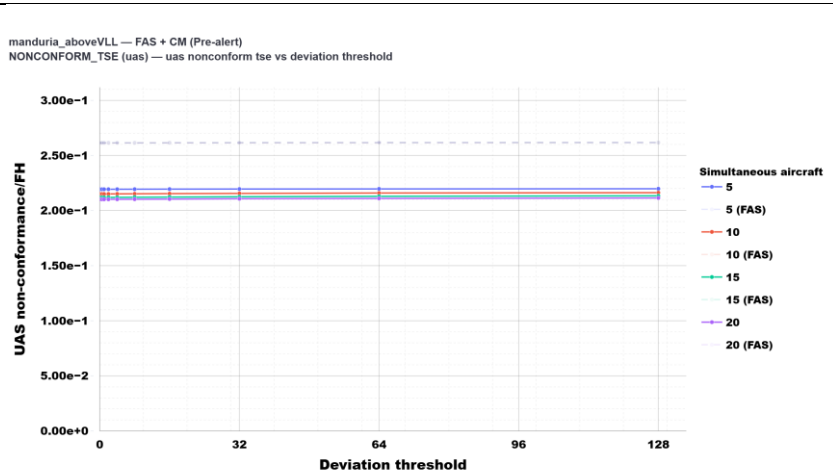
The NMAC Risk Ratio remains close to one in several configurations, particularly at low deviation thresholds, showing that earlier recovery does not always produce a clear reduction in the number of encounters entering the larger NMAC volume. Nevertheless, RR values below one are observed for larger deviation thresholds. At these values, the wider strategic separation provided by FAS, together with the earlier recovery initiated by pre-alerting, can help prevent some deviations from progressing into the NMAC volume. The effect remains less consistent than for MAC because NMAC is defined by a substantially larger separation volume.

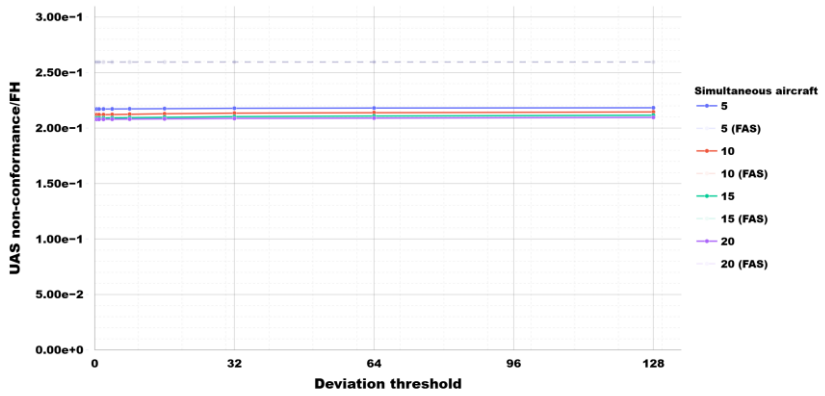
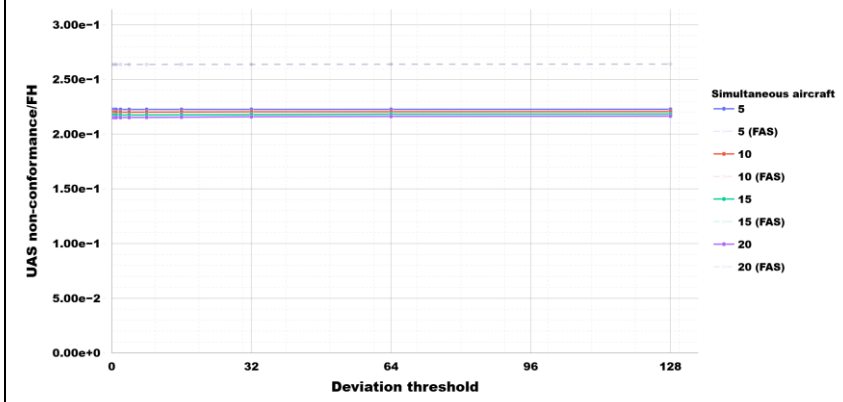
At sufficiently large deviation thresholds, the reference and mitigated frequencies may both become zero within the simulated exposure. In these cases, the Risk Ratio cannot be calculated because the resulting expression is $0/0$, and the corresponding points are therefore omitted from the plots. Their absence indicates that no events of the corresponding type were observed in either configuration for that deviation threshold and simulated exposure, rather than a deterioration in performance or missing simulation results.

As observed for Conformance Monitoring without pre-alerting, the effect on UAS–manned encounters remains limited, with RR values generally close to one across the assessed scenarios. The introduction of pre-alerting does not substantially change this behaviour, since Conformance Monitoring acts on UAS deviations but does not directly mitigate encounters with manned aircraft. Any variations should therefore be interpreted as limited indirect effects of returning deviating UAS towards their authorised trajectories at an earlier stage. Consequently, the clearest additional safety benefit of pre-alerting continues to be observed in the UAS–UAS results.

In addition to the collision-frequency results, TSE non-conformance events per UAS flight hour are analysed to characterise the containment performance achieved with pre-alerting. In this configuration, recovery is initiated when the UAS reaches the monitored TSE boundary, rather than after it reaches the outer boundary defined by the TSE and the deviation threshold. The results are presented as a function of the deviation threshold and the number of simultaneous aircraft, together with the corresponding FAS reference values. This indicator complements the Risk Ratio analysis by showing how the earlier recovery strategy affects the frequency of TSE-boundary exceedances.

Figure 57: UPV - UAS non-conformance in CM with pre-alert per UAS flight hour

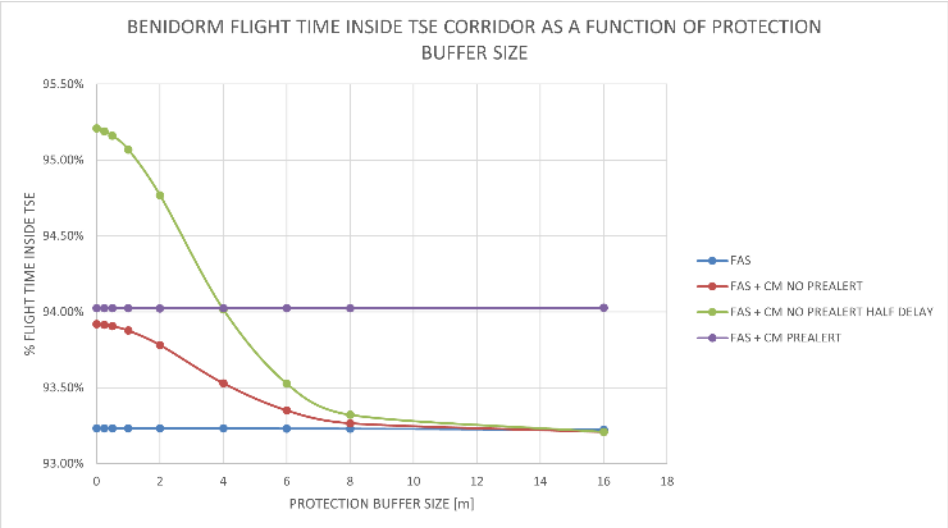
	Below VLL	Above VLL
Benidorm		
Manduria		

Shannon		

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The TSE non-conformance results show the effect of initiating recovery at the TSE boundary. Compared with the corresponding FAS reference, Conformance Monitoring with pre-alerting generally reduces the frequency of TSE non-conformance by returning the affected UAS towards its authorised trajectory at an earlier stage. Unlike the configuration without pre-alerting, the recovery process does not wait until the UAS reaches the outer monitoring boundary. The magnitude of the reduction varies across traffic levels and operational scenarios, but the overall results indicate improved containment of UAS deviations. Since the monitored TSE boundary itself does not depend on the deviation threshold, any remaining variation with this parameter should be attributed to indirect changes in the authorised traffic population and simulation exposure, rather than to a change in the TSE limit.

Compared with Conformance Monitoring without pre-alerting, the main advantage of pre-alerting is that recovery is initiated at the TSE boundary, before the UAS reaches the outer monitoring boundary. This earlier intervention improves containment and reduces the opportunity for a trajectory deviation to consume the separation margin established during Flight Authorisation. The FAS-only baseline, without Conformance Monitoring, remains nearly constant at approximately 93.2%, independently of the protection buffer size. When CM with pre-alert is enabled, the containment increases to around 94.0% and remains essentially unaffected by the protection buffer. This is because the recovery manoeuvre is triggered when the aircraft reaches the TSE boundary, making the intervention independent of the external protection buffer. In contrast, when the alert is generated only upon reaching the protection buffer boundary (CM without pre-alert), the recovery action is initiated later in space. As the protection buffer increases, the aircraft consumes a larger portion of the available margin before corrective action begins, progressively reducing the time spent inside the TSE corridor. Consequently, the containment performance gradually converges towards the FAS-only baseline for large protection buffers (approximately 16 m). Reducing the response latency (half-delay configuration) follows the same overall trend but consistently achieves higher containment, as the earlier recovery manoeuvre limits the aircraft excursion outside the TSE corridor.



The clearest benefit is observed in the UAS–UAS MAC results and in the reduction of TSE non-conformance, whereas the additional effect on NMAC and UAS–manned encounters remains limited. Nevertheless, the magnitude of the improvement varies across scenarios, traffic levels and deviation thresholds, and should therefore be evaluated using the combined collision and containment indicators.

The earlier recovery provided by pre-alerting may allow higher UAS traffic levels to satisfy the applicable MAC safety criterion than under FAS alone or Conformance Monitoring without pre-

alerting. The resulting capacity increment is reported for each scenario and altitude environment in the corresponding KPI table, considering the relaxed success criterion associated with TIS.

The results obtained for the KPIs associated with this validation objective are summarised in the following table. The values are presented separately for each scenario and altitude configuration, covering the corresponding KPAs. Together, these indicators provide a consolidated view of the additional safety benefit provided by Conformance Monitoring with pre-alerting, its effect on UAS non-conformance, and the resulting capacity under the FAS+CM with pre-alerting + TIS configuration.

Scenario	KPA	KPI	Value obtained
Benidorm below VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** The NMAC Risk Ratio remains close to 1 for most configurations; limited reductions are observed at larger deviation thresholds. The absolute NMAC/FH is obtained by applying the corresponding RR to the FAS result. **UAS-manned per UAS flight hours** No clear additional reduction compared with FAS+TIS. **UAS-manned per manned flight hours** No clear additional reduction compared with FAS+TIS.
		U-AGREE-KPI-02 **Number of non-conformance events/FH**	**TSE non-conformance** The frequency of non-conformance is reduced through earlier recovery at the TSE boundary and remains broadly independent of the deviation threshold. Earlier recovery reduces TSE non-conformance relative to FAS and CM without pre-alerting.
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** Pre-alerting may increase the capacity derived from the UAS–UAS MAC criterion when the applicable NMAC Risk Ratio is below 1. The increase is configuration-dependent and must be calculated for each traffic level and deviation threshold. **UAS–manned per UAS flight hours** Unchanged from FAS+TIS. **UAS–manned per manned flight hours** Unchanged from FAS+TIS.
		U-AGREE-KPI-04 **Average number of authorised U-plans**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring is applied after authorisation and does not modify the number of U-plans authorised by FAS.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring does not modify the Flight Authorisation process.
Benidorm above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** The NMAC Risk Ratio remains close to 1 for most configurations; limited reductions are observed at larger deviation thresholds. The

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			absolute NMAC/FH is obtained by applying the corresponding RR to the FAS result. **UAS-manned per UAS flight hours** No clear additional reduction compared with FAS+TIS. **UAS-manned per manned flight hours** No clear additional reduction compared with FAS+TIS.
		U-AGREE-KPI-02 **Number of non-conformance events/FH**	**TSE non-conformance** The frequency of non-conformance is reduced through earlier recovery at the TSE boundary and remains broadly independent of the deviation threshold. Earlier recovery reduces TSE non-conformance relative to FAS and CM without pre-alerting.
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** Pre-alerting may increase the capacity derived from the UAS–UAS MAC criterion when the applicable NMAC Risk Ratio is below 1. The increase is configuration-dependent and must be calculated for each traffic level and deviation threshold. **UAS–manned per UAS flight hours** Unchanged from FAS+TIS. **UAS–manned per manned flight hours** Unchanged from FAS+TIS.
		U-AGREE-KPI-04 **Average number of authorised U-plans**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring is applied after authorisation and does not modify the number of U-plans authorised by FAS.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring does not modify the Flight Authorisation process.
Manduria below VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** The NMAC Risk Ratio remains close to 1 for most configurations; limited reductions are observed at larger deviation thresholds. The absolute NMAC/FH is obtained by applying the corresponding RR to the FAS result. **UAS-manned per UAS flight hours** No clear additional reduction compared with FAS+TIS. **UAS-manned per manned flight hours** No clear additional reduction compared with FAS+TIS.
		U-AGREE-KPI-02 **Number of non-conformance events/FH**	**TSE non-conformance** The frequency of non-conformance is reduced through earlier recovery at the TSE boundary and remains broadly independent of the deviation threshold. Earlier recovery reduces TSE non-conformance relative to FAS and CM without pre-alerting.

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	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** Pre-alerting may increase the capacity derived from the UAS–UAS MAC criterion when the applicable NMAC Risk Ratio is below 1. The increase is configuration-dependent and must be calculated for each traffic level and deviation threshold. **UAS–manned per UAS flight hours** Unchanged from FAS+TIS. **UAS–manned per manned flight hours** Unchanged from FAS+TIS.
		U-AGREE-KPI-04 **Average number of authorised U-plans**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring is applied after authorisation and does not modify the number of U-plans authorised by FAS.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring does not modify the Flight Authorisation process.
Manduria above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** The NMAC Risk Ratio remains close to 1 for most configurations; limited reductions are observed at larger deviation thresholds. The absolute NMAC/FH is obtained by applying the corresponding RR to the FAS result. **UAS-manned per UAS flight hours** No clear additional reduction compared with FAS+TIS. **UAS-manned per manned flight hours** No clear additional reduction compared with FAS+TIS.
		U-AGREE-KPI-02 **Number of non-conformance events/FH**	**TSE non-conformance** The frequency of non-conformance is reduced through earlier recovery at the TSE boundary and remains broadly independent of the deviation threshold. Earlier recovery reduces TSE non-conformance relative to FAS and CM without pre-alerting.
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** Pre-alerting may increase the capacity derived from the UAS–UAS MAC criterion when the applicable NMAC Risk Ratio is below 1. The increase is configuration-dependent and must be calculated for each traffic level and deviation threshold. **UAS–manned per UAS flight hours** Unchanged from FAS+TIS. **UAS–manned per manned flight hours** Unchanged from FAS+TIS.
		U-AGREE-KPI-04	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring is applied after

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		Average number of authorised U-plans	authorisation and does not modify the number of U-plans authorised by FAS.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring does not modify the Flight Authorisation process.
Shannon below VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** The NMAC Risk Ratio remains close to 1 for most configurations; limited reductions are observed at larger deviation thresholds. The absolute NMAC/FH is obtained by applying the corresponding RR to the FAS result. **UAS-manned per UAS flight hours** No clear additional reduction compared with FAS+TIS. **UAS-manned per manned flight hours** No clear additional reduction compared with FAS+TIS.
		U-AGREE-KPI-02 **Number of non-conformance events/FH**	**TSE non-conformance** The frequency of non-conformance is reduced through earlier recovery at the TSE boundary and remains broadly independent of the deviation threshold. Earlier recovery reduces TSE non-conformance relative to FAS and CM without pre-alerting.
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** Pre-alerting may increase the capacity derived from the UAS–UAS MAC criterion when the applicable NMAC Risk Ratio is below 1. The increase is configuration-dependent and must be calculated for each traffic level and deviation threshold. **UAS–manned per UAS flight hours** Unchanged from FAS+TIS. **UAS–manned per manned flight hours** Unchanged from FAS+TIS.
		U-AGREE-KPI-04 **Average number of authorised U-plans**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring is applied after authorisation and does not modify the number of U-plans authorised by FAS.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring does not modify the Flight Authorisation process.
Shannon above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS-UAS** The NMAC Risk Ratio remains close to 1 for most configurations; limited reductions are observed at larger deviation thresholds. The

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			absolute NMAC/FH is obtained by applying the corresponding RR to the FAS result. **UAS-manned per UAS flight hours** No clear additional reduction compared with FAS+TIS. **UAS-manned per manned flight hours** No clear additional reduction compared with FAS+TIS.
		U-AGREE-KPI-02 **Number of non-conformance events/FH**	**TSE non-conformance** The frequency of non-conformance is reduced through earlier recovery at the TSE boundary and remains broadly independent of the deviation threshold. Earlier recovery reduces TSE non-conformance relative to FAS and CM without pre-alerting.
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** Pre-alerting may increase the capacity derived from the UAS–UAS MAC criterion when the applicable NMAC Risk Ratio is below 1. The increase is configuration-dependent and must be calculated for each traffic level and deviation threshold. **UAS–manned per UAS flight hours** Unchanged from FAS+TIS. **UAS–manned per manned flight hours** Unchanged from FAS+TIS.
		U-AGREE-KPI-04 **Average number of authorised U-plans**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring is applied after authorisation and does not modify the number of U-plans authorised by FAS.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Same as reported for OBJ-SOL0520-ERP-002. Conformance Monitoring does not modify the Flight Authorisation process.

Table 42: UPV - KPIs for OBJ-SOL0520-ERP-004 (FAS+TIS+CMS with pre-alert)

A.4.3 Unexpected behaviours/results

No problem reports are documented for the preparation, execution or analysis of validation exercise #01. Accordingly, no associated corrective action or impact on dependent validation activities is identified.

Some results nevertheless require careful interpretation. The UAS-UAS MAC risk ratios (RRs) for Conformance Monitoring are dispersed and not consistently monotonic across traffic levels, deviation thresholds and scenarios. This behaviour is consistent with the small number of observed MAC events, for which minor changes in event counts can produce comparatively large changes in the RR. Where the reference and mitigated frequencies are both zero within the simulated exposure, the RR is undefined and the corresponding result is omitted. Rare-cell Monte Carlo variability can also produce local diagnostic RRs close to or slightly above one under degraded conditions or extreme pilot-profile assumptions. These effects are treated as statistical limitations rather than unexpected operational behaviours.

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A.4.4 Confidence in results of validation exercise #01

Confidence in the results is supported by the fast-time Monte Carlo approach, normalisation by accumulated flight-hour exposure, paired comparison of mitigated and unmitigated encounters, scenario-specific traffic weighting and separate treatment of UAS-UAS and UAS-manned encounters. The assessment covers Benidorm, Manduria and Shannon-Limerick in both below-VLL and above-VLL configurations and includes sensitivity analyses for the principal TIS modelling parameters. Within these assumptions, the results provide a sound basis for comparing the simulated baseline and mitigation configurations. Confidence is lower for absolute estimates of very rare events and for conclusions that depend on incomplete result fields.

A.4.4.1. Level of significance/limitations of validation exercise results

The validation results are representative of the modelled Benidorm, Manduria and Shannon-Limerick traffic mixes, the below-VLL and above-VLL configurations, and the sustained concurrent-traffic conditions implemented in the UPV fast-time simulation. Realistic trajectories, a stochastic Total System Error (TSE) model, segment-based conflict detection and consistent flight-hour normalisation support comparison across the assessed traffic levels and mitigation configurations. The paired encounter design also enables like-for-like comparison of TIS mitigated and unmitigated cases using the same sampled geometry and traffic-class combination.

Extrapolation beyond these conditions requires caution. The TIS encounter model is conditional and conflict-rich and uses synthetic traffic, pairwise encounters and predominantly planar, rectilinear and level reference trajectories. It does not estimate the operational frequency of encounters and does not represent multi-aircraft coordination, network demand, strategic deconfliction, pilot workload, alert comprehension, learning, weather, terrain or cooperative avoidance by manned aircraft. The Uniform (1/3) pilot profile is a modelling assumption rather than a measured workforce distribution. The factor of two applied to the aggregated TIS RRs provides a conservative transfer margin for these idealisations but does not constitute a statistical confidence bound.

Rare-event estimation is further limited by finite simulated exposure. A zero observed MAC frequency means that no MAC was recorded during that exposure; it does not establish a zero-underlying frequency. The retained outputs do not include the trial histories, random-number streams, confidence intervals for every aggregate or a common convergence assessment for all parameter cases.

A.4.4.2. Quality of validation exercises results

The main quality strengths are the controlled and reproducible comparison framework, the separation of encounter families, and the traceable aggregation of traffic and pilot-profile weights before calculation of the RRs. The TIS campaign comprises 1,296 parameter cases and 90,720 checked post-processed rows, with no missing values for RR, loss ratio (LR), probability of false alert (Pfa) or alert probability. The reporting baseline is clearly separated from the sensitivity cases, and the conservative factor of two is applied once, after aggregation. The consistency between the raw and reported Benidorm below-VLL RRs provides an additional traceability check.

Absolute rare-event estimates are less robust than the relative comparisons. MAC frequencies are sensitive to finite exposure, and sparse event counts can produce dispersed or non-monotonic RRs. Without confidence intervals or a common convergence assessment, statistical precision cannot be quantified for every aggregate. Zero-event cases and undefined 0/0 RRs are handled consistently, but do not demonstrate that the underlying risk is zero.

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A.4.4.3. Significance of validation exercises results

The exercise provides statistically meaningful comparative evidence for the behaviour of the assessed barriers within the executed simulation campaigns. For TIS, the complete parameter sweep, paired branch construction, scenario weighting and sensitivity analyses show that the selected baseline is an executed configuration and allow the influence of horizontal separation, operational perturbations, CNS conditions and pilot profiles to be examined. The results show residual reported Risk Ratios below one for all six scenario and altitude combinations in Table 4, while Conformance Monitoring results generally show an additional UAS-UAS MAC benefit, with a less consistent effect on NMAC.

The statistical significance of very small MAC frequencies remains constrained by finite exposure and the absence of aggregate confidence intervals. Accordingly, zero observed frequencies, local non-monotonic behaviour and omitted 0/0 ratios shall not be interpreted as proof of zero risk or as precise estimates of extremely low underlying frequencies. The report does not provide the number of simulation runs or accumulated exposure for every plotted case, so a more specific statistical-significance statement cannot be concluded from the available information.

From an operational perspective, the results are significant for comparing the unmitigated baseline with FAS, TIS and Conformance Monitoring under the three modelled scenario traffic mixes. They demonstrate the safety and access trade-off associated with the deviation threshold, the lower conflict frequencies generally observed above VLL, the direct effect of FAS on UAS-UAS encounters, and the containment benefit of Conformance Monitoring, particularly for UAS-UAS MAC. Operational significance remains bounded by the model limitations described above. Consequently, the report supports conclusions on relative barrier behaviour within the simulated environments, but it does not support an unqualified Europe-wide extrapolation or a complete conclusion on the final capacity increments.

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A.5 Validation exercise #01 results - CRA

A.5.1 Summary of validation exercise #01 results

This sub-section summarises the results of validation exercise #01 from the CRA simulator. It presents the summary of results compared to the success criteria identified within the ERP per validation objective. The analysis covers the validation objectives embedded in the validation exercise as per the corresponding ERP.

Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
OBJ-SOL0520-ERP-001	Identification of the baseline capacity (N_0).	CRT-SOL0520-TRL2-ERP-001.001	The MAC frequency between UAS shall not exceed 4.35×10^{-5} per flight-hour in Scenario 1.	Scenario 1: The city of Benidorm (non U-space sub-OE)	The baseline capacities for Scenarios 1, 2, and 3 are 1.001, 1.00, 1.002 UAS in average. Even two simultaneous UAS exceed the maximum allowable NMAC per hour. These results highlight the need for at least one U-space service in all scenarios.	Partially OK
		CRT-SOL0520-TRL2-ERP-001.002	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 1.			
		CRT-SOL0520-TRL2-ERP-001.003	The MAC frequency between UAS shall not exceed $1{,}5 \times 10^{-4}$ per flight-hour in Scenario 2.	Scenario 2: The city of Manduria (non U-space sub-OE)		

Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
		CRT-SOL0520-TRL2-ERP-001.004	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 2.			
		CRT-SOL0520-TRL2-ERP-001.005	The MAC frequency between UAS shall not exceed $1{,}7 \times 10^{-2}$ per flight hour in Scenario 3.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)		
		CRT-SOL0520-TRL2-ERP-001.006	The MAC frequency between UAS and manned aircraft in uncontrolled airspace shall not exceed 10^{-7} per flight-hour in Scenario 3.			
		CRT-SOL0520-TRL2-ERP-001.007	The MAC frequency between UAS and manned aircraft in controlled airspace shall not exceed 10^{-9} per flight-hour in Scenario 3, for exercise #01 and #02.			

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
OBJ-SOL0520-ERP-002	Quantification of capacity increment (ΔN_1) because of the introduction of mitigation measures based on Flight Authorisation and Traffic Information services.	CRT-SOL0520-TRL2-ERP-002.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 1: The city of Benidorm (non U-space sub-OE)	The capacities for Scenarios 1, 2, and 3 increase to 1.19, 1.58, 45.24 UAS in average. While traffic information service ensures safe operations in Shannon, Benidorm and Manduria require further U-Space services to ensure target level of safety.	Partially OK
		CRT-SOL0520-TRL2-ERP-002.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 2: The city of Manduria (non U-space sub-OE)		
		CRT-SOL0520-TRL2-ERP-002.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)		

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
OBJ-SOL0520-ERP-003	Quantification of capacity increment (ΔN_2) because of the introduction of mitigation measures based on Flight Authorisation, Traffic Information, and Conformance Monitoring (without pre-alerting) services.	CRT-SOL0520-TRL2-ERP-003.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 1: The city of Benidorm (non U-space sub-OE)	The capacities for Scenarios 1, 2, and 3 increase to 1.21, 1.62, 41.22 UAS in average. While conformance monitoring service without pre-alert ensures safe operations in Shannon, Benidorm and Manduria require further U-Space services to ensure target level of safety.	Partially OK
		CRT-SOL0520-TRL2-ERP-003.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 2: The city of Manduria (non U-space sub-OE)		
		CRT-SOL0520-TRL2-ERP-003.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)		

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Exercise #01 validation objective ID	Exercise #01 validation objective title	Exercise #01 success criterion ID	Exercise #01 success criterion	Sub-operating environment	Exercise #01 validation results	Exercise #01 validation objective status
OBJ-SOL0520-ERP-004	Quantification of the capacity increment (ΔN_3) because of the introduction of mitigation measures based on Flight Authorisation, Traffic Information, and Conformance Monitoring (with pre-alerting) services.	CRT-SOL0520-TRL2-ERP-004.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 1: The city of Benidorm (non U-space sub-OE)	The capacities for Scenarios 1, 2, and 3 increase to 1.21, 1.62, 41.22 UAS in average. While conformance monitoring service with pre-alert ensures safe operations in Shannon, Benidorm and Manduria require further U-Space services to ensure target level of safety.	Partially OK
		CRT-SOL0520-TRL2-ERP-004.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 2: The city of Manduria (non U-space sub-OE)		
		CRT-SOL0520-TRL2-ERP-004.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)		

Table 43: validation exercise #01 results – CRA

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A.5.2 Analysis of validation exercise #01 results per validation objective

A.5.2.1. OBJ-SOL0520-ERP-001 Results

Figure 58, Figure 59, and Figure 60 describe the baseline MAC and NMAC frequencies in Benidorm, Manduria, and Shannon respectively, where no U-Space services are implemented. Over a one-week duration, flight plans are randomly executed to ensure between 1 and 10 simultaneous UAS at any given time instant. The MAC and NMAC frequencies shown on the y-axis are calculated across 100 different random selections of flight plans. The average NMAC (blue line) is fitted with a linear function (black line). It is notable that both MAC and NMAC increase approximately linearly with the airspace density, although this tendency may not hold at higher airspace densities.

Although the target level of safety is defined based on MAC, NMAC is used as the primary indicator for baseline capacity and for evaluating subsequent capacity increments resulting from flight authorisation, traffic information, and conformance monitoring. The reason is that MAC exhibits inconsistent trends across different numbers of UAS and deviation thresholds, primarily due to its relatively higher variance compared to its magnitude. In contrast, NMAC shows more stable behaviour across these parameters, and is therefore adopted as the main indicator. Since MAC values are always lower than NMAC, the resulting capacity estimates can be considered conservative and ensure that the target level of safety is strictly met.

Based on the fitted NMAC functions, even two simultaneous UAS exceed the maximum allowable NMAC per hour, which are 4.35E-5, 1.5E-4, and 1.7E-2 for UAS–UAS interactions, and 10E-7 for UAS–manned aviation interactions. The exact baseline capacity values, along with the slopes of the linear regressions, are presented in Table 44. These results highlight the need for at least one U-space service in all scenarios.

When comparing MAC and NMAC across the three scenarios, it might be expected that the NMAC/MAC ratio would be smaller in Manduria and Shannon due to their larger areas (Benidorm: 21.3 km², Manduria: 462 km², Shannon: 846 km²). However, the values are of a similar scale across all scenarios. This is because the traffic patterns in Manduria and Shannon are more hub-centred (star-shaped), with departures and arrivals concentrated around specific locations. In contrast, Benidorm features more uniformly distributed flight plans, resulting in fewer conflicts for the same number of flights. Considering both scenario size and traffic pattern, the overall scale of NMAC remains comparable across the three scenarios. A notable difference is that the ratio between MAC and NMAC is higher in Manduria and Shannon, indicating relatively more MAC events when UAS trajectories are concentrated around hubs.

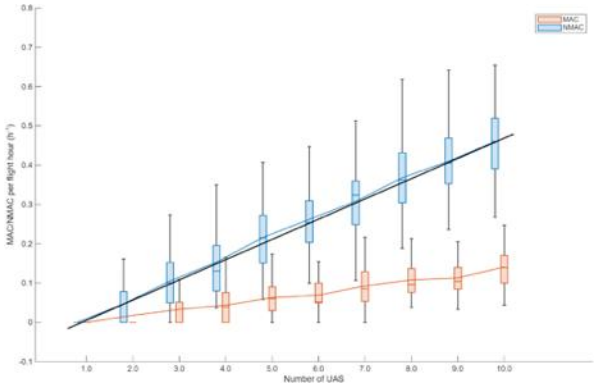


Figure 58: Baseline capacity evaluation for Benidorm

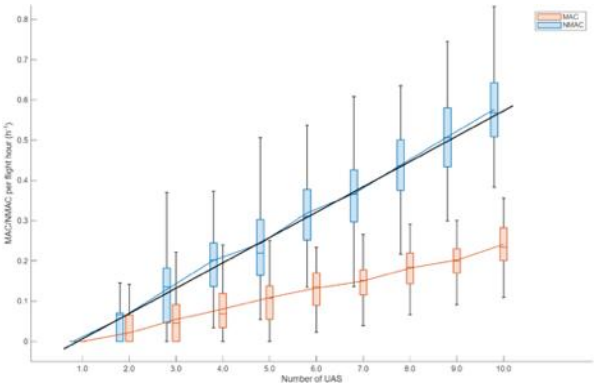


Figure 59: Baseline capacity evaluation for Manduria

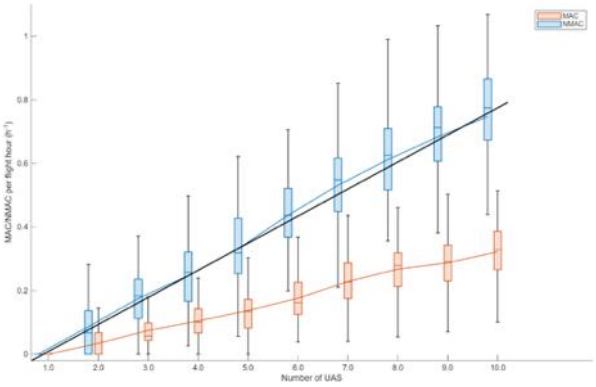


Figure 60: Baseline capacity evaluation for Shannon

Scenario	NMAC target	Curve fitting	Capacity
Scenario 1 (Benidorm)	0.0000435	0.04688049	1.001
Scenario 2 (Manduria)	0.00015	0.06387942	1.002
Scenario 3 (Shannon)	0.017	0.08035334	1.212

Table 44: Baseline capacity evaluation summary

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A.5.2.2. OBJ-SOL0520-ERP-002 Results

Figure 61, Figure 62, and Figure 63 present the MAC and NMAC frequencies in Benidorm, Manduria, and Shannon with the use of the flight authorisation service only. Different deviation thresholds of 8, 16, 32, 64, and 128 m are applied across varying numbers of UAS (from 1 to 10). MAC is reduced to the order of 10E-3; however, it shows inconsistent patterns due to an insufficient number of Monte Carlo runs to ensure statistical validity. Therefore, NMAC is the primary focus of the analysis. The flight authorisation service is highly effective: even with an 8 m threshold, it reduces NMAC by approximately 90% in Benidorm, 98% in Manduria, and 99% in Shannon. The effectiveness of risk mitigation increases exponentially with the deviation threshold, reaching up to 99.5% reduction in NMAC.

However, even a 99.5% reduction in risk does not allow more than two simultaneous UAS to meet the maximum allowable NMAC frequencies in Benidorm and Manduria. The reasons why the flight authorisation service does not reduce risk further are envisaged as follows:

- High excursion rate: Approximately 27% in the Cranfield simulator, driven by sensor noise, wind effects, and a 5% probability of loss of control, modelled as 100 seconds of constant velocity and heading.
- Point-to-point flight authorisation implementation: The current version checks distances between discrete points along flight plans interpolated at a 1-second resolution, but it does not check for potential intersections between line segments (see ENGage results for implementations including intersection checking). It is worth noting that reducing the interpolation interval significantly lowers the risk, although it increases computational complexity.

In Shannon, where the maximum admissible NMAC frequency is considerably higher (1.7E-2), the capacity increases substantially to 41 UAS. The full capacity values, together with the slopes of the linear regression, are provided in Table 45.

When analysing the effect of the deviation threshold, different trends are observed across the three scenarios. Benidorm follows an almost purely exponential trend, whereas Manduria and Shannon show a saturation effect, converging towards a limiting risk ratio as the threshold increases. It is notable that the NMAC values at an 8 m threshold differ significantly across the scenarios, while the results at 128 m become nearly identical. The higher effectiveness at smaller thresholds in Manduria and Shannon may be attributed to differences in trajectory distribution. Since these scenarios feature more star-patterned traffic (with flights concentrated around hubs), even small deviation thresholds are more effective at reducing conflicts compared to Benidorm's more uniformly distributed trajectories. As the limitations associated with high excursion rates and the point-to-point flight authorisation approach apply equally across all scenarios, the minimum achievable risk levels tend to converge to similar values.

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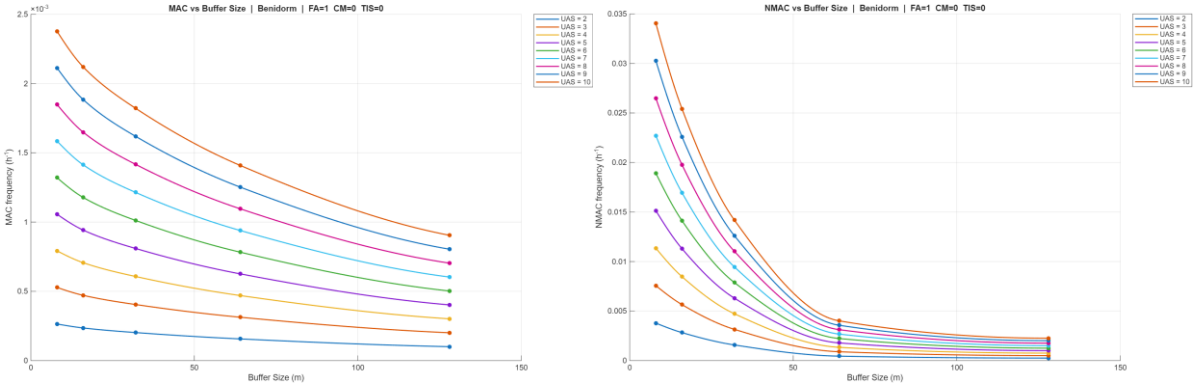


Figure 61: Flight authorisation capacity evaluation for Benidorm; MAC (left), NMAC (right)

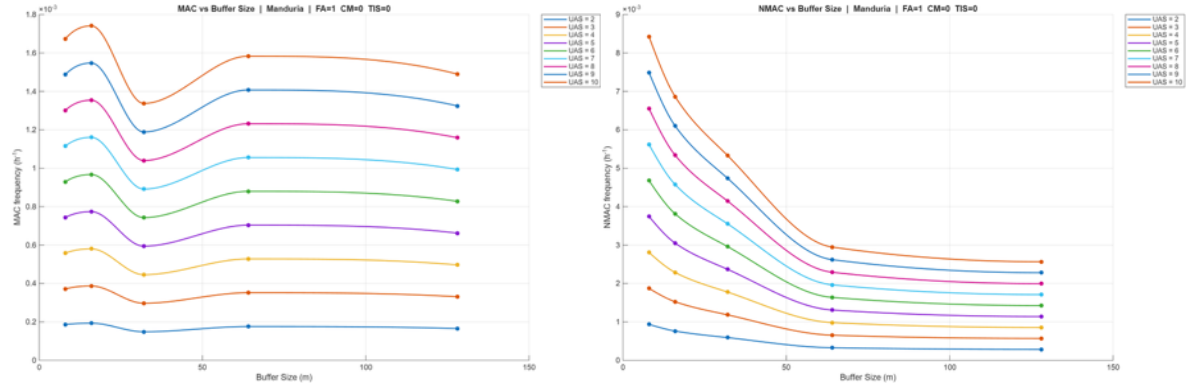


Figure 62: Flight authorisation capacity evaluation for Manduria; MAC (left), NMAC (right)

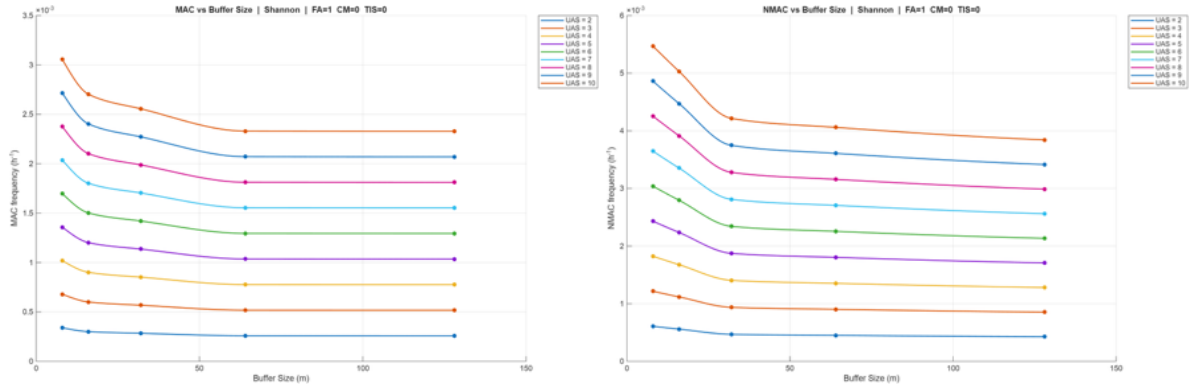


Figure 63: Flight authorisation capacity evaluation for Shannon; MAC (left), NMAC (right)

Scenario	Capacity with DT 8m	Capacity with DT 16m	Capacity with DT 32m	Capacity with DT 64m	Capacity with DT 128m
Scenario 1	1.01	1.02	1.03	1.10	1.17
Scenario 2	1.16	1.20	1.25	1.46	1.53
Scenario 3	28.98	31.41	37.29	38.69	40.82

Table 45: Flight authorisation capacity evaluation summary

The traffic information service is primarily implemented through an encounter model, of which the instants are obtained differently across the three scenarios, as shown in Figure 64, Figure 65, and

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Figure 66. The number of encounters is significantly higher in Benidorm, where the scenario size is smaller than in Manduria and Shannon. For the same number of UAS, aircraft in a smaller airspace are more likely to experience encounters. The trajectories following each encounter are then simulated separately using a unified encounter model, for the following reasons:

- One-to-one nature of the rules of the air: The model assumes pairwise interactions and does not account for multiple simultaneous conflicts or vertical separation conflicts.
- Time-step requirements for accurate modelling: It has been shown that the simulation time step should be no greater than 0.1 seconds to accurately capture pilot behaviour under the rules of the air.
- Number of Monte Carlo runs: Encounter models can be executed with a higher number of Monte Carlo runs, as they do not simulate full trajectories, thereby providing more statistically robust results.

Figure 67 presents the risk ratio of the traffic information service under different simulation time steps. The results indicate that the traffic information service is highly effective only when the response delay is short, which is unlikely to be less than 6 seconds for human operators. Considering a realistic average human response delay, the effectiveness of the traffic information service is estimated at approximately 10%, leading to the safe capacity values shown in Table 46. Under these assumptions, the capacity increases to 45 UAS in Shannon when the traffic information service is applied.

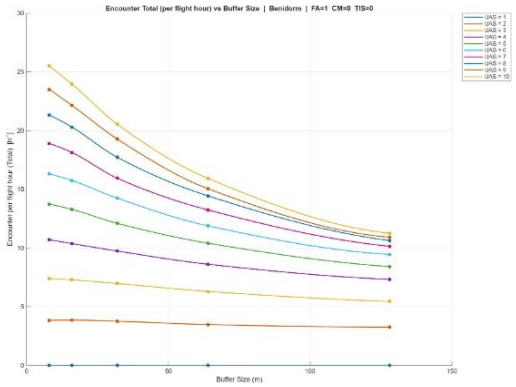


Figure 64: Encounter numbers in Benidorm

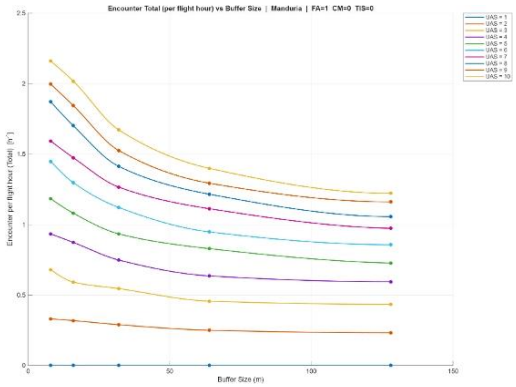


Figure 65: Encounter numbers in Manduria

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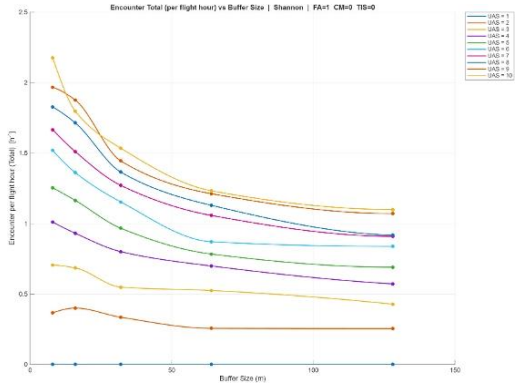


Figure 66: Encounter numbers in Shannon

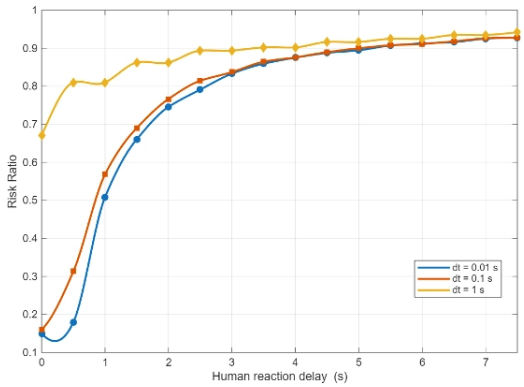


Figure 67: Traffic information service effectiveness in encounter model

Scenario	Capacity with DT 8m	Capacity with DT 16m	Capacity with DT 32m	Capacity with DT 64m	Capacity with DT 128m
Scenario 1	1.01	1.02	1.03	1.11	1.19
Scenario 2	1.18	1.22	1.28	1.51	1.58
Scenario 3	32.08	34.79	41.32	42.87	45.24

Table 46: Traffic information service capacity evaluation summary

A.5.2.3. OBJ-SOL0520-ERP-003 Results

Figure 68, Figure 69, and Figure 70 present MAC and NMAC in Benidorm, Manduria, and Shannon, respectively, with the combined use of flight authorisation and conformance monitoring (without pre-alert). As before, NMAC is taken as the primary focus of the analysis to ensure statistical robustness. Compared with the NMAC results in Figure 61, Figure 62, and Figure 63 (flight authorisation only), the addition of conformance monitoring without pre-alert reduces risk only marginally, on the order of 10E-3 NMAC/FH. This result is somewhat unexpected, as the conformance ratio—defined as the percentage of time that UAS operate within the TSE—increases significantly from 73% to 93%. In principle, this improvement should lead to a reduction in NMAC, provided that the authorised flight plans are well deconflicted. However, this tendency is consistently observed across all three simulators.

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Several research hypotheses have been tested to explain this behaviour, including variations in the loss-of-control rate, human response time, and the magnitude of sensor noise and wind effects. The results indicate a consistent trend: when the flight authorisation service is more effective, conformance monitoring also tends to have a greater impact. These findings suggest that, while conformance monitoring is effective in increasing the conformance ratio, it does not necessarily result in a reduction in NMAC unless the underlying flight authorisation process has already achieved sufficient deconfliction of trajectories. The detailed capacity increments are summarised in Table 47.

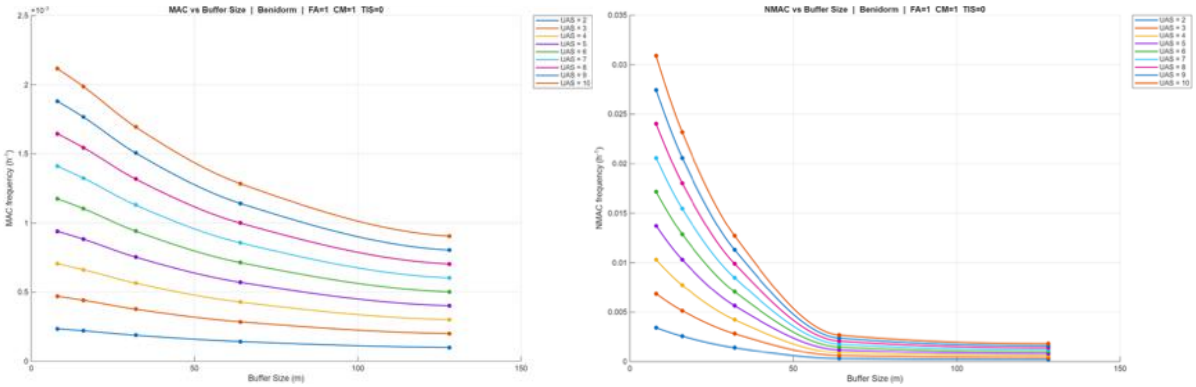


Figure 68: Conformance monitoring capacity evaluation for Benidorm (without pre-alert)

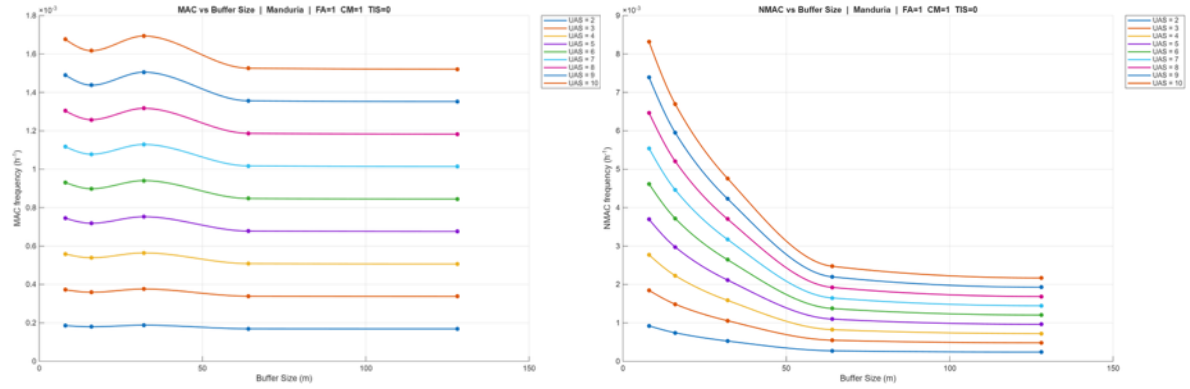


Figure 69: Conformance monitoring capacity evaluation for Manduria (without pre-alert)

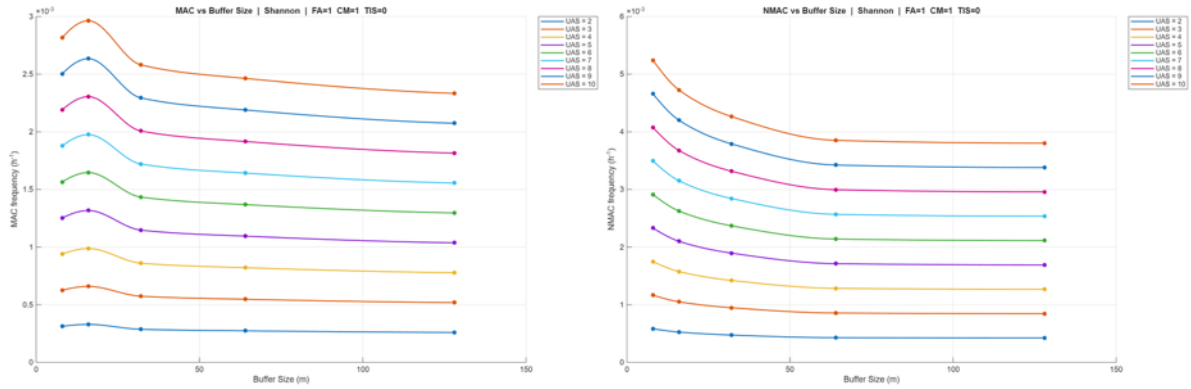


Figure 70: Conformance monitoring capacity evaluation for Shannon (without pre-alert)

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Scenario	Capacity with DT 8m	Capacity with DT 16m	Capacity with DT 32m	Capacity with DT 64m	Capacity with DT 128m
Scenario 1	1.01	1.02	1.03	1.11	1.19
Scenario 2	1.18	1.22	1.28	1.51	1.58
Scenario 3	32.08	34.79	41.32	42.87	45.24

Table 47: Conformance monitoring capacity evaluation summary

A.5.2.4. OBJ-SOL0520-ERP-004 Results

Figure 71, Figure 72, and Figure 73 present MAC and NMAC in Benidorm, Manduria, and Shannon, respectively, with the combined use of flight authorisation and conformance monitoring with pre-alert. The conformance ratio increases from 93% to 98% compared with conformance monitoring without pre-alert. However, the impact on MAC and NMAC, as well as the resulting capacity increment, remains minimal. This indicates that the performance of conformance monitoring is more dependent on the effectiveness of the flight authorisation service than on its ability to ensure conformance alone. In other words, improving conformance does not significantly reduce risk unless the underlying flight plans are already sufficiently deconflicted. The detailed capacity increments therefore remain unchanged, as shown in Table 47.

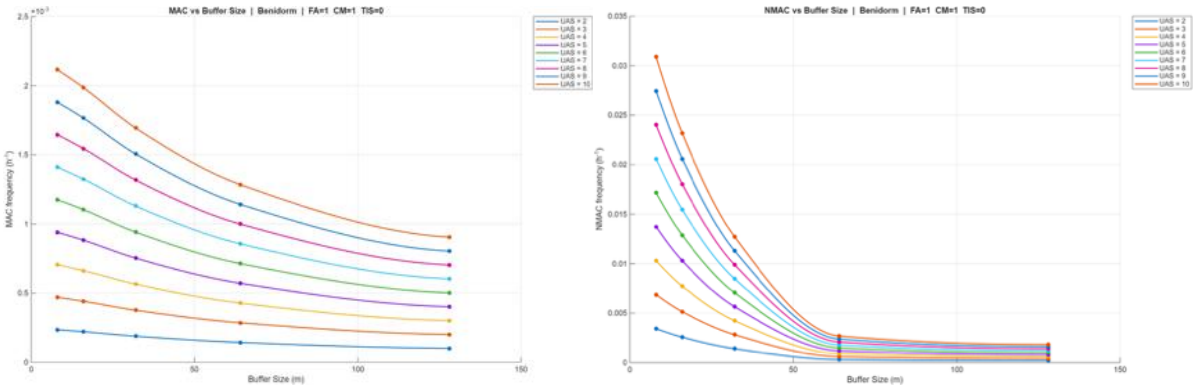


Figure 71: Conformance monitoring capacity evaluation for Benidorm (with pre-alert)

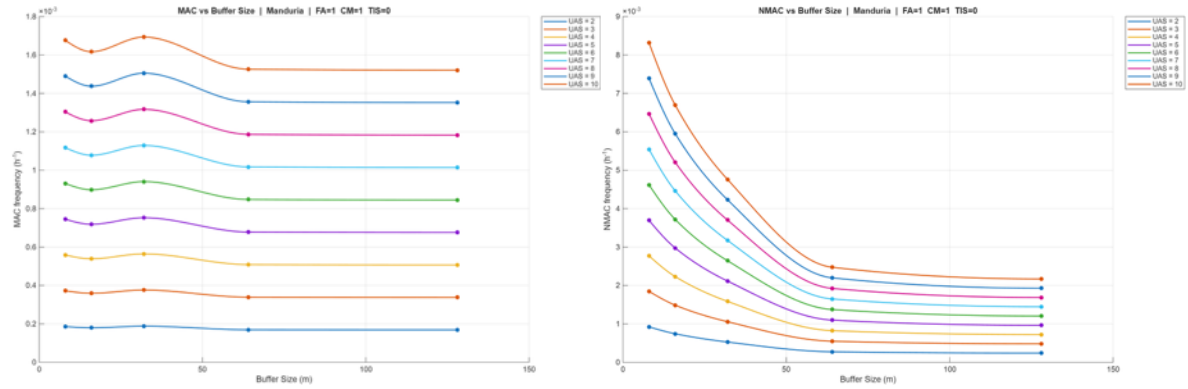


Figure 72: Conformance monitoring capacity evaluation for Manduria (with pre-alert)

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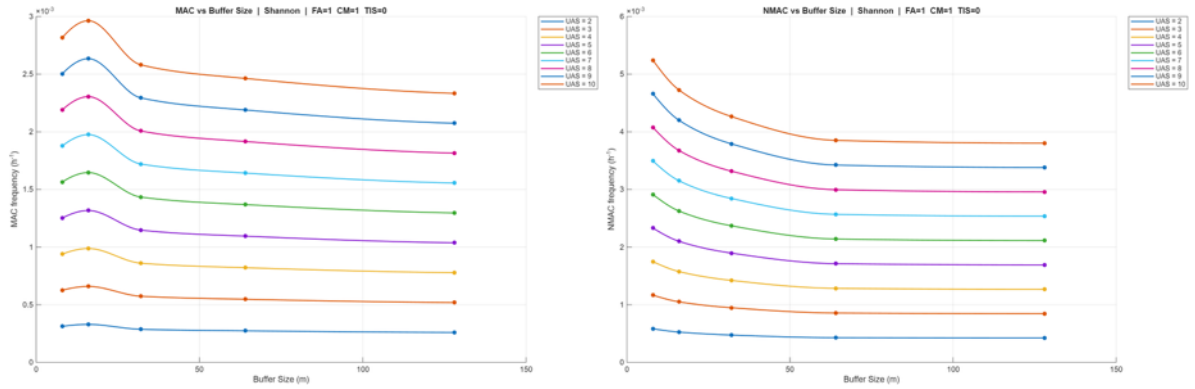


Figure 73: Conformance monitoring capacity evaluation for Shannon (with pre-alert)

A.5.3 Unexpected behaviours/results

One of the most notable findings is the limited impact of conformance monitoring on risk reduction, despite its strong improvement in operational performance metrics. Specifically, the conformance ratio increases significantly—from approximately 73% to 93%, and up to 98% with pre-alert mechanisms—indicating that aircraft spend substantially more time within the intended trajectory envelope. Intuitively, this level of improvement would be expected to translate into a meaningful reduction in conflict risk. However, the results show only marginal reductions in NMAC. This outcome suggests that strict adherence to a flight plan does not necessarily improve safety if the plan itself is not sufficiently deconflicted. Conformance monitoring is effective in ensuring that aircraft follow their assigned trajectories, but it has limited ability to reduce risk when the underlying trajectories already contain embedded conflict potential. This highlights a fundamental dependency on the quality of upstream flight authorisation.

Closely related to this is the observation of high residual risk levels, even after substantial relative risk mitigation. Flight authorisation reduces NMAC by up to 99.5%, which would typically be interpreted as a highly effective safety intervention. However, in absolute terms, the remaining risk still exceeds the target level of safety in scenarios such as Benidorm and Manduria, limiting safe operations to very low traffic densities (no more than two simultaneous UAS). This result underscores the necessity of advanced U-Space services, including strategic and tactical deconfliction.

A further unexpected outcome relates to the role of scenario size versus traffic pattern in shaping risk levels. It might reasonably be expected that larger operational areas, such as Manduria and Shannon, would exhibit lower conflict rates compared with smaller areas like Benidorm. However, the results show that NMAC levels are of a similar scale across all three scenarios. This can be explained by differences in traffic structure: Manduria and Shannon exhibit hub-centred (star-patterned) traffic, where departures and arrivals are concentrated around specific locations, increasing the likelihood of interactions. In contrast, Benidorm features more uniformly distributed trajectories, which naturally reduces conflict probability for a given number of aircraft. As a result, traffic distribution effects offset the influence of airspace size, indicating that spatial extent alone is not a sufficient predictor of safety performance. Instead, the organisation of traffic flows plays a critical role.

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A.5.4 Confidence in results of validation exercise #01

A.5.4.1. Level of significance/limitations of validation exercise results

The results provide a high level of confidence, as they have been cross-validated using three independent simulation platforms. While the absolute numerical values do not match exactly across the simulators, the key trends and behavioural insights are consistently observed, which reinforces the robustness of the findings. In particular, all simulators demonstrate the same fundamental tendencies: the high effectiveness of flight authorisation, the limited impact of conformance monitoring on direct risk reduction, the presence of non-negligible residual risks, and the strong interplay between scenario size and traffic patterns. The consistency of these observations across different modelling approaches indicates that these are not artefacts of a specific simulator, but rather inherent characteristics of the system behaviour.

It is acknowledged that the exact capacity values and risk levels are sensitive to modelling assumptions, including sensor performance, wind effects, simulation time step, excursion rate, and the modelling of loss-of-control events. However, while these factors influence quantitative outputs, they do not alter the underlying relationships between U-space services and safety performance. Although absolute values may vary depending on the simulation configuration, the insights into the relative effectiveness of different U-space services—as well as the impact of parameters such as deviation thresholds and human response behaviour—are considered transferable across different operational environments.

A.5.4.2. Quality of validation exercises results

The quality of the results are backed from large-scale Monte Carlo simulations and parameter studies of different number of UAS, deviation threshold, and human response. The simulations include realistic factors such as environmental disturbances, sensor uncertainties, and failure scenarios, which enhances their practical relevance. The analysis focuses on robust indicators, particularly NMAC, to minimise the impact of variability in low-frequency events. Although quantitative results depend on modelling assumptions (e.g., noise levels, wind, and time step), the key trends and insights remain consistent. Overall, the results are considered sufficiently reliable to support system design and regulatory decision-making.

A.5.4.3. Significance of validation exercises results

The results of the validation exercises provide important insights into the effectiveness and limitations of current U-space services. While basic services such as flight authorisation, conformance monitoring, and traffic information demonstrate measurable risk reduction, they are not sufficient on their own to consistently meet the target level of safety, particularly in more complex or dense operational scenarios. The persistence of residual risks, even after significant relative reductions, highlights the limitations of relying solely on these baseline services. In particular, the strong dependency on initial trajectory deconfliction and the limited contribution of downstream corrective measures emphasise the need for more proactive approaches to risk mitigation. Ultimately, the results underline that achieving scalable and safe UAS operations requires an integrated, multi-layered framework, where advanced services play a critical role in meeting regulatory safety targets.

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A.6 Conclusions

This section provides a summary of the conclusions raised by the validation exercise #01 results analysis, arguing and preparing the recommendations from this exercise.

A.6.1 Conclusions on concept clarification

The Batch 1 validation results confirm that the U-AGREE solution concept is well defined and operationally coherent. The progressive introduction of Flight Authorisation, Traffic Information and Conformance Monitoring provides a consistent layered approach in which each service addresses a different part of the collision-risk management process. No fundamental modification of the concept has been identified as necessary. Instead, Validation Exercise #01 has clarified the operational role, boundaries and dependencies of the assessed services.

Flight Authorisation acts as the strategic preventive layer by determining which UAS trajectories can be introduced into the active traffic environment. The results confirm that increasing the deviation threshold generally provides greater separation between authorised UAS trajectories and reduces UAS–UAS collision frequencies. However, larger separation margins also make the allocation of acceptable trajectories more restrictive and reduce the Authorisation Approval Rate. The deviation threshold therefore represents an operational trade-off between safety improvement, capacity and access to the airspace.

The results also clarify the distinction between safety-based capacity and operationally achievable capacity. In some configurations, the applicable safety criterion supports traffic levels above the number of trajectories that can actually be generated, allocated and authorised within the available scenario airspace. In these cases, safety is no longer the limiting factor; operational capacity is instead constrained by trajectory availability and the performance of the Flight Authorisation process.

Traffic Information provides a tactical layer for the management of residual encounters. Its operational contribution depends not only on the timely provision of accurate information but also on the subsequent response. The expected mitigation effect can only be achieved if the information is correctly interpreted and an appropriate manoeuvre is executed within the available look-ahead time. The effectiveness attributed to TIS is therefore conditional on the CNS and Human Performance levels that can be assured in operation.

Conformance Monitoring provides an additional in-flight layer by detecting and managing deviations from authorised trajectories. Without pre-alerting, recovery is initiated when the UAS reaches the outer monitoring boundary, limiting the continuation of the excursion but not preventing the initial TSE exceedance. With pre-alerting, recovery starts at the TSE boundary, allowing earlier corrective action and improving containment. The results therefore support the functional distinction between Conformance Monitoring with and without pre-alerting.

Overall, Validation Exercise #01 confirms the operational feasibility and internal coherence of the layered solution concept under the assessed conditions. FAS reduces the probability that UAS–UAS conflicts are introduced into the active traffic environment; TIS supports the management of residual encounters; and Conformance Monitoring limits the consequences of deviations from authorised trajectories. The services perform distinct but complementary functions and should therefore be considered successive mitigation layers rather than interchangeable alternatives. This does not preclude the possibility that, under conditions of low ground risk, very low or negligible air risk, and low traffic demand, the tactical mitigation provided by the TIS may be sufficient to achieve the required capacity while satisfying the applicable safety criteria. However, even in these edge-case scenarios, a

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minimum level of demand management may still be required to prevent the tactical barriers from becoming overloaded.

A.6.2 Conclusions on technical feasibility

Validation Exercise #01 confirms the technical feasibility of implementing and assessing the main functions of Flight Authorisation, Traffic Information and Conformance Monitoring in fast-time simulation environments. The simulation platforms were able to represent the main elements required for the assessment, including traffic generation, trajectory propagation, strategic deconfliction, conflict detection, alerting, response and recovery.

The simulators converged on the main baseline conclusion: without mitigation, collision-related frequencies increase with traffic density, and the applicable safety criteria allow negligible or very limited concurrent UAS operations. This consistency provides confidence in the overall baseline interpretation, despite differences in the absolute frequencies obtained across platforms. The remaining numerical differences are mainly due to parameters used in the implementation of the barriers. These include the simulation time step and conflict-detection method, the construction of protected volumes, the treatment of aircraft after a MAC, and the handling of rejected U-plans. In particular, when an authorisation request is rejected, some implementations discard the flight, whereas others attempt to introduce a replacement trajectory from the dataset. Although both approaches are technically valid, they lead to different effective traffic levels and affect the interpretation of capacity, the number of authorisation attempts and the Authorisation Approval Rate.

The baseline comparison shows that scenario size and traffic mix and density alone are insufficient to explain the resulting collision frequencies. The way in which trajectories are locally organised, including their spatial concentration, vertical distribution, crossing patterns and encounter geometries (i.e., the local traffic pattern) has a significant influence on the observed risk as presented in D3.6. Consequently, the performance of a mitigation barrier cannot be transferred directly from one operational environment to another solely on the basis of an equivalent traffic mix or traffic density. This indicates that the definition of a traffic mix alone is insufficient for defining a scenario. Additionally, it is necessary to specify the specific patterns that a scenario may present, such as delivery hubs or scan flights.

The validation therefore indicates that the level of detail provided in the common specifications was sufficient to support implementation of the principal service functions, but not to ensure full convergence of the simulations in all assessed configurations. This limitation became particularly relevant when mitigation barriers were introduced, as small differences in deconfliction, dynamic vehicles state propagation, alerting, response and recovery logic could produce different numerical effects when residual events were rare or close to the applicable safety threshold.

For Flight Authorisation, further specification is required regarding the deconfliction method, protected-volume construction, treatment of manned aircraft, trajectory-allocation process and handling of rejected U-plans. For Traffic Information, the complete alert-and-response chain should be characterised, including CNS assumptions, alert timing, pilot reaction, manoeuvre selection and successful execution. For Conformance Monitoring, the monitored boundaries, communication and reaction delays, recovery trigger, return-to-track logic and excursions handling should be defined consistently.

Common event-counting and exposure rules are also required. These should specify when an event begins and ends, whether repeated infringements involving the same aircraft are counted separately, and whether an aircraft is removed or retained after a MAC. Differences in these rules can materially

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affect the number of recorded events and therefore limit direct numerical comparison between platforms, even where the same qualitative behaviour is reproduced.

Overall, the simulation platforms demonstrate sufficient technical maturity to support exploratory assessment of the U-AGREE services. The principal baseline trends and the dominant effect of Flight Authorisation are consistent across the assessed implementations. However, full numerical convergence, particularly for the incremental contribution of tactical and containment barriers, requires more detailed common specifications, harmonised benchmark cases and explicit verification of the sensitivity to the principal simulation parameters.

A.6.3 Conclusions on performance assessments

Safety

The baseline results consistently show that collision-related frequencies increase as traffic density increases and that the unmitigated operating environments provide negligible or very limited capacity against the applicable safety criteria. Although the precise numerical values differ between validation platforms and scenario configurations, the common conclusion is that scalable concurrent UAS operations require the introduction of U-space mitigation services.

FAS provides a clear and repeatable reduction in UAS–UAS collision risk. Residual MAC and NMAC frequencies generally decrease as the deviation threshold increases, with the largest assessed thresholds producing very low or zero observed event counts in several configurations. The relative improvement is observed across the three operational environments, although the magnitude and the threshold required to meet the applicable safety criterion remain scenario-dependent.

The results show that the providence associated with progression from NMAC to MAC changes substantially after the application of FAS. While the estimated providence in the unmitigated baseline ranges from approximately 20% to 60%, depending on the scenario, it decreases to below 1% in the FAS-mitigated configurations. However, the NMAC safety criterion is derived from the MAC criterion using a fixed providence assumption of 10%. This assumption therefore overestimates the probability of progression from NMAC to MAC after FAS is applied and results in a conservative NMAC safety criterion for the mitigated configurations. Consequently, compliance with the derived NMAC criterion is generally achieved only at the larger deviation thresholds, despite the substantially lower progression to MAC observed after strategic deconfliction. Nevertheless, sufficient statistical evidence would be required before the observed mitigated providence values could be used to revise the applicable safety criterion.

The results also show that risk reduction does not translate continuously into capacity gains. Capacity increases only when the residual frequency falls below the applicable safety limit. Consequently, a configuration may provide a substantial reduction relative to the baseline while still producing no increase in compliant capacity because the residual value remains above a particularly stringent safety threshold.

The dedicated TIS assessment reports residual Risk Ratios smaller than one for the evaluated UAS–UAS and UAS–manned scenario and altitude combinations. This supports the potential contribution of TIS as a tactical safety barrier once a relevant encounter exists. However, the results are conditional on the assessed encounter population, CNS assumptions, pilot-response distributions, manoeuvre strategies and successful execution. TIS was not included in every partner simulation campaign; consequently, the available results represent dedicated evidence of its conditional effectiveness rather than a result independently reproduced across all validation platforms.

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The CM results are more nuanced. The UPV contribution identifies an additional UAS–UAS MAC benefit and improved containment, with a more limited effect on NMAC and UAS–manned encounters. Other Batch 1 results show that NMAC performance with CM, with or without pre-alerting, generally remains within the simulation variability of FAS alone, particularly where the deviation threshold has already reduced the residual event frequency to the detection floor. These findings are compatible with the different spatial scales of MAC and NMAC: reducing the duration or magnitude of an excursion may prevent progression towards the smaller MAC volume without producing an equally visible change in the larger NMAC volume.

CM without pre-alerting provides a measurable containment contribution by detecting excursions reaching the outer monitoring boundary and initiating recovery. However, the initial TSE exceedance is not prevented, and the resulting benefit depends on the distance between the TSE and the recovery-trigger boundary. Pre-alerting initiates recovery at the TSE boundary and therefore provides a clearer functional containment benefit. The UPV results show an increase in containment from approximately 93.2% under FAS to approximately 94.0% with pre-alerting (dependant on HP and recovery logic). Nevertheless, Batch 1 does not demonstrate a uniform additional NMAC reduction across all scenarios and simulation implementations.

The most robust overall safety conclusion is that FAS provides the dominant and most consistent UAS–UAS collision-risk reduction, while TIS and CM provide complementary tactical and containment benefits. The magnitude of their additional contribution depends on the scenario, safety indicator, deviation threshold, response assumptions and available statistical exposure.

Capacity

The unmitigated baseline provides negligible or very limited capacity across the assessed operational environments. While exact capacity values depend on the selected safety indicator and modelling approach, the partners' results consistently show that meaningful concurrent traffic cannot be supported without mitigation.

FAS provides the clearest direct capacity contribution because it changes the set of trajectories accepted before operation. Capacity generally increases when the deviation threshold becomes sufficiently large for the residual collision frequency to satisfy the applicable safety criterion. However, the capacity response is strongly scenario-dependent:

- Benidorm generally shows limited capacity improvement at smaller thresholds and a more pronounced increase once a sufficiently large threshold is applied.
- Manduria requires comparatively large deviation thresholds before the risk reduction translates into demonstrable compliance.
- Shannon–Limerick generally supports larger capacity increments, although the results remain dependent on the trajectory population and available airspace.

These differences confirm that a single deviation threshold cannot be assumed to provide equivalent capacity performance in every operational environment.

The safety-based capacity may exceed the traffic that can be operationally accommodated. Where the theoretical result is particularly high, the limiting factor becomes the number of trajectories that FAS can generate, allocate and authorise within the scenario airspace. Capacity should therefore be reported together with trajectory availability, the average number of authorised U-plans and the Authorisation Approval Rate.

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The UAS–manned criterion may also remain more restrictive than the UAS–UAS criterion where manned aircraft are not included in the strategic deconfliction process. A substantial increase in UAS–UAS safety-based capacity does not necessarily produce an equivalent increase in overall capacity when all applicable encounter types are considered.

CM produced configuration-dependent capacity results. Some individual cases show a higher capacity than with FAS alone, whereas others show no improvement, a lower estimate or a statistically indistinguishable result. These differences are affected by rare-event variability and by whether the residual frequency lies close to the applicable safety limit. CM should therefore be considered primarily a containment and residual-safety barrier. Any capacity credit should be established through an integrated scenario-level assessment and should not be generalised across scenarios, thresholds or simulation platforms.

Access & Equity

The Authorisation Approval Rate decreases as traffic demand and deviation threshold increase. This represents the operational cost of reserving larger protected volumes around authorised trajectories. The magnitude of the reduction depends on the scenario geometry, available airspace and vertical distribution of traffic. Above-VLL configurations may support higher acceptance rates where greater vertical distribution facilitates the allocation of acceptable U-plans.

The operational configuration should not therefore be selected by maximising the deviation threshold. A larger threshold may improve safety-based capacity while simultaneously reducing the proportion of requested operations that can be authorised. Selection of the operating point must balance residual collision risk, compliant capacity, trajectory availability and equitable access.

CM does not directly modify the initial Flight Authorisation process in the Batch 1 architecture. The average number of authorised U-plans and the Authorisation Approval Rate are therefore determined primarily by FAS. Any effect of CM on Access and Equity is indirect and should not be reported as a change in approval rate unless CM is integrated into a revised authorisation or capacity-management process.

Overall performance conclusion

Validation Exercise #01 demonstrates that Safety, Capacity and Access & Equity cannot be assessed independently. Strategic separation can substantially reduce collision risk and increase safety-based capacity, but increasingly conservative separation may reduce the number of acceptable trajectories. Tactical information and monitoring can reduce residual risk or improve containment without directly increasing trajectory-allocation capability.

The preferred operational configuration should therefore be selected through a balanced assessment of collision frequency, safety-based capacity, trajectory availability, Authorisation Approval Rate, containment performance and the reliability of the tactical response chain. No single KPI is sufficient to characterise the overall performance of the solution.

A.6.4 Conclusions on Human Performance

The main Human Performance conclusion is that the TIS assessment provides an exploratory sensitivity model, not an empirically validated representation of remote-pilot performance. No representative human-in-the-loop experiment, operational dataset or validated workforce distribution was available to calibrate the pilot categories, response-time distributions, manoeuvre choices or compliance probabilities. This is particularly important for TIS because the service provides information but does

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not itself complete the avoidance action: its safety contribution depends on the information being received and understood and on a suitable manoeuvre being selected, commanded and successfully executed within the available encounter time.

The common assessment represented expert, intermediate and novice response through shifted-Gamma distributions with a five-second minimum delay and mean response times of approximately 20, 40 and 60 seconds. The UPV campaign retained the full set of ordered pilot-pair combinations and used the prescribed uniform population as the common reporting reference. These profiles also apply different manoeuvre strategies and return-to-track behaviour. They must therefore be understood as combined assumptions about timing, decision logic and manoeuvre execution, rather than as measured pilot populations or as a pure comparison of reaction time or expertise.

UPV simulation results confirm that these assumptions materially affect the TIS outcome. All the scenarios' results report residual Risk Ratios below one for the assessed UAS–UAS and UAS–manned encounters, supporting the potential of TIS to reduce conditional collision risk. However, the pilot-population sensitivities change both Risk Ratio and Loss-of-separation Ratio, and the direction and magnitude of the change differ between encounter families because response time and manoeuvre strategy vary together. CRA likewise found that the modelled benefit decreased substantially when a longer assumed human response was introduced. The consistent conclusion across the available evidence is therefore that the time and quality of the response are dominant sensitivities; the different numerical results do not validate any one Human Performance assumption.

Systems Performance and Human Performance must remain separate. CNS delay, packet loss, surveillance error, processing and display updates determine when and how accurately the information becomes available. Human monitoring, comprehension, decision-making, manoeuvre selection and command entry occur after that point, while aircraft dynamics determine when the manoeuvre becomes effective. Combining these stages into a single delay would conceal the cause of an unsuccessful outcome and prevent meaningful performance requirements from being assigned.

Human Performance is intrinsically difficult to reproduce in a fast-time pairwise encounter model because operational response depends on interface design, alert salience, information quality, encounter geometry, workload, fatigue, training, trust, competing tasks, procedures and organisational responsibilities. The assessed models cannot represent human prioritisation in case of multiple simultaneous alerts, interruption, supervision of several UAS, team coordination or mode confusion. Their results may therefore underrepresent both response variability and the probability of an inappropriate, delayed or incomplete action.

The evidence consequently supports a conditional conclusion: TIS can contribute to safety when accurate and timely information is followed by a correct and successfully executed response, but its operational mitigation credit cannot be guaranteed from the current pilot assumptions alone. The principal achievement of the Batch 1 Human Performance work is to expose this dependency, quantify its sensitivity under controlled assumptions and identify the stages that require separate requirements. Until the assumed distributions and behaviours are calibrated through representative human-in-the-loop trials using the intended interface, traffic, procedures and workload, TIS safety and capacity conclusions must remain conditional on an unverified Human Performance level.

A.7 Recommendations

Based on the results of Validation Exercise #01, future R&I activities should provide more detailed and harmonised specifications for the implementation and assessment of the U-space services. Although the validation platforms reproduced the main functions and showed consistent qualitative trends,

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differences in implementation assumptions affected the quantitative results, particularly when residual events were rare or close to the applicable safety limits.

For Flight Authorisation, further specification is recommended regarding the treatment of TSE and aircraft dimensions, the trajectory-allocation process and the handling of rejected U-plans. These aspects should be defined consistently because they affect the effective traffic level, collision frequencies, safety-based capacity and Authorisation Approval Rate.

For Traffic Information, the complete alert-and-response chain should be specified, including CNS assumptions, alert timing, response delays and the criteria used to select and execute the avoidance manoeuvre. The expected behaviour of each participant, the manoeuvring responsibility in UAS–UAS and UAS–manned encounters, the treatment of unsuccessful or invalid manoeuvres and the conditions for returning to the original trajectory should also be clearly defined. Since the mitigation benefit depends on a suitable manoeuvre being correctly executed within the available encounter time, the operational credit assigned to TIS should remain conditional on the CNS and Human Performance levels that can be demonstrated.

For Conformance Monitoring, the monitored boundaries, alerting conditions, communication and reaction delays, recovery triggers and return-to-track logic should also be harmonised. The distinction between configurations with and without pre-alerting should be preserved, as they trigger recovery at different stages and therefore provide different containment benefits.

Finally, future validation activities should establish common simulation and event-counting rules, supported by harmonised benchmark cases. This additional level of specification would reduce cross-platform dispersion, improve the comparability and traceability of results, and provide a more robust basis for assessing the individual and combined contribution of the services in subsequent validation phases. In this context, the outcomes of U-AGREE provide the foundation for future research activities focused on the specification and validation of a higher-maturity U-space simulator. Such a capability would enable stakeholders to assess the U-space services required for specific local implementations, together with the associated performance levels, thereby supporting evidence-based deployment decisions through reliable and trustworthy simulation results.

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Appendix B Validation exercise #02 report

B.1 Summary of the validation exercise #02 plan

Validation TVAL.02.0 has been better defined since the submission of the ERP. Details on the implementation of this exercise are provided in paragraph B.2 *Deviation from the planned activities*.

B.1.1 Validation exercise description and scope

Exercise #02 integrates the final risk models developed within the project and focuses on the assessment of the effectiveness of the final U-AGREE mitigation barriers [9] in reducing risks within U-space operational environments. The exercise evaluates the impact of strategic Flight Authorisation Service and of advanced tactical mitigation services, naming Tactical Conflict Prediction and Resolution (TCP&R) service which are part of the more advanced U-space services (U3) described in the U-space Concept of Operations (Edition 4.0) developed by the CORUS and CORUS-XUAM projects [10].

Fast-time simulations, based on Monte-Carlo technique, have been conducted to generate statistically significant results and to calculate the relevant KPIs addressing the **Safety**, **Capacity**, **Security**, **Environment** and **Access & Equity** Key Performance Areas, as defined in the ERP.

The validation methodology mirrors the one adopted in Exercise #01. For each mitigation barrier, KPIs are recalculated and compared against the corresponding reference scenario to derive risk ratios quantifying the effectiveness of the implemented mitigation mechanisms.

In this exercise, DAR affected volumes are considered in the Flight Authorisation Service process only for the Shannon-Limerick scenario, which includes a portion of controlled airspace.

B.1.2 Summary of validation exercise #02 validation objectives and success criteria

Since this exercise has been extensively discussed following the ERP submission, the following validation objectives and success criteria have undergone deviations:

- OBJ-U-AGREE-ERP-001 related success criteria,
- OBJ-U-AGREE-ERP-006 related success criteria,
- OBJ-U-AGREE-ERP-010, as a new addition.

Further information on these objectives is provided in paragraph B.2 *Deviation from the planned activities.*

For validation objectives and success criteria not explicitly mentioned therein, no deviations from the ERP are reported.

B.1.3 Summary of validation exercise #02 validation scenarios

Validation scenarios for exercise #02 are based on the same sub-operating environments defined for exercise #01, namely Benidorm, Manduria and the Shannon–Limerick Area. No changes have been introduced with respect to the operating environment.

The exercise includes the same reference scenario as Exercise #01 and a set of solution scenarios implementing additional mitigation barriers.

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The reference scenario considers operations without U-space services, in which UAS operate in shared airspace without mitigation mechanisms (Figure 3). Risk estimation is conducted using the final U-AGREE risk models under a no-mitigation assumption. This scenario provides the baseline against which the effectiveness of the additional mitigation measures introduced in exercise #02 is evaluated.

The solution scenarios introduce advanced tactical mitigation barriers based on the Flight Authorisation Service (FAS) and the Tactical Conflict Prediction and Resolution Service (TCP&R), as defined in U-AGREE D4.2 [9]. The simulations evaluate the contribution of these services to risk reduction and to the support of scalable high-density UAS operations.

A detailed definition of the solution scenarios, detailed after ERP submission, is provided in Section B.2, *Deviation from the Planned Activities*.

B.1.4 Summary of validation exercise #02 validation assumptions

In addition to the assumptions defined at ERP level, which apply to both exercises, the following assumptions are specifically introduced for exercise #02. They represent a deviation from the ones defined in the ERP, as they have been introduced after a better understanding on exercise #02 execution.

Assumption ID	Assumption title	Assumption description	Justification	Impact assessment
Assumption 14	Dynamic Airspace reconfiguration	DAR affected volumes are considered only in the Shannon-Limerick scenario due to the presence of controlled airspace (CTR).	DAR services are relevant only in scenarios involving controlled airspace interactions.	Results related to DAR impact are related to only 1 scenario.
Assumption 15	Multi-USSP latency constraint	A multi-USSP architecture is assumed with inter-USSP latency below 1–2 seconds.	Ensures feasibility of near real-time coordination between USSPs.	Higher latency may degrade coordination efficiency and conflict management performance.
Assumption 16	Sequential TCP&R resolution	TCP&R resolves one conflict at a time (the most imminent), freezing all other UAS intent during manoeuvre computation.	Simplifies real-time tactical conflict resolution complexity.	May underestimate interactions between simultaneous conflicts in dense traffic scenarios.
Assumption 17	Independent USSP conflict resolution	Each USSP performs conflict resolution independently while applying the same ruleset (e.g. fixed-wing priority over multirotor, rules of the air), ensuring consistent outcomes across providers.	Ensures harmonised decision logic across distributed service providers while maintaining architectural independence.	May not capture discrepancies arising from implementation differences or edge-case interpretations of rules.

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Assumption 18	Resolution methods by partner	Different TCP&R implementation methods are adopted by the validation partners: ENGage applies an RRT (Rapidly-exploring Random Tree) algorithm, Cranfield uses a differential geometry approach, and UPV applies the encounter model directly.	Enables cross-validation of the tactical mitigation concept using heterogeneous implementation approaches.	Differences in implementation logic may introduce variability in the resulting KPIs and conflict resolution behaviours.
Assumption 19	Environmental relevance of Shannon geozone	The Shannon estuary geozone is considered relevant for the environmental KPA due to potential fauna presence associated with water areas. [21]	Introduces environmental considerations into the geozone model using a simplified implementation approach.	Environmental risk may be simplified compared to the detailed ecological dynamics represented in WP3.
Assumption 20	Static geozone implementation	Conditional and time-activated geozones are not implemented in the simulations.	Simplifies geozone implementation within the current simulation framework.	May underestimate the operational flexibility achievable through dynamic geozone management.

Table 48: validation exercise #02 assumptions overview

B.2 Deviation from the planned activities

Exercise #02 was not specified in sufficient level of detail at the time of ERP submission. At that stage, only a high-level concept of the exercise was available. The detailed specification was subsequently developed and refined based on Deliverable D4.2 *Final Barrier Characterisation* [9] and further consolidated through dedicated discussions in a WP5 workshop held in Naples (Italy) on 15/04/2026. All deviations are here reported in an organized manner: objectives and success criteria, KPA, reference and solution scenarios.

1. Objectives and Success Criteria

The following objectives are characterized by a deviation with respect to the ERP:

[21] The environmental constraint is modelled through a standard U-space geozone, while the detailed Air risk model illustrated in Deliverable D3.4 [12] accounts for species, seasonality, time of day, altitude, and bird movement corridors.

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OBJ-U-AGREE-ERP-001

Please refer to paragraph *Summary of validation objectives and success criteria.*

OBJ-U-AGREE-ERP-006

Please refer to paragraph *Summary of validation objectives and success criteria.*

2. Validation assumptions

Additional assumptions have been introduced and are described in paragraph B.1.4 *Summary of validation exercise #02 validation assumptions.*

3. Reference Scenario

Reference scenarios for exercise #02 coincide with #01 ones: it is assumed that no U-space services are provided within the sub-operating environments, and risk estimations are calculated using the final risk models. In this configuration, UAS operate freely alongside manned aircraft, without supervision or conflict detection and resolution. U-AGREE has identified, based on a risk-based classification, an expected traffic mix for each of these scenarios, distinguishing between operations below VLL and above VLL. These coincide with exercise #01 ones.

4. Solution Scenario

As previously said, the solution scenarios introduce advanced tactical mitigation barriers based on the Flight Authorisation Service, the Conformance Monitoring and the Tactical Conflict Prediction and Resolution Service, as defined in U-AGREE D4.2 [9].

The reference and solution scenarios considered in this assessment are structured as follows (Figure 3):

- **Reference scenario:** no U-space services are provided.
- **Solution scenario 1:** Flight Authorisation Service (FAS) + Tactical Conflict Prediction and Resolution Service (TCPRS).
- **Solution scenario 2:** Flight Authorisation Service (FAS), limited to geozones management.
- **Solution scenario 3:** Flight Authorisation Service (FAS) + Conformance Monitoring Service (CMS), limited to geozones management.

A detailed explanation of these services is here provided:

Flight Authorisation Service

Compared to exercise #01, FAS has been enhanced with advanced features, according to the Final Barriers Characterisation document [9] and will be defined from here on as Final FAS:

1. Dynamic Airspace Reconfiguration

The Dynamic Airspace Reconfiguration (DAR) functionality is assessed in a reduced portion of the Shannon–Limerick Area, representing a rural operational environment with a limited number of simultaneously active UAS flights. The selected area contains several airspace volumes that may become unavailable following a dynamic change in the airspace configuration, as shown in Figure 74.

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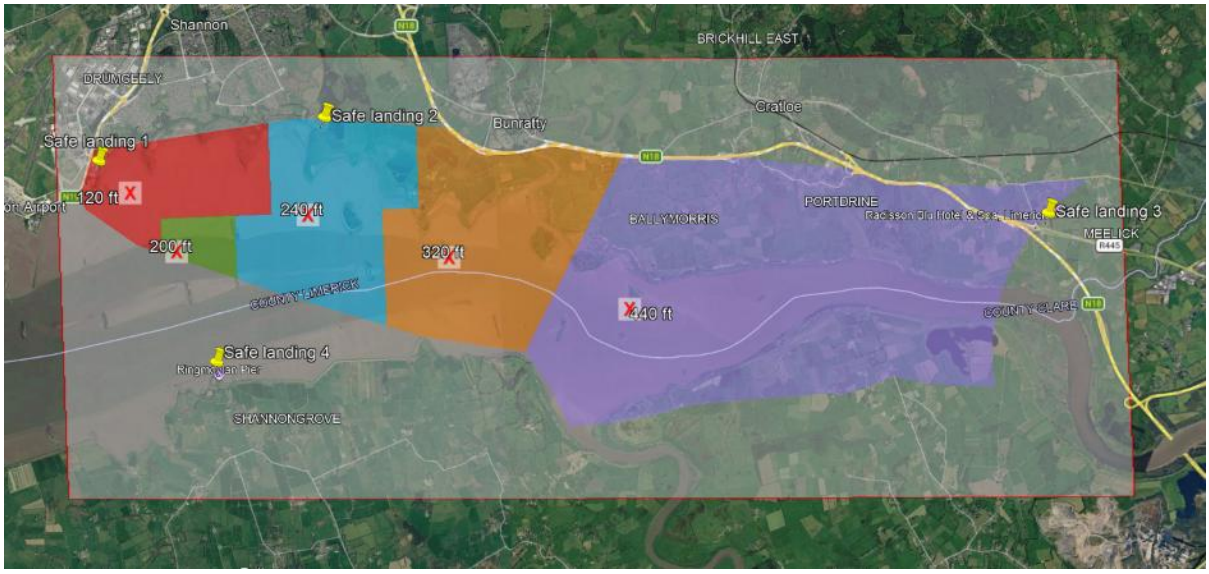


Figure 74: Reduced Shannon-Limerick U-space for the DAR zone

The DAR is applied in the coloured areas from Figure 74, and the pinned points represent the spots where the landing has been identified as safe. The scenario represents the activation of a DAR while several UAS flights are already in operation. At the time of activation, the airspace occupied by these flights becomes unavailable, and the affected UAS can no longer continue their planned missions. Consequently, the final Flight Authorisation Service manages their diversion towards the predefined safe landing locations.

The position of each UAS[22] at the instant of DAR activation is considered as the starting point for the diversion. Two alternative solutions are represented:

- **Uncoordinated operator diversion**, in which each operator is assumed to direct the affected UAS along a straight-line path from its position at the time of DAR activation to the nearest predefined safe-landing location. These paths are calculated independently, without considering the simultaneous diversions assigned to the other affected UAS. This represents the reference case without coordinated rerouting.
- **Coordinated rerouting**, in which the routes towards the safe landing locations are recalculated considering the simultaneous diversion of the affected flights, with the objective of avoiding conflicts between their trajectories.

The coordinated rerouting functionality is intended to support the safe and orderly diversion of multiple UAS following DAR activation, minimising interactions between the resulting trajectories and facilitating the safe termination of the affected operations.

2. Strategic Conflict Resolution

[22] Only UAS operating within the DAR-affected area at the time of activation are considered in the simulations. Active UAS outside this area are assumed either to continue their operations without entering the affected airspace or to perform a safe landing at a suitable location in their vicinity.

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In exercise #02, Strategic Conflict Resolution is implemented by UPV to provide an alternative trajectory to the operator when a conflict is detected. The Strategic Conflict Resolution (SCR) supports the resolution of conflicts identified during the strategic planning of UAS operations, and it is included as part of the advanced functions of the final FAS. When a submitted flight plan conflicts with previously authorised operations, the SCR searches for an alternative route that avoids the identified conflicts while preserving the intended operation whenever possible.

The resolution process considers the origin, destination and intermediate waypoints specified by the UAS operator. These intermediate waypoints are retained as constraints, and conflict resolution is therefore performed separately for each segment connecting two consecutive waypoints. If a mandatory waypoint is located within an unavailable or previously occupied area, an alternative route cannot be generated while preserving the submitted flight intent.

The resulting conflict-free alternative route is provided to the UAS operator for consideration as part of the flight authorisation process. For the purposes of the exercise, the operator is assumed to accept the proposed route, allowing the performance of the service to be evaluated.

3. Geozones

In exercise #02, geozones have been defined based on an analysis of sensitive areas within each scenario, addressing both the Security and Environment KPAs in ENGage simulator.

S1 For the city of Benidorm, in Spain, general UAS geozones have been established for the protection of facilities and infrastructure for public security reasons, categorised into four groups:

- health centers and hospitals (Figure 75),
- critical supplies: water treatment facility (Figure 76),
- transportation facilities: bus station and marina (Figure 77),
- police infrastructure (Figure 78).

Following the national regulation, these geozones are declared in a buffer of 10 meters around the external perimeter of the infrastructure with a height of 50 meters above the highest point of the infrastructure.

Additionally, an environmental geozone has been defined covering the Serra Gelada Natural Park (Figure 79).

S2 For the city of Manduria, in South of Italy, a geozone has been defined to protect areas of significant archaeological relevance, encompassing the *Mura Messapiche Archaeological Park* and the remains of *Messapic tombs* (Figure 80).

S3 For the Shannon-Limerick Area, an environmental geozone has been defined over the Shannon estuary, given its relevance for fauna presence associated with water areas (Figure 81).

It is noted that geozones are implemented as static structures in the simulation; conditional and time-activated geozones are not supported within the current simulation framework. This simplification may underestimate the operational flexibility achievable through dynamic geozone management.

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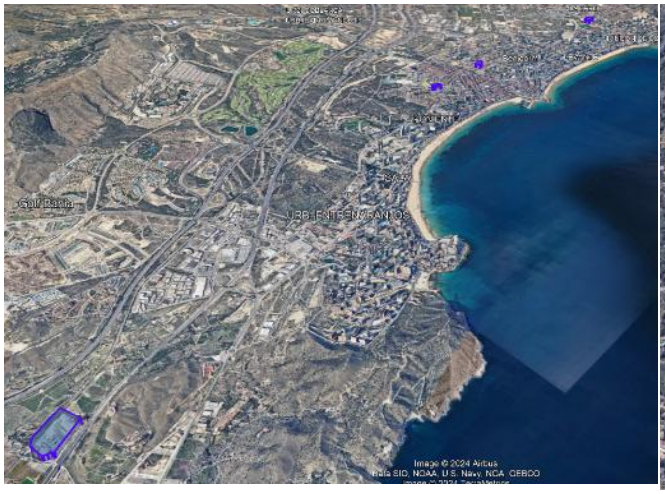


Figure 75: Benidorm - Medical facilities Geozones



Figure 76: Benidorm - Public service facility Geozone



Figure 77: Benidorm - Public transportation Facilities Geozones



Figure 78: Benidorm - Police related Geozones



Figure 79: Benidorm - General picture and Serra Gelada Natural Park (pink)

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Figure 80: Manduria – *Mura Messapiche* (archaeological site) Geozone

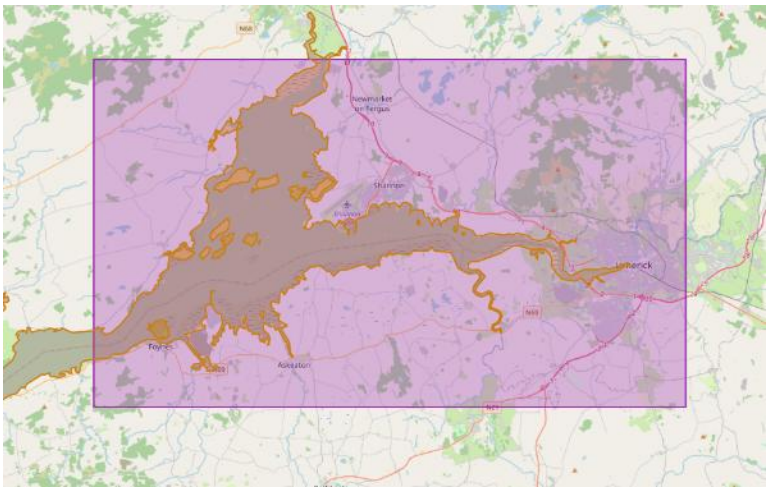


Figure 81: Shannon - Limerick - Estuary Geozone (in yellow) inside the operational volume (in purple)

Tactical Conflict Prediction and Resolution Service

The TCP&R service is modelled within a federated multi-USSP architecture, in which each provider operates independently while applying a harmonised conflict detection and resolution logic. This ensures that, given the same input conditions, all USSPs produce consistent and non-contradictory resolution outcomes, functionally equivalent to those of a centralised system. Inter-USSP information exchanges are assumed to remain compatible with tactical intervention time constraints, such that coordination latency does not degrade operational safety performance. Values of latency are provided in Table 48.

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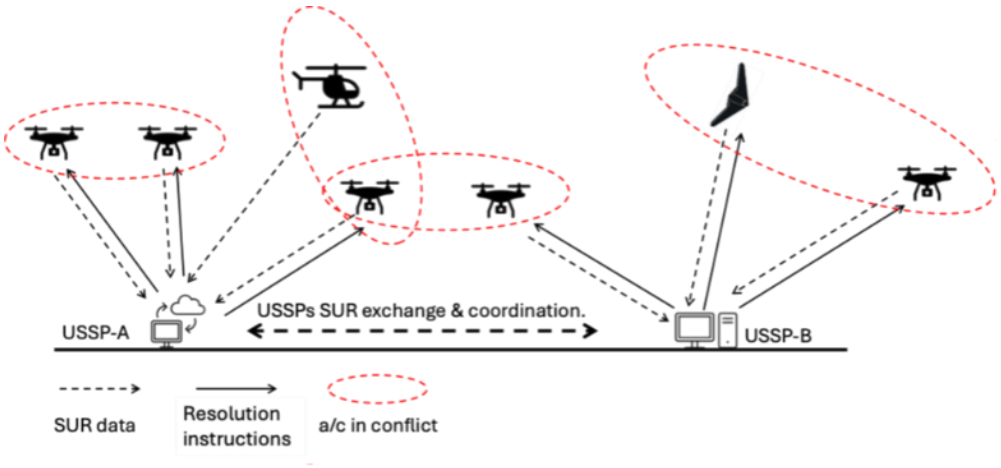


Figure 82: Tactical conflict detection and resolution architecture in the U-space [9]

The TCP&R process is implemented in different steps, illustrated in Figure 83:

Step 1: Potential conflicts among UAS are detected within the relevant encounter distance, with *priority assigned to the most imminent conflict*. During this step, the intents of surrounding UAS are assumed to remain unchanged for the purpose of computation.
Step 2: Flight intent information is retrieved from the relevant USSP for all vehicles involved in the detected conflict.
Step 3: A resolution manoeuvre is formulated in accordance with applicable priority rules (e.g., rules of the air) and aircraft-specific kinematic constraints (e.g. multirotor vs fixed-wing manoeuvrability).
Step 4: The manoeuvre is executed.

This is implemented through three alternative execution modes of the TCP&R functions, defined in Table 49.

Mode	Description	Response time
Full automation	All TCP&R functions are executed autonomously by the system, from conflict detection to resolution issuance, without any human intervention.	~1 s
Human on the loop	UAS operator must accept the maneuver implementation. The system executes the full process autonomously while the human operator monitors the operation and retains the ability to intervene and override the proposed resolution.	~3–5 s
Human in the loop	The system performs conflict detection and resolution formulation, but the resolution manoeuvre is executed directly by the human operator.	~25–30 s

Table 49: TCR&R service level of implementation

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The TCP&R service has been implemented in accordance with the characteristics of each simulation environment, using simulator-specific resolution algorithms.

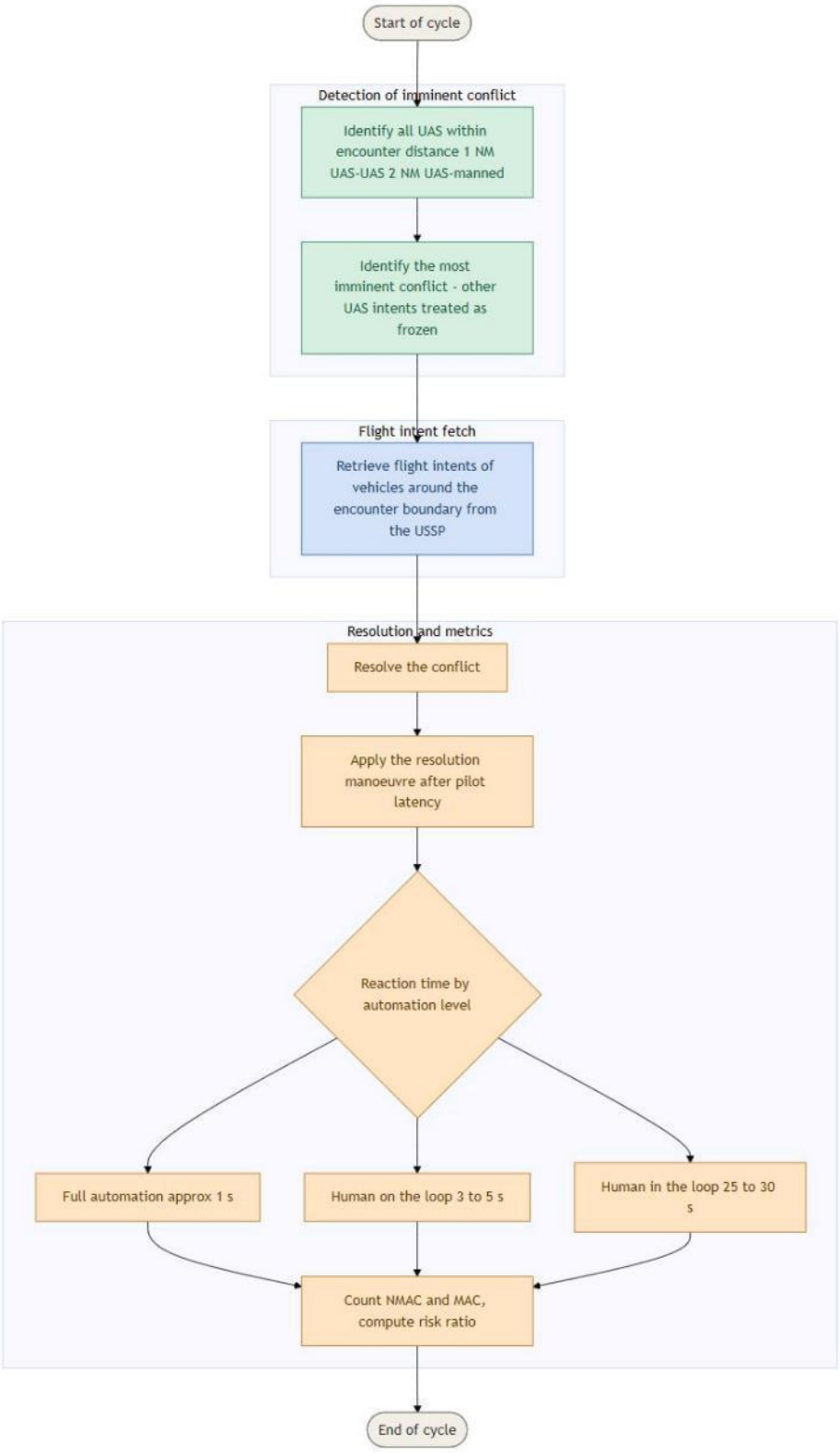


Figure 83: Tactical conflict prediction and resolution service steps

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ENGage TCP&R Implementation

The TCP&R service has been implemented in accordance with the characteristics of the ENGage simulation environment. The following steps have been adopted in ENGage simulator:

Step 1. Conflict detection

For each pair of trajectories, pairs in which both vehicles are manned are excluded from conflict processing as they are out of the scope of U-AGREE, as are pairs in which either UAS already has a pending manoeuvre, as a resolution is already in progress. For the remaining pairs, both vehicles are projected linearly forward over the forecast horizon H from their current 3D state (position and velocity vector). An analytical conflict check fires the trigger when the projected relative geometry comes within the per-pair tactical conflict distance taken from the vehicle catalogue — a tighter, per-vehicle threshold rather than a single global encounter distance. Unlike the reference flow, which assigns priority to the single most imminent conflict and treats the remaining intents as frozen, ENGage collects all triggered pairs in a single pass so that they can be resolved coherently together within the same cycle.

Step 2. Flight intent Retrieval

Flight intent information is retrieved locally for all vehicles involved in the detected conflicts. An affected space is constructed as the union of encounter circles centred on each conflict pair's midpoint (1 NM UAS–UAS, 2 NM UAS–manned). Every vehicle whose current position falls within this space contributes its planned flight intent, truncated to the waypoints whose time-of-arrival falls within the forecast window starting at the current simulation time and extending up to the forecast horizon H, and whose position is geometrically inside the affected space.

Step 3. Pre-authorisation

Retrieved intents are then subject to an explicit iterative pre-authorisation, First, all non-conflicting flight intents within the affected space are loaded into an authorised set — that is, a collection of trajectories that have been validated and can be used as a reference for subsequent conflict checks. Manned vehicles involved in conflict pairs are also included in this set, as manned aircraft are never required to replan.

Conflicting UAS are then processed one at a time, in descending priority order — Certified type #2 > Specific SAIL IV–V > SAIL III–IV > SAIL I–II > PDRA/STS > Open A3 > Open A2 > Open A1. When two UAS share the same priority level, the processing order is determined alphabetically by their unique identifier. For each UAS, the system checks whether its nominal flight intent is compatible with all trajectories already in the authorised set, applying the same spatial separation criteria used by the Flight Authorisation Service, with a separation buffer equal to the sum of the Total System Error and the Deviation Threshold. If the intent is compatible, it is added to the authorised set and the UAS retains its planned trajectory. If it is not compatible, the UAS is flagged for resolution in Step 4.

This sequential processing ensures that, when multiple conflicts share the same airspace, the trajectory of each lower-priority UAS is evaluated against the already-validated decisions of higher-priority ones, producing a globally consistent set of authorised intents.

Step 4. Resolution via *Rapidly exploring random tree (RRT)* Algorithm

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Rather than applying rules of the air as a deterministic kinematic correction, ENGage formulates resolution manoeuvres using RRT path planning. The algorithm seeks a conflict-free path whose goal is the first nominal waypoint outside the encounter circle, or the next nominal waypoint as fallback. Obstacles are the protected zone corridors constructed around each authorised flight intent — the same spatial buffers, equal to the sum of the Total System Error and the Deviation Threshold, used by the Flight Authorisation Service for its own conflict checks. If a valid path is found, **it replaces the UAS's nominal flight intent**, is **added to the authorised set** so that lower-priority UAS encounter it as **an obstacle** during their own resolution and is scheduled to be applied once the corresponding reaction latency has elapsed (step 5). If no valid path is found, the UAS continues along its original planned trajectory, and the conflict is re-evaluated at the following simulation cycle.

Step 5. Manoeuvre Execution

The resolution manoeuvre is not executed immediately upon formulation. Instead, it is applied after a reaction latency that reflects the time required for the pilot or system to respond, sampled from a statistical distribution parameterised per automation level, as defined in previous paragraphs. NMAC and MAC events are accumulated over the simulation horizon with and without TCP&R active, and used to compute the Risk Ratio, to understand the effectiveness of this barrier.

CRA TCP&R Implementation

Cranfield University's TCP&R service follows similar steps, but differs in the manoeuvre computation algorithm implemented based on [32]. For each UAS, lines of sight to the other UAS are compensated by their relative velocities to calculate the collision cones. For the UAS sharing their flight intent, the collision cone is compensated not by its current relative velocity, but the intended heading to the next waypoint. Bearing angles to geofences are also calculated at this step to avoid not only the other UAS but also to avoid geofence infringements. The conflict is detected if the current heading angle falls within any of the collision cones, where each collision cone is enlarged from deviation threshold by the scale of sensor and environment uncertainties captured as TSE, to ensure safe separation. If the conflict is detected, all the collision cones are unified to calculate the smallest lateral deviation angle change to avoid the conflict with all possible aircraft. Unlike rules of the air any direction that is minimising the deviation is chosen, but it is fixed to one per each conflict event. The manoeuvre is calculated from the differential geometry algorithm, to ensure asymptotic stability to the desired separation in time. The waypoints created by the manoeuvre are replaced as new flight intent. The conflict detection and resolution are conducted at every timestep until the conflict is resolved.

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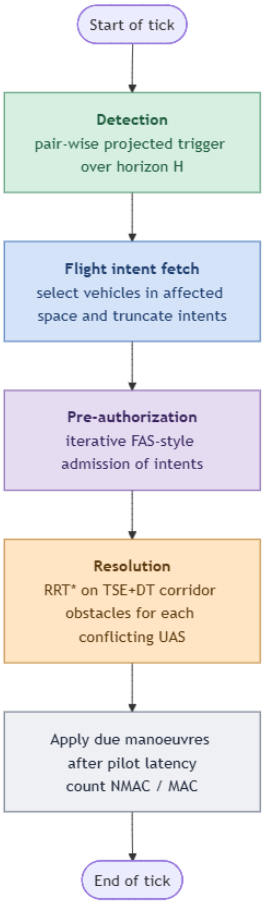


Figure 84: ENGage TCP&R Implementation

UPV TCP&R Implementation

The UPV campaign evaluates pairwise encounters with a cylindrical conflict predictor and a constant-velocity look-ahead. A conflict must persist for three consecutive one-second detections and be approaching before it is passed to the resolution logic. The final resolver uses the CPA/velocity-obstacle heading search with aircraft kinematic limits and return-to-track enabled. Detection and scoring use the three-dimensional state, while the commanded avoidance manoeuvre is a horizontal heading change.

The final post-processing explicitly separates UAS–UAS and UAS–manned encounters. For UAS–UAS, all combinations among the eleven UAS classes are retained. For UAS–manned, both matrix directions between the eleven UAS classes and Manned VFR are retained. In each branch, the original scenario traffic weights are masked to the selected family and renormalised to one before RR, LR, Pfa and alert rate are aggregated. Each encounter family therefore has its own paired baseline and its own final RR.

The response assumptions used in the executed campaign are shown in Figure 85. Autonomous response follows Gamma($k = 9$, $\theta = 1/3$), with mean 3 s and standard deviation 1 s. RPAS response follows Gamma($k = 4$, $\theta = 1$) plus a 3 s minimum shift, with mean 7 s. The definitive reporting baseline

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uses the autonomous family; RPAS remains a sensitivity case for the effect of human-mediated response.

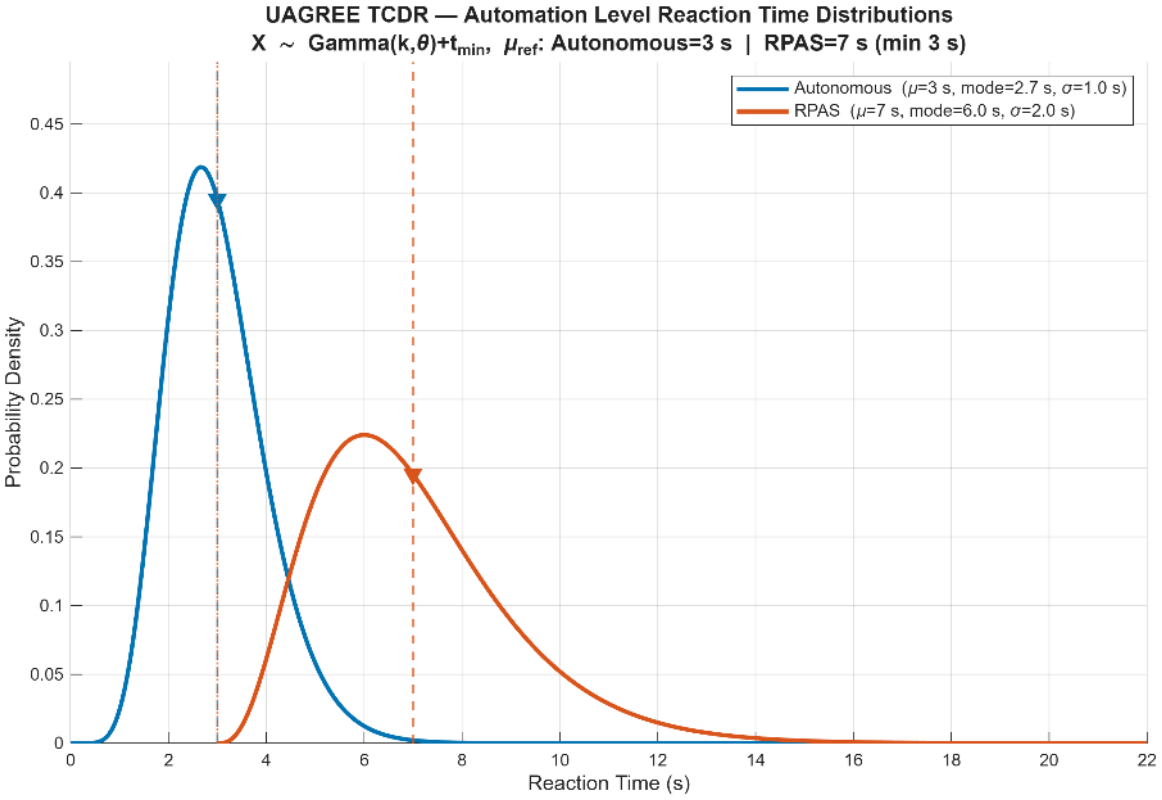


Figure 85: Automation-level reaction-time distributions used in the definitive UPV TCP&R campaign.

Communication latency, surveillance delay and reaction time remain separate model stages, as illustrated in Figure 86. The nominal single-USSP case uses GNSS bounds of 1.87 m horizontally and 3.16 m vertically, 1.1 s latency parameters for both aircraft and 2% packet loss for both links. Multi-USSP and degraded cases vary these parameters without changing the tactical algorithm.

The final UPV TCP&R results are reported using a single, reproducible baseline configuration. Results are presented separately for UAS–UAS and UAS–manned encounters, rather than being blended into one overall Risk Ratio (RR), because both families involve different NMAC dimensions and different operational responsibilities. In each case, the corresponding traffic weights are masked to the selected encounter family and renormalised before the scenario-weighted metrics are computed. This approach is applied consistently across the Benidorm, Scenario 2 / Manduria and Shannon traffic mixes, both below and above VLL. In the source post-processing, the CORUS label is used as the representative Scenario 2 / Manduria mix.

The baseline configuration corresponds to the definitive automated TCP&R case. It uses the autonomous response model, with a gamma response time distribution of mean 3 s and standard deviation 1 s, together with the Base, Unique-USSP CNS architecture. This CNS case uses GNSS errors of 1.87 m / 3.16 m, latency of 1.1 s / 1.1 s, and packet loss of 2% / 2%. The look-ahead time is fixed at 45 s, the longest executed detection horizon, and the full U-AGREE separation minima are retained by setting SFH = 1 and SFV = 1. The reference case also assumes MF = 0, RT = [0, 0] and CP = [0, 0], so that commanded manoeuvres are executed and the encounters remain rectilinear and level. This avoids confounding the reported RR/LR values with manoeuvre failures or stochastic trajectory perturbations.

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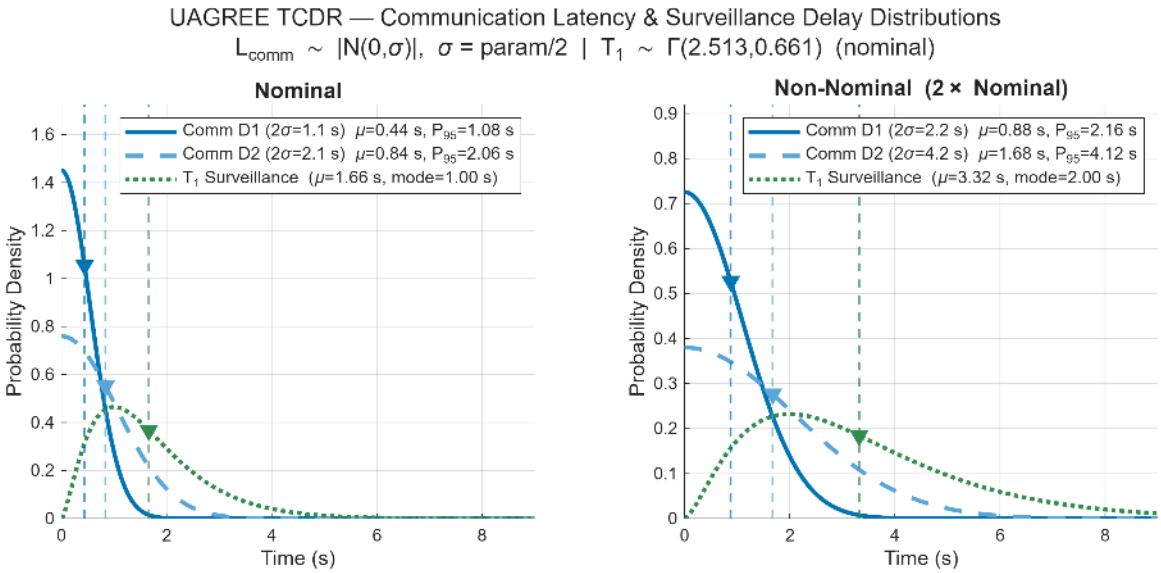


Figure 86: Communication-latency and surveillance-delay distributions used in the definitive UPV TCP&R campaign.

The resolution method is the algorithm, based on a CPA / velocity-obstacle horizontal heading search, which is the resolver executed in the definitive campaign. The RR is computed against the paired unmitigated branch, meaning that the same sampled encounter is evaluated with TCP&R enabled and disabled. This controls the encounter geometry and stochastic exposure in the numerator and denominator.

Parameter degradations are therefore not mixed into the final quoted RR. Multi-USSP, degraded CNS, manoeuvre failure and trajectory perturbation cases are retained as controlled sensitivity evidence. The values placed in the final TCP&R result tables are also multiplied by the same consortium-agreed factor of 2 used for TIS. This adjustment is applied to the scenario-specific RR obtained from the selected baseline and is already included in the values used by the final calculations. It conservatively limits the mitigation credit transferred from a conflict-rich simulation setting to the final reported scenario-level TCP&R results.

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B.3 Validation exercise #02 results - ENGage

B.3.1 Summary of validation exercise #02 results

Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
OBJ-SOL0520-ERP-001	Identification of the baseline capacity (N_0).[23]	CRT-SOL0520-TRL2-ERP-001.002	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 1, for exercise #01 and #02.	Scenario 1: The city of Benidorm (non U-space sub-OE)	The number of concurrent UAS compatible with the required TLS has been calculated. At any tested density, including the minimum simulated concurrency (N = 2). This underlines the necessity to include U-space services in this scenario to obtain the required TLS.	OK
		CRT-SOL0520-TRL2-ERP-001.004	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 2, for	Scenario 2: The city of Manduria (non U-space sub-OE)		OK

[23] Only success criteria related to exercise 2 are reported here.

Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
			exercise #01 and #02.			
		CRT-SOL0520-TRL2-ERP-001.006	The MAC frequency between UAS and manned aircraft in uncontrolled airspace shall not exceed 10^{-7} per flight-hour in Scenario 3, for exercise #01 and #02.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)		OK
		CRT-SOL0520-TRL2-ERP-001.007	The MAC frequency between UAS and manned aircraft in controlled airspace shall not exceed 10^{-9} per flight-hour in Scenario 3, for exercise #01 and #02.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)		OK
		CRT-SOL0520-TRL2-ERP-001.008	The MAC frequency between UAS shall not exceed 1.41×10^{-4} per flight-hour in	Scenario 1: The city of Benidorm (non U-space sub-OE)		OK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
			Scenario 1, for exercise #02.			
		CRT-SOL0520-TRL2-ERP-001.009	The MAC frequency between UAS shall not exceed 1.29×10^{-4} per flight-hour in Scenario 2, for exercise #02.	Scenario 2: The city of Manduria (non U-space sub-OE)		OK
		CRT-SOL0520-TRL2-ERP-001.010	The MAC frequency between UAS shall not exceed 6.25×10^{-3} per flight hour in Scenario 3, for exercise #02.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)		OK
OBJ-SOL0520-ERP-005	Quantification of the capacity increment (ΔN_4) because of the introduction of mitigation measures based on Final FAS and adding a Tactical Conflict	CRT-SOL0520-TRL2-ERP-005.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 1: The city of Benidorm (non U-space sub-OE)	No capacity increment with respect to baseline is observed ($\Delta N_4 = 0$) for both FAS and tactical services.	Partially OK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
	Prediction and Resolution services.	CRT-SOL0520-TRL2-ERP-005.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 2: The city of Manduria (non U-space sub-OE)	No capacity increment with respect to baseline is observed ($\Delta N_4 = 0$) for both FAS and tactical services.	Partially OK
		CRT-SOL0520-TRL2-ERP-005.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	No capacity increment with respect to baseline is observed ($\Delta N_4 = 0$) for both FAS and tactical services.	Partially OK
OBJ-SOL0520-ERP-006	Quantification of baseline geographical zone infringements per flight-hour ($Ninf_0$).	CRT-SOL0520-TRL2-ERP-006.001	The geographical zones in Scenario 1 shall be defined such that, during the baseline run, at least one infringement of	Scenario 1: The city of Benidorm (non U-space sub-OE)	Geozones have not been included in this scenario.	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
			a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.			
		CRT-SOL0520-TRL2-ERP-006.002	The geographical zones in Scenario 2 shall be defined such that, during the baseline run, at least one infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.	Scenario 2: The city of Manduria (non U-space sub-OE)	The geozones introduced in the scenario generate a sufficiently high number of infringements, providing the baseline conditions required for the evaluation of the subsequent objectives. The number of geozones infringements is $Ninf_0$ = 0.803 /fh across UAS density.	OK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
		CRT-SOL0520-TRL2-ERP-006.003	The geographical zones in Scenario 3 shall be defined such that, during the baseline run, at least one infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	The geozones introduced in the scenario generate a sufficiently high number of infringements, providing the baseline conditions required for the evaluation of the subsequent objectives. The number of geozones infringements is $Ninf_0 \in [0.45, 1.11]$ /fh across UAS density.	OK
OBJ-SOL0520-ERP-007	Quantification of the variation in geographical zone infringements per flight-hour ($\Delta Ninf_1$) due to the	CRT-SOL0520-TRL2-ERP-007.001	The total number of geographical zones infringements varies compared to the baseline in scenario 1.	Scenario 1: The city of Benidorm (non U-space sub-OE)	Geozones have not been included in this scenario.	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
	implementation of mitigation measures based on Flight Authorisation service.	CRT-SOL0520-TRL2-ERP-007.002	The total number of geographical zones infringements varies compared to the baseline in scenario 2.	Scenario 2: The city of Manduria (non U-space sub-OE)	$\Delta Ninf_1$ of −0.803/fh (−100%) across UAS density and DT values.	OK
		CRT-SOL0520TRL2-ERP-007.003	The total number of geographical zones infringements varies compared to the baseline in scenario 3.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	$\Delta Ninf_1$ of −0.911/fh (−100%) across UAS density and DT values.	OK
OBJ-SOL0520-ERP-008	Quantification of the variation in geographical zone infringements per flight-hour ($\Delta Ninf_2$) due to the implementation of mitigation measures based on Conformance Monitoring service.	CRT-SOL0520-TRL2-ERP-008.001	The total number of geographical zones infringements varies compared to the baseline in scenario 1.	Scenario 1: The city of Benidorm (non U-space sub-OE)	Geozones have not been included in this scenario.	NOK
		CRT-SOL0520-TRL2-ERP-008.002	The total number of geographical zones infringements varies compared to the baseline in scenario 2.	Scenario 2: The city of Manduria (non U-space sub-OE)	0 infringements/fh across density, providing $\Delta Ninf_2$=$\Delta Ninf_1$.	OK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
		CRT-SOL0520-TRL2-ERP-008.003	The total number of geographical zones infringements varies compared to the baseline in scenario 3.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	0 infringements/fh across density, providing $\Delta Ninf_2$=$\Delta Ninf_1$.	OK
OBJ-SOL0520-ERP-009	Quantification of the impact of fauna on air risk.	CRT-SOL0520-TRL2-ERP-009.001	The TLS defined for scenario 1 is maintained.	Scenario 1: The city of Benidorm (non U-space sub-OE)	Geozones have not been included in this scenario.	NOK
		CRT-SOL0520-TRL2-ERP-009.002	The TLS defined for scenario 2 is maintained.	Scenario 2: The city of Manduria (non U-space sub-OE)	Geozone included in this scenario is not compatible with fauna-related risks.	NOK
		CRT-SOL0520-TRL2-ERP-009.003	The TLS defined for scenario 3 is maintained.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	0 infringements/fh at every DT tested.	OK

Table 50: validation exercise #02 results - ENGage

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B.3.2 Analysis of validation exercise #02 results per validation objective

Exercise #02 builds on the exercise #01 (Batch 1) configuration by adding elements outside the strict Regulation (EU) 2021/664 mandate: manned flight-plan awareness (the FAS additionally deconflicts UAS candidates against declared manned corridors at the same deviation threshold), geozone enforcement (candidate corridors must also stay clear of a designated no-fly zone), and tactical conflict resolution on top of the strategic FAS layer, evaluated at three automation levels (full-automatic, human-on-the-loop, human-in-the-loop). The UAS–UAS safety target is revised for exercise #02 according to the new safety criteria that take into account the final risk models.

B.3.2.1. OBJ-SOL0520-ERP-001 Results

This objective reports the same unmitigated traffic baseline used throughout exercise #01 — no U-space services — now compared against the exercise #02 success criteria.

Scenario 1: The city of Benidorm (non U-space sub-OE)

UAS–UAS NMAC/fh grows almost linearly with density, exceedingly even the loosened TLS already at the minimum tested density (N_o=1); UAS–manned NMAC/fh follows the same law and remains many orders of magnitude above the TLS.

KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	UAS–UAS NMAC/fh grows almost linearly with density, exceeding TLS already at N = 2. UAS–manned follows the same law, exceeding the required TLS.
Capacity	U-AGREE-KPI-03 **Area drone density**	**N_o=1** against the defined TLS.

Table 51: KPIs for OBJ-SOL0520-ERP-001 Benidorm, exercise 2

Scenario 2: The city of Manduria (non U-space sub-OE)

The baseline behaves as in exercise #01: UAS–UAS NMAC/fh exceeds the TLS already at the lowest tested density; the same applies to UAS–manned NMAC/fh.

KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	UAS–UAS NMAC/fh grows almost linearly with density, exceeding TLS already at N = 2. UAS–manned follows the same law, exceeding the required TLS.
Capacity	U-AGREE-KPI-03 **Area drone density**	**N_o=1** against the defined TLS.

Table 52: KPIs for OBJ-SOL0520-ERP-001 Manduria, exercise 2

Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)

Under the exercise #02 target TLS, the baseline's capacity is unchanged from exercise #01, confirming the unmitigated baseline cannot sustain meaningful concurrent traffic under either exercise's target.

KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	UAS–UAS NMAC/fh grows almost linearly with density, exceeding TLS already at N = 2. UAS–manned follows the same law, exceeding the required TLS.
Capacity	U-AGREE-KPI-03 **Area drone density**	**N_o=1** against the defined TLS.

Table 53: KPIs for OBJ-SOL0520-ERP-001 Shannon Limerick, exercise 2

B.3.2.2. OBJ-SOL0520-ERP-005 Results

This objective reports the two mitigation layers introduced beyond the baseline that this exercise can attribute a capacity increment to: manned-aware Flight Authorisation and Tactical Conflict Prediction and Resolution on top of the FAS .

Scenario 1: The city of Benidorm (non U-space sub-OE)

The Flight Authorisation Service additionally deconflicts UAS candidates against declared manned corridors. As shown in Figure 88, UAS–manned NMAC/fh falls from the manned-blind baseline of 0.474/fh to 0.207/fh at DT0 (−56%), continuing to fall with DT to 0.00044/fh at DT64— manned awareness cuts UAS–manned NMACs roughly 2.3× already at DT0 and drives them toward the detection floor by DT64. Even this near-zero residual rate corresponds to a measurable minimum on the order of 3.7×10^{-5}/fh — still around three orders of magnitude above the 10^{-7}/fh target, so the UAS–manned criterion remains an exposure limitation rather than a demonstrated compliance. Capacity is therefore **not increased**.

No Tactical Conflict Prediction and Resolution campaign was run for Benidorm. The objective cannot be evaluated for this scenario.

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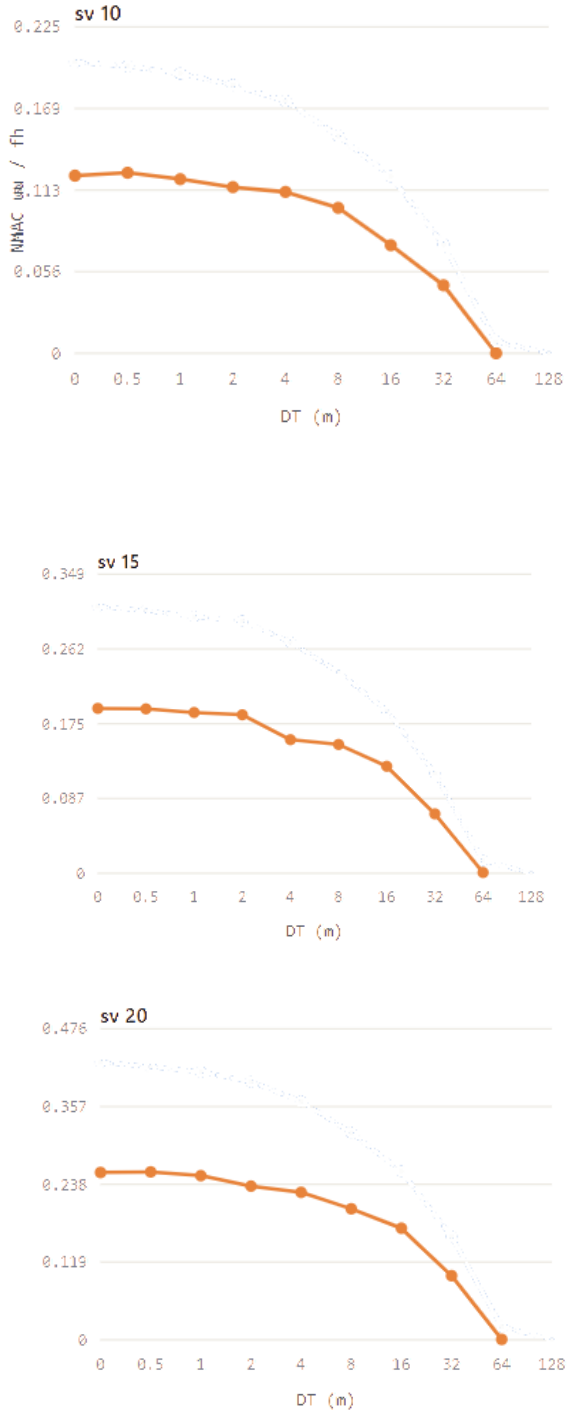


Figure 87: NMAC/fh vs DT in Benidorm with manned aircrafts deconflicted

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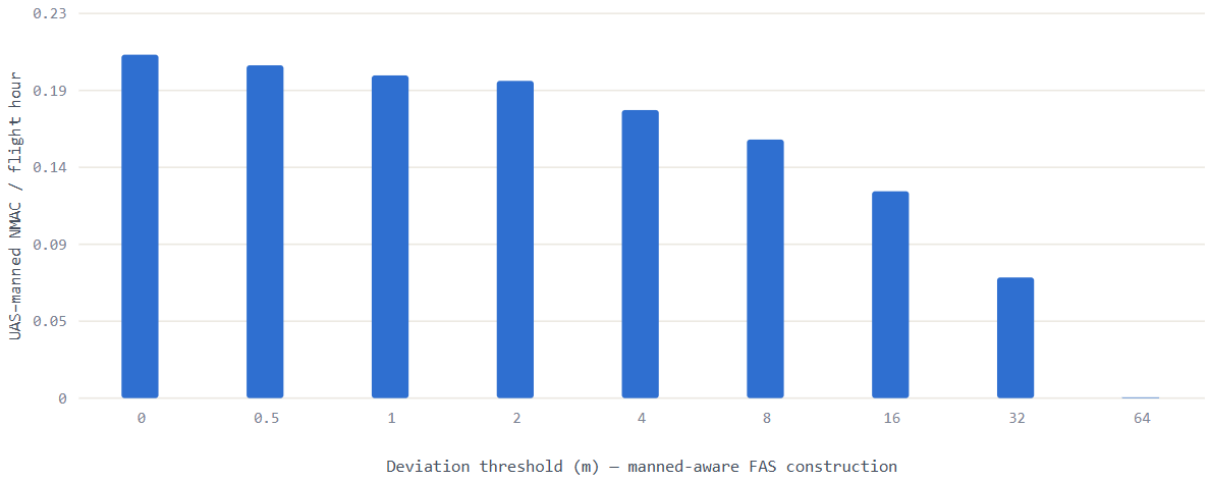


Figure 88: UAS–manned NMAC/fh vs DT — manned-aware FAS vs manned-blind references

KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	UAS–manned NMAC/fh falls to 0 with increasing DT.
Capacity	U-AGREE-KPI-03 **Area drone density**	**N_o=1** against the defined TLS.

Table 54: KPIs for OBJ-SOL0520-ERP-005 Benidorm, exercise 2

Scenario 2: The city of Manduria (non U-space sub-OE)

UAS–manned NMAC/fh falls from the baseline 0.291/fh to 0.018/fh at DT4 (−94%) and 0.012/fh at DT16 (−96%), reaching exactly zero residual events at DT64 and DT128. As in Benidorm, these near-zero counts represent a measurable floor on the order of 10^{-4}/fh at best — still far above the 10^{-7}/fh target, so the capacity increase compatible with TLS is still **not found**.

FAS therefore proves once again to be necessary to reduce the NMAC/fh between UAS-UAS and UAS-manned but the strict TLS for the scenario does not allow the capacity to increase.

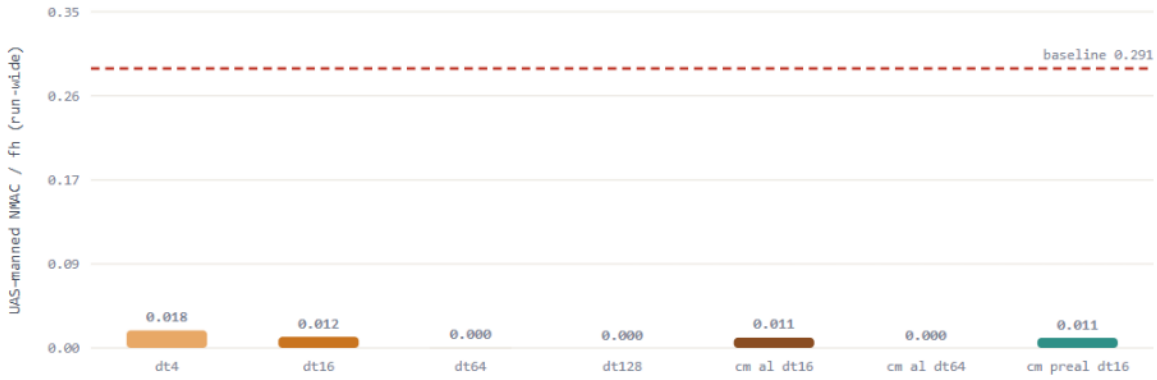


Figure 89: NMAC/fh vs DT in Manduria with manned aircrafts deconflicted

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Six tactical automation variants (full-automatic, human-on-the-loop, human-in-the-loop, each at DT16 and DT64) were executed.

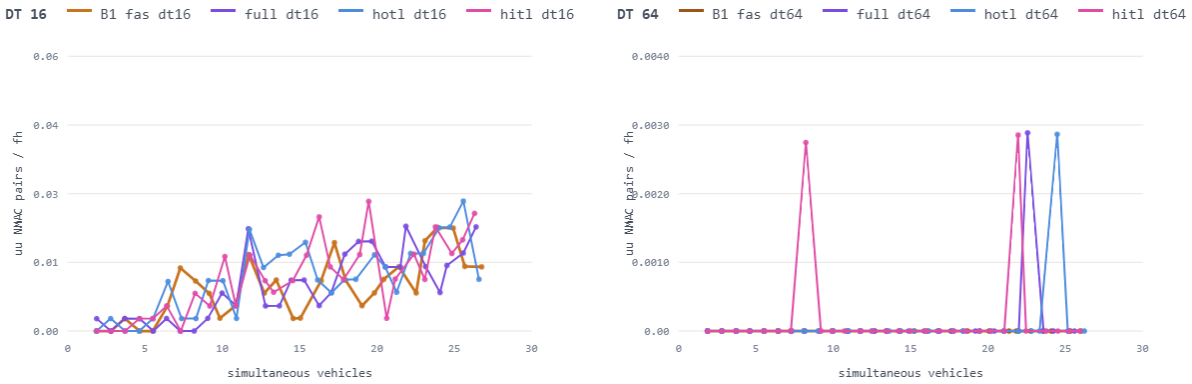


Figure 90: NMAC/fh vs simultaneous vehicles in Manduria with TCPR

All tactical configurations remain comparable to the plain FAS case within the simulation variability at both DT16 and DT64. Under the modelled reaction delays, **tactical resolution does not provide a measurable additional reduction of UAS–UAS residual risk**.

In absolute terms, the modelled NMAC-constrained capacity gain with respect to baseline due to tactical services at DT64 is substantial:

	FULL	HOTL	HITL
DT64	$\Delta N_4 = 12$	$\Delta N_4 = 12$	$\Delta N_4 = 12$

But these values are derived from a single observed near-miss event and are therefore **single-event slope estimates, not robust fitted trends**. At this TLS, one or two NMAC events falls within expected statistical noise, so these absolute capacity gains **should not be reported as reliably measured**. They are retained as indicative bounds only, pending additional replicates or extended exposure. Therefore, a capacity gain of 0 is reported.

KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	UAS–manned NMAC/fh (run-wide) falls from baseline 0.291 to 0.018 at DT4 (−94%), 0.012 at DT16 (−96%), 0 at DT64/DT128. Tactical: all three modes (full/HOTL/HITL, DT16 and DT64) All tactical configurations show results comparable to the Batch-1 FAS case, with no measurable increment attributable to tactical resolution.
Capacity	U-AGREE-KPI-03 **Area drone density**	No capacity increment with respect to baseline is observed ($\Delta N_4 = 0$) for both FAS and tactical services.

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		Compatibly, we have: ≈ 0.002 UAS/km² for Tactical Full DT16 ≈ 0.002 UAS/km² for Tactical Hotl DT16 ≈ 0.002 UAS/km² for Tactical Hitl DT16. ≈ 0.030 UAS/km² for Tactical Full DT64 ≈ 0.028 UAS/km² for Tactical Hotl DT64 ≈ 0.024 UAS/km² for Tactical Hitl DT64.

Table 55: KPIs for OBJ-SOL0520-ERP-005 Manduria, exercise 2

Variant	RR for sv=5	RR for sv=10	RR for sv=15	RR for sv=20	RR for sv=25	Mean RR
DT 4	0.027	0.024	0.019	0.025	0.022	0.023
DT 16	0.0030	0.012	0.012	0.010	0.012	0.0099
DT 64	0	0.0008	0.0005	0.0003	0	0.0003
DT128	0	0	0	0	0	0
tactical full DT16	0.0045	0.012	0.0077	0.013	0.0086	0.0090
tactical hotl DT16	0.010	0.015	0.014	0.0094	0.011	0.012
tactical hitl DT16	0.0060	0.016	0.014	0.010	0.011	0.011
tactical full DT64	0	0	0	0	0.0003	0.0001
tactical hotl DT64	0	0	0	0	0.0003	0.0001
tactical hitl DT64	0	0.0008	0	0.0003	0	0.0002

Table 56: Risk Ratios for FAS and TCPR - Manduria

Table 56: Risk Ratios for FAS and TCPR - Manduria shows that as DT widens, mean RR falls sharply, from 0.023 (DT4) to 0 (DT128): a wider corridor makes the FAS reject a larger share of conflicting flight-plan placements, leaving progressively **less residual risk**, with UAS–UAS MAC remaining zero throughout.

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The tactical full/HOTL/HITL rows add a tactical resolution layer on top of DT16 and DT64. At DT16, RR for all three automation levels (0.009–0.012) sits within the same range as the plain FAS reference (0.010), with the observed spread falling within cycle noise rather than reflecting a genuine automation-level effect. At DT64, both the FAS-only baseline and all three tactical configurations sit at or below the detection floor (0–2 residual events over ~10,300 flight hours), too sparse to distinguish. Given the modelled reaction delays, **tactical resolution therefore adds no measurable risk reduction beyond strategic deconfliction at either threshold, and no distinct capacity or safety benefit can be attributed to the tactical layer from this data**.

Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)

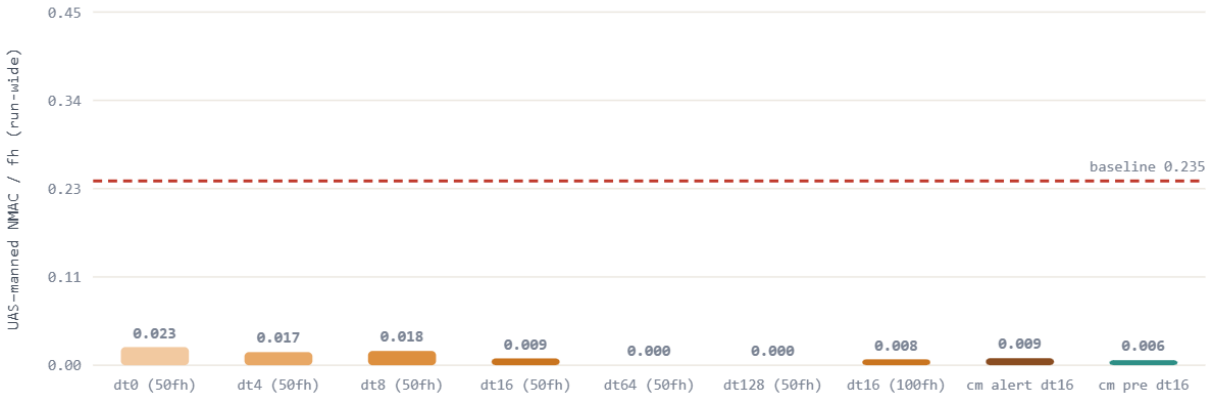


Figure 91: NMAC/fh vs DT in Shannon-Limerick with manned aircrafts deconflicted

Under the manned-aware Batch-2 FAS, UAS–manned NMAC/fh falls from the 0.235/fh baseline to 0.023/fh at DT0 and 0.009/fh at DT16, reaching exactly zero events at DT64 and DT128. As in the other scenarios, this NMAC/fh values are not compatible with desired TLS so no capacity gain is obtained.

Tactical deconfliction (full-automatic, human-on-the-loop, human-in-the-loop), with a forecast horizon of 20 seconds and mode-specific default reaction delays, was evaluated on top of the FAS at DT16 and DT64. All three automation levels track plain FAS within cycle noise at both thresholds: **tactical resolution adds no measurable residual-NMAC margin beyond what strategic separation already buys**, and MAC stays at zero throughout.

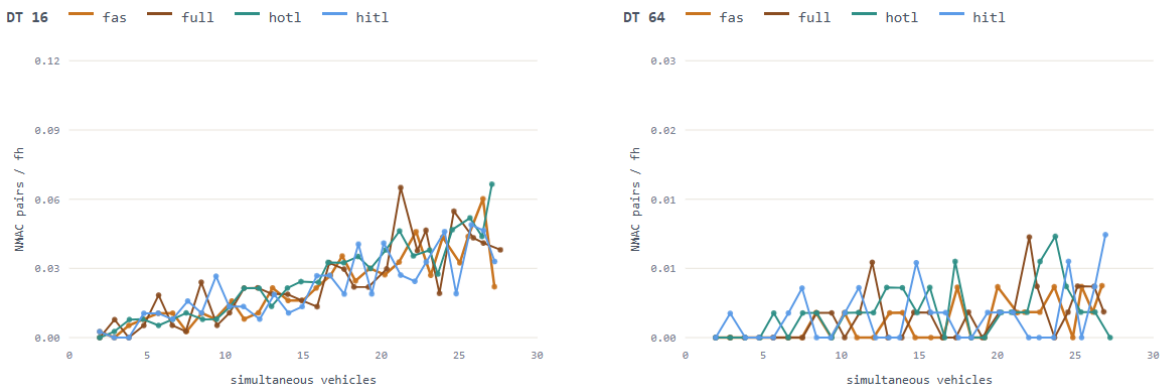


Figure 92: NMAC/fh vs simultaneous vehicles in Shannon-Limerick with TCPR

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KPA	KPI	Value obtained
Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	FAS (manned-aware) substantially reduces UAS–manned risk, with the largest improvement achieved at the widest deviation thresholds. Tactical configurations remain comparable to FAS within simulation variability, with no measurable additional benefit attributable to tactical resolution. UAS–UAS MAC remains zero throughout.
Capacity	U-AGREE-KPI-03 Area drone density	No capacity increment with respect to baseline is observed $(\Delta N_4 = 0)$ for both FAS and tactical services. Compatibly, we have: ≈ 0.006 UAS/km² for Tactical Full DT16 ≈ 0.006 UAS/km² for Tactical Hotl DT16 ≈ 0.006 UAS/km² for Tactical Hitl DT16. ≈ 0.033 UAS/km² for Tactical Full DT64 ≈ 0.033 UAS/km² for Tactical Hotl DT64 ≈ 0.033 UAS/km² for Tactical Hitl DT64.

Table 57: KPIs for OBJ-SOL0520-ERP-005 Shannon Limerick, exercise 2

Calculated risk ratios are:

Variant	RR @sv10	@sv20	@sv25	RR mean
DT0	0.132	0.095	0.086	0.104
DT4	0.104	0.016	0.071	0.064
DT8	0.029	0.047	0.046	0.041
DT16	0.027	0.046	0.036	0.036
DT64	0.0074	0.0033	0	0.0036
DT128	0	0	0	0
tactical full DT16	0.036	0.031	0.028	0.032
tactical hotl DT16	0.032	0.033	0.032	0.032
tactical hitl DT16	0.032	0.026	0.026	0.028

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tactical full DT64	0.0059	0.0035	0.0026	0.0040
tactical hotl DT64	0.0049	0.0015	0.0035	0.0033
tactical hitl DT64	0.0035	0.0012	0.0029	0.0025

Figure 93: Table 14: Risk Ratios for FAS and TCPR – Shannon Limerick

The DT ladder confirms the expected behaviour: increasing the deviation threshold progressively reduces UAS–UAS residual risk. For the tactical configurations, UAS–UAS risk remains comparable to the FAS configurations. As a result, **trajectory modifications intended to resolve UAS conflicts could occasionally lead to trajectories closer to manned-aircraft paths**.

B.3.2.3. OBJ-SOL0520-ERP-006 Results

Scenario 1: The city of Benidorm (non U-space sub-OE)

This objective is not fulfilled for Benidorm, since simulations were not conducted with geozones implemented.

Scenario 2: The city of Manduria (non U-space sub-OE)

The *Mura Messapiche park* is enforced as no-fly zone, as defined in paragraph B.2. Over the unmitigated 100 fh run, UAS traffic crosses into this zone at a run-wide rate of $Ninf_0$ = 0.803 infringements per flight hour, essentially flat with UAS density.

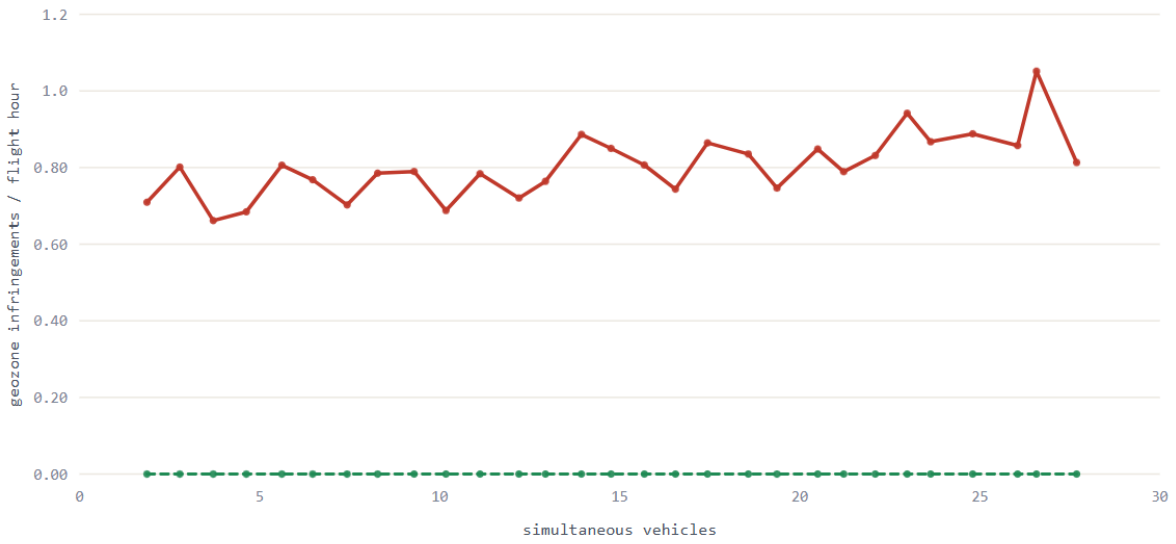


Figure 94: Geozones infringements per flight-hour, Manduria

KPA	KPI	Value obtained
Security,	U-AGREE-KPI-06 —	$Ninf_0$= 0.803 /fh across UAS density.

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Environment	**Number of geozones infringement/FH**	

Table 58: KPIs for OBJ-SOL0520-ERP-006 Manduria, exercise 2

Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)

The Shannon Estuary Special Protection Area is enforced as a no-fly zone, as defined in paragraph B.2. Over the unmitigated baseline run, UAS traffic crosses into the estuary NFZ at a run-wide rate of $Ninf_0$ =0.911 infringements per flight hour, rising from $Ninf_0$= 0.45/fh at low density to $Ninf_0$= 1.11/fh at the highest tested UAS density.

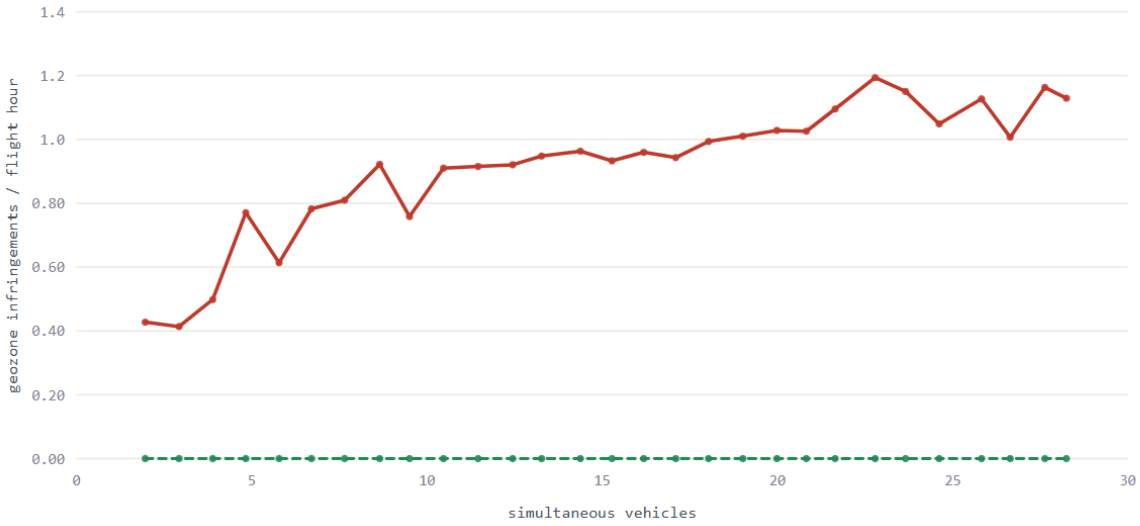


Figure 95: Geozones infringements per flight-hour, Shannon Limerick

KPA	KPI	Value obtained
Security, Environment	U-AGREE-KPI-06 — **Number of geozones infringement/FH**	$\mathrm{Ninf}_0 \in [0.45, 1.11]$ /fh across UAS density.

Table 59: KPIs for OBJ-SOL0520-ERP-006 Shannon Limerick, exercise 2

B.3.2.4. OBJ-SOL0520-ERP-007 Results

Scenario 1: The city of Benidorm (non U-space sub-OE)

Not applicable: no NFZ in this scenario implemented in ENGage simulator.

Scenario 2: The city of Manduria (non U-space sub-OE)

Activating the geozone-enforcing Flight Authorisation Service removes the geozone infringements entirely: at every deviation threshold (DT4, DT16, DT64, DT128) the infringement rate falls from 0.803/fh to exactly 0/fh — a uniform $\Delta Ninf_1$ of −0.803/fh (−100%).

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The additional geozone and manned-aircraft constraints make the available airspace more restrictive for UAS operations. Consequently, **a smaller proportion of candidate flight plans can be authorised compared with the exercise 1 configuration**.

Figure 96 shows the difference in the percentage of authorised U-plans between Exercises 1 and 2. This difference results from the broader set of constraints considered in Exercise 2: while Exercise 1 accounts only for UAS–UAS deconfliction, Exercise 2 also considers manned-aircraft traffic and no-fly zones, resulting in a more constrained operational airspace and a lower authorisation rate.

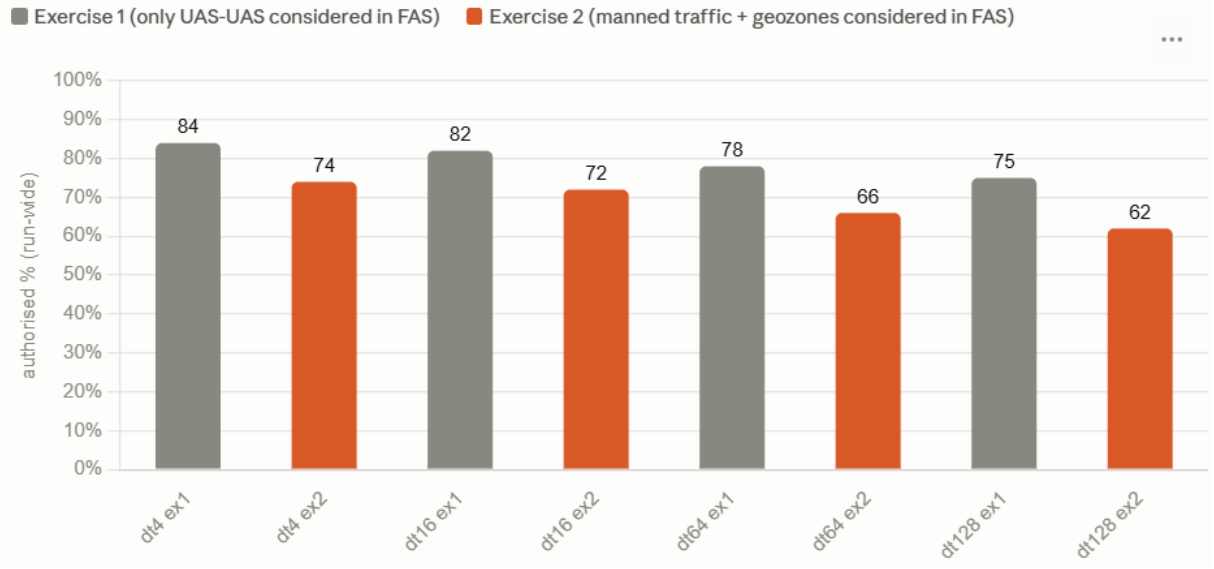


Figure 96: Authorisation approval rate in Manduria, exercise 2

KPA	KPI	Value obtained
Security, Environment	U-AGREE-KPI-06 — **Number of geozones infringement/FH**	$\Delta Ninf_1$ of −0.803/fh (−100%) across UAS density and DT values.
Access & Equity	U-AGREE-KPI-07 **Authorisation approval rate**	It decreases with increasing DT. Values are lower with respect to exercise 1 due to the presence of manned aviation and no-fly zones.

Table 60: KPIs for OBJ-SOL0520-ERP-007 Manduria, exercise 2

Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)

Activating the Flight Authorisation Service removes the estuary infringement entirely: at every tested deviation threshold — DT0, DT4, DT8, DT16, DT64, DT128 — the NFZ infringement count falls from 0.911/fh to exactly 0/fh, a uniform $\Delta Ninf_1$ of −0.9.11/fh (−100%) at every deviation threshold and density.

KPA	KPI	Value obtained

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Security, Environment	U-AGREE-KPI-06 — **Number of geozones infringement/FH**	$\Delta Ninf_1$ of −0.911/fh (−100%) across UAS density and DT values.
Access & Equity	U-AGREE-KPI-07 **Authorisation approval rate**	It decreases with increasing DT. Values are lower with respect to exercise 1 due to the presence of manned aviation and no-fly zones.

Table 61: KPIs for OBJ-SOL0520-ERP-007 Shannon Limerick, exercise 2

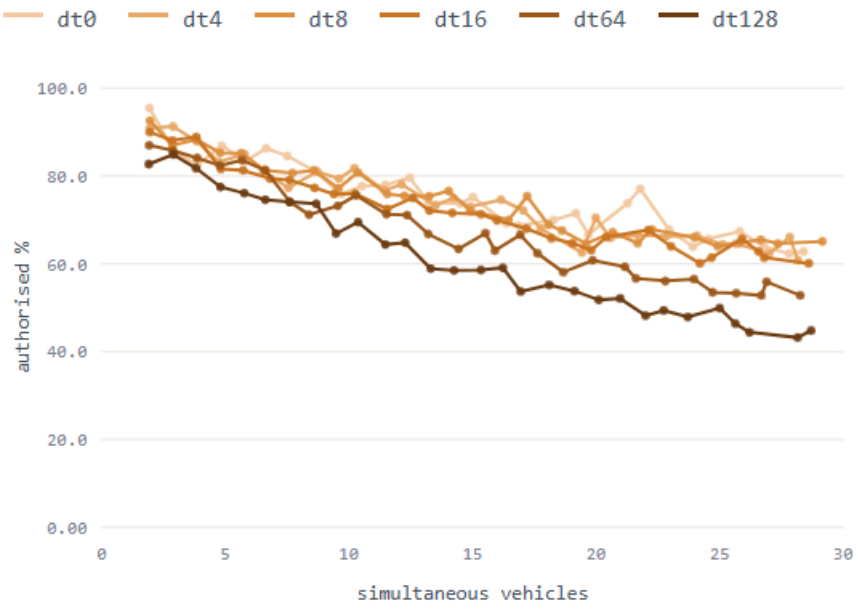


Figure 97: Authorisation approval rate in Shannon Limerick, exercise 2

Also in Shannon, the introduction of geozone and manned-aircraft constraints reduces the available airspace for UAS operations. As a result, FAS rejects a larger share of candidate flight plans compared with the Batch-1 FAS, leading to a **lower authorisation rate with respect to exercise 1.**

B.3.2.5. OBJ-SOL0520-ERP-008 Results

Scenario 1: The city of Benidorm (non U-space sub-OE)

Not applicable: no NFZ in this scenario implemented in ENGage simulator.

Scenario 2: The city of Manduria (non U-space sub-OE)

CM alert at DT16 and DT64, and CM pre-alert at DT16, all hold the geozone infringement rate at exactly 0/fh (−100% vs. baseline) matching the plain-FAS result, $\Delta Ninf_2$=$\Delta Ninf_1$. Indeed, in this scenario, the FAS alone reduces geozone infringements to zero by preventing authorised trajectories from entering the geozone. CM does not directly consider geozone constraints; it only monitors deviations from the authorised trajectory, which could potentially result in a geozone infringement. Therefore, in this specific scenario, CM provides no additional measurable benefit for geozone protection, while introducing an additional operational and implementation cost. *This does not imply that CM is*

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unnecessary in general, but rather that its added value for geozone protection is not demonstrated here, as the FAS already prevents geozone infringements by design.

KPA	KPI	Value obtained
Security, Environment	U-AGREE-KPI-06 — **Number of geozones infringement/FH**	0/fh across density, providing $\Delta Ninf_2$=$\Delta Ninf_1$.

Table 62: KPIs for OBJ-SOL0520-ERP-008 Manduria, exercise 2

Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)

Both CM modes (alert and pre-alert) at DT16 hold the estuary infringement rate at exactly 0/fh (−100% vs. baseline), matching the plain-FAS result at the same threshold, $\Delta Ninf_2$=$\Delta Ninf_1$.

KPA	KPI	Value obtained
Security, Environment	U-AGREE-KPI-06 — **Number of geozones infringement/FH**	0/fh across density, providing $\Delta Ninf_2$=$\Delta Ninf_1$.

Table 63: KPIs for OBJ-SOL0520-ERP-008 Shannon Limerick, exercise 2

The same applies to this scenario as in Manduria: the FAS alone reduces geozone infringements to zero by preventing authorised trajectories from entering the geozone. Therefore, CM provides no additional measurable benefit for geozone protection, while introducing an additional operational and implementation cost in this scenario.

B.3.2.6. OBJ-SOL0520-ERP-009 Results

Theis objective addresses fauna-related air risk through the same geozone mechanism reported under OBJ-SOL0520-ERP-006/007/008

Scenario 1: The city of Benidorm (non U-space sub-OE)

Not applicable: no NFZ in this scenario implemented in ENGage simulator.

Scenario 2: The city of Manduria (non U-space sub-OE)

Not applicable The *Mura Messapiche park* geozone is not documented in the available data as fauna-protection areas (unlike Shannon's Special Protection Area), so no fauna-specific data can be derived.

Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)

The River Shannon & Fergus Estuaries Special Protection Area — enforced as the estuary NFZ throughout this batch — has been designated for its bird population; keeping UAS out of it is therefore a fauna-risk mitigation as much as an airspace-deconfliction measure. Since the Flight Authorisation

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Service already drives NFZ infringement to zero at every tested deviation threshold, UAS simply do not enter the airspace where fauna exposure would occur.

KPA	KPI	Value obtained
Security, Environment	U-AGREE-KPI-06 — **Number of geozones infringement/FH**	0/fh across density.

Table 64: KPIs for OBJ-SOL0520-ERP-009 Shannon Limerick, exercise 2

B.3.3 Unexpected behaviours/results

B.3.4 Confidence in results of validation exercise #02

No unexpected behaviours affecting the expected functioning of the mitigation mechanisms were identified during validation exercise #02.

B.3.4.1. Level of significance/limitations of validation exercise results

Exercise #02 introduces revised UAS–UAS safety targets while retaining the UAS–manned targets from exercise #01. The geozone and tactical-resolution objectives (ERP-006 to ERP-010) represent new capabilities that were not evaluated in exercise #01; therefore, no direct cross-exercise baseline is available for these mechanisms. Their impact is assessed against the corresponding unmitigated baseline defined within each scenario.

The applicability of some objectives depends on the scenario configuration. Benidorm does not include a no-fly zone, therefore ERP-006 to ERP-009 are not applicable for this scenario. The available assessment is limited to the FAS manned-awareness results (ERP-005 Part A), while the tactical-resolution assessment (ERP-005 Part B) was not performed.

The interpretation of some tactical and CM results is affected by the execution conditions. These results therefore provide limited evidence of the complete exercise #02 configuration.

In Shannon-Limerick, tactical-resolution runs were also executed under geozone-blind and manned-blind conditions, by design, to maintain consistency with the Manduria assessment. Consequently, the combined effect of geozone enforcement, manned awareness, and tactical resolution was not jointly evaluated in any of the three scenarios.

B.3.4.2. Quality of validation exercises results

The quality of the validation results varies depending on the objective considered. Geozone-infringement metrics provide the most robust evidence: in both Manduria and Shannon-Limerick, the baseline cases show thousands of infringement events, while all tested gate-active FAS/CM configurations completely eliminate these events. The consistency and magnitude of this effect provide high confidence in the observed mitigation capability.

The assessment of OBJ-SOL0520-ERP-009 is instead limited by the availability of representative environmental constraints. Only the Shannon-Limerick scenario includes a documented fauna-protection area, namely the Shannon Estuary Special Protection Area, allowing a direct evaluation of

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the related objective. The areas considered in Manduria are not documented as fauna-protection zones, and the assessment has not been performed in Benidorm; therefore, no fauna-impact assessment is reported for these cases.

B.3.4.3. Significance of validation exercises results

The interpretation of the exercise #02 results should again consider both the statistical robustness of the findings and their operational representativeness. From a statistical perspective, the geozone-enforcement and manned-awareness analyses for Manduria and Shannon-Limerick are based on substantial simulation exposure (more than 10,000 flight-hours for the baseline and 100-flight-hour repetitions over the mitigated configurations), providing high confidence in the observed effects. In both scenarios, geozone infringements are eliminated and the UAS–manned risk is reduced by approximately one order of magnitude or more. By contrast, the tactical deconfliction and Conformance Monitoring comparisons at DT64 remain limited by the very small number of residual events, so the observed differences fall within the simulation variability, consistently with the findings of exercise #01. Their interpretation in Manduria and Shannon-Limerick is further constrained by the Batch-1 conditions under which these simulations were performed.

From an operational perspective, the Batch-2 configuration extends the Batch-1 Flight Authorisation Service by enforcing both geozone constraints and manned-aircraft separation, resulting in a measured reduction of the authorisation rate of approximately 10–13 percentage points across all tested deviation thresholds in both Manduria and Shannon-Limerick. Whether this trade-off is operationally acceptable depends on the characteristics of the real traffic demand, which is outside the scope of these simulations, as traffic was generated to maintain a target number of simultaneous vehicles rather than to reproduce operational demand patterns. In addition, the complete exercise #02 service chain has not yet been evaluated as a fully integrated configuration: geozone enforcement, manned awareness and tactical conflict resolution have so far been assessed only individually or in partial combinations.

B.4 Validation exercise #02 results - UPV

B.4.1 Summary of validation exercise #02 results

This sub-section summarises the results of validation exercise #01 from the UPV simulator. The table presents the summary of results compared to the success criteria identified within the ERP per validation objective. The analysis covers the validation objectives embedded in the validation exercise as per the corresponding ERP.

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
OBJ-SOL0520-ERP-001	**Identification of the baseline capacity (N_0)[24]**	CRT-SOL0520-TRL2-ERP-001.002	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 1, for exercise #01 and #02.	Scenario 1: The city of Benidorm (non U-space sub-OE)	The baseline collision frequencies obtained in Validation Exercise #01 were reassessed against the updated maximum allowable frequencies derived from the final U-AGREE risk models. The updated criteria do not produce an increase in the limiting baseline capacity. Benidorm and Manduria retain a UAS–UAS capacity of one simultaneous UAS in both altitude configurations. Shannon retains a capacity of one UAS below VLL, while its above-VLL UAS–UAS	OK
		CRT-SOL0520-TRL2-ERP-001.004	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 2, for exercise #01 and #02.	Scenario 2: The city of Manduria (non U-space sub-OE)		OK
		CRT-SOL0520-TRL2-ERP-001.006	The MAC frequency between UAS and manned aircraft in uncontrolled airspace shall not exceed 10^{-7} per flight-hour in Scenario 3, for exercise #01 and #02.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)		OK

[24] Only success criteria related to exercise 2 are reported here.

Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
		CRT-SOL0520-TRL2-ERP-001.007	The MAC frequency between UAS and manned aircraft in controlled airspace shall not exceed 10^{-9} per flight-hour in Scenario 3, for exercise #01 and #02.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	capacity decreases from five to two UAS. Since the UAS–manned capacity remains equal to one UAS in all configurations, the overall baseline capacity remains limited to one simultaneous UAS in every assessed scenario.	OK
		CRT-SOL0520-TRL2-ERP-001.008	The MAC frequency between UAS shall not exceed 1.41×10^{-4} per flight-hour in Scenario 1, for exercise #02.	Scenario 1: The city of Benidorm (non U-space sub-OE)		OK
		CRT-SOL0520-TRL2-ERP-001.009	The MAC frequency between UAS shall not exceed 1.29×10^{-4} per flight-hour in Scenario 2, for exercise #02.	Scenario 2: The city of Manduria (non U-space sub-OE)		OK
		CRT-SOL0520-TRL2-ERP-001.010	The MAC frequency between UAS shall not exceed 6.25×10^{-3} per flight hour in Scenario 3, for exercise #02.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)		OK
OBJ-SOL0520-ERP-005	Quantification of the capacity increment (ΔN_4) because of the introduction of mitigation measures	CRT-SOL0520-TRL2-ERP-005.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline,	Scenario 1: The city of Benidorm (non U-space sub-OE)	The Final FAS functionalities provide complementary benefits across the	Partially OK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
	based on an enhanced FAS and adding a Tactical Conflict Prediction and Resolution services.		while maintaining the same target level of safety.		three scenarios. In the above-VLL assessment, the overall safety-based capacity increases from the baseline value of one simultaneous UAS to 50 UAS in Benidorm, 286 UAS in Manduria and 745 UAS in Shannon–Limerick when the deviation threshold reaches the UAS–manned NMAC separation scale. At smaller deviation thresholds, the UAS–manned criterion remains limiting despite the higher UAS–UAS capacities. SCR additionally increases the number of U-plans that can be authorised in the assessed Benidorm trajectory sets by generating alternative conflict-free routes, while coordinated	
		CRT-SOL0520-TRL2-ERP-005.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 2: The city of Manduria (non U-space sub-OE)		Partially OK
		CRT-SOL0520-TRL2-ERP-005.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)		Partially OK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
					DAR rerouting increases the proportion of conflict-free diversions in Shannon–Limerick. TCP&R provides an additional reduction in the residual conditional collision risk after strategic deconfliction. The reported Risk Ratios range from 0.040 to 0.048 for UAS–UAS encounters in Benidorm and Manduria and decrease to 0.00128 in Shannon–Limerick, while the UAS–manned Risk Ratios range from 0.759 to 0.801. Overall, the results demonstrate an increase in capacity relative to the unmitigated baseline, although the achievable capacity remains dependent on the selected	

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
					deviation threshold, the limiting UAS–manned criterion and the number of trajectories that Final FAS can operationally allocate.	
OBJ-SOL0520-ERP-006	Quantification of baseline geographical zone infringements per flight-hour ($\Delta Ninf_0$).	CRT-SOL0520-TRL2-ERP-006.001	The geographical zones in Scenario 1 shall be defined such that, during the baseline run, at least one infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.	Scenario 1: The city of Benidorm (non U-space sub-OE)	Geographical-zone infringements were not assessed within the UPV simulation activities, as geographical-zone management was outside the scope of the UPV implementation for Validation Exercise #02. Consequently, no UPV-specific evidence is available to demonstrate achievement of the success criterion. The NOK status reflects the absence of validation evidence and not an observed failure of the	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
					geographical-zone implementation.	
		CRT-SOL0520-TRL2-ERP-006.002	The geographical zones in Scenario 2 shall be defined such that, during the baseline run, at least one infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.	Scenario 2: The city of Manduria (non U-space sub-OE)	Geographical-zone infringements were not assessed within the UPV simulation activities, as geographical-zone management was outside the scope of the UPV implementation for Validation Exercise #02. Consequently, no UPV-specific evidence is available to demonstrate achievement of the success criterion. The NOK status reflects the absence of validation evidence and not an observed failure of the geographical-zone implementation.	NOK
		CRT-SOL0520-TRL2-ERP-006.003	The geographical zones in Scenario 3 shall be defined such that, during the	Scenario 3: The Shannon-Limerick	Geographical-zone infringements were not assessed within the UPV simulation	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
			baseline run, at least one infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.	Area (APT-small/non U-space sub-OE)	activities, as geographical-zone management was outside the scope of the UPV implementation for Validation Exercise #02. Consequently, no UPV-specific evidence is available to demonstrate achievement of the success criterion. The NOK status reflects the absence of validation evidence and not an observed failure of the geographical-zone implementation.	
OBJ-SOL0520-ERP-007	Quantification of the variation in geographical zone infringements per flight-hour ($\Delta Ninf_1$) due to the implementation of mitigation measures	CRT-SOL0520-TRL2-ERP-007.001	The total number of geographical zones infringements varies compared to the baseline in scenario 1.	Scenario 1: The city of Benidorm (non U-space sub-OE)	Geographical-zone infringements were not assessed within the UPV simulation activities, as geographical-zone management was outside the scope of the UPV implementation for	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
	based on Flight Authorisation service.				Validation Exercise #02. Consequently, no UPV-specific evidence is available to demonstrate achievement of the success criterion. The NOK status reflects the absence of validation evidence and not an observed failure of the geographical-zone implementation.	
		CRT-SOL0520-TRL2-ERP-007.002	The total number of geographical zones infringements varies compared to the baseline in scenario 2.	Scenario 2: The city of Manduria (non U-space sub-OE)	Geographical-zone infringements were not assessed within the UPV simulation activities, as geographical-zone management was outside the scope of the UPV implementation for Validation Exercise #02. Consequently, no UPV-specific evidence is available to demonstrate achievement of the	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
					success criterion. The NOK status reflects the absence of validation evidence and not an observed failure of the geographical-zone implementation.	
		CRT-SOL0520TRL2-ERP-007.003	The total number of geographical zones infringements varies compared to the baseline in scenario 3.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	Geographical-zone infringements were not assessed within the UPV simulation activities, as geographical-zone management was outside the scope of the UPV implementation for Validation Exercise #02. Consequently, no UPV-specific evidence is available to demonstrate achievement of the success criterion. The NOK status reflects the absence of validation evidence and not an observed failure of the	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
					geographical-zone implementation.	
OBJ-SOL0520-ERP-008	Quantification of the variation in geographical zone infringements per flight-hour ($\Delta Ninf_2$) due to the implementation of mitigation measures based on Conformance Monitoring service.	CRT-SOL0520-TRL2-ERP-008.001	The total number of geographical zones infringements varies compared to the baseline in scenario 1.	Scenario 1: The city of Benidorm (non U-space sub-OE)	Geographical-zone infringements were not assessed within the UPV simulation activities, as geographical-zone management was outside the scope of the UPV implementation for Validation Exercise #02. Consequently, no UPV-specific evidence is available to demonstrate achievement of the success criterion. The NOK status reflects the absence of validation evidence and not an observed failure of the geographical-zone implementation.	NOK
		CRT-SOL0520-TRL2-ERP-008.002	The total number of geographical zones infringements varies	Scenario 2: The city of Manduria (non U-space sub-OE)	Geographical-zone infringements were not assessed within	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
			compared to the baseline in scenario 2.		the UPV simulation activities, as geographical-zone management was outside the scope of the UPV implementation for Validation Exercise #02. Consequently, no UPV-specific evidence is available to demonstrate achievement of the success criterion. The NOK status reflects the absence of validation evidence and not an observed failure of the geographical-zone implementation.	
		CRT-SOL0520-TRL2-ERP-008.003	The total number of geographical zones infringements varies compared to the baseline in scenario 3.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	Geographical-zone infringements were not assessed within the UPV simulation activities, as geographical-zone management was outside the scope of the UPV	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
					implementation for Validation Exercise #02. Consequently, no UPV-specific evidence is available to demonstrate achievement of the success criterion. The NOK status reflects the absence of validation evidence and not an observed failure of the geographical-zone implementation.	
OBJ-SOL0520-ERP-009	Quantification of the impact of fauna on air risk.	CRT-SOL0520-TRL2-ERP-009.001	The TLS defined for scenario 1 is maintained.	Scenario 1: The city of Benidorm (non U-space sub-OE)	Geographical-zone infringements were not assessed within the UPV simulation activities, as geographical-zone management was outside the scope of the UPV implementation for Validation Exercise #02. Consequently, no UPV-specific evidence is available to demonstrate	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
					achievement of the success criterion. The NOK status reflects the absence of validation evidence and not an observed failure of the geographical-zone implementation.	
		CRT-SOL0520-TRL2-ERP-009.002	The TLS defined for scenario 2 is maintained.	Scenario 2: The city of Manduria (non U-space sub-OE)	Geographical-zone infringements were not assessed within the UPV simulation activities, as geographical-zone management was outside the scope of the UPV implementation for Validation Exercise #02. Consequently, no UPV-specific evidence is available to demonstrate achievement of the success criterion. The NOK status reflects the absence of validation evidence and not an observed	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #02 validation objective status
					failure of the geographical-zone implementation.	
		CRT-SOL0520-TRL2-ERP-009.003	The TLS defined for scenario 3 is maintained.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	Geographical-zone infringements were not assessed within the UPV simulation activities, as geographical-zone management was outside the scope of the UPV implementation for Validation Exercise #02. Consequently, no UPV-specific evidence is available to demonstrate achievement of the success criterion. The NOK status reflects the absence of validation evidence and not an observed failure of the geographical-zone implementation.	NOK

Table 65: validation exercise #02 results - UPV

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B.4.2 Analysis of validation exercise #02 results per validation objective

B.4.2.1. OBJ-SOL0520-ERP-001 Results

The baseline collision frequencies used in Validation Exercise #02 are the same as those obtained in Validation Exercise #01, since the reference scenarios, traffic configurations and frequency-calculation methodology remain unchanged. However, the results are reassessed against the updated maximum allowable frequencies derived from the final U-AGREE risk models. Consequently, any variation in the resulting baseline capacity is caused by the updated safety criterion rather than by a change in the simulated collision frequencies.

The baseline capacity N_0 is determined by comparing the previously obtained collision-frequency curves from Exercise #01 with the updated success criterion $\lambda_{\max}$ applicable to each scenario in Exercise#2. The intersection between the frequency curve and the corresponding maximum allowable frequency defines the revised baseline capacity used as the reference for the Exercise #02 solution scenarios.

Scenario	UAS–UAS capacity	UAS–manned capacity per UAS FH	UAS–manned capacity per manned FH
Benidorm below VLL	1	1	1
Benidorm above VLL	1	1	1
Manduria below VLL	1	1	1
Manduria above VLL	1	1	1
Shannon below VLL	1	1	1
Shannon above VLL	2	1	1

Table 66: UPV - Exercise #02 baseline capacity.

The reassessment against the maximum allowable frequencies derived from the final U-AGREE risk models does not result in an increase in the limiting baseline capacity. In Benidorm, the updated criterion appears to provide additional margin; however, the simulated frequency remains incompatible with traffic levels above one simultaneous UAS. In Manduria, the comparison with the updated maximum allowable frequency leads to the same capacity as in Validation Exercise #01. For Shannon, the final risk-model criterion results in a more restrictive UAS–UAS capacity, particularly above VLL, where the estimated capacity decreases from five to two simultaneous UAS. Nevertheless, the UAS–manned capacity remains equal to one UAS in all assessed configurations. Consequently, when all applicable safety criteria are considered together, the limiting baseline capacity remains one simultaneous UAS for every scenario and altitude configuration.

The KPIs for the

B.4.2.2. OBJ-SOL0520-ERP-005 Results

This objective presents an overview of the results obtained for OBJ-SOL0520-ERP-005 within the UPV simulation platform. UPV's platform assessed three different enhancements for the final FAS:

- Dynamic Airspace Reconfiguration – coordinated rerouting.
- Strategic Conflict Resolution.
- Deconfliction with manned aircraft.
- Tactical Conflict Prediction and Resolution.

These new features of the final FAS have been incorporated across the different scenarios as follows:

- Benidorm: manned deconfliction+SCR + TCP&R.
- Manduria: manned deconfliction+TCP&R.
- Shannon: manned deconfliction+DAR+TCP&R.

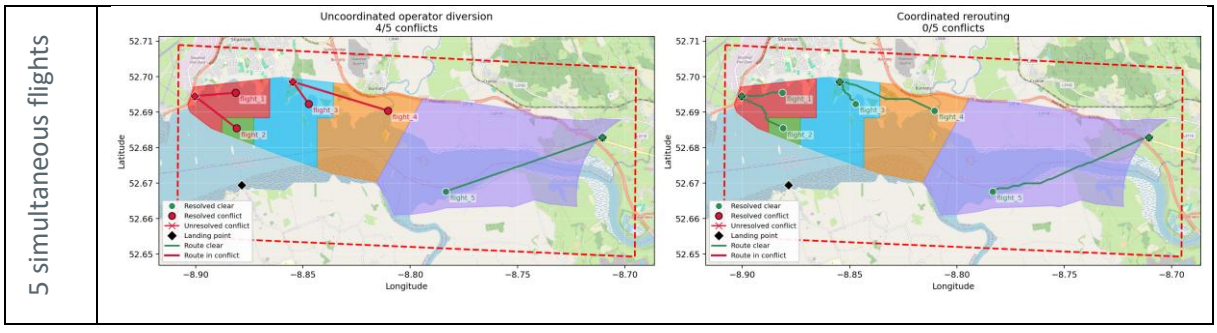
Final Flight Authorisation Service

Dynamic Airspace Reconfiguration

The assessment is performed for configurations involving 5, 10 and 20 simultaneous flights within the DAR-affected area at the time of activation. These traffic levels are considered representative of the relatively low traffic demand expected in the Shannon–Limerick environment.

For each traffic level, the uncoordinated operator-diversion case serves as the reference: each affected UAS is assumed to follow a straight-line path to the nearest predefined safe-landing location, without considering the paths followed by the other affected UAS. This reference is compared with the **coordinated rerouting** case, in which conflict-free routes to the safe-landing locations are searched while accounting for the simultaneous diversion of all affected flights. The comparison considers the number of routes successfully obtained, unresolved flights, conflicts between the resulting routes and the corresponding conflict rate.

Figure 98 presents the results for the three assessed traffic levels. For each traffic level, the left-hand plot shows the assumed uncoordinated straight-line paths towards the nearest safe-landing locations, while the right-hand panel shows the routes generated through coordinated rerouting.



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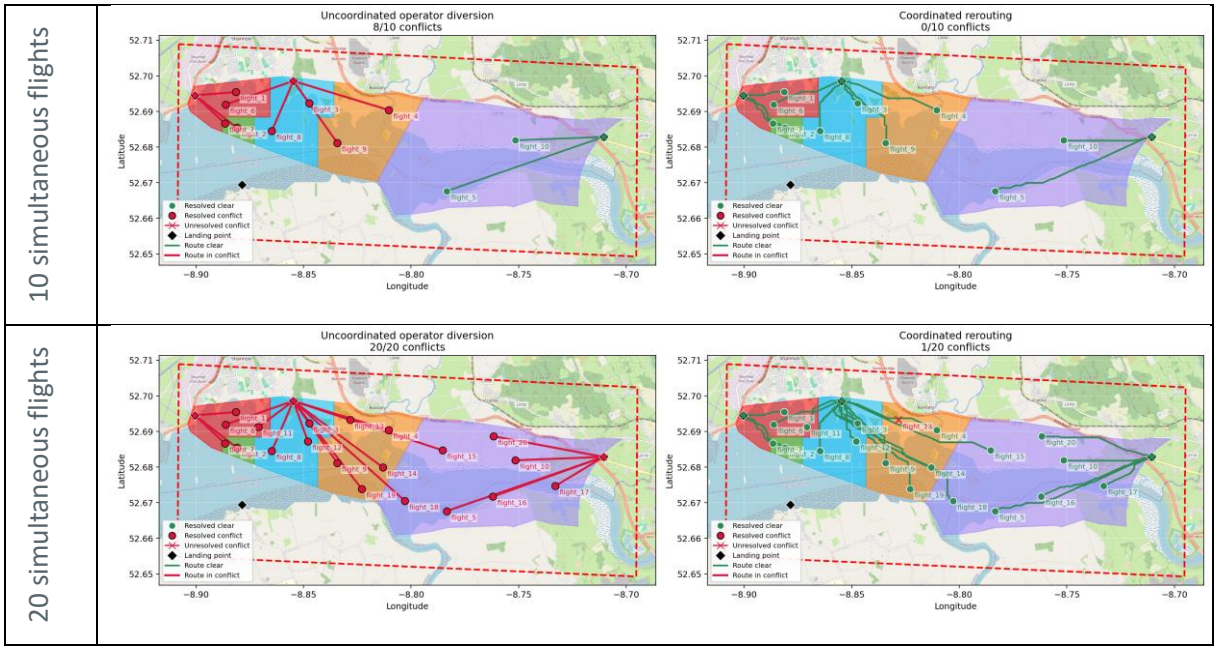


Figure 98: UPV - Shannon traffic density within DAR

The corresponding quantitative results are summarised in Table 67:

	Flights without conflicts	
Simultaneous UAS	**Uncoordinated operator diversion**	**Coordinated rerouting**
5	1/5 (20%)	5/5 (100%)
10	2/10 (20%)	10/10 (100%)
20	0/20 (0%)	19/20 (95%)

Table 67: UPV - DAR results

The results demonstrate that independently diverting the affected UAS towards their nearest safe-landing locations may introduce new conflicts between the resulting trajectories. By contrast, coordinated rerouting accounts for all simultaneous diversions and generates mutually compatible routes towards the predefined safe-landing locations. This has a direct positive impact on Safety, as it prevents the emergency response to DAR activation from creating additional collision risks and supports the safe and orderly termination of the affected operations. The assessment also indicates that the functionality remains effective as traffic demand increases within the evaluated range, although further testing would be required to determine its performance limits under more demanding traffic and airspace configurations.

Strategic Conflict Resolution

The Strategic Conflict Resolution (SCR) proposed by UPV consists of a Machine Learning-Based tool that finds alternative routes, thereby providing the UAS operator with a conflict-free, optimal route. The resolution is calculated by a Machine Learning (ML) algorithm that has been trained to emulate classical shortest path algorithms (such as A*), achieving much lower inference time and an optimality accuracy of more than 90%. Route optimisation considers both travelled distance and the estimated energy consumption of multirotor UAS through an in-house energy model. However, ML methods are

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not deterministic. Thus, in some specific scenarios, a route can't be found. In such cases, the tool falls back to A* to further solve those routes. If a route can't be found even with A*, it means that there doesn't exist an alternative route in that moment, so a different timespan should be proposed to the operator.

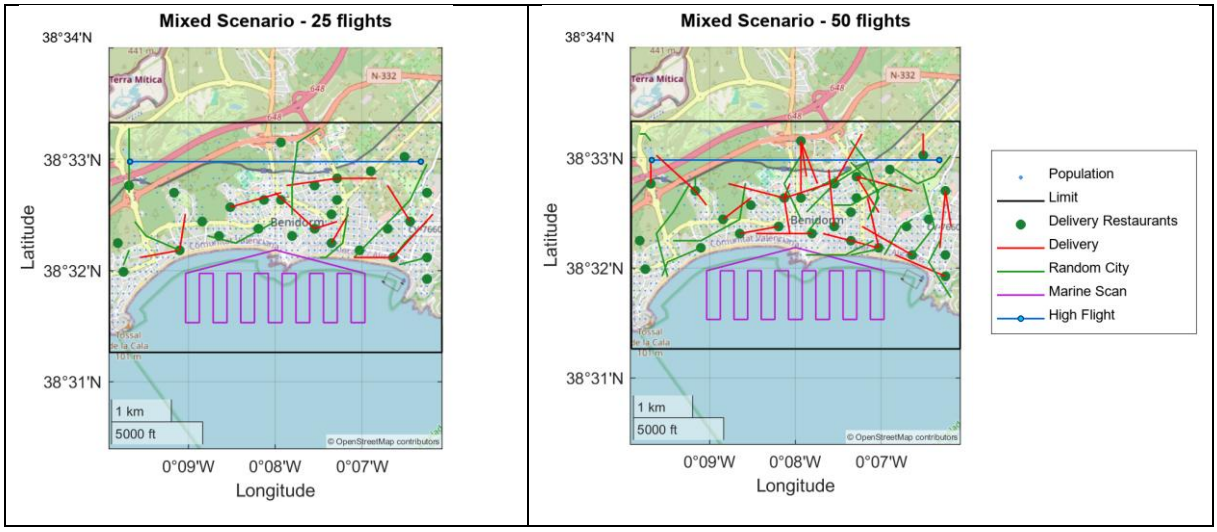
The qualitative SCR assessment is performed in the Benidorm scenario, which is considered the operational environment with the highest expected traffic demand. Four predefined traffic configurations comprising 25, 50, 75 and 100 submitted U-plans are evaluated for a given deviation threshold that meets the TLS. Each configuration contains a mixture of representative operation types, including delivery, random urban, maritime scanning and high-traffic routes. Figure 99 illustrates the spatial distribution of the trajectories for the assessed traffic configurations.

These configurations represent specific trajectory sets rather than statistically generated traffic samples. No Monte Carlo campaign was conducted for this assessment; therefore, the comparison is intended to demonstrate the functional feasibility of SCR under different predefined levels of traffic demand. The results should not be interpreted as statistically representative resolution probabilities, general Authorisation Approval Rates or maximum airspace-capacity values.

The following assumptions apply to the assessment:

- The waypoints originally specified by the UAS operator must be preserved. Route resolution is therefore performed independently between consecutive waypoints. If a mandatory waypoint lies within a cell already occupied by a previously authorised trajectory, no alternative route can be generated for that U-plan.
- Each U-space airspace volume is assumed to be supported by its own SCR function, operating with the trajectory and occupancy information applicable to that volume.
- If the ML model does not identify an alternative route, the resolution process falls back to A*. Therefore, whenever a feasible route exists within the discretised search space and under the stated waypoint constraints, the route-search process is expected to find it.

For each traffic-demand configuration, the number of U-plans initially accepted without resolution is compared with the number finally accepted after applying SCR. Both 2D and 3D resolution are evaluated to examine the effect of considering vertical cell occupancy during route generation. The assessment identifies the U-plans recovered through SCR and examines the reasons why some requests remain unresolved.



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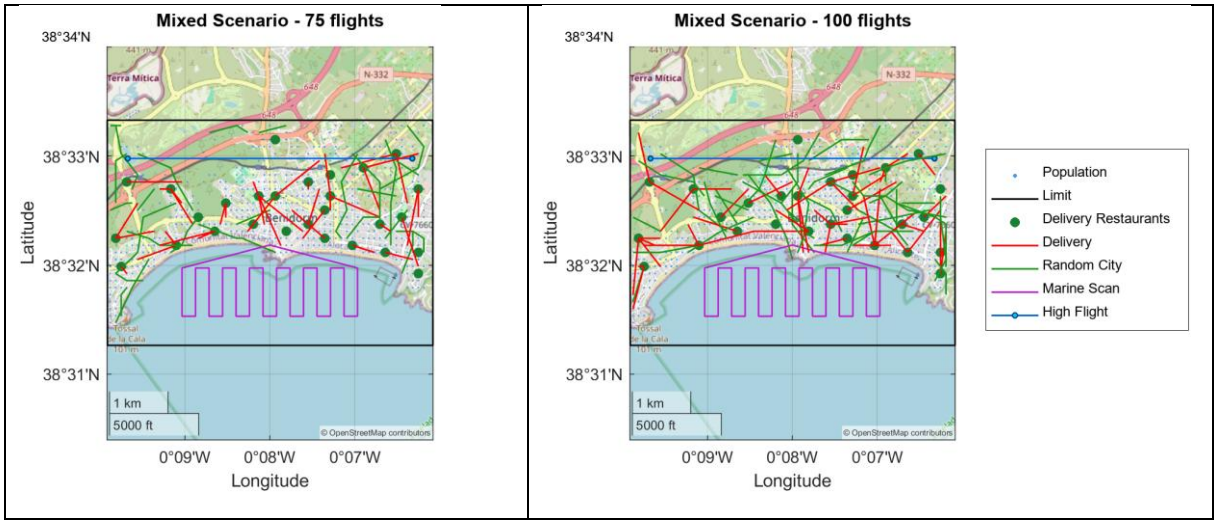


Figure 99: Benidorm mixed-traffic configurations used for the qualitative SCR assessment.

For each predefined traffic configuration, the number of U-plans initially accepted by the Flight Authorisation process is compared with the number finally accepted after applying SCR. Both 2D and 3D resolution are assessed. The 2D implementation searches for alternative horizontal paths, whereas the 3D implementation evaluates the availability of the complete route, including vertical segments associated with take-off, landing and altitude transitions. The results are summarised in Table 68.

Submitted U-plans	Initially accepted	Accepted after 2D SCR	Accepted after 3D SCR
25	21/25 (**84%**)	23/25 (**92%**)	22/25 (**88%**)
50	46/50 (**92%**)	49/50 (**98%**)	48/50 (**96%**)
75	65/75 (**86.7%**)	72/75 (**96%**)	71/75 (**94.7%**)
100	79/100 (**79%**)	91/100 (**91%**)	86/100 (**86%**)

Table 68: UPV - U-plan acceptance results for the qualitative SCR assessment.[25]

The selected cases show that SCR can recover U-plans that would otherwise be rejected by the Flight Authorisation process. Additional accepted U-plans are obtained in every assessed traffic configuration using both 2D and 3D resolution. The absolute number of recovered requests is higher in the larger trajectory sets, although this should not be interpreted as a statistically demonstrated relationship with traffic demand because each configuration contains a different predefined set of trajectories. The result depends on the spatial distribution of those trajectories, their mandatory waypoints and the cells already occupied by previously authorised flights.

The 2D implementation accepts more U-plans than the 3D implementation in all four assessed cases. This difference results from the treatment of vertical trajectory segments. The 2D search does not consider additional occupied cells along the vertical ascent and descent segments during horizontal route resolution, whereas the 3D implementation evaluates the complete route. Consequently, some

[25] Percentages represent descriptive acceptance rates for the specific trajectory sets assessed. Since no Monte Carlo campaign was performed, they should not be interpreted as statistically representative Authorisation Approval Rates or probabilities of successful resolution

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U-plans for which a horizontal solution is found cannot be accepted once the corresponding vertical segment is checked. The 3D results therefore provide the more complete and conservative representation of route feasibility.

The remaining unresolved U-plans are mainly associated with mandatory operator-defined waypoints located in cells already occupied by previously authorised trajectories. Since the assessment assumes that the original waypoints must be preserved, no valid alternative route can be generated in those cases. When the mandatory waypoints remain available, the combined ML and A* resolution process is used to search for a feasible alternative route.

Overall, the assessment demonstrates the functional feasibility of using SCR to recover part of the traffic demand rejected by the initial Flight Authorisation process. However, because the assessment is based on four specific trajectory sets and does not include repeated Monte Carlo sampling, the results do not establish a general resolution probability, a statistically representative approval rate or the maximum capacity of the Benidorm airspace.

Tactical Conflict Prediction and Resolution Service

The following figures demonstrate why LA = 45 s, SFH = 1, SFV = 1 and zero trajectory perturbations form a coherent reporting baseline for both encounter families.

For UAS–UAS encounters, increasing look-ahead produces the clearest and most consistent reduction in RR and LR, while SFH = 1 applies the full horizontal separation minima. For UAS–manned encounters the RR response is less monotonic because the larger manned-aircraft NMAC dimensions dominate more of the geometry, but the 45 s horizon remains the common conservative temporal choice and avoids selecting a different horizon after inspecting each scenario.

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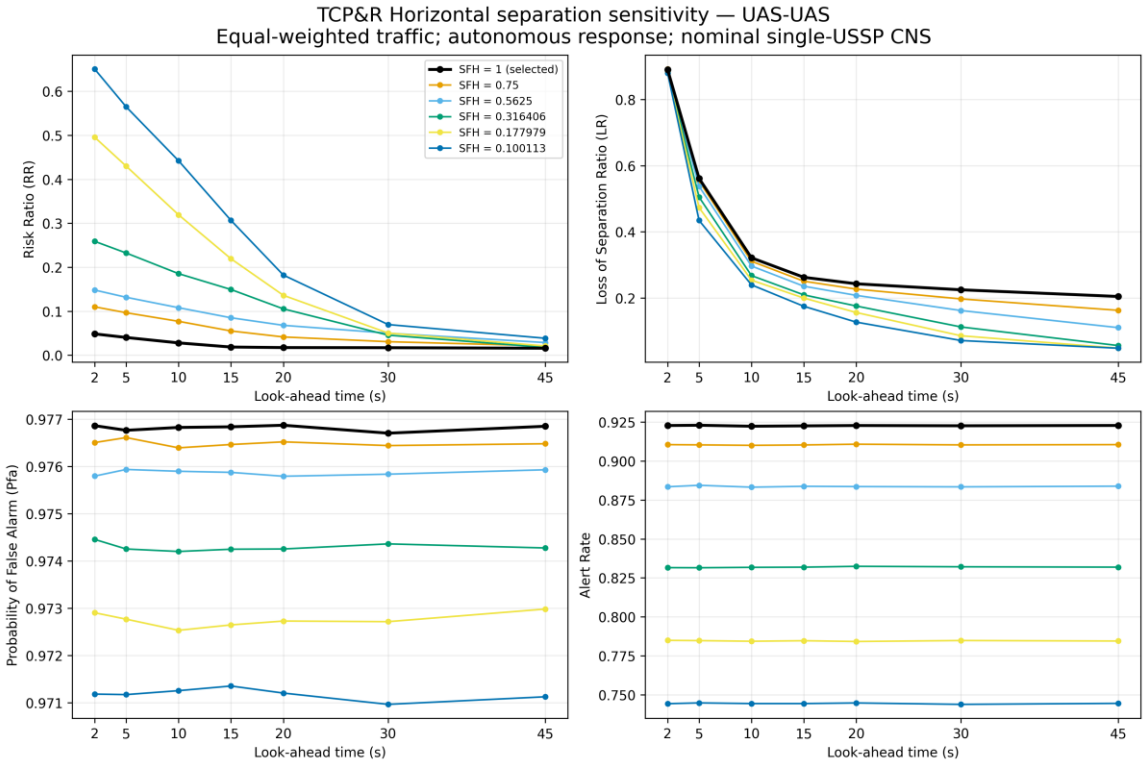


Figure 100: TCP&R sensitivity to look-ahead and horizontal separation factor for UAS–UAS encounters. SFV = 1 and all other parameters are fixed at the nominal baseline; the selected SFH = 1 curve is shown in black.

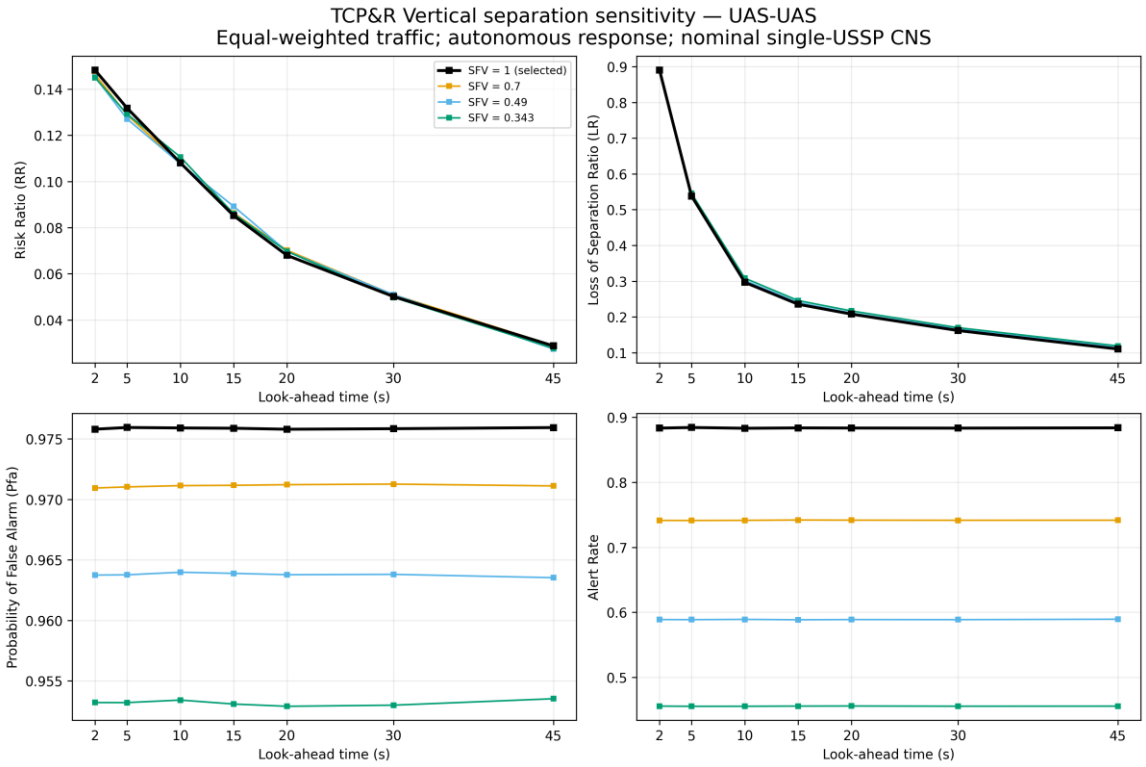


Figure 101: TCP&R sensitivity to look-ahead and vertical separation factor for UAS–UAS encounters. The crossed campaign mesh evaluates SFV at SFH = 0.5625; the selected SFV = 1 curve is shown in black.

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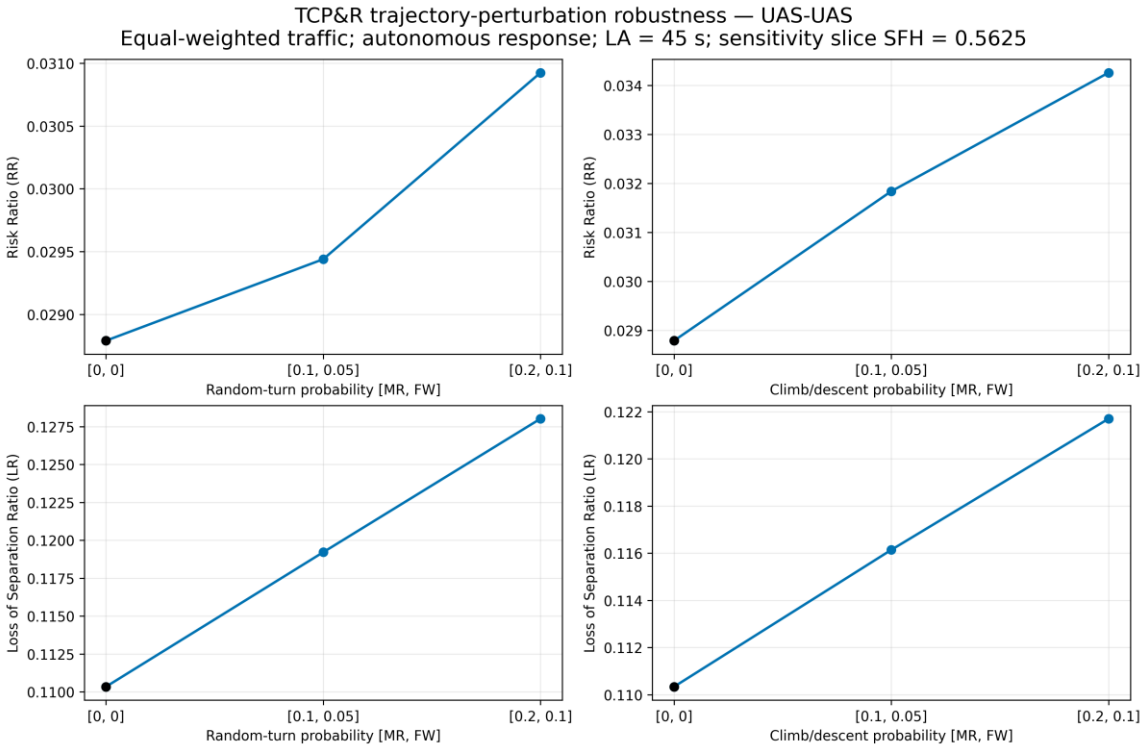


Figure 102: Effect of random turns and climb/descent perturbations on UAS–UAS RR and LR at LA = 45 s. The black point identifies the zero-perturbation reference.

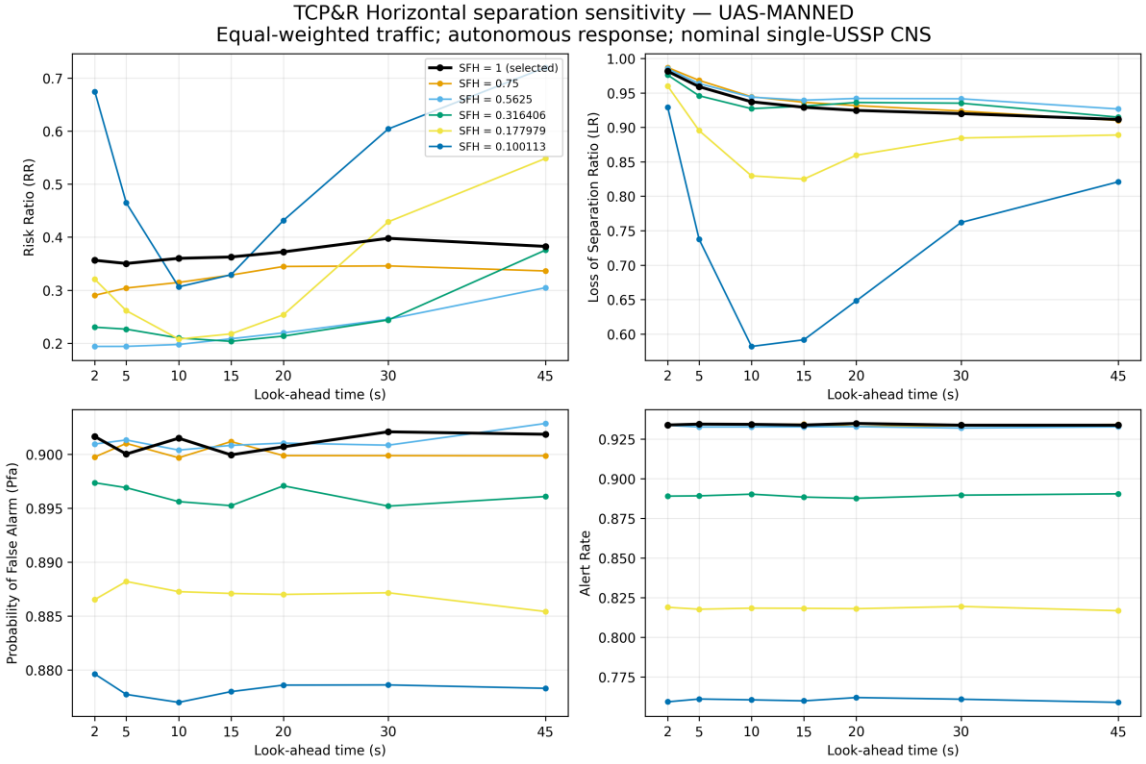


Figure 103: TCP&R sensitivity to look-ahead and horizontal separation factor for UAS–manned encounters. SFV = 1 and all other parameters are fixed at the nominal baseline; the selected SFH = 1 curve is shown in black.

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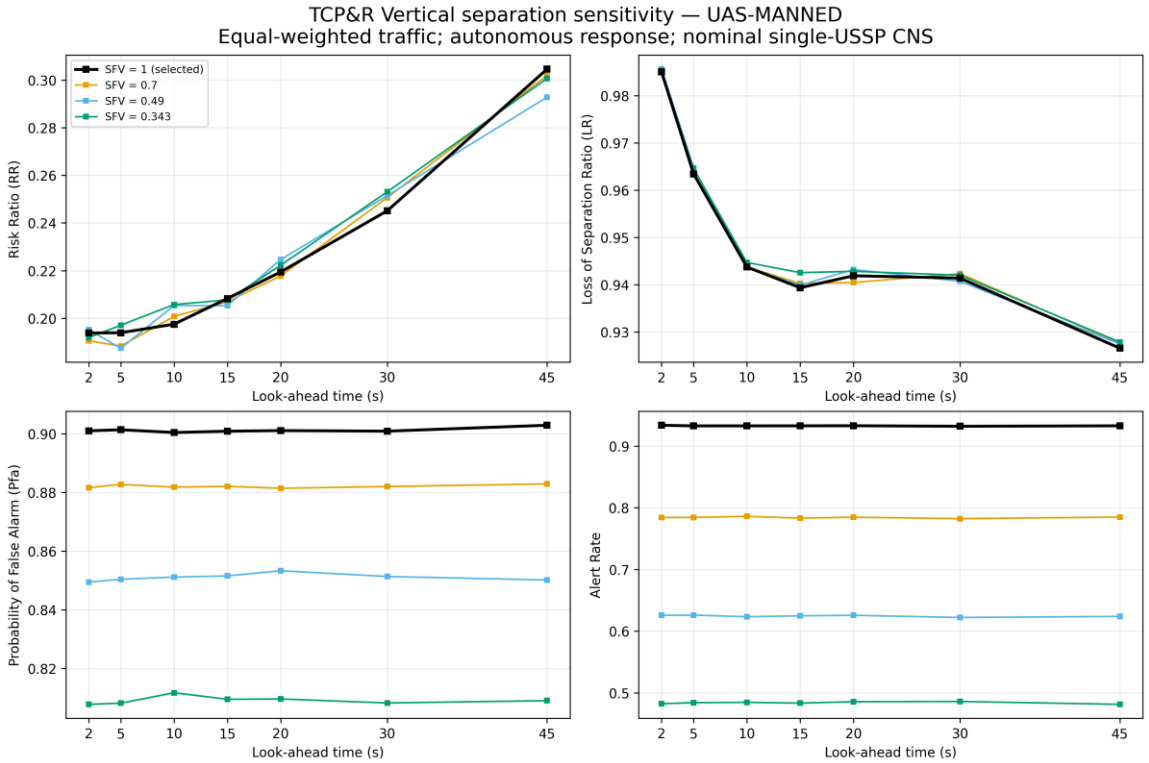


Figure 104: TCP&R sensitivity to look-ahead and vertical separation factor for UAS–manned encounters. The crossed campaign mesh evaluates SFV at SFH = 0.5625; the selected SFV = 1 curve is shown in black.

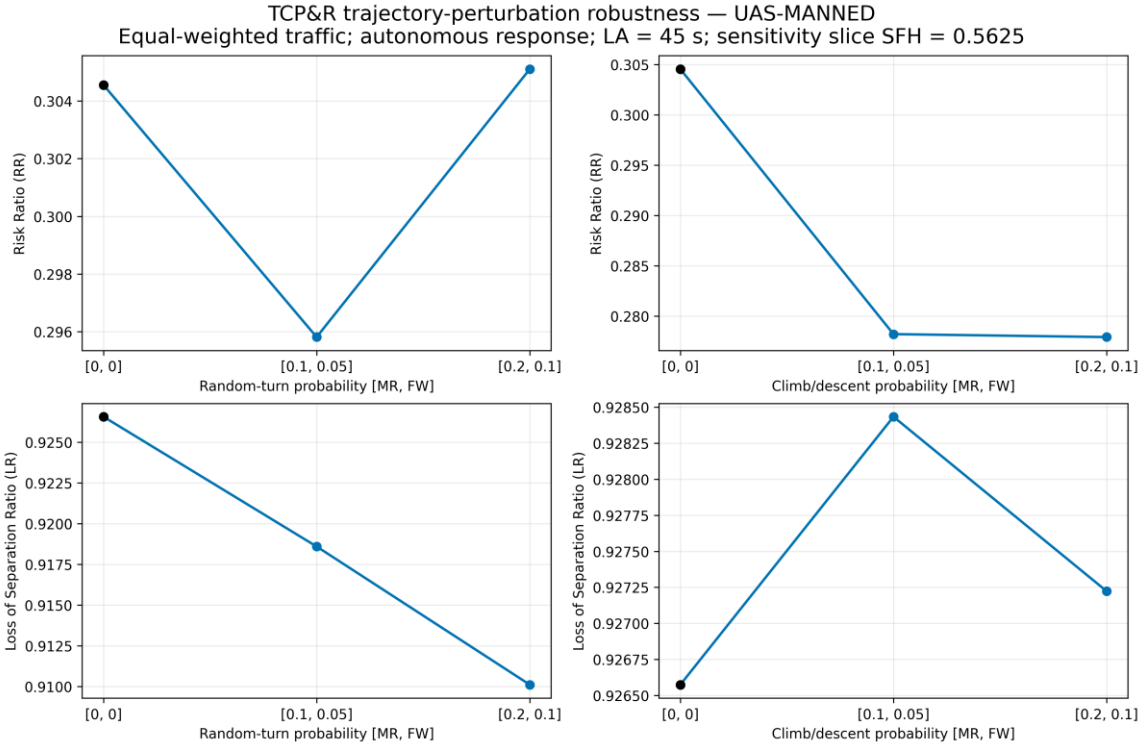


Figure 105: Effect of random turns and climb/descent perturbations on UAS–manned RR and LR at LA = 45 s. The black point identifies the zero-perturbation reference.

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The vertical-factor curves are closely grouped for both encounter families. SFV therefore has a limited effect on RR and LR compared with look-ahead, whereas reducing SFV clearly lowers Pfa and alert rate. The same trade-off is visible horizontally: smaller protected volumes can reduce alerting load, but they no longer represent the full U-AGREE separation minima. SFH = 1 and SFV = 1 are consequently retained as the conservative safety baseline rather than selecting reduced factors to optimise workload indicators.

Random-turn and climb/descent sweeps introduce secondary, and in the UAS–manned branch non-monotonic, changes in RR and LR. Their effect is useful as robustness evidence but does not define a stable alternative baseline. Fixing RT and CP to zero preserves straight and level reference encounters and isolates the TCP&R barrier; the factor-of-two transfer margin then prevents these idealised geometries from producing excessive mitigation credit in the integrated calculations.

Pfa and alert rate are conditional campaign indicators. Because the generated population is deliberately conflict-rich, they quantify the selectivity and activation load of the detection chain within relevant encounters; they are not interpreted as absolute operational alert frequencies per flight hour.

This common baseline makes the result comparison auditable: traffic mix and encounter family change, while response, CNS, look-ahead, separation factors, manoeuvre success and trajectory perturbations remain fixed.

Automation-response comparison: Autonomous and RPAS

The campaign operation types represent two response-assumption families applied to the same aircraft classes and encounter definitions; they are not different airframes. Autonomous response uses Gamma($k = 9$, $\theta = 1/3$) with mean 3 s and standard deviation 1 s. RPAS response uses Gamma($k = 4$, $\theta = 1$) plus a 3 s minimum shift, with mean 7 s and standard deviation 2 s. These are comparative model assumptions rather than empirically calibrated distributions for all automated systems or remote pilots.

The two definitive aggregate files contain 8,960 rows per encounter family and form 4,480 exact parameter-matched pairs after operation type is removed from the key. RR and LR are read directly from each aggregate row. The comparison variable is Δ = RPAS − Autonomous for the same traffic mix, CNS case, look-ahead, separation factors, manoeuvre-failure setting and trajectory perturbations. In this comparison, technical communication and surveillance latency remains a separate model stage: changing response family does not redefine the CNS latency distribution.

At the Equal Weighted reporting baseline, Figure 106 shows that the longer RPAS response assumption increases both conditional ratios for UAS–UAS encounters. At LA = 45 s, raw RR changes from 0.015927 for Autonomous to 0.020111 for RPAS, while raw LR changes from 0.204563 to 0.220903. The separation between the curves is much larger at short look-ahead and narrows as the available response horizon increases.

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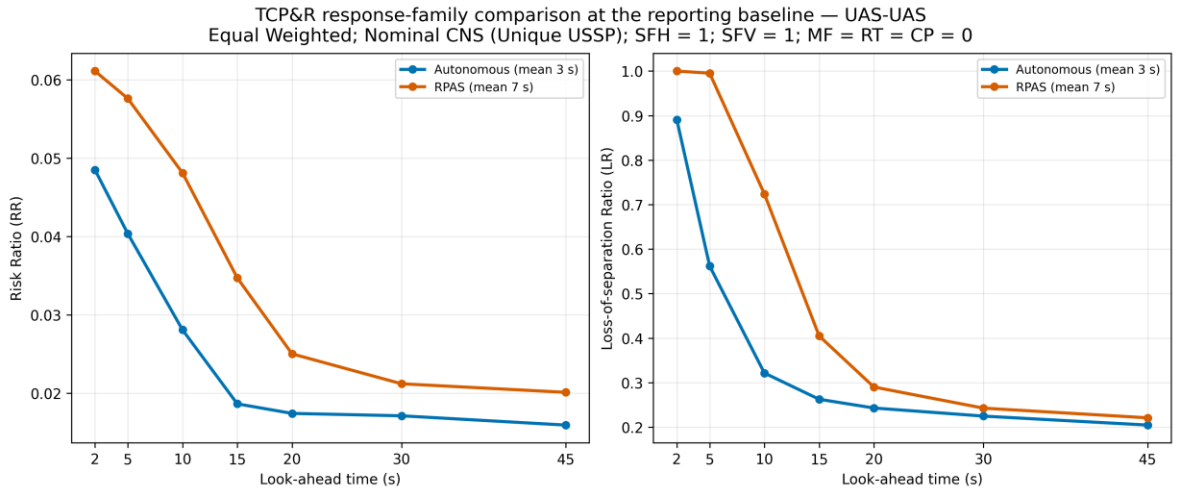


Figure 106: Raw RR and LR comparison between the executed Autonomous and RPAS response assumptions for UAS–UAS encounters at the definitive reporting baseline. The values precede the separate reporting factor of two.

The broader paired comparison in Figure 107 confirms that this is a campaign-wide response effect rather than a single baseline point. RPAS produces the higher LR in all 4,480 matched UAS–UAS cases and the higher RR in 4,364 cases (97.41%). The RR gap is amplified by the smallest horizontal separation factors and the shorter look-ahead values; SFV and the tested CNS alternatives mainly change its magnitude. The non-cooperative case produces the largest execution-slice gap at LA = 45 s.

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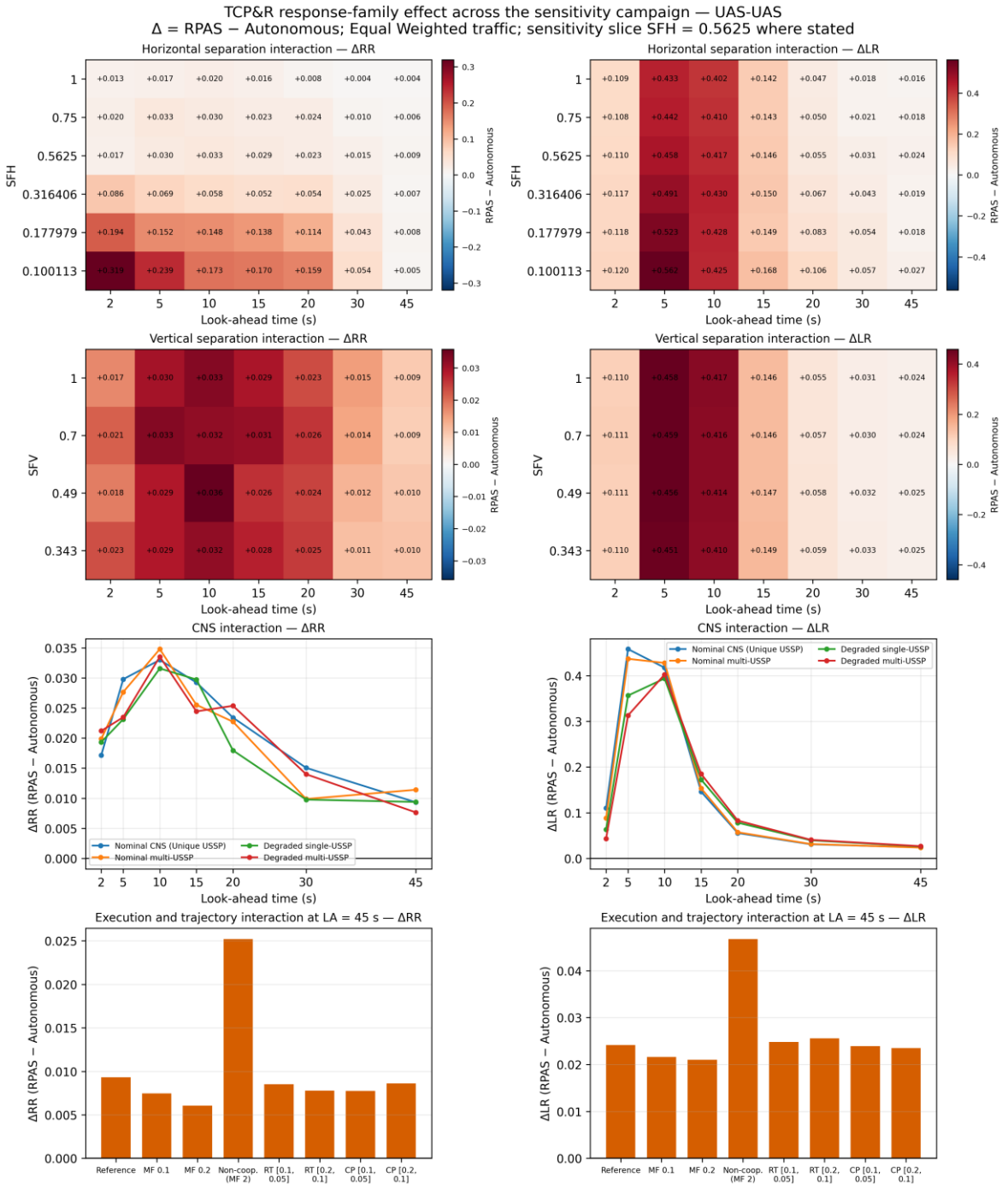


Figure 107: Matched RPAS minus Autonomous change in UAS–UAS RR and LR across horizontal and vertical separation, CNS, manoeuvre-failure, random-turn and climb/descent sensitivity slices. Positive values mean that the RPAS response assumption produces the higher conditional ratio.

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For UAS–manned encounters, Figure 108 shows a different pattern. LR remains higher for the RPAS response assumption throughout the reporting-baseline look-ahead sweep, but the RR curves cross. At LA = 45 s, raw RR is 0.382465 for Autonomous and 0.385668 for RPAS, while raw LR is 0.911448 and 0.920067, respectively. The larger manned-aircraft encounter dimensions and the fixed non-manoeuvring role of the manned participant make the NMAC-level ratio less monotonic than in UAS–UAS encounters.

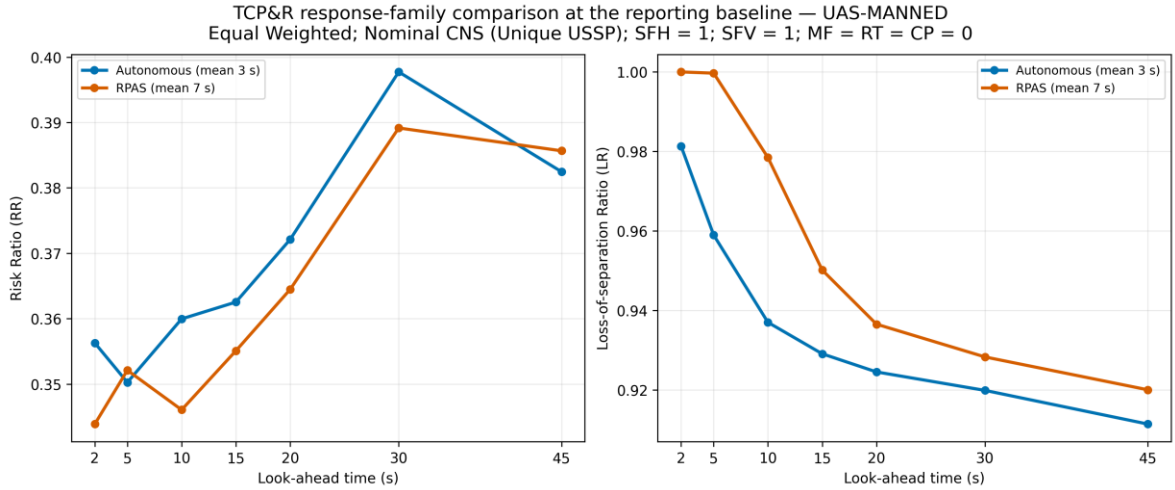


Figure 108: Raw RR and LR comparison between the executed Autonomous and RPAS response assumptions for UAS–manned encounters at the definitive reporting baseline. The manned aircraft retains its reference trajectory in both response families.

The complete UAS–manned sensitivity view in Figure 109 preserves those sign changes. RPAS gives the higher RR in 2,184 of 4,480 matched cases and Autonomous gives the higher RR in 2,296; the median ΔRR is −0.000822. LR is higher for RPAS in 4,257 cases (95.02%). Horizontal and vertical separation, CNS architecture and look-ahead can therefore reverse the small RR difference even when the broader loss-of-separation response remains predominantly positive.

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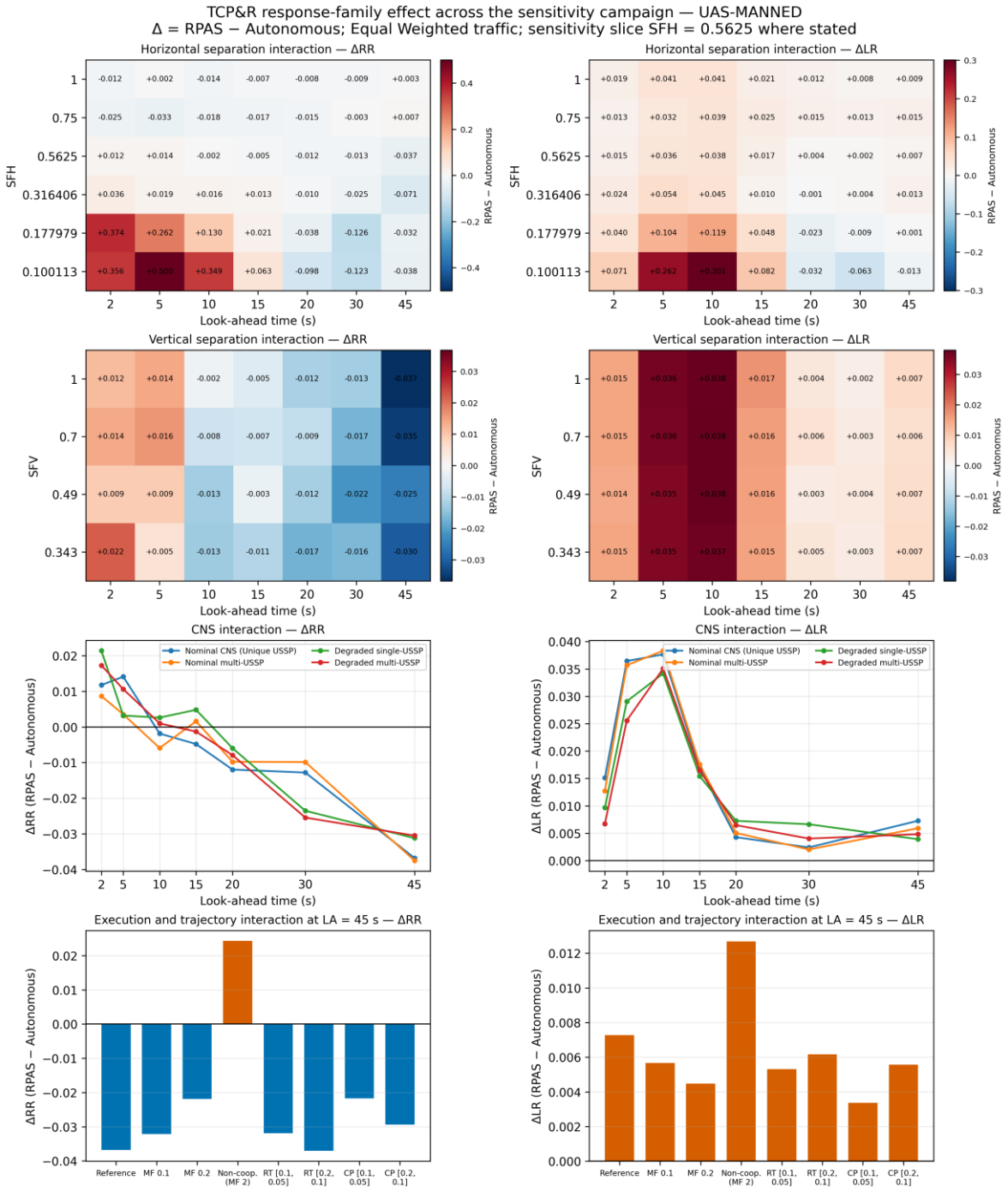


Figure 109: Matched RPAS minus Autonomous change in UAS–manned RR and LR across the same admitted sensitivity slices. The diverging RR response shows why the operation comparison cannot be reduced to a universal response-family ranking.

Interpretation boundary. The figures isolate the effect of the executed response assumptions inside a synthetic, conflict-rich and traffic-weighted pairwise campaign. This evidence does not support a universal ranking of autonomous and remotely piloted operations, an absolute collision-frequency estimate or an empirically validated Human Performance conclusion. All plotted values are raw

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diagnostic aggregates before the single consortium reporting factor of two; they do not replace or modify the controlled final RR tables.

Traffic-mix-resolved UAS–UAS and UAS–manned results

The following twelve figures expose RR and LR separately for the six U-AGREE traffic mixes admitted here: Benidorm BVLL and AVLL, CORUS BVLL and AVLL, and Shannon BVLL and AVLL. The Equal Weighted aggregate is deliberately not plotted. Every panel overlays four curves from the same source configuration: UAS–UAS and UAS–manned, each under the executed Autonomous and RPAS response assumptions.

In every left-hand panel, look-ahead varies over 2, 5, 10, 15, 20, 30 and 45 s while SFH = 1. In every right-hand panel, SFH varies over the six executed values while LA = 45 s. Both panels hold Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0. Colour distinguishes Autonomous from RPAS and line style distinguishes UAS–UAS from UAS–manned. The plotted quantities are raw aggregate ratios before the separate consortium reporting factor of two.

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Combined encounter traffic mix: Benidorm BVLL

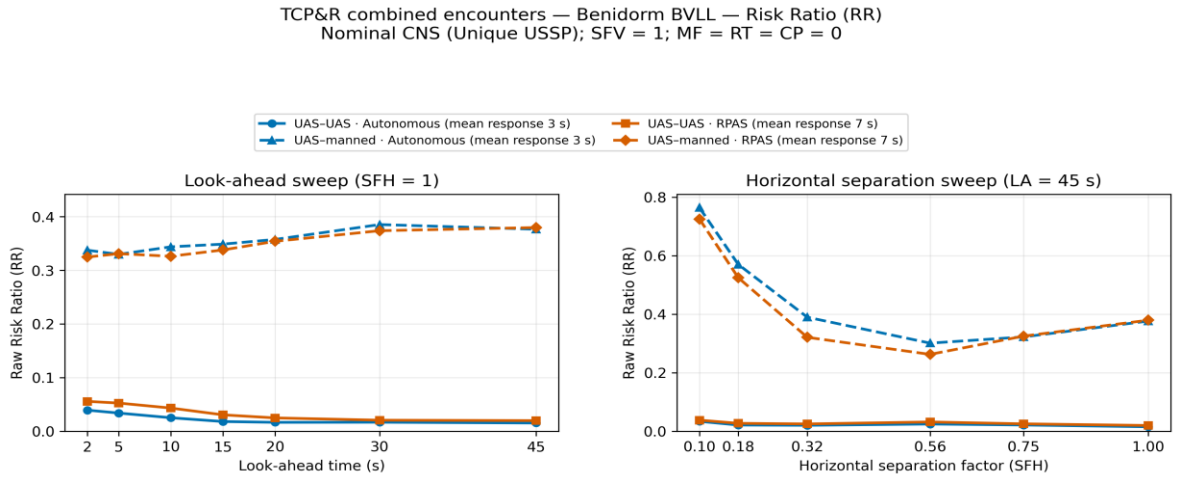


Figure 110: Combined UAS–UAS and UAS–manned raw Risk Ratio (RR) for Benidorm BVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0.

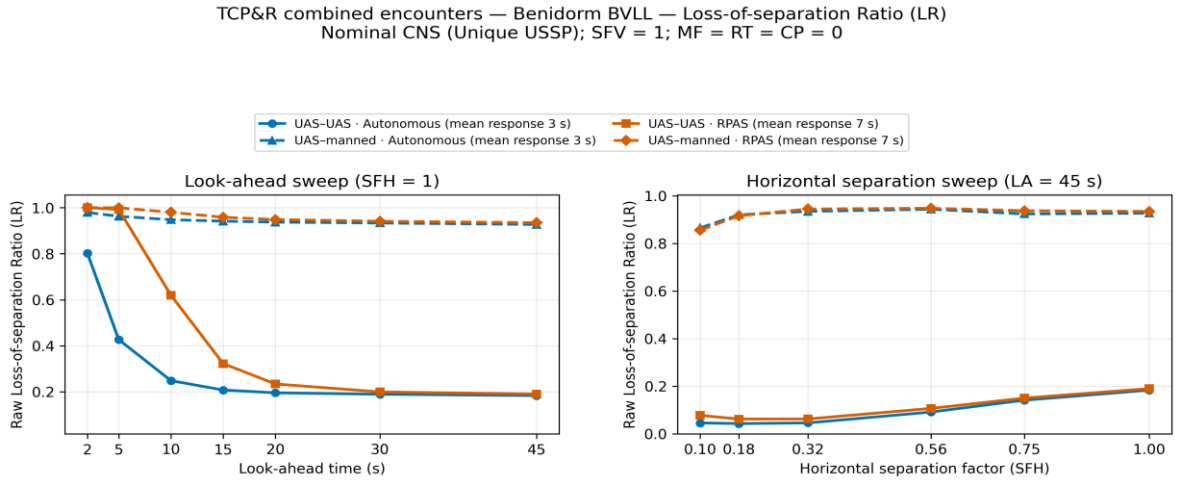


Figure 111: Combined UAS–UAS and UAS–manned raw Loss-of-separation Ratio (LR) for Benidorm BVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0.

For Benidorm BVLL, Figure 110 and Figure 111 compare two distinct encounter-family responses on common axes. For UAS–UAS, RPAS remains above Autonomous at every RR and LR point in both slices. For UAS–manned, RPAS remains above Autonomous for LR at all look-ahead values, but the SFH ordering is mixed; RR is also mixed and Autonomous is higher at most admitted points. The larger UAS–manned ratio level is a property of these conditional encounter definitions, not an absolute event-frequency comparison.

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Combined encounter traffic mix: Benidorm AVLL

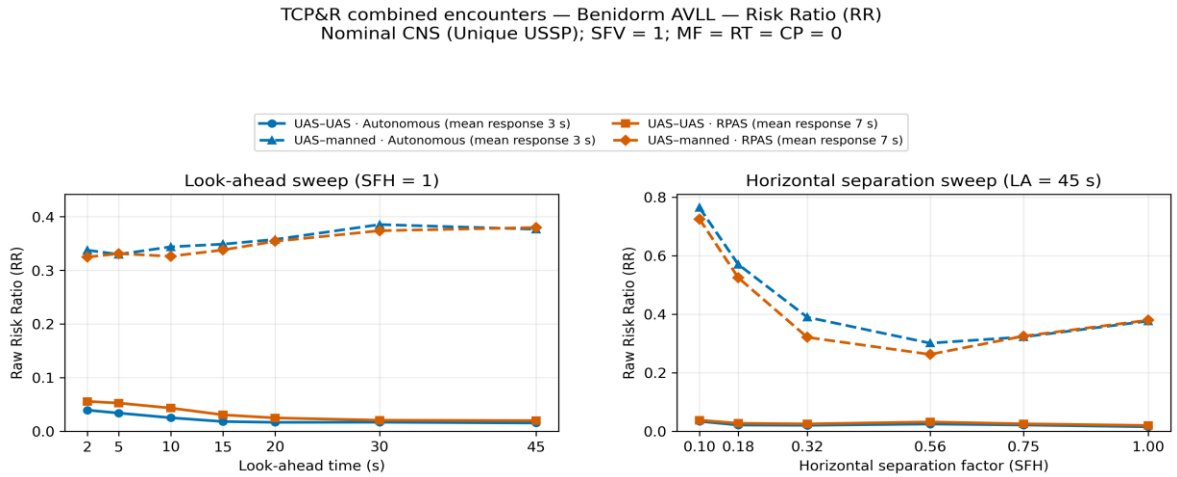


Figure 112: Combined UAS–UAS and UAS–manned raw Risk Ratio (RR) for Benidorm AVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0.

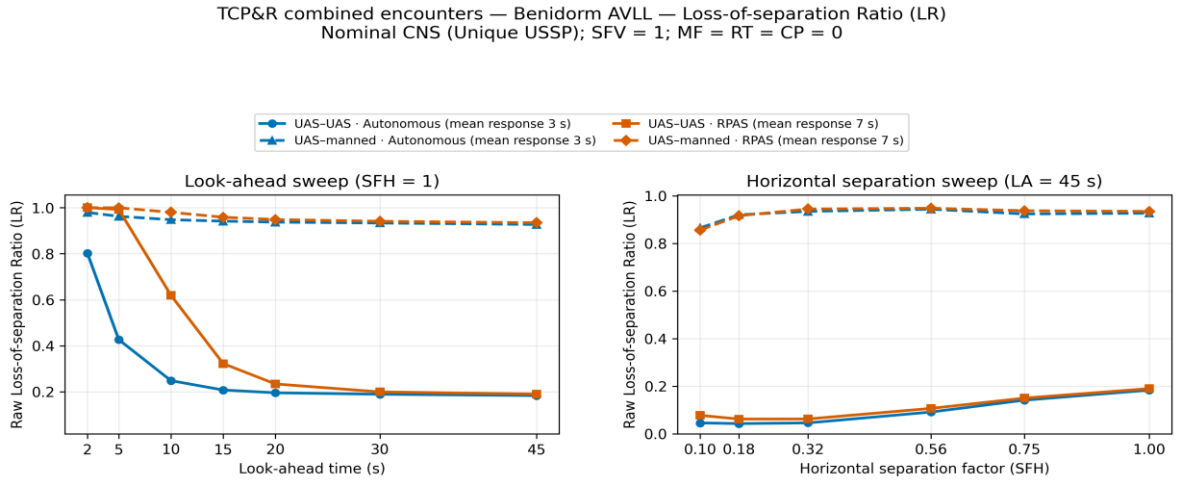


Figure 113: Combined UAS–UAS and UAS–manned raw Loss-of-separation Ratio (LR) for Benidorm AVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0.

For Benidorm AVLL, Figure 112 and Figure 113 reproduce the Benidorm BVLL curves to the displayed precision for both encounter families. The UAS–UAS response keeps RPAS above Autonomous throughout RR and LR, whereas UAS–manned RR has no common response-family ordering and its LR SFH ordering changes locally. The AVLL/BVLL proximity is therefore reported as an observed result of the executed source weights, not as general operational equivalence.

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Combined encounter traffic mix: CORUS BVLL

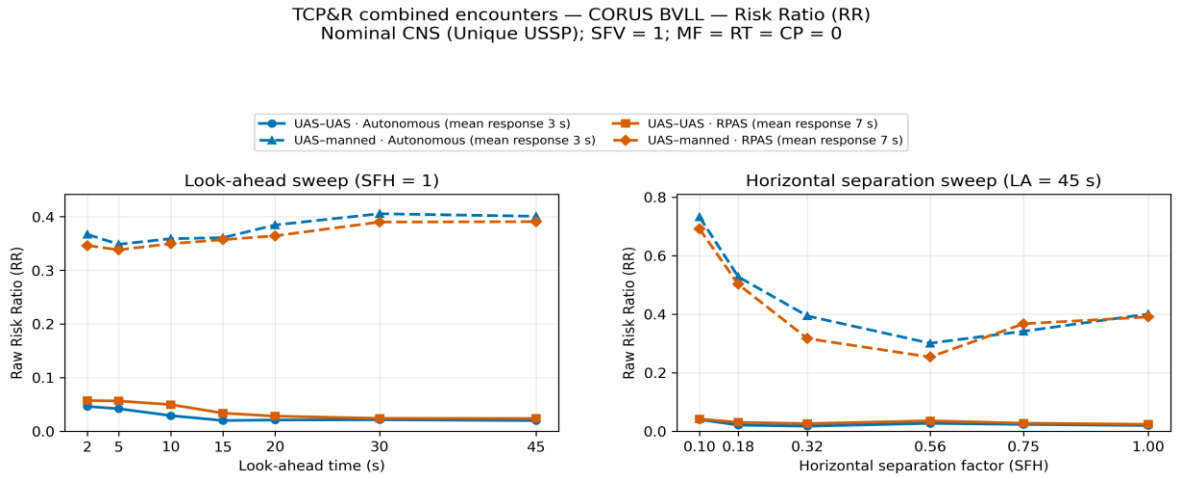


Figure 114: Combined UAS–UAS and UAS–manned raw Risk Ratio (RR) for CORUS BVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0.

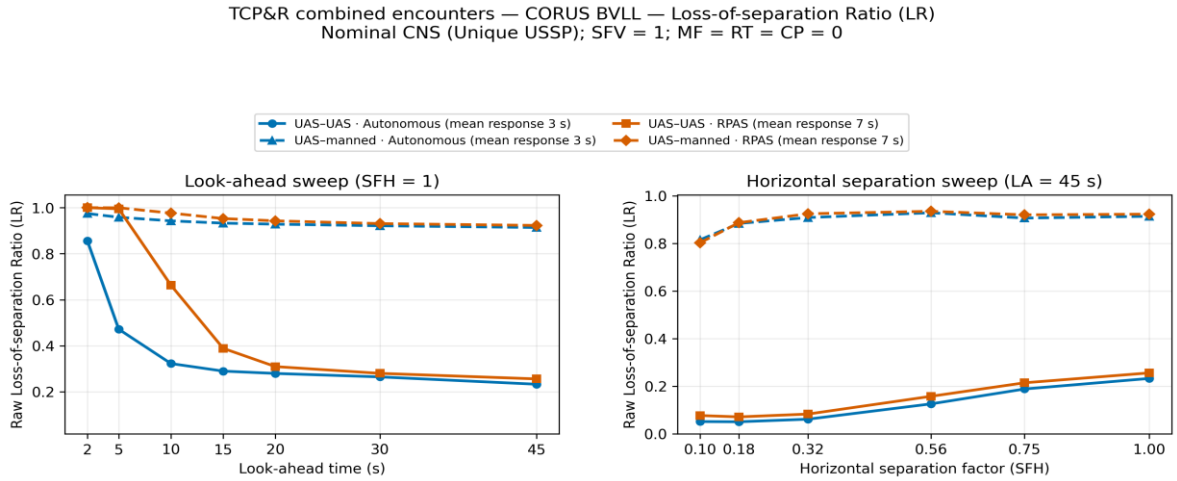


Figure 115: Combined UAS–UAS and UAS–manned raw Loss-of-separation Ratio (LR) for CORUS BVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0.

For CORUS BVLL, Figure 114 and Figure 115 show a stable contrast between the two encounter families. UAS–UAS keeps RPAS above Autonomous at every RR and LR point. In UAS–manned, RR has RPAS below Autonomous at all seven look-ahead values and at five of six SFH values, while LR has RPAS above Autonomous at every look-ahead value and at five of six SFH values. The common axes make the distinct conditional scales visible without converting them to absolute rates.

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Combined encounter traffic mix: CORUS AVLL

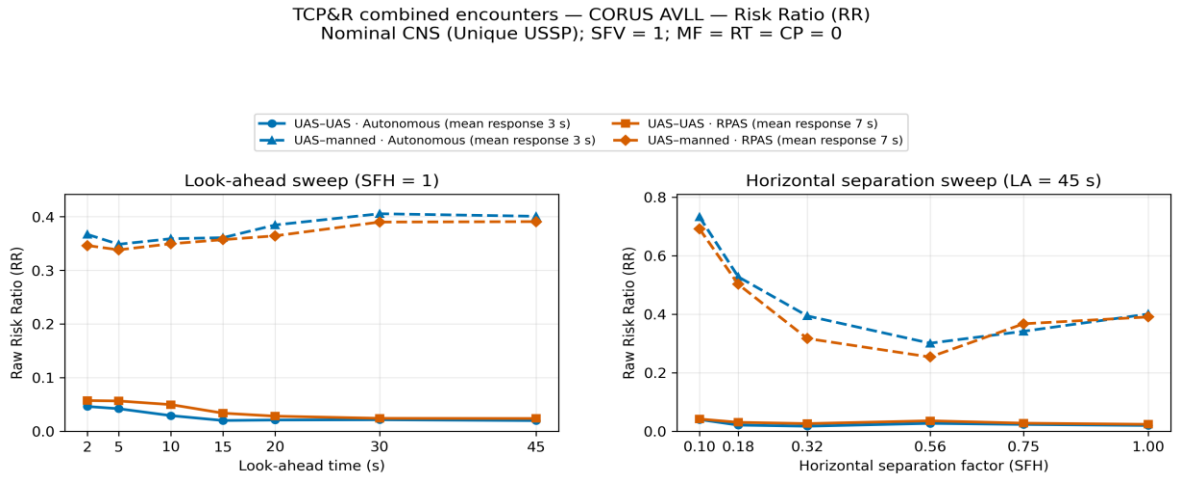


Figure 116: Combined UAS–UAS and UAS–manned raw Risk Ratio (RR) for CORUS AVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0.

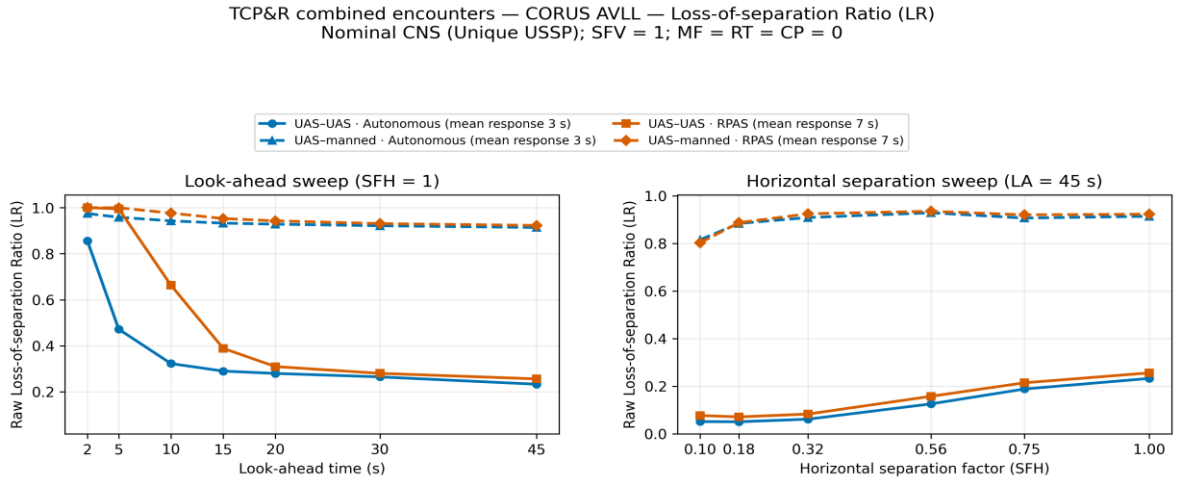


Figure 117: Combined UAS–UAS and UAS–manned raw Loss-of-separation Ratio (LR) for CORUS AVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0.

For CORUS AVLL, Figure 116 and Figure 117 closely track the CORUS BVLL results for both encounter families. The UAS–UAS curves retain RPAS above Autonomous throughout; the UAS–manned curves retain the opposite dominant ordering for RR and the mostly positive RPAS-minus-Autonomous ordering for LR. As in Benidorm, the close BVLL/AVLL agreement is a numerical property of these traffic-weighted aggregates rather than evidence of general operational equivalence.

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Combined encounter traffic mix: Shannon BVLL

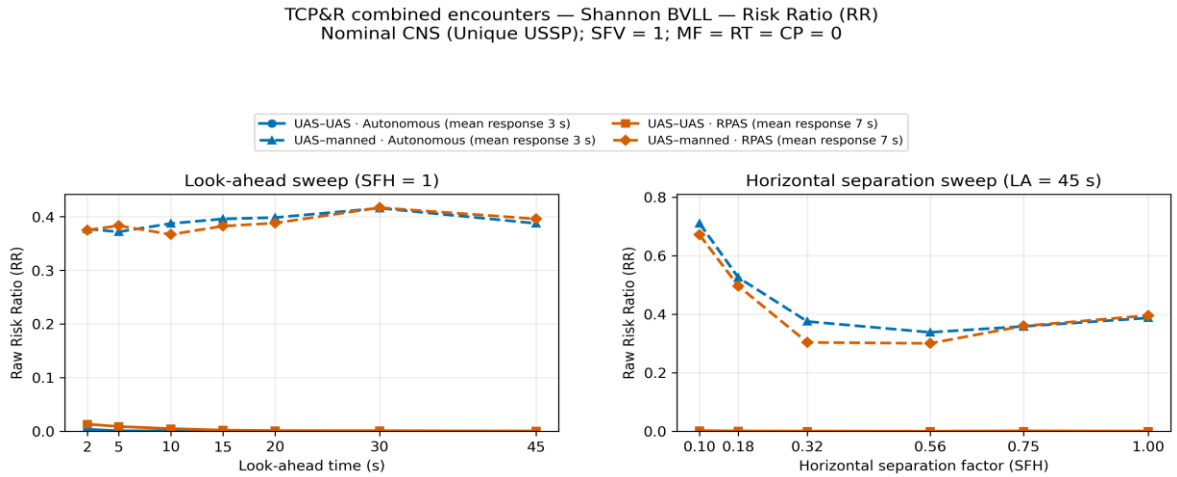


Figure 118: Combined UAS–UAS and UAS–manned raw Risk Ratio (RR) for Shannon BVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0.

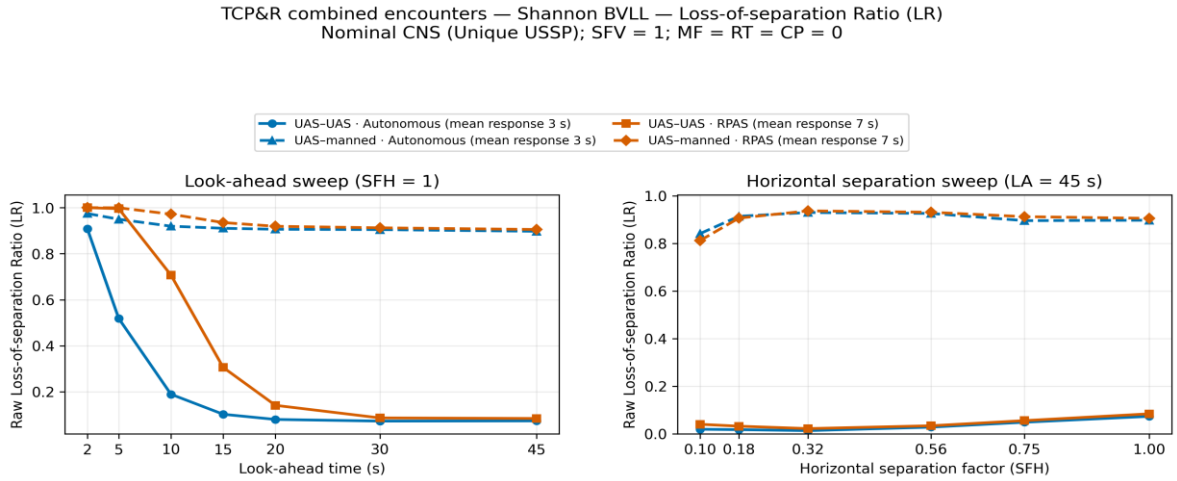


Figure 119: Combined UAS–UAS and UAS–manned raw Loss-of-separation Ratio (LR) for Shannon BVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0.

For Shannon BVLL, Figure 118 and Figure 119 expose the least uniform response ordering. UAS–UAS RR has RPAS above Autonomous at six of seven look-ahead points and three of six SFH points, while its LR keeps RPAS above throughout. UAS–manned RR is also mixed, with Autonomous higher at four of seven look-ahead and four of six SFH points. UAS–manned LR keeps RPAS above at all look-ahead values but changes ordering at two SFH values.

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Combined encounter traffic mix: Shannon AVLL

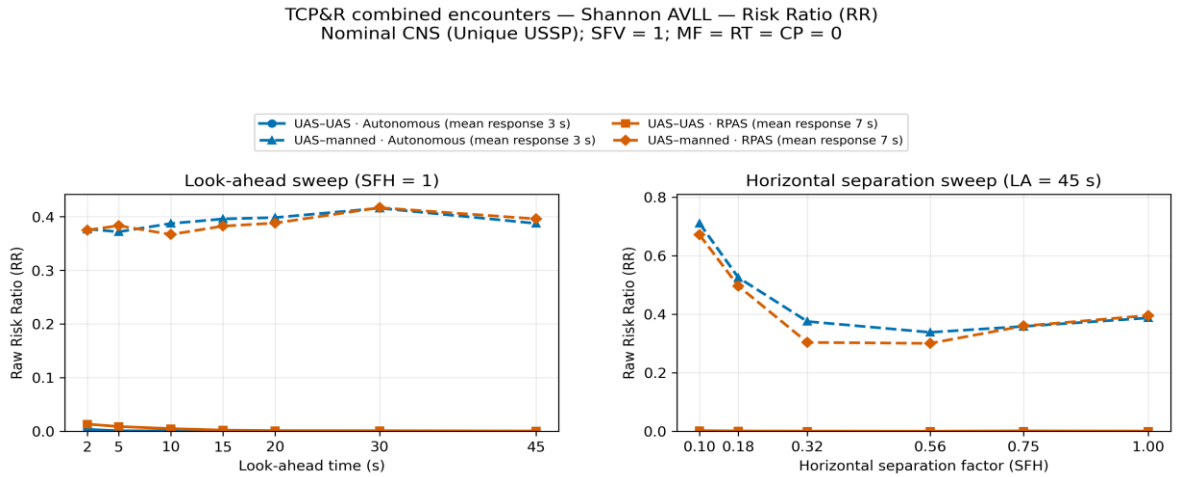


Figure 120: Combined UAS–UAS and UAS–manned raw Risk Ratio (RR) for Shannon AVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0.

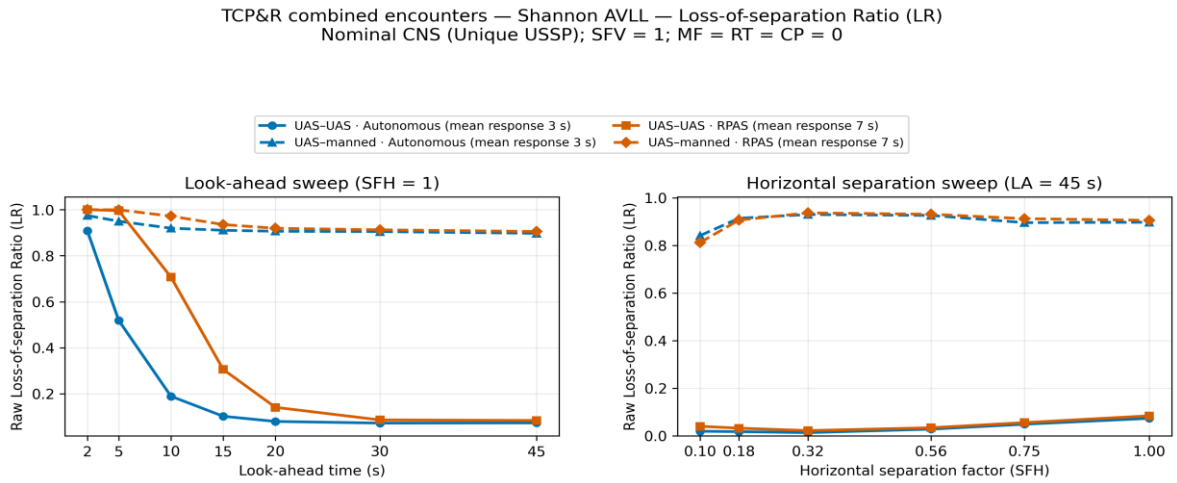


Figure 121: Combined UAS–UAS and UAS–manned raw Loss-of-separation Ratio (LR) for Shannon AVLL: Autonomous and RPAS curves across look-ahead at SFH = 1 and across SFH at LA = 45 s. Nominal CNS (Unique USSP), SFV = 1 and MF = RT = CP = 0.

For Shannon AVLL, Figure 120 and Figure 121 mirror the Shannon BVLL patterns to the plotted precision. Shannon UAS–UAS RR remains much lower than the Benidorm and CORUS UAS–UAS levels and changes response ordering within the admitted slices. UAS–manned RR likewise has no universal response ranking, whereas LR is consistently RPAS-higher over look-ahead and mostly RPAS-higher over SFH. The AVLL/BVLL similarity remains an observed aggregate result only.

Cross-traffic and encounter-family synthesis. All six requested traffic mixes contain complete seven-point look-ahead and six-point SFH sweeps for both response assumptions and both encounter families. UAS–UAS Benidorm and CORUS keep RPAS above Autonomous throughout the admitted RR and LR slices; Shannon retains that ordering for LR but not for every RR point. UAS–manned LR is RPAS-higher over every look-ahead curve and most SFH points, whereas UAS–manned RR has no universal response ranking. Within each city, BVLL and AVLL remain nearly coincident at the plotted scale. These

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are conditional, source-weighted campaign ratios; their different family-specific levels are not absolute operational event frequencies.

Pfa and alert rate are conditional campaign indicators. Because the generated population is deliberately conflict-rich, they quantify the selectivity and activation load of the detection chain within relevant encounters; they are not interpreted as absolute operational alert frequencies per flight hour.

Results on Final FAS+TCP&R

At the selected TCP&R reporting baseline—LA = 45 s, SFH = 1, SFV = 1, baseline CNS, unique USSP, no manoeuvre failure and no trajectory perturbations—the raw Risk Ratio was extracted separately for the Autonomous and RPAS response assumptions. Since neither response family is uniformly conservative across all scenarios and encounter types, the highest of the two values was retained for each configuration. The consortium reporting factor of two was then applied to avoid assigning excessive mitigation credit. The resulting reported TCP&R Risk Ratios range from approximately 0.040 to 0.048 for UAS–UAS encounters in Benidorm and Manduria, decrease to approximately 0.00128 in Shannon, and range from approximately 0.759 to 0.801 for UAS–manned encounters. These values are used to derive the relaxed maximum allowable frequencies applied in the integrated Final FAS+TCP&R capacity assessment.

Scenario		$RR_{UAS-UAS}$	$RR_{UAS-manned}$
Benidorm	Below VLL	0.040	0.759
Benidorm	Above VLL	0.040	0.759
Manduria	Below VLL	0.048	0.801
Manduria	Above VLL	0.048	0.801
Shannon	Below VLL	0.00128	0.792
Shannon	Above VLL	0.00128	0.792

Table 69: UPV – TCP&R Risk Ratio for the different scenarios

Following the methodology used in Exercise #1 for the TIS, we obtain the updated success criteria for Final FAS when applying TCP&R presented in Table 70.

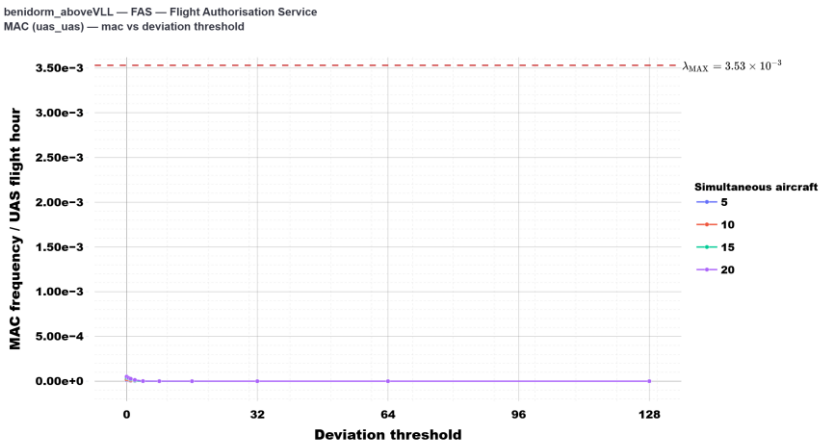
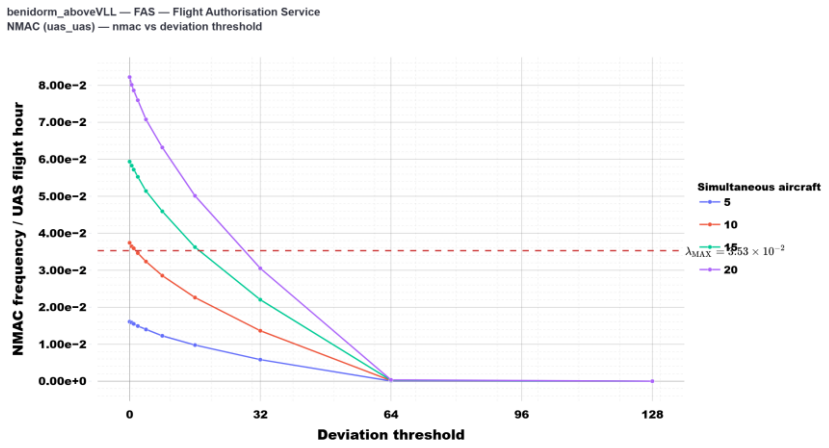
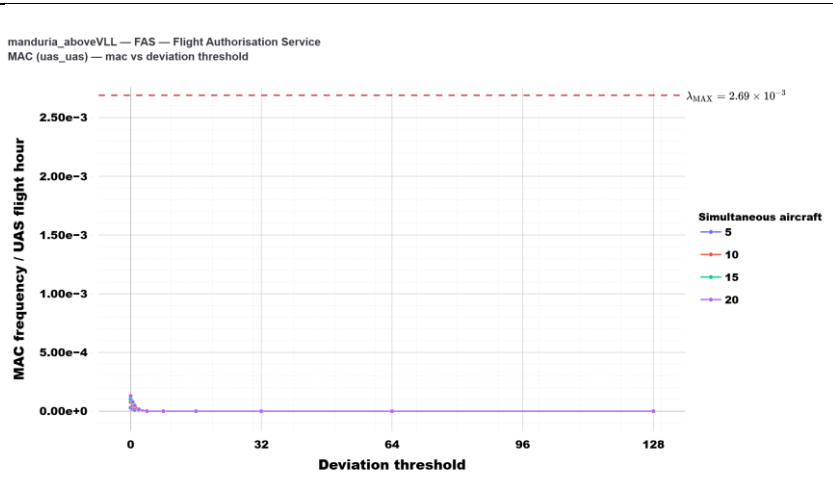
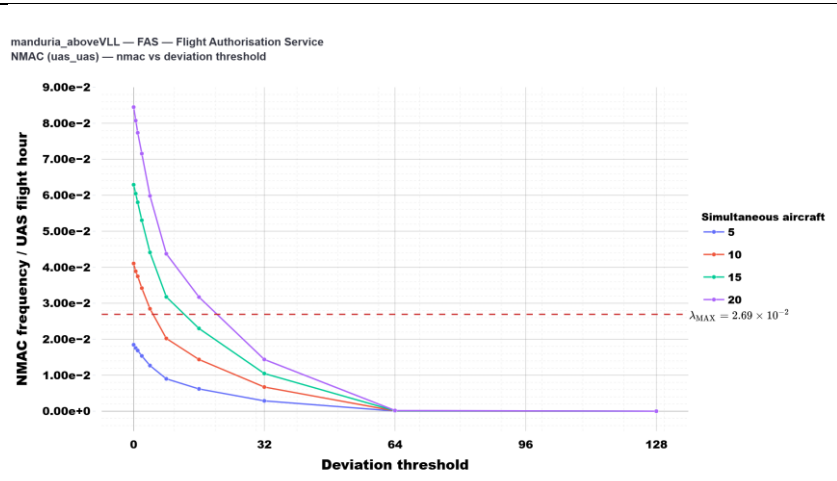
Scenario		$\lambda_{MAX\ UAS-UAS}$	$\lambda_{MAX\ UAS-manned}$
Benidorm	Below VLL	3.530E-3	1.317E-7
Benidorm	Above VLL	3.530E-3	1.317E-7
Manduria	Below VLL	2.694E-3	1.248E-7
Manduria	Above VLL	2.694E-3	1.248E-7
Shannon	Below VLL	4.898E+0	1.263E-7
Shannon	Above VLL	4.898E+0	1.263E-9

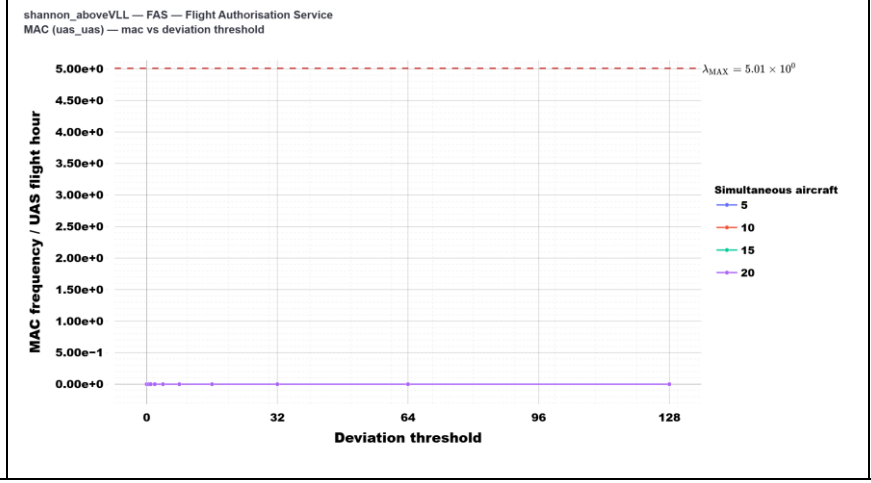
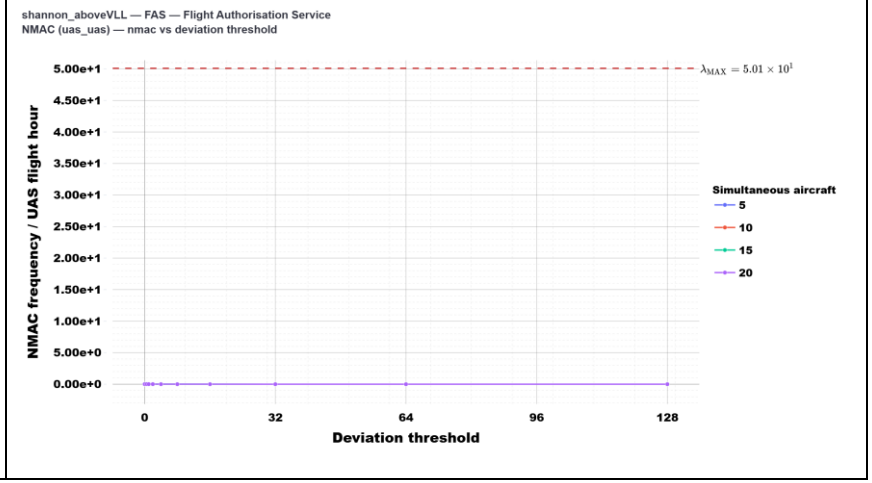
Table 70: UPV - Final FAS updated success criterion when applying TCP&R

The quantitative collision-frequency and safety-based capacity assessment presented in this section focuses on the above-VLL configurations of Benidorm, Manduria and Shannon–Limerick.

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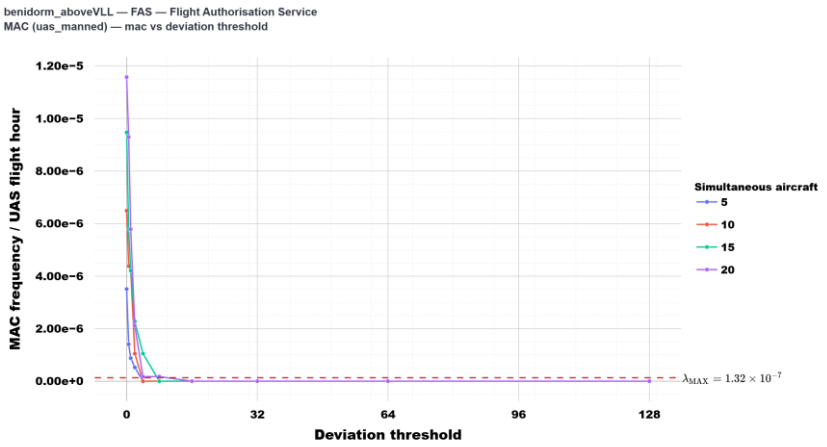
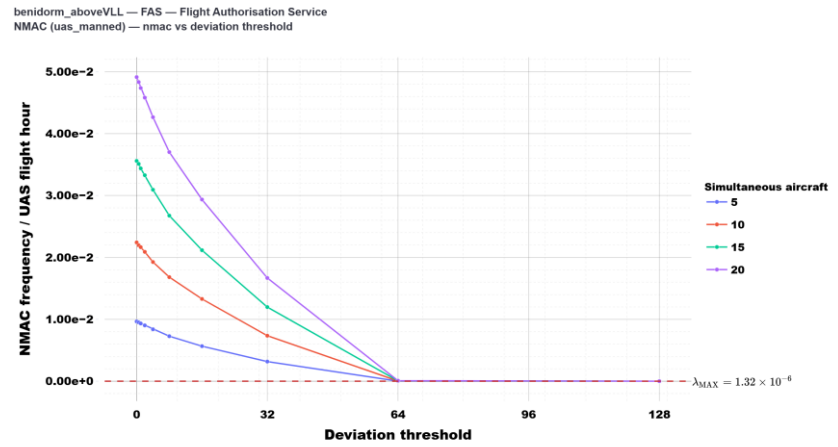
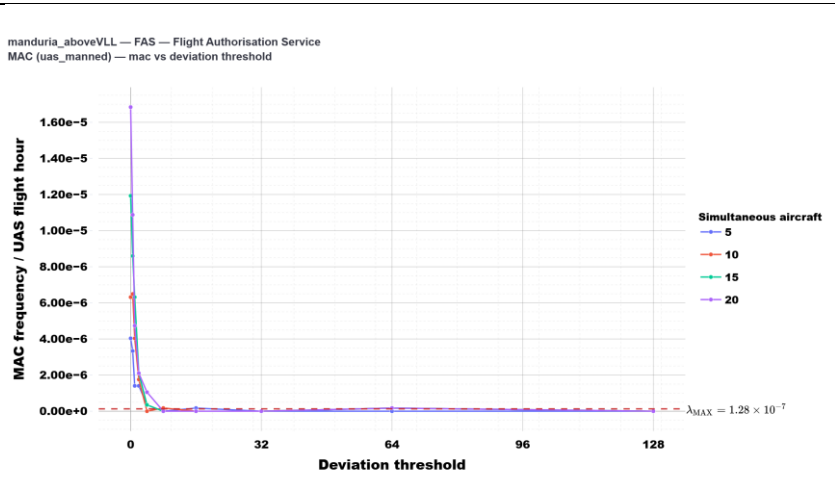
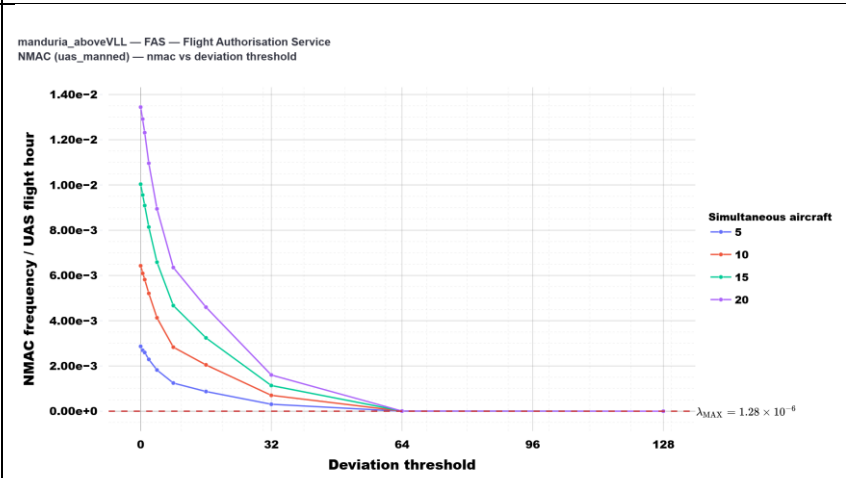
Figure 122: UPV – Final FAS+TCP&R above VLL UAS-UAS frequency

	MAC	NMAC
Benidorm above VLL		
Manduria above VLL		

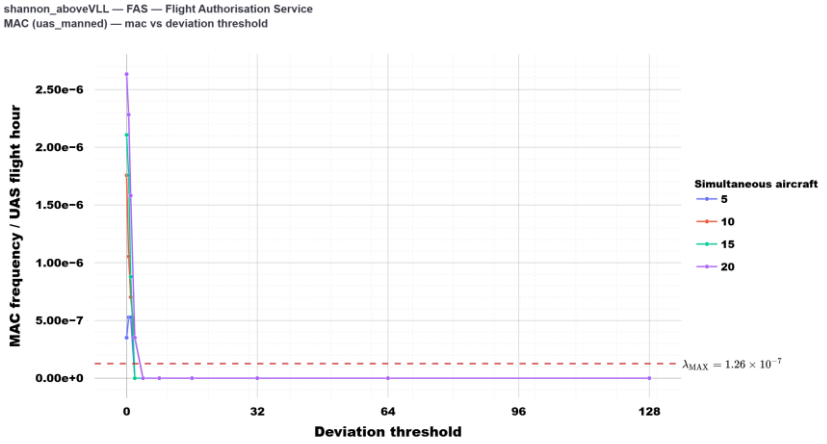
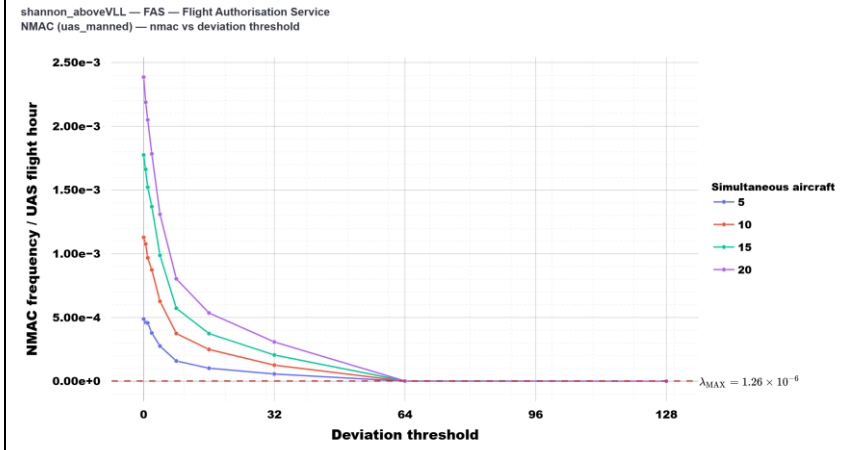
Shannon above VLL		

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Figure 123: UPV – Final FAS+TCP&R above VLL UAS-manned frequency in UAS flight hours

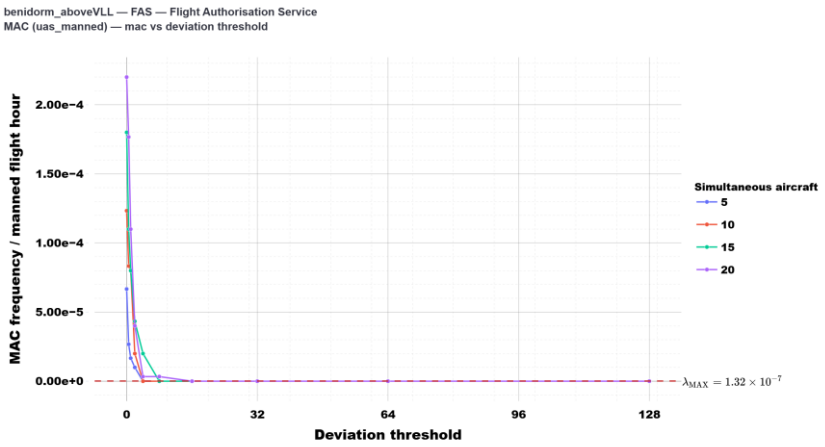
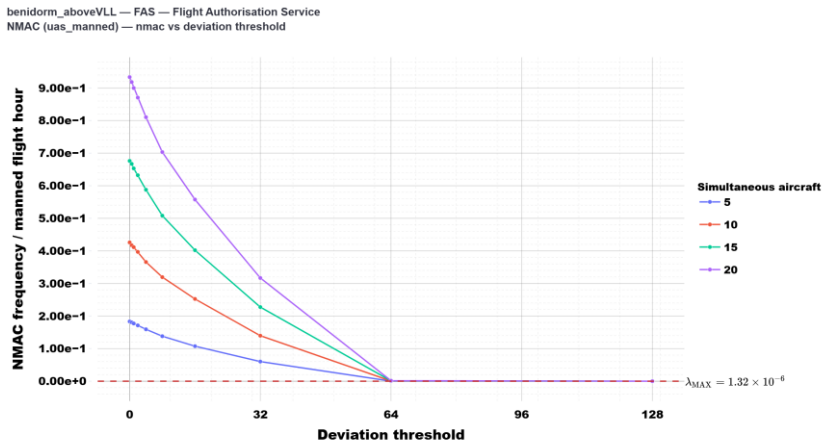
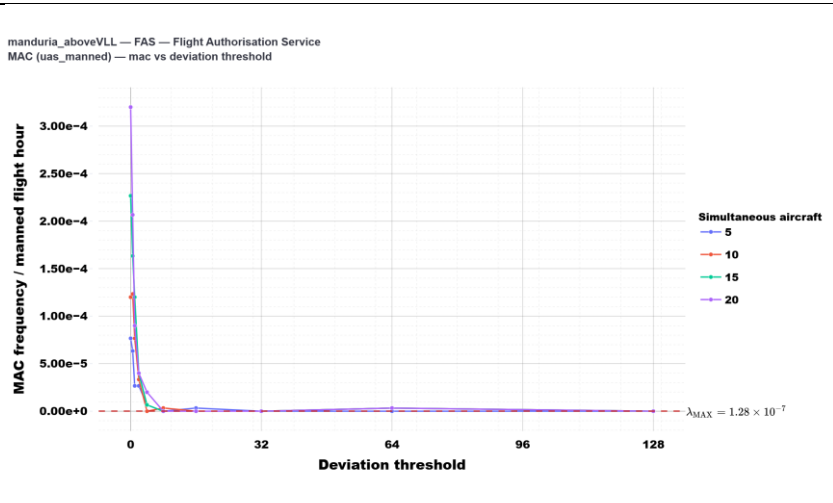
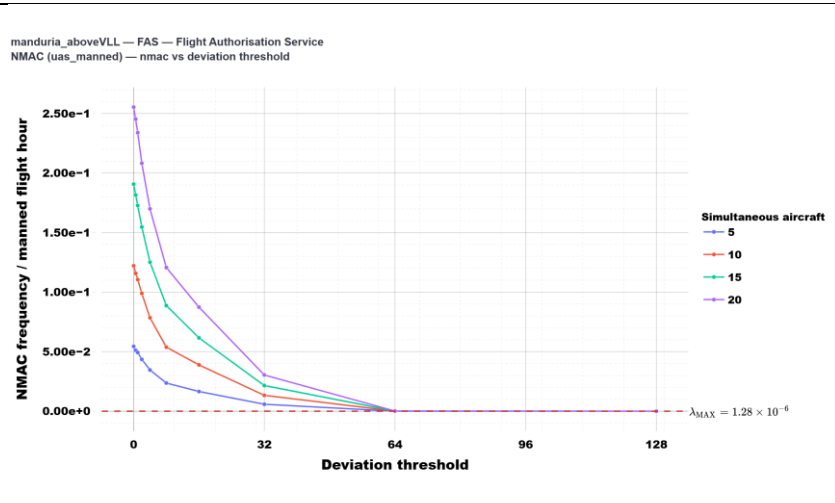
	MAC	NMAC
Benidorm above VLL		
Manduria above VLL		

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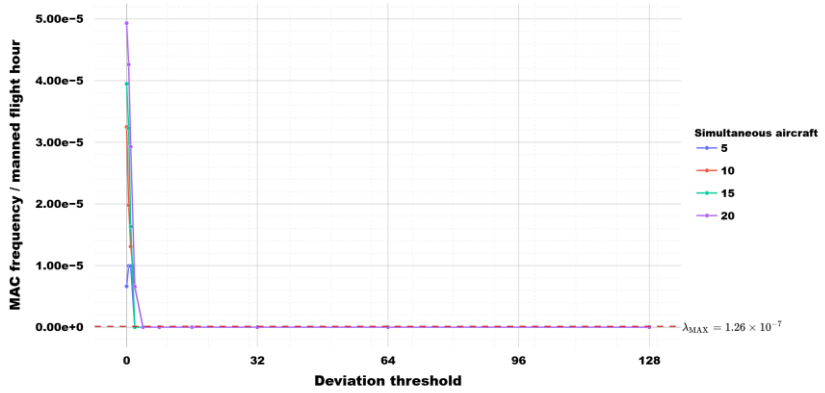
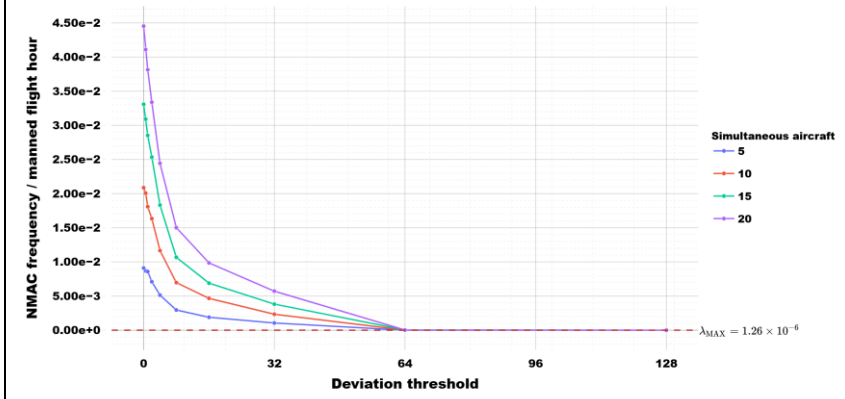
Shannon above VLL		

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Figure 124: UPV – Final FAS+TCP&R above VLL UAS-manned frequency in manned flight hours

	MAC	NMAC
Benidorm above VLL		
Manduria above VLL		

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Shannon above VLL		

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For UAS–UAS encounters, the Final FAS maintains the strategic-deconfliction mechanism assessed in Validation Exercise #01. Increasing the deviation threshold enlarges the protected volume used during Flight Authorisation and therefore progressively reduces the opportunity for authorised UAS trajectories to generate MAC and NMAC events. The reduction is generally more rapid for MAC, since the strategic separation distance reaches the MAC scale at smaller deviation thresholds, whereas larger thresholds may be required to produce an equivalent reduction in NMAC frequency.

Unlike the FAS configuration assessed in Validation Exercise #01, the Final FAS also considers manned-aircraft trajectories during the strategic-deconfliction process. Consequently, the reduction observed in UAS–manned MAC and NMAC frequencies must be interpreted as a direct effect of the Final FAS rather than as an indirect consequence of redistributing UAS traffic. A proposed UAS trajectory is authorised only if the corresponding protected volume remains compatible with both the previously authorised UAS trajectories and the relevant manned-aircraft trajectories during their overlapping time intervals.

For UAS–manned encounters, Final FAS directly reduces collision frequencies by considering manned-aircraft trajectories during strategic deconfliction. At smaller deviation thresholds, the protected distance may be sufficient to prevent MAC events while residual NMAC events remain possible because the authorised separation does not yet cover the larger UAS–manned NMAC volume. A more substantial reduction in NMAC frequency is expected once the complete protected distance—including the applicable trajectory-error margins, aircraft dimensions and deviation threshold—reaches the UAS–manned NMAC separation distance.

This distinction is fundamental when comparing the two validation exercises. In Validation Exercise #01, FAS directly modified only the UAS–UAS encounter population, while the UAS–manned frequencies remained broadly independent of the deviation threshold or changed only through indirect traffic-redistribution effects. In Validation Exercise #02, both encounter populations are directly affected by strategic deconfliction. Therefore, the UAS–UAS and UAS–manned frequencies must both be calculated separately for each deviation threshold and scenario configuration.

TCP&R provides an additional tactical mitigation layer for the residual encounters remaining after application of the Final FAS. The reported TCP&R Risk Ratios are substantially lower for UAS–UAS encounters than for UAS–manned encounters. TCP&R therefore provides a particularly strong conditional reduction for residual UAS–UAS encounters, while the additional tactical benefit for UAS–manned encounters is more moderate.

The combined Final FAS+TCP&R configuration must consequently be interpreted as two consecutive mitigation layers. Final FAS reduces the frequency with which strategically conflicting UAS–UAS and UAS–manned trajectories are introduced into the active traffic environment, while TCP&R reduces the conditional risk associated with encounters that remain during operation. TCP&R does not directly change the frequencies generated by Final FAS; its mitigation effect is incorporated through the scenario- and encounter-specific Risk Ratios used to derive the relaxed maximum allowable frequencies.

To derive the safety-based capacity for the Final FAS configuration, the P_{NMAC} parameter is obtained by normalising the simulated NMAC frequency according to the number of potential interactions, as implemented by UPV in batch 1. Since Final FAS directly deconflicts UAS trajectories against both UAS and manned-aircraft trajectories, P_{NMAC} is calculated separately for each encounter family, scenario configuration and deviation threshold.

Scenario	Deviation threshold	P_{NMAC} for UAS-UAS
Benidorm above VLL	4	3.62E-03
	64	1.71E-05
	128	N/A[26]
Manduria above VLL	4	3.16E-03
	64	9.53E-06
	128	N/A
Shannon above VLL	4	2.32E-04
	64	N/A
	128	N/A

Table 71: UPV – Final FAS independent of the number of simultaneous vehicles parameter on the UAS-UAS NMAC frequency

Scenario	Deviation threshold	P_{NMAC} UAS-manned per UAS FH
Benidorm above VLL	4	2.17E-03
	64	4.01E-06
	128	N/A
Manduria above VLL	4	4.64E-04
	64	4.18E-07
	128	N/A
Shannon above VLL	4	6.95E-05
	64	7.86E-08
	128	N/A

Table 72: UPV – Final FAS independent of the number of simultaneous vehicles parameter on the UAS-manned NMAC frequency per UAS FH

Scenario	Deviation threshold	P_{NMAC} UAS-manned per manned FH
Benidorm above VLL	4	4.13E-02
	64	7.62E-05
	128	N/A
	4	8.81E-03

[26] N/A values represent frequencies of NMAC of 0 for a given deviation threshold.

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Manduria above VLL	64	7.95E-06
	128	N/A
Shannon above VLL	4	1.29E-03
	64	1.46E-06
	128	N/A

Table 73: UPV – Final FAS independent of the number of simultaneous vehicles parameter on the UAS-manned NMAC frequency per manned FH

For both UAS-UAS and UAS-manned events, P_{NMAC} is calculated separately for each deviation threshold. Increasing the deviation threshold may support a higher safety-based capacity by reducing collision frequency; however, larger separation margins also make the acceptance of new U-plans more restrictive.

Scenario	Deviation threshold	UAS–UAS capacity	UAS–manned capacity per UAS FH	UAS–manned capacity per manned FH
Benidorm above VLL	4	10	1	1
	64	119	1	1
	128	50	50	50
Manduria above VLL	4	9	1	1
	64	482	3	1
	128	286	286	286
Shannon above VLL	4	1468	1	1
	64	925	16	1
	128	745	745	745

Table 74: UPV - Capacity results for the Final FAS+TCPR

The grey-shaded cells in Table 74 indicate cases where the safety-based capacity exceeds the number of trajectories[27]. The resulting safety-based capacities are presented in the following table. The results show that Final FAS can increase both UAS–UAS and UAS–manned capacity as the deviation threshold increases. However, the UAS–manned criterion remains the limiting factor until the protected distance reaches the applicable UAS–manned NMAC separation distance, after which the capacities obtained from the different safety criteria converge.

The Conformance Monitoring results are similar to those obtained in Exercise #01. Risk Ratios based on NMAC frequencies are approximately one, except for bigger deviation thresholds. The impact of this barrier is mainly on the non-conformance frequencies, which are similar to those frequencies obtained in Exercise #01.

[27] The trajectories are generated independently for each scenario configuration.

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The results obtained for the KPIs associated with this validation objective are summarised in the following table. The values are presented separately for each scenario and altitude configuration, covering the Safety, Capacity, and Access and Equity KPAs. Together, these indicators provide a consolidated view of the safety performance, the traffic levels that can be accommodated, and the operational impact of the Final FAS and the TCPR.

Scenario	KPA	KPI	Value obtained
Benidorm above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS–UAS:** ≈ 1.45E-2 NMAC/FH for 5 simultaneous UAS and ≈ 6.88E-2 NMAC/FH for 20 simultaneous UAS (DT = 4) – 0.0 NMAC/FH (DT = 128). **UAS-manned per UAS flight hours** ≈ 8.68E-3 NMAC/UAS FH for 5 simultaneous UAS and ≈ 4.12E-2 NMAC/UAS FH for 20 simultaneous UAS (DT = 4) – 0.0 NMAC/UAS FH (DT = 128). **UAS-manned per manned flight hours** ≈ 1.65E-1 NMAC/manned FH for 5 simultaneous UAS and ≈ 7.85E-1 NMAC/manned FH for 20 simultaneous UAS (DT = 4) – 0.0 NMAC/manned FH (DT = 128).
	Capacity	U-AGREE-KPI-03 **Area drone density**	The qualitative SCR assessment shows that additional U-plans can be accommodated through alternative route generation. **UAS-UAS** ≈ 0.4690 UAS/km² for DT = 4 ≈ 5.5791 UAS/km² for DT = 64 ≈ 2.3450 UAS/km² for DT = 128 **UAS–manned per UAS flight hours** ≈ 0.0469 UAS/km² for DT = 4 ≈ 0.0469 UAS/km² for DT = 64 ≈ 2.3450 UAS/km² for DT = 128 **UAS–manned per manned flight hours** ≈ 0.0469 UAS/km² for DT = 4 ≈ 0.0469 UAS/km² for DT = 64 ≈ 2.3450 UAS/km² for DT = 128
		U-AGREE-KPI-04 **Average number of authorised U-plans**	Results show that SCR increases the number of U-plans that can be authorised by generating alternative conflict-free routes for operations that would otherwise be rejected. TCP&R does not directly modify the number of U-plans authorised by FAS, but reduces the residual risk associated with the accepted operations.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Results show that SCR improves the Authorisation Approval Rate in all the assessed Benidorm traffic configurations. TCP&R is applied after strategic authorisation and therefore does not directly modify the approval rate, although its risk reduction supports the safe operation of the authorised traffic.

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Manduria above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	**UAS–UAS:** ≈ 1.3E-2 NMAC/FH for 5 simultaneous UAS and ≈ 6E-2 NMAC/FH for 20 simultaneous UAS (DT = 4) – 0.0 NMAC/FH (DT = 128). **UAS-manned per UAS flight hours** ≈ 1.8E-3 NMAC/UAS FH for 5 simultaneous UAS and ≈ 9E-3 NMAC/UAS FH for 20 simultaneous UAS (DT = 4) – 0.0 NMAC/UAS FH (DT = 128). **UAS-manned per manned flight hours** ≈ 3.5E-2 NMAC/manned FH for 5 simultaneous UAS and ≈ 1.7E-1 NMAC/manned FH for 20 simultaneous UAS (DT = 4) – 0.0 NMAC/manned FH (DT = 128).
	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** ≈ 0.0195 UAS/km² for DT = 4 ≈ 1.0433 UAS/km² for DT = 64 ≈ 0.6190 UAS/km² for DT = 128 **UAS–manned per UAS flight hours** ≈ 0.0022 UAS/km² for DT = 4 ≈ 0.0065 UAS/km² for DT = 64 ≈ 0.6190 UAS/km² for DT = 128 **UAS–manned per manned flight hours** ≈ 0.0022 UAS/km² for DT = 4 ≈ 0.0022 UAS/km² for DT = 64 ≈ 0.6190 UAS/km² for DT = 128
		U-AGREE-KPI-04 **Average number of authorised U-plans**	TCP&R does not directly modify the number of U-plans authorised by the Final FAS, as the tactical service acts on residual encounters after flight authorisation.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	TCP&R does not directly modify the Authorisation Approval Rate because it is applied after the Flight Authorisation process. Its contribution concerns the reduction of residual risk for authorised operations rather than the initial acceptance of submitted U-plans.
Shannon above VLL	Safety	U-AGREE-KPI-01 **Number of NMAC/FH**	Coordinated DAR rerouting provides complementary qualitative Safety evidence by preventing simultaneous diversion routes from introducing additional conflicts. **UAS–UAS:** ≈ 1E-3 NMAC/FH for 5 simultaneous UAS and ≈ 4.1E-3 NMAC/FH for 20 simultaneous UAS (DT = 4) – 0.0 NMAC/FH (DT = 128). **UAS-manned per UAS flight hours** ≈ 2.8E-4 NMAC/UAS FH for 5 simultaneous UAS and ≈ 1.3E-3 NMAC/UAS FH for 20 simultaneous UAS (DT = 4) – 0.0 NMAC/UAS FH (DT = 128). **UAS-manned per manned flight hours** ≈ 5.1E2 NMAC/manned FH for 5 simultaneous UAS and ≈ 2.5E-2 NMAC/manned FH for 20 simultaneous UAS (DT = 4) – 0.0 NMAC/manned FH (DT = 128).

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	Capacity	U-AGREE-KPI-03 **Area drone density**	**UAS-UAS** ≈ 1.7352 UAS/km² for DT = 4 ≈ 1.0934 UAS/km² for DT = 64 ≈ 0.8806 UAS/km² for DT = 128 **UAS–manned per UAS flight hours** ≈ 0.0012 UAS/km² for DT = 4 ≈ 0.0189 UAS/km² for DT = 64 ≈ 0.8806 UAS/km² for DT = 128 **UAS–manned per manned flight hours** ≈ 0.0012 UAS/km² for DT = 4 ≈ 0.0012 UAS/km² for DT = 64 ≈ 0.8806 UAS/km² for DT = 128
		U-AGREE-KPI-04 **Average number of authorised U-plans**	TCP&R does not directly modify the number of authorised U-plans because it acts after flight authorisation. Similarly, the DAR assessment concerns flights already active when the airspace is reconfigured.
	Access & Equity	U-AGREE-KPI-06 **Authorisation Approval Rate**	Neither TCP&R nor the assessed DAR coordinated-rerouting functionality directly modifies the Authorisation Approval Rate, as both act after the affected flights have been authorised. Their contribution concerns the safe management of residual encounters and ongoing operations.

Table 75: UPV - KPIs for OBJ-SOL0520-ERP-005.

B.4.3 Unexpected behaviours/results

No problem reports are documented for the preparation, execution or analysis of Validation Exercise #02. Accordingly, no associated corrective action or impact on dependent validation activities is identified.

Some results nevertheless require careful interpretation. In the TCP&R assessment, the relative performance of the Autonomous and RPAS response assumptions is not uniform across all encounter families and parameter configurations. In particular, the UAS–manned Risk Ratio presents non-monotonic behaviour and no universal response-family ranking can be established. This behaviour is associated with the larger UAS–manned encounter dimensions, the fixed non-manoeuvring role of the manned aircraft and the sensitivity of the resulting geometry to look-ahead and separation parameters. The highest Risk Ratio obtained from the two response assumptions is therefore retained for each configuration as the conservative reporting value.

For Final FAS, zero observed NMAC frequencies at the largest deviation threshold indicate that no events were recorded within the simulated exposure. These values should not be interpreted as proof that the underlying collision frequency is mathematically zero. Similarly, the unresolved U-plans identified in the SCR assessment and the single unresolved diversion in the 20-flight DAR case are considered outcomes of the assessed trajectory constraints and route availability rather than unexpected system behaviours.

B.4.4 Confidence in results of validation exercise #02

Confidence in the Final FAS collision-frequency results is supported by the fast-time Monte Carlo approach, consistent flight-hour normalisation, separate treatment of UAS–UAS and UAS–manned encounters and assessment of the same three operational environments considered in Validation Exercise #01. The analysis provides a consistent basis for comparing deviation thresholds and for estimating the corresponding safety-based capacities in the above-VLL configurations.

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Confidence in the TCP&R results is supported by the paired mitigated/unmitigated design, four million simulated pairs in each campaign case, deterministic case definitions, explicit traffic weighting and independent reporting of the UAS–UAS and UAS–manned matrices. The complete sensitivity assessment supports the selection of the reporting baseline and provides traceability of the influence of look-ahead, separation factors, CNS assumptions, response family and trajectory perturbations.

The DAR and SCR results provide additional functional evidence, although with a different level of statistical confidence. The DAR assessment covers three predefined traffic levels, while the SCR assessment considers four specific trajectory sets and does not include repeated Monte Carlo sampling. These results therefore support conclusions on the functional feasibility of coordinated rerouting and strategic conflict resolution under the assessed conditions, but they should not be interpreted as statistically representative success probabilities or general capacity estimates.

B.4.4.1. Level of significance/limitations of validation exercise results

The quantitative Final FAS assessment is representative of the modelled Benidorm, Manduria and Shannon–Limerick above-VLL configurations, the traffic and trajectory populations implemented by UPV and the assessed deviation thresholds. The results support comparison of the relative effect of increasing strategic separation and demonstrate the direct influence of Final FAS on both UAS–UAS and UAS–manned collision frequencies.

The TCP&R assessment is based on a conditional, conflict-rich and traffic-weighted pairwise encounter model. It is suitable for evaluating the relative reduction in residual risk under controlled conditions but does not estimate the operational frequency with which encounters occur. The selected response-time distributions, manoeuvre responsibilities, look-ahead, separation factors and CNS configurations are modelling assumptions and should not be interpreted as universally representative of all autonomous or remotely piloted operations. The consortium reporting factor of two provides a conservative transfer margin for these modelling assumptions but is not a statistical confidence bound.

The SCR assessment is limited to four predefined Benidorm trajectory sets and preserves the mandatory waypoints submitted by the operator. Consequently, the results depend on the spatial distribution of the trajectories, occupancy of the corresponding cells and availability of feasible alternative routes. The reported percentages are descriptive acceptance rates for the assessed sets and do not establish a general Authorisation Approval Rate or maximum airspace capacity.

The DAR assessment is similarly limited to the assessed Shannon–Limerick configuration, predefined safe-landing locations and traffic levels of 5, 10 and 20 simultaneously affected flights. The results demonstrate the benefit of coordinated rerouting relative to independent straight-line diversion, but further testing would be required to establish performance limits under higher traffic demand, different safe-landing distributions or more restrictive airspace conditions.

Rare-event estimation remains limited by the finite simulated exposure. Therefore, zero observed events at the larger deviation thresholds do not demonstrate zero underlying risk, and very high theoretical safety-based capacities should not be interpreted as operationally achievable traffic levels where trajectory availability or Flight Authorisation performance becomes limiting.

B.4.4.2. Quality of validation exercises results

The main quality strengths are the separation of the different evidence streams, the independent treatment of UAS–UAS and UAS–manned encounters and the traceable integration of strategic and

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tactical mitigation effects. Final FAS collision frequencies are calculated independently for each scenario, deviation threshold and encounter family, while TCP&R is incorporated through the corresponding reported Risk Ratios rather than by directly modifying the simulated Final FAS frequencies.

For TCP&R, the reporting baseline is clearly distinguished from the sensitivity cases. Raw diagnostic values are separated from the reported Risk Ratios, and the conservative factor of two is applied once after aggregation. Retaining the highest value obtained from the Autonomous and RPAS response assumptions also avoids selecting the response family that provides the greatest mitigation credit for each configuration.

The SCR and DAR results are presented as qualitative or descriptive functional evidence and are not combined with the Monte Carlo results as though they had the same statistical basis. Their assumptions and limitations are explicitly stated, including the use of predefined trajectory sets, mandatory waypoints, safe-landing locations and the absence of repeated random sampling.

Absolute estimates of very rare events remain less robust than the relative comparison between configurations. In particular, zero-event cases and safety-based capacities exceeding the number of available trajectories require cautious interpretation and do not establish zero risk or directly achievable operational capacity.

B.4.4.3. Significance of validation exercises results

Validation Exercise #02 provides meaningful comparative evidence of the additional safety and capacity contribution of the Final FAS functionalities assessed by UPV. Final FAS extends strategic deconfliction to both UAS–UAS and UAS–manned trajectories, producing a direct reduction in both encounter families as the deviation threshold increases. TCP&R provides an additional tactical reduction in the residual conditional risk, with a substantially stronger effect for UAS–UAS encounters than for UAS–manned encounters.

The integrated results show that safety-based capacity can increase considerably relative to the unmitigated baseline. However, the overall capacity remains constrained by the most restrictive applicable criterion. At the smaller deviation thresholds, this is generally the UAS–manned criterion; the capacities obtained from the different encounter criteria converge only when the protected distance reaches the applicable UAS–manned NMAC separation scale. The operational significance of very high theoretical capacities remains dependent on the number of trajectories that Final FAS can allocate and authorise.

The SCR results demonstrate that alternative conflict-free route generation can recover U-plans that would otherwise be rejected by the initial Flight Authorisation process. The DAR results demonstrate that coordinating simultaneous diversions can prevent the response to an airspace reconfiguration from introducing additional conflicts. These results provide operationally relevant evidence of the potential contribution of both functionalities, while remaining specific to the predefined trajectory sets and traffic configurations assessed.

Overall, the exercise supports conclusions on the relative performance and complementary role of Final FAS, SCR, DAR and TCP&R within the simulated environments. However, the results do not support an unqualified extrapolation of the reported capacities, Risk Ratios or descriptive acceptance percentages to other operational environments without considering their traffic structure, trajectory availability, encounter geometry and service-implementation assumptions.

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B.5 Validation exercise #02 results - CRA

B.5.1 Summary of validation exercise #02 results

CRA assessed the UAS–manned baseline capacity and the residual tactical risk reduction delivered by the Tactical Conflict Prediction and Resolution service in the three validation scenarios. The table reports each success criterion separately. Criteria concerning geographical-zone management and fauna risk were outside the CRA exercise scope and are marked NOK because no CRA-specific evidence was produced.

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #01 validation objective status
OBJ-SOL0520-ERP-001	Identification of the baseline capacity (N_0).[28]	CRT-SOL0520-TRL2-ERP-001.002	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 1, for exercise #01 and #02.	Scenario 1: The city of Benidorm (non U-space sub-OE)	The baseline capacity is 1.000 UAS. Even two simultaneous UAS exceed the maximum allowable NMAC per hour. These results highlight the need for at least one U-space service in Benidorm.	OK
		CRT-SOL0520-TRL2-ERP-001.004	The MAC frequency between UAS and manned aircraft shall not exceed 10^{-7} per flight-hour in Scenario 2, for exercise #01 and #02.	Scenario 2: The city of Manduria (non U-space sub-OE)	The baseline capacity is 1.000 UAS. Even two simultaneous UAS exceed the maximum allowable NMAC per hour. These results highlight the need for at least one U-space service in Manduria.	OK

[28] Only success criteria related to exercise 2 are reported here. For example CRT-SOL0520-TRL2-ERP-001.001 is related to exercise 1, therefore not reported here.

Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #01 validation objective status
		CRT-SOL0520-TRL2-ERP-001.006	The MAC frequency between UAS and manned aircraft in uncontrolled airspace shall not exceed 10^{-7} per flight-hour in Scenario 3, for exercise #01 and #02.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	The baseline capacity is 1.000 UAS. Even two simultaneous UAS exceed the maximum allowable NMAC per hour. These results highlight the need for at least one U-space service in Shannon.	OK
		CRT-SOL0520-TRL2-ERP-001.007	The MAC frequency between UAS and manned aircraft in controlled airspace shall not exceed 10^{-9} per flight-hour in Scenario 3, for exercise #01 and #02.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	UAS-manned baseline capacity of 1.000 simultaneous UAS; no separate controlled and uncontrolled airspace values are reported.	OK
		CRT-SOL0520-TRL2-ERP-001.008	The MAC frequency between UAS shall not exceed 1.41×10^{-4} per flight-hour in Scenario 1, for exercise #02.	Scenario 1: The city of Benidorm (non U-space sub-OE)	The baseline capacity is 1.003 UAS. Even two simultaneous UAS exceed the maximum allowable NMAC per hour.	OK
		CRT-SOL0520-TRL2-ERP-001.009	The MAC frequency between UAS shall not exceed 1.29×10^{-4} per flight-hour in	Scenario 2: The city of Manduria (non U-space sub-OE)	The baseline capacity is 1.002 UAS. Even two simultaneous UAS exceed the	OK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #01 validation objective status
			Scenario 2, for exercise #02.		maximum allowable NMAC per hour.	
		CRT-SOL0520-TRL2-ERP-001.010	The MAC frequency between UAS shall not exceed 6.25×10^{-3} per flight hour in Scenario 3, for exercise #02.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	The baseline capacity is 1.078 UAS. Even two simultaneous UAS exceed the maximum allowable NMAC per hour.	OK
OBJ-SOL0520-ERP-005	Quantification of the capacity increment (ΔN_4) because of the introduction of mitigation measures based on adding a Tactical Conflict Prediction and Resolution services.	CRT-SOL0520-TRL2-ERP-005.001	The maximum number of UAS operations in scenario 1 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 1: The city of Benidorm (non U-space sub-OE)	For Benidorm, at a 45s look-ahead and a protection volume of 32 times the NMAC radius, the conditional UAS-UAS NMAC risk ratio falls to 0.018, increasing the capacity to 2.31 UAS.	OK
		CRT-SOL0520-TRL2-ERP-005.002	The maximum number of UAS operations in scenario 2 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 2: The city of Manduria (non U-space sub-OE)	For Manduria, at a 45 s look-ahead and a protection volume of 32 times the NMAC radius, the conditional UAS-UAS NMAC risk ratio falls to 0.022, increasing	OK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #01 validation objective status
					the capacity to 2.19 UAS.	
		CRT-SOL0520-TRL2-ERP-005.003	The maximum number of UAS operations in scenario 3 increases with respect to the unmitigated baseline, while maintaining the same target level of safety.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	For Shannon-Limerick, at a 45 s look-ahead and a protection volume of 32 times the NMAC radius, the conditional UAS-UAS NMAC risk ratio falls to 0.016, increasing the capacity to 1.92 UAS.	OK
OBJ-SOL0520-ERP-006	Quantification of baseline geographical zone infringements per flight-hour ($\Delta Ninf_0$).	CRT-SOL0520-TRL2-ERP-006.001	The geographical zones in Scenario 1 shall be defined such that, during the baseline run, at least one infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.	Scenario 1: The city of Benidorm (non U-space sub-OE)	Not assessed by CRA	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #01 validation objective status
		CRT-SOL0520-TRL2-ERP-006.002	The geographical zones in Scenario 2 shall be defined such that, during the baseline run, at least one infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.	Scenario 2: The city of Manduria (non U-space sub-OE)	Not assessed by CRA	NOK
		CRT-SOL0520-TRL2-ERP-006.003	The geographical zones in Scenario 3 shall be defined such that, during the baseline run, at least one infringement of a UAS geographical zone is recorded, establishing a measurable reference level for subsequent comparison.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	Not assessed by CRA	NOK
OBJ-SOL0520-ERP-007	Quantification of the variation in geographical zone	CRT-SOL0520-TRL2-ERP-007.001	The total number of geographical zones infringements varies	Scenario 1: The city of Benidorm (non U-space sub-OE)	Not assessed by CRA	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #01 validation objective status
	infringements per flight-hour ($\Delta Ninf_1$) due to the implementation of mitigation measures based on Flight Authorisation service.		compared to the baseline in scenario 1.			
		CRT-SOL0520-TRL2-ERP-007.002	The total number of geographical zones infringements varies compared to the baseline in scenario 2.	Scenario 2: The city of Manduria (non U-space sub-OE)	Not assessed by CRA	NOK
		CRT-SOL0520TRL2-ERP-007.003	The total number of geographical zones infringements varies compared to the baseline in scenario 3.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	Not assessed by CRA	NOK
OBJ-SOL0520-ERP-008	Quantification of the variation in geographical zone infringements per flight-hour ($\Delta Ninf_2$) due to the implementation of mitigation measures based on Conformance Monitoring service.	CRT-SOL0520-TRL2-ERP-008.001	The total number of geographical zones infringements varies compared to the baseline in scenario 1.	Scenario 1: The city of Benidorm (non U-space sub-OE)	Not assessed by CRA	NOK
		CRT-SOL0520-TRL2-ERP-008.002	The total number of geographical zones infringements varies compared to the baseline in scenario 2.	Scenario 2: The city of Manduria (non U-space sub-OE)	Not assessed by CRA	NOK
		CRT-SOL0520-TRL2-ERP-008.003	The total number of geographical zones infringements varies	Scenario 3: The Shannon-Limerick	Not assessed by CRA	NOK

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Exercise #02 validation objective ID	Exercise #02 validation objective title	Exercise #02 success criterion ID	Exercise #02 success criterion	Sub-operating environment	Exercise #02 validation results	Exercise #01 validation objective status
			compared to the baseline in scenario 3.	Area (APT-small/non U-space sub-OE)		
OBJ-SOL0520-ERP-009	Quantification of the impact of fauna on air risk.	CRT-SOL0520-TRL2-ERP-009.001	The TLS defined for scenario 1 is maintained.	Scenario 1: The city of Benidorm (non U-space sub-OE)	Not assessed by CRA	NOK
		CRT-SOL0520-TRL2-ERP-009.002	The TLS defined for scenario 2 is maintained.	Scenario 2: The city of Manduria (non U-space sub-OE)	Not assessed by CRA	NOK
		CRT-SOL0520-TRL2-ERP-009.003	The TLS defined for scenario 3 is maintained.	Scenario 3: The Shannon-Limerick Area (APT-small/non U-space sub-OE)	Not assessed by CRA	NOK

Table 76: validation exercise #02 results - CRA

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B.5.2 Analysis of validation exercise #02 results per validation objective

B.5.2.1. OBJ-SOL0520-ERP-001 Results

The UAS–manned baseline capacity was assessed using the same fitted-NMAC approach applied in exercise #01. For each scenario, the mean UAS–manned NMAC frequency was fitted as a function of the number of simultaneous UAS and compared with the target level of safety of 1.0×10^{-7} per flight-hour. The fitted coefficients for Benidorm, Manduria, and Shannon are 7.9422×10^{-4}, 8.5394×10^{-4}, and 1.27725×10^{-3}, respectively, resulting in a baseline capacity of 1.000 simultaneous UAS in all three scenarios. Therefore, even two simultaneous UAS exceed the applicable UAS–manned NMAC threshold, highlighting the need for at least one U-space mitigation service in each scenario.

Scenario	NMAC target	Curve fitting	Capacity
Scenario 1 (UAS-manned)	0.0000001	0.00079422	1.000
Scenario 2 (UAS-manned)	0.0000001	0.00085394	1.000
Scenario 3 (UAS-manned)	0.0000001	0.00127725	1.000

Table 77: CRA - UAS–manned baseline capacity.

B.5.2.2. OBJ-SOL0520-ERP-005 Results

The CRA contribution to this objective quantifies the residual risk reduction attributable to the Tactical Conflict Prediction and Resolution (TCPR) service once strategic deconfliction has already been applied. The service is evaluated with the paired Monte-Carlo encounter model also used for the Traffic Information Service in exercise #01. Each Monte-Carlo run generates a conflict pair on a converging course, propagates it twice — once with the tactical service disabled and once with it enabled — and counts the resulting NMAC and loss-of-separation events. Because both branches see the identical sampled geometry, the reported ratios are paired and are conditional on an encounter having occurred; they are therefore comparable with conditional ratios reported by other partners but cannot be read as absolute frequencies per flight hour. One thousand encounters were simulated for each configuration, giving between 865 and 898 NMAC events in the service-disabled branch. Aircraft classes are drawn from the traffic mix of the scenario under test, so that the distribution of protection volumes and the share of manned traffic are those of that scenario.

Two parameters were swept. The look-ahead time was varied between 2 s and 45 s, and the protection volume applied by the service was varied between one and thirty-two times the applicable NMAC radius. Three response assumptions were applied: an instantaneous response, retained as an upper bound on what the service could achieve rather than as an operational case; an autonomous response drawn from a Gamma distribution with a mean of 3 s and a standard deviation of 1 s; and a remotely piloted response drawn from a Gamma distribution with a mean of 7 s and a standard deviation of 2 s. The reaction delay is drawn afresh at each alert rather than applied as a fixed value. Results are reported separately for UAS–UAS and UAS–manned encounters, because the two families respond very differently to the swept parameters.

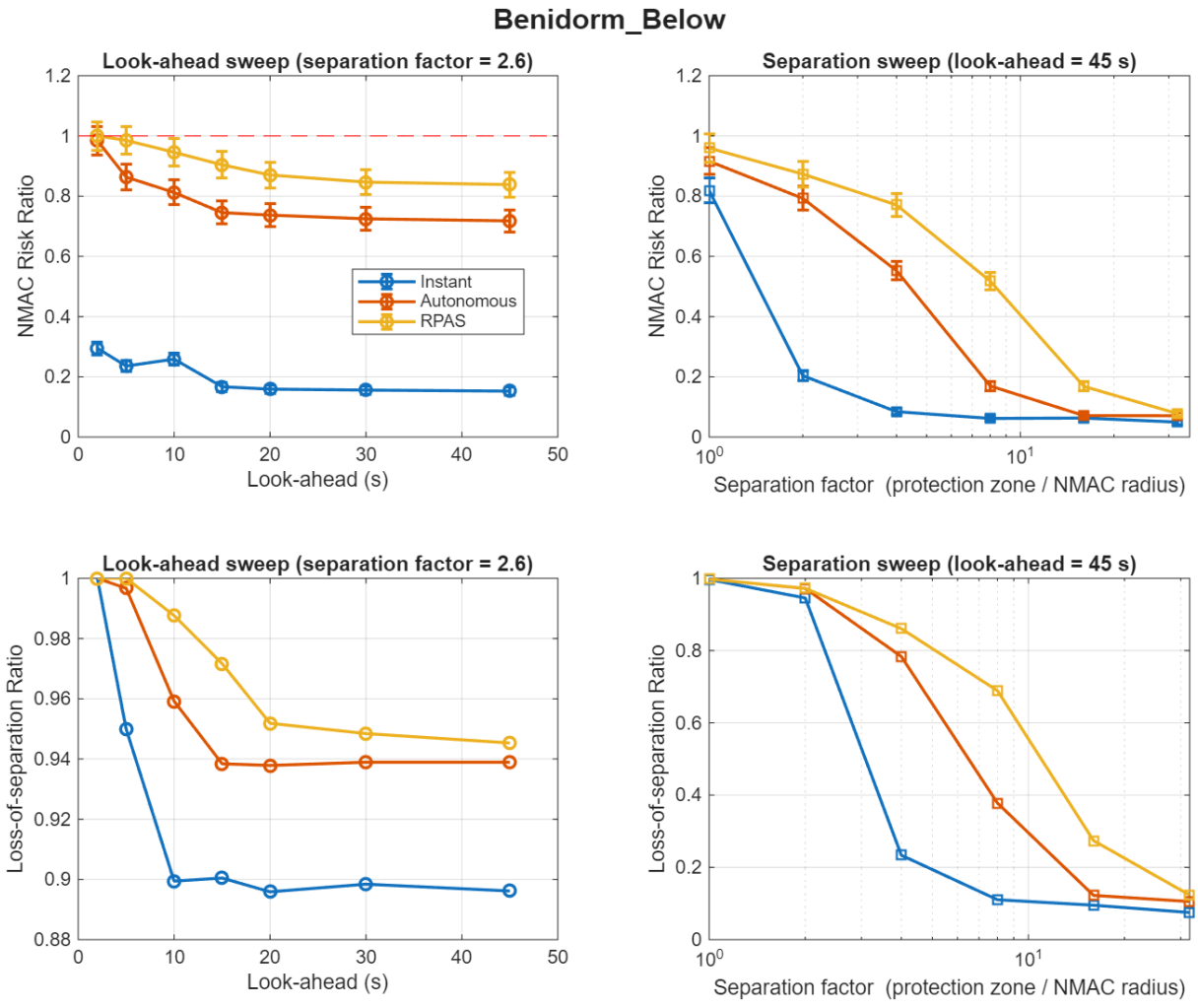
The capacity increment is calculated from the curve fitting of the baseline UAS–manned NMAC values, divided by the FA risk ratios, and then adjusted to account for the combined effectiveness of strategic

and tactical deconfliction. On this basis, the risk ratios of 0.018, 0.022, and 0.016 correspond to capacities of 2.31, 2.19, and 1.92 UAS in Benidorm, Manduria, and Shannon, respectively.

Scenario 1: The city of Benidorm

As shown in Figure 125, with the protection volume set to the planning buffer applied by the Final Flight Authorisation Service, approximately 2.6 times the NMAC radius, the conditional UAS–UAS risk ratio under the autonomous response assumption falls from 0.98 at a 2 s look-ahead to 0.80 at 10 s and 0.71 at 45 s. The improvement is therefore modest and is essentially exhausted beyond a 15 s horizon. Increasing the protection volume at a fixed 45 s look-ahead is far more effective: the ratio falls from 0.911 at one NMAC radius to 0.535 at four, 0.123 at eight and 0.018 at thirty-two. Under the remotely piloted response assumption the same sweep gives 0.960, 0.764, 0.493 and 0.018, so the two response families differ by a factor of four at intermediate protection volumes but converge at the largest.

The loss-of-separation ratio follows the same pattern against protection volume but is insensitive to the look-ahead horizon. This is expected rather than anomalous: the avoidance manoeuvre is computed to clear the protection volume, which at the reference setting is smaller than the loss-of-separation volume against which the ratio is measured, so lengthening the detection range does not change whether the larger volume is cleared.



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Figure 125: CRA–TCPR conditional UAS–UAS NMAC risk ratio and UAS–UAS loss-of-separation ratio in Benidorm, evaluated through a look-ahead-time sweep using the reference protection volume and a protection-volume sweep using a fixed 45 s look-ahead time.

Scenario 2: The city of Manduria

Manduria behaves comparably, as shown in Figure 126. At the reference protection volume the autonomous conditional UAS–UAS risk ratio falls from 0.99 at 2 s to 0.83 at 10 s and 0.63 at 45 s, again saturating beyond approximately 15 s. Over the protection-volume sweep at a 45 s look-ahead the ratio falls from 0.893 to 0.475 at four NMAC radii, 0.119 at eight and 0.022 at thirty-two, with the remotely piloted assumption giving 0.944, 0.670, 0.415 and 0.026. Manduria carries the largest share of traffic with the wider protection volumes, approximately 14.7% against 8.2% in Benidorm, and shows correspondingly slightly better performance at the intermediate settings.

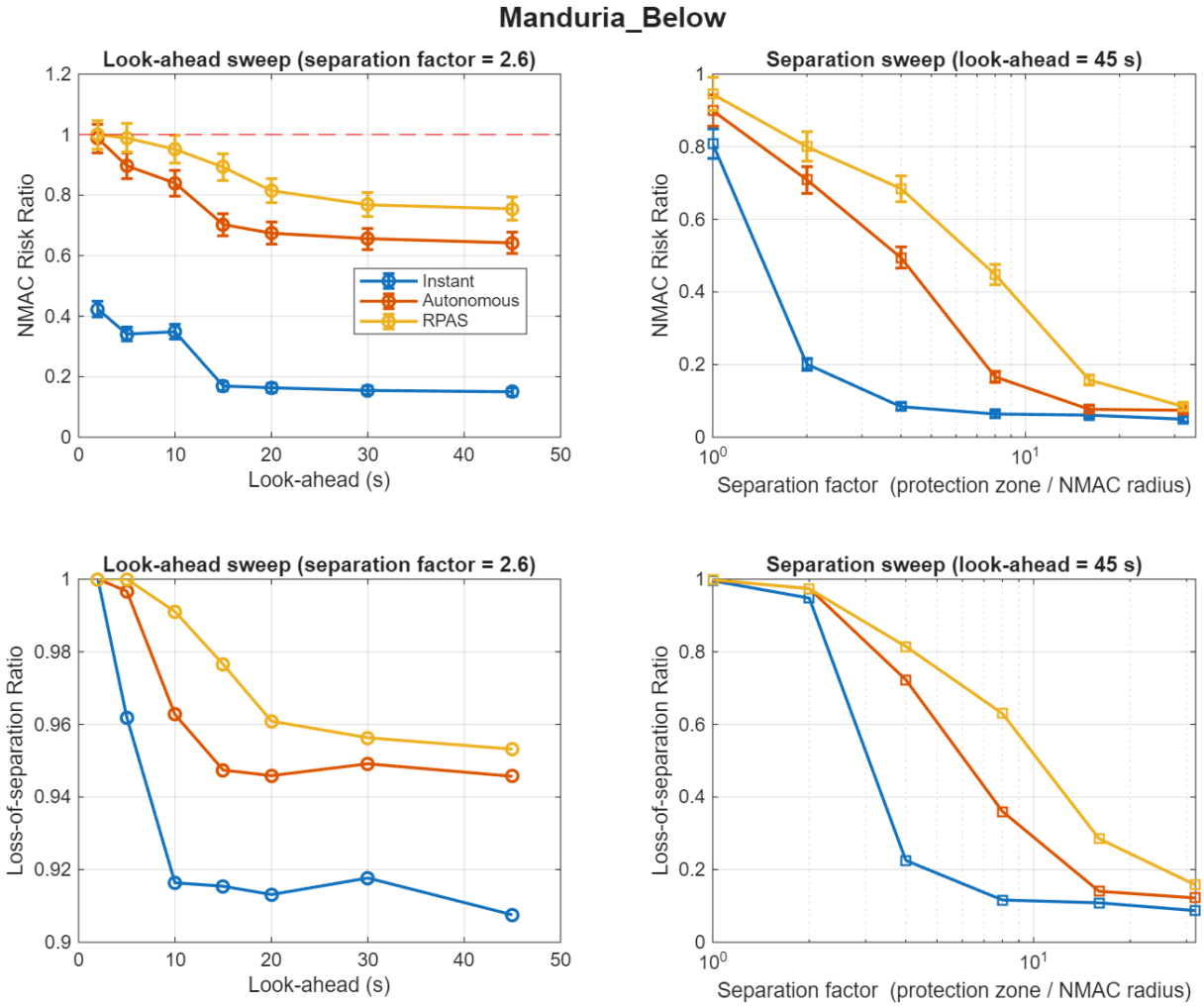


Figure 126: CRA–TCPR conditional UAS–UAS NMAC risk ratio and UAS–UAS loss-of-separation ratio in Manduria, evaluated through a look-ahead-time sweep using the reference protection volume and a protection-volume sweep using a fixed 45 s look-ahead time.

Scenario 3: The city of Shannon

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As shown in Figure 127, Shannon–Limerick carries the smallest share of traffic with wider protection volumes, approximately 3.1%, and shows the weakest response to the look-ahead sweep: the autonomous conditional UAS–UAS risk ratio falls from 0.98 at 2 s to 0.77 at 10 s and then remains between 0.77 and 0.79 out to 45 s, with no further improvement at all. The protection-volume sweep nevertheless produces the lowest final value of the three scenarios, falling from 0.918 to 0.582 at four NMAC radii, 0.126 at eight and 0.016 at thirty-two; the remotely piloted assumption gives 0.965, 0.831, 0.542 and 0.017.

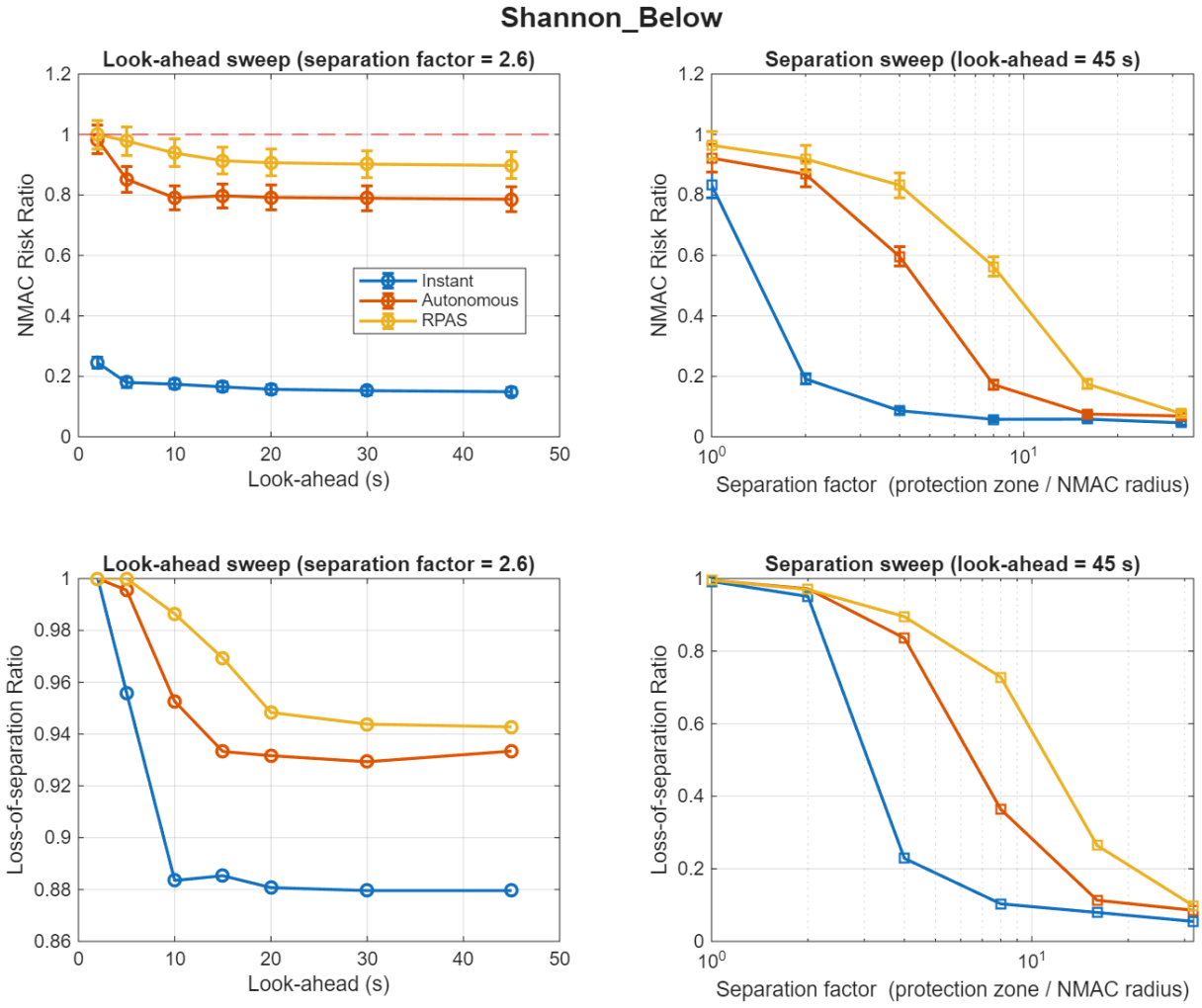


Figure 127: CRA–TCPR conditional UAS–UAS NMAC risk ratio and UAS–UAS loss-of-separation ratio in Shannon, evaluated through a look-ahead-time sweep using the reference protection volume and a protection-volume sweep using a fixed 45 s look-ahead time.

Scenario Analysis

Resolving the result by encounter family shows where that floor originates, as shown in Figure 128. The UAS–manned ratio remains between 0.72 and 0.81 across the whole protection-volume sweep and does not improve as the volume is increased, in contrast to the UAS–UAS ratio which falls by nearly two orders of magnitude over the same range. Manned aircraft carry an NMAC radius of 152.4 m against 15.24 m for the UAS classes, and only the UAS manoeuvres in a mixed encounter. At the larger protection volumes the resulting required clearance exceeds the detection range, so such encounters

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are already inside the required separation when they are first detected and the manoeuvre cannot be completed within the available time. Increasing the separation margin therefore mitigates UAS–UAS encounters but does not mitigate UAS–manned encounters. These UAS–manned results rest on between 42 and 74 events per configuration and should be read as a trend rather than as a precise level.

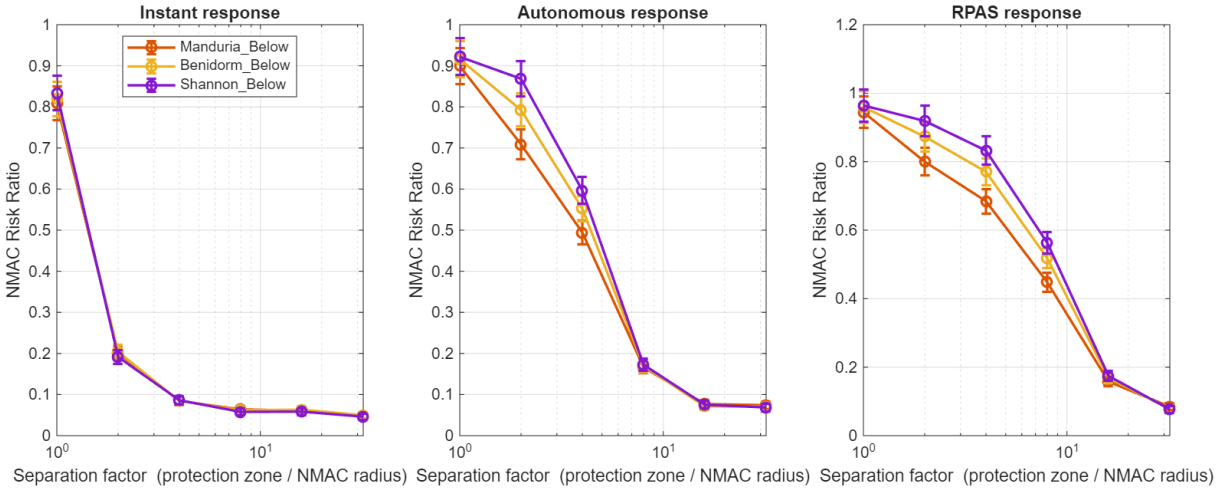


Figure 128: CRA– Aggregate NMAC risk ratio across the three scenarios.

B.5.3 Unexpected behaviours/results

No simulator failure, aborted run or showstopper is documented in the CRA material reviewed for this report.

B.5.4 Confidence in results of validation exercise #02

B.5.4.1. Level of significance/limitations of validation exercise results

The Monte Carlo results are conditional on an encounter and are expressed as paired risk ratios. They are not absolute frequencies per flight hour and cannot by themselves establish a directly achievable traffic capacity.

Each configuration contains 1,000 paired encounters and 865–898 NMAC events in the service-disabled branch, providing a stable basis for UAS–UAS comparisons. UAS–manned conclusions rely on 42–74 events per configuration and should be read as directional trends rather than precise estimates.

Representativeness is limited to the Benidorm, Manduria and Shannon–Limerick traffic mixes; look-ahead times from 2 s to 45 s; protection volumes from one to thirty-two times the applicable NMAC radius; and the instantaneous, autonomous and remotely piloted response assumptions used by the model.

Objectives OBJ-SOL0520-ERP-006 to OBJ-SOL0520-ERP-009 were outside the CRA scope. The results cannot be extrapolated to geographical-zone management, fauna-related risk or other operating environments without additional validation.

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B.5.4.2. Quality of validation exercises results

Result quality is supported by the paired design: each conflict geometry is propagated once with the tactical service disabled and once with it enabled. This controls encounter-to-encounter variation and isolates the service effect. The parameter sweeps, three response assumptions and separate UAS–UAS and UAS–manned reporting provide consistent cross-checks across the three scenarios.

The main quality constraints are the smaller UAS–manned event samples, the use of conditional ratios and the absence of an absolute flight-hour denominator. Reported decimal values should therefore be interpreted as simulation outputs rather than exact operational predictions.

B.5.4.3. Significance of validation exercises results

The UAS–UAS result is consistent across the three scenarios. At a 45 s look-ahead and a protection volume of thirty-two NMAC radii, the autonomous conditional NMAC risk ratio is 0.018 in Benidorm, 0.022 in Manduria and 0.016 in Shannon–Limerick. Gains from look-ahead time largely saturate beyond approximately 15 s, while increasing the protection volume has the stronger effect.

Operationally, the exercise provides evidence that the tactical service reduces residual UAS–UAS risk after strategic deconfliction. It does not demonstrate an unconditional capacity increment because the UAS–manned risk floor remains and the results are conditional on an encounter.

B.6 Conclusions

This section provides a summary of the conclusions raised by the Validation Exercise #02 results analysis and prepares the recommendations derived from the exercise.

B.6.1 Conclusions on concept clarification

Validation Exercise #02 confirms and further develops the layered U-AGREE mitigation concept introduced in Validation Exercise #01. Final Flight Authorisation provides the strategic preventive layer by considering UAS–UAS conflicts, declared manned-aircraft trajectories and, where implemented, geographical-zone constraints before an operation is authorised. Tactical Conflict Prediction and Resolution subsequently addresses residual encounters arising during operation. It should be noted that, when used in combination with the TCPR service, the primary role of the Conflict Management Service (CMS) is not to provide tactical conflict mitigation. Instead, it contributes to reducing the residual strategic risk and, where applicable, supports compliance with Performance-Based Navigation (PBN) containment requirements. Tactical conflict prevention and resolution remain the responsibility of the TCPR service.

The exercise clarifies the safety contribution of extending strategic deconfliction to mixed UAS–manned traffic. Unlike the Flight Authorisation configuration assessed in Validation Exercise #01, Final FAS can directly reduce UAS–manned MAC and NMAC frequencies by checking proposed UAS trajectories against the relevant manned-aircraft trajectories. However, the UAS–manned criterion remains considerably more restrictive than the UAS–UAS criterion in several configurations and may continue to determine the overall safety-based capacity until the protected distance reaches the applicable UAS–manned NMAC separation scale.

The results also clarify the distinction between strategic and tactical risk reduction. Final FAS modifies the population of trajectories admitted into the operational environment, whereas TCP&R reduces the conditional risk associated with encounters that remain after strategic deconfliction. TCP&R does not

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directly modify the collision frequencies generated by Final FAS; its contribution is transferred to the integrated assessment through encounter-family- and scenario-specific Risk Ratios.

The assessment of Strategic Conflict Resolution demonstrates the functional feasibility of recovering U-plans that would otherwise be rejected by the initial Flight Authorisation process. The alternative route is authorised only when a conflict-free solution compatible with the retained operator-defined waypoints can be found. The 3D implementation provides the more complete and conservative representation because it also considers vertical trajectory segments. Nevertheless, the results are specific to the predefined Benidorm trajectory sets and do not establish a general resolution probability or maximum airspace capacity.

Dynamic Airspace Reconfiguration coordinated rerouting provides a complementary operational function for flights already active when an airspace volume becomes unavailable. The Shannon–Limerick results show that coordination between simultaneous diversions substantially reduces the conflicts that could be introduced if each operator independently diverted its aircraft towards the nearest safe-landing location. The functionality therefore supports the safe and orderly termination of affected operations rather than the initial allocation or authorisation of traffic.

The geozone results clarify the role of FAS as a preventive barrier for Security and Environment. Where geozones were implemented, the service prevented the authorisation of trajectories entering the restricted volumes and eliminated the observed infringements. In these configurations, Conformance Monitoring did not produce an additional measurable reduction because the FAS had already reduced the infringement rate to zero. This does not remove the general containment role of Conformance Monitoring, but shows that its incremental benefit depends on whether deviations from authorised trajectories can still create exposure to a geozone.

Overall, Validation Exercise #02 confirms the operational coherence of the advanced layered concept. Final FAS acts on strategic trajectory compatibility, including mixed traffic and geographical constraints; SCR supports the recovery of strategically conflicting requests; DAR coordinated rerouting manages ongoing flights affected by airspace changes; and TCP&R provides an additional tactical barrier for residual encounters.

B.6.2 Conclusions on technical feasibility

Validation Exercise #02 confirms the technical feasibility of implementing the advanced U-AGREE functions in fast-time simulation environments. Final FAS, geographical-zone enforcement, SCR, DAR coordinated rerouting and TCP&R were implemented and assessed through different partner platforms and algorithmic approaches. The platforms were able to represent strategic trajectory assessment, tactical conflict prediction, resolution-manoeuvre generation, response delays, trajectory replacement and the separate evaluation of UAS–UAS and UAS–manned encounters.

The use of different TCP&R implementations demonstrates the feasibility of more than one technical approach. ENGage applies an RRT-based trajectory-resolution process, CRA uses a differential-geometry method and UPV applies a CPA/velocity-obstacle heading search within a paired encounter model. These implementations reproduce the intended tactical function but differ in conflict construction, resolution geometry, processing of simultaneous encounters, look-ahead time, protected-volume definition and response assumptions. These differences materially affect the numerical Risk Ratios and explain why the exact mitigation credit cannot be transferred directly between platforms.

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The results show that TCP&R performance is particularly sensitive to the separation factor, available look-ahead time, participant responsibilities and response delay. It's performance is also affected by CNS performance, as in the case of Exercise #01. CRA observed that increasing the protection volume provides a much stronger UAS–UAS reduction than extending the look-ahead time beyond approximately 15 seconds. UPV similarly identified look-ahead time as a relevant parameter within its executed range and retained the baseline U-AGREE separation minima as the conservative reporting value. By contrast, the ENGage tactical configurations remained comparable to FAS alone within simulation variability in Manduria and Shannon–Limerick, particularly where strategic deconfliction had already reduced residual events to the detection floor.

The UAS–manned tactical results are less favourable and less monotonic than the UAS–UAS results. Only the UAS manoeuvres in the assessed mixed encounters, while the larger manned-aircraft NMAC dimensions can require a clearance that is difficult to achieve within the available detection and response time. Consequently, increasing the tactical protection volume does not necessarily provide an equivalent reduction in UAS–manned risk. This confirms that UAS–UAS and UAS–manned encounters require separate models, metrics and operational interpretation.

The implementations of SCR and DAR also demonstrate technical feasibility but reveal dependencies that should be retained in future specifications. SCR depends on the availability of free cells and on whether mandatory operator-defined waypoints can be preserved. The combination of an ML-based route search with an A* fallback improves the ability to identify an existing feasible solution but cannot resolve a request when no compatible route exists. DAR coordinated rerouting similarly depends on the spatial distribution of the affected flights, safe-landing locations and available routing space. A Monte Carlo campaign was not performed because applying the complete ML-based resolution chain to a sufficiently large number of randomly generated traffic sets would require a substantially more complex and computationally demanding assessment. Moreover, each accepted route changes the occupancy available to subsequent requests, making the result dependent on trajectory distribution and authorisation order. The percentages therefore demonstrate functional feasibility for the four assessed cases, but should not be interpreted as general resolution probabilities, statistically representative Authorisation Approval Rates or maximum capacity values. Overall, SCR acts mainly as a Capacity enabler, with an indirect positive contribution to Access & Equity. All recovered routes are conflict-free by construction, although no dedicated Safety KPI was calculated.

The geozone-enforcement results provide strong technical evidence that static restricted volumes can be incorporated into the Flight Authorisation process. However, the current implementation does not represent conditional or time-activated geozones. The exercise therefore demonstrates static enforcement but not the additional operational flexibility or coordination requirements associated with dynamic geographical-zone activation and deactivation.

Overall, the results confirm the technical feasibility of the assessed services but also show that more detailed common specifications are required to support quantitative convergence. These should cover conflict-detection logic, protected-volume construction, processing of simultaneous conflicts, priority rules, manoeuvre generation and execution, response assumptions, inter-USSP coordination, handling of failed resolutions and the integration of strategic, tactical and geographical-zone constraints.

B.6.3 Conclusions on performance assessments

Safety

The unmitigated baseline results confirm that the assessed operational environments cannot safely accommodate meaningful levels of concurrent UAS traffic without mitigation. Final FAS provides the

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principal strategic contribution by preventing incompatible trajectories from being authorised. Unlike the Batch-1 implementation, Final FAS considers both UAS–UAS and UAS–manned interactions for deconfliction, producing a direct reduction in the collision frequencies of both encounter families as the deviation threshold increases. However, the UAS–manned criterion generally remains more restrictive and may continue to determine the overall capacity until the protected distance reaches the applicable UAS–manned NMAC separation scale.

TCP&R provides an additional tactical barrier for residual encounters, although its measured contribution depends strongly on the implementation, encounter family and residual event population. The UPV and CRA results demonstrate a substantial potential reduction for UAS–UAS encounters when sufficient look-ahead time and protection volume are available. By contrast, the reduction obtained for UAS–manned encounters is more limited because of the larger NMAC dimensions, the non-manoeuvring role assigned to the manned aircraft and the time required for the UAS to achieve the necessary clearance. In the ENGage simulations, the tactical configurations remained comparable to FAS alone within simulation variability, particularly where strategic deconfliction had already reduced the number of residual events to the detection floor. The results therefore support TCP&R as a complementary tactical mitigation, but do not establish a common quantitative mitigation credit applicable across all implementations and scenarios.

The SCR and DAR assessments provide additional functional safety evidence. SCR only authorises an alternative U-plan when a conflict-free solution can be found, preserving the strategic separation requirements applied by Final FAS. Coordinated DAR rerouting substantially improves the safety of simultaneous diversions in Shannon–Limerick: conflict-free outcomes increase from 1/5 to 5/5 for five affected flights, from 2/10 to 10/10 for ten flights and from 0/20 to 19/20 for twenty flights. These results show that coordinating the affected routes prevents the response to an airspace reconfiguration from introducing new conflicts between flights already in operation.

Capacity

Final FAS can produce a substantial increase in safety-based capacity relative to the unmitigated baseline, but the magnitude of this increase depends on the applicable criterion, simulated exposure and modelling approach. In the UPV above-VLL assessment, the overall safety-based capacity reaches 50 UAS in Benidorm, 286 in Manduria and 745 in Shannon–Limerick when the protected distance reaches the UAS–manned NMAC separation scale. At smaller deviation thresholds, the higher UAS–UAS capacity does not translate into an equivalent overall capacity because the UAS–manned criterion remains limiting.

The ENGage results provide a more conservative conclusion. Although manned-aware FAS substantially reduces UAS–manned NMAC frequencies, the remaining measurable frequencies do not demonstrate compliance with the strict applicable criteria, and no robust capacity increment is reported. Some apparent tactical capacity increments are based on only one or very few residual events and are therefore retained as indicative bounds rather than reliable capacity estimates. These differences reinforce the need to distinguish between model-derived safety-based capacity and operationally demonstrated capacity, particularly when the estimate is based on zero or very low event counts.

SCR provides a complementary qualitative capacity benefit by recovering U-plans that would otherwise be rejected by the initial Flight Authorisation process. Across the four predefined Benidorm configurations, the initial acceptance rates of 84%, 92%, 86.7% and 79% increase to 92%, 98%, 96% and 91% with 2D SCR, and to 88%, 96%, 94.7% and 86% with the more conservative 3D

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implementation. The unresolved cases mainly correspond to mandatory operator-defined waypoints located in cells already occupied by authorised trajectories. These results demonstrate improved accommodation of the assessed demand but do not establish a statistically representative resolution rate or the maximum capacity of the Benidorm airspace.

Security and Environment

Final FAS provides complete prevention of geographical-zone infringements in the two scenarios where no-fly zones were implemented in the ENGage assessment. The unmitigated infringement rate is 0.803 infringements/FH in Manduria and an average of 0.911 infringements/FH in Shannon–Limerick, increasing from approximately 0.45 to 1.11 infringements/FH with traffic density. Once geographical-zone enforcement is activated, the rate decreases to zero at every tested deviation threshold, representing a 100% reduction in both scenarios.

This effect is independent of the deviation threshold because the geographical-zone check operates as a hard authorisation constraint rather than as a separation buffer. Any candidate trajectory entering the restricted volume is rejected from the smallest tested threshold onwards. Conformance Monitoring, with either alerting or pre-alerting, produces no additional measurable improvement in these configurations because FAS has already eliminated all authorised trajectories entering the geographical zones. This should not be interpreted as evidence that Conformance Monitoring cannot protect geographical zones in general, but rather as an indication that no residual infringement remained for it to mitigate under the assessed conditions.

In Shannon–Limerick, the same result provides fauna-risk mitigation because the enforced geographical zone corresponds to the River Shannon and River Fergus Estuaries Special Protection Area. Preventing UAS from entering the zone removes the simulated exposure to the protected bird area. However, this remains a simplified, static geozone-based representation and does not model species, seasonality, time of day, altitude or bird movement corridors. An equivalent fauna-related conclusion cannot be drawn for Manduria, where the assessed geographical zone protects an archaeological site, or for Benidorm, where no geozone was implemented in the ENGage assessment.

Access and Equity

The additional safety, security and environmental constraints introduced in Batch 2 affect access to the airspace. Relative to the geozone-blind and manned-blind FAS assessed in Batch 1, the combined consideration of manned-aircraft corridors and geographical zones reduces the Authorisation Approval Rate by approximately 10–13 percentage points in Manduria and Shannon–Limerick. This reflects the operational cost of requiring candidate trajectories to remain compatible with a broader set of constraints.

SCR can partly compensate for this reduction by proposing alternative conflict-free routes instead of directly rejecting incompatible U-plans. The improvement is observed in every assessed Benidorm traffic configuration, although the 3D implementation produces more conservative results because it also considers take-off, landing and altitude-transition segments. Since the assessment uses four predefined trajectory sets and does not include repeated Monte Carlo sampling, the resulting percentages should be interpreted as descriptive acceptance rates rather than general Authorisation Approval Rates.

DAR and TCP&R do not directly modify the Authorisation Approval Rate because both act after the affected flights have been authorised. Their contribution concerns the management of ongoing

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operations: DAR supports the safe diversion of active flights following an airspace reconfiguration, while TCP&R reduces the conditional risk associated with residual encounters during flight.

Overall performance conclusion

Validation Exercise #02 confirms that the advanced U-AGREE services provide complementary performance benefits. Final FAS delivers the dominant strategic contribution by reducing UAS–UAS and UAS–manned collision frequencies and preventing geographical-zone infringements. TCP&R can provide an additional tactical reduction in residual risk, particularly for UAS–UAS encounters, although its measurable contribution depends on the algorithm, encounter geometry, response assumptions and residual event population. SCR improves the ability of Final FAS to accommodate submitted operations, while coordinated DAR rerouting prevents simultaneous contingency diversions from generating additional conflicts.

The results also confirm that Safety, Capacity, Security, Environment and Access and Equity cannot be considered independently. More restrictive strategic constraints reduce collision and infringement risk but may also reduce the proportion of U-plans that can be authorised. Conversely, high safety-based capacities may not represent operationally achievable traffic levels when they exceed the available trajectory population or are derived from zero or very few observed events. The preferred operational configuration should therefore be selected through a balanced assessment of collision risk, geographical-zone protection, safety-based capacity, trajectory availability and Authorisation Approval Rate, rather than by maximising any individual parameter or KPI.

B.6.4 Conclusions on automation levels

The UPV TCP&R campaign assessed two automation-response families under exactly matched encounter and system configurations. The Autonomous case uses a Gamma response distribution with a mean of 3 seconds, while the RPAS case uses a shifted-Gamma distribution with a three-second minimum and a mean of 7 seconds to represent a slower human-mediated response. Communication and surveillance latency remain separate model stages. The comparison therefore isolates the executed response-time assumption; it does not compare different aircraft or provide an empirically calibrated model of every automated system or remote pilot.

For UAS–UAS encounters, the shorter Autonomous response provides the strongest and most consistent temporal margin. Across the 4,480 matched configurations, the RPAS assumption produces a higher Loss-of-separation Ratio in every case and a higher Risk Ratio in 4,364 cases (97.41%). At the reporting baseline and 45-second look-ahead, raw RR increases from 0.015927 for Autonomous to 0.020111 for RPAS, while raw LR increases from 0.204563 to 0.220903. The difference is much larger at short look-ahead and generally narrows as more response time becomes available, confirming that earlier detection can partly compensate for a slower response.

The UAS–manned results do not support the same universal ordering. The RPAS assumption produces the higher Loss-of-separation Ratio in 4,257 of the 4,480 matched cases (95.02%), but the Risk Ratio is almost evenly divided: RPAS is higher in 2,184 cases and Autonomous in 2,296, with a small negative median difference. At the 45-second reporting baseline the two raw RR values are also close, while LR remains higher for RPAS. Although a 45-second look-ahead time is relatively long for an automated system, reducing it would be expected to affect the RPAS RR much more strongly than the Autonomous RR. In the RPAS case, pilot response and manoeuvre-execution delays would consume a substantially larger fraction of the available resolution window, whereas autonomous systems could still react within shorter time horizons and would therefore be less sensitive to the reduction. The larger manned-aircraft encounter dimensions, the non-manoeuvring role assigned to the manned participant

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and the interactions with look-ahead, separation and CNS assumptions can reverse the small RR difference. UAS–UAS and UAS–manned results must therefore remain separate.

Overall, the comparison shows that reducing the response delay through automation can improve the tactical opportunity, most clearly for UAS–UAS encounters, and that a slower human-mediated chain can erode the benefit of an otherwise correct detection and resolution. However, response time is only one element of the end-to-end chain. Surveillance, communication and processing determine when usable data are available; human acceptance and command entry depend on the automation mode; and vehicle dynamics and manoeuvre success determine when the resolution becomes effective.

Automation does not eliminate Human Performance considerations. It changes the human role from direct command execution towards configuration, supervision, override, exception management and recovery. The appropriate automation level therefore cannot be selected solely by choosing the shortest mean response. It must also consider authority, workload, situation awareness, trust, the consequences of an incorrect automated manoeuvre, assurance of the resolution logic, failure detection and safe fallback.

The response distributions are modelling assumptions and the pairwise campaign does not include representative human-in-the-loop trials, multiple simultaneous alerts, operator workload, prioritisation or multi-USSP coordination. The principal conclusion is that increased automation offers a credible way to preserve tactical time margin, but its safety credit remains conditional on validation of both the automated function and the people, interfaces and procedures that govern its use.

B.7 Recommendations

Based on the results of Validation Exercise #02, future R&I activities should provide more detailed and harmonised specifications for the implementation and integration of Final FAS, TCP&R, SCR, DAR, Conformance Monitoring and geographical-zone management. The specifications should clarify protected-volume construction, mixed UAS–manned deconfliction, conflict prioritisation, processing of simultaneous encounters, manoeuvre responsibilities, response assumptions, inter-USSP coordination and the handling of unsuccessful resolution attempts.

Further TCP&R validation should use harmonised benchmark encounters and common reporting configurations before comparing algorithm-specific results. UAS–UAS and UAS–manned encounters should continue to be assessed separately, and the operational conditions under which a tactical mitigation credit is transferred to the integrated safety assessment should be explicitly defined. Particular attention should be given to mixed encounters where the manned aircraft does not manoeuvre and the required NMAC clearance may exceed the effective detection and response range.

The complete service chain should be assessed as an integrated configuration. In particular, future campaigns should combine manned-aware FAS, geozone enforcement and TCP&R within the same simulations rather than assessing these functions only individually or in partial combinations. Multi-conflict situations should also be included to evaluate interactions between simultaneous tactical resolutions and the consistency of decisions across multiple USSPs.

SCR and DAR should be evaluated over a wider and statistically generated range of traffic configurations. Future SCR assessments should consider different waypoint-flexibility assumptions and quantify the relationship between route availability, computational performance and U-plan recovery. DAR assessments should include higher traffic levels, alternative safe-landing distributions and more restrictive airspace configurations to determine the operational limits of coordinated rerouting.

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Future geographical-zone assessments should extend beyond static restricted volumes to conditional and time-activated geozones. This is particularly relevant for temporary operational restrictions and environment-related constraints such as fauna activity. The assessment should also distinguish between prevention through FAS and containment of actual trajectory deviations through Conformance Monitoring, so that the incremental contribution of each service can be identified.

Finally, future capacity assessments should explicitly report statistical uncertainty, simulated exposure, trajectory availability and authorisation performance alongside the calculated safety-based capacity. Zero observed events should not be interpreted as zero underlying risk, and capacity estimates derived from one or very few residual events should be treated as indicative until confirmed through additional repetitions or extended simulation exposure.

In addition, Soft FAS deconfliction based on stochastic approaches and combined with highly automated TCP&R could not be assessed in the present validation exercise because the available information was insufficient to define and implement the concept consistently. Further exploratory research at TRL2 is therefore required to specify the interaction between probabilistic strategic deconfliction and automated tactical resolution, together with the corresponding safety conditions and fallback mechanisms, before progression to a higher TRL can be considered.

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Annex A – Representative scenarios

The representative scenarios identified in U-AGREE were selected to encompass a diverse range of operational conditions, ensuring comprehensive coverage of potential U-space environments. These scenarios reflect different levels of airspace complexity, operational challenges, and safety considerations.

Each scenario was analysed based on a predefined list of factors and formulated with inputs from project partners and refined through stakeholder workshops. The aim was to establish a framework that not only represents current operational realities but also anticipates future developments in U-space deployment.

Annex A.1 Scenario Selection Methodology

The methodology followed for the selection of representative scenarios in U-AGREE was based on a collaborative approach involving the project partners and key stakeholders. The process was designed to ensure that the selected scenarios are both representative of real-world U-space deployments and aligned with the operational and safety considerations relevant to the project.

To begin with, all participating partners in the U-AGREE project were requested to provide detailed descriptions of the scenarios they deemed relevant for analysis. These descriptions included an overview of the operational environment along with the key characteristics listed in the table developed in the previous section. The descriptions were expected to cover various aspects such as air traffic density, CNS capabilities, population density, coexistence with manned aviation, and presence of critical or restricted areas, among other features. Additionally, partners were asked to identify the main hazards associated with their proposed scenarios and their potential impact on operations within a U-space airspace.

The initial set of scenarios defined for evaluation was:

- Urban U-space operations in uncontrolled airspace.
- U-space BVLOS operations in low-density peri-urban and rural areas within Class-C.
- Dynamic U-space operations for infrastructure inspection.
- Medical transport operations from suburban to urban areas.
- U-space corridors for Vertical Take-off and Landing (VTOL) capable aircraft (VCA) traffic.
- U-space corridors exclusively for controlled and urban environments.

Once all the scenario proposals were collected, a dedicated workshop was organized with relevant stakeholders, including representatives from air navigation service providers, aviation regulatory bodies, aerospace research institutions, urban air mobility experts, and civil aviation authorities from different countries. The objective of this workshop was to refine the selection process by incorporating expert insights and ensuring that the chosen scenarios align with both regulatory and operational priorities.

The workshop was structured into three breakout sessions, each focusing on specific aspects of the scenarios. Participants were provided with supporting materials, including scenario presentations, whiteboards, markers, and post-it notes for face-to-face sessions, while an online session utilized the Miro board platform. The discussions in these sessions aimed to:

- Assess the completeness of the proposed scenarios, ensuring no critical elements were omitted.

- Evaluate the representativeness of the scenarios in real-world U-space operations and suggest necessary adjustments.
- Identify hazards that were overlooked or not adequately addressed.
- Highlight any additional relevant operational issues within the scenarios.

During the workshop, stakeholders were given the opportunity to review the proposed scenarios and provide their expert opinions on their relevance and representativeness. They were encouraged to highlight key aspects they considered crucial for U-AGREE, as well as to raise any concerns or suggest modifications to the proposed scenarios. The interactive format of the workshop allowed for a dynamic exchange of ideas, where participants could ask questions, challenge assumptions, and identify the strengths and weaknesses of each scenario.

Through this participatory process, a consensus was reached on which scenarios were most representative of the expected U-space operational environments. The selected scenarios were those that best captured the diversity of challenges and operational conditions that U-AGREE seeks to address. The feedback gathered during the workshop was instrumental in finalizing the following set of representative scenarios:

- Urban U-space operations in uncontrolled airspace [Section 0], associated with case 1.
- U-space BVLOS operations in low-density peri-urban and rural areas within Class-C [Section 0], associated with case 2.
- Dynamic U-space operations for infrastructure inspection [Section 0], associated with case 2.
- Medical transport operations from suburban to urban areas [Section 0], associated with case 1.

By employing this methodology, U-AGREE ensured that the scenario selection was not only based on theoretical assumptions but also validated by industry experts and stakeholders with real-world operational experience. This approach strengthens the credibility of the selected scenarios and enhances their applicability in assessing the risks and benefits of U-space deployments in different environments.

Annex A.2 Scenario Descriptions and Risk Mitigation

Annex A.2.1 Urban U-space operations in uncontrolled airspace

This scenario explores the establishment of a U-space airspace in Benidorm, aimed at providing a safe and efficient operational environment for multiple simultaneous UAS operations. The Benidorm U-space is one of the goals of the project U-elcome, a 3-year project, launched in 2022 and coordinated by the **EUROCONTROL Innovation Hub** that involves 51 European partners. Given Benidorm's status as a high-density touristic city with numerous hotels, rental apartments, and second residences, it presents unique challenges in air risk and ground risk management, particularly within an uncontrolled airspace (Class G).

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Figure 129: Aerial view of Benidorm - Urban U-space operations in uncontrolled airspace scenario

The implementation of U-space services in this environment is intended to facilitate drone operations in areas where they were previously limited due to safety and regulatory constraints. The designated U-space airspace encompasses the urban area of Benidorm, extending slightly into the surrounding periurban, unpopulated, and coastal areas. This creates a complex airspace environment, where extreme population density in certain areas transitions to unpopulated zones along the shore.

As illustrated in the diagram below, Figure 130, the entire U-space area is set at a common altitude of 275m Above Mean Sea Level (AMSL), ensuring a minimum 150m Above Ground Level (AGL) volume for safe drone operations across all designated zones.



Figure 130: Geographical delimitation of the Benidorm U-space area - Urban U-space operations in uncontrolled airspace scenario

Annex A.2.1.1 Operational Characteristics

This U-space airspace is designed to accommodate a wide range of **UAS operations**, including:

- **Beyond Visual Line of Sight (BVLOS) missions** for long-range drone operations.

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- **Multiple simultaneous Visual Line of Sight (VLOS) operations**.
- **Autonomous flights with varying levels of automation**, including operations under **non-certified categories**.

While the airspace is classified as Class G (uncontrolled), there are instances where manned aviation may enter the designated U-space area. In such cases, it is expected that these aircraft will be equipped with electronic conspicuity (e-conspicuity) devices, ensuring their visibility to other airspace users and minimizing the risk of conflict.

Annex A.2.1.2 U-space Architecture and Governance

The U-space airspace in Benidorm will operate under a centralized architecture, with a CISP facilitating the flow of operational data between USSPs, privileged users, ANSPs, and other relevant stakeholders.

In Spain, ENAIRE has been designated as the national CISP, responsible for providing trusted, high-quality, accurate, and secure all common information for U-space stakeholders in all U-space airspaces within the country. In the context of Benidorm's U-space, ENAIRE will also act as the ANSP, although its role in this environment is limited given that the airspace is entirely outside controlled areas.

Annex A.2.1.3 Designated Testing Areas

Flight tests related to U-space services have already been conducted in specific areas of **Benidorm**, as depicted in the Figure 131.



Figure 131: Testing areas for U-space operations in Benidorm - Urban U-space operations in uncontrolled airspace scenario

These areas are classified into three distinct **testing environments**:

- **Yellow Zone:** Heliport (Suburban Area) – Designed for testing drone operations in semi-urban environments.
- **Blue Zone:** Urban Lab (City Centre) – A controlled testing space surrounded by skyscrapers, used for validations and experimental drone flight trials.

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Red Zone: Beach Area – An open environment suitable for diverse drone operations. The types of missions developed in each area are:

Type of mission	Testing areas		
	Beach	Urban (Lab)	Heliport (Suburban)
Logistics		X	X
Recreative	X	X	
Security/Emergency	X	X	
Photography	X	X	
Surveillance/Traffic monitoring	X	X	X

Table 78: Type of missions - Urban U-space operations in uncontrolled airspace scenario

Annex A.2.1.4 Environmental and Regulatory Considerations

Several factors impact the operational feasibility of U-space in Benidorm, including:

- **Touristic Environment:** High fluctuations in population density due to seasonal tourism.
- **Diverse Land Use:** A combination of dense urban environments, periurban areas, and unpopulated coastal zones.
- **Proximity to Natural Areas:** Inclusion of Serra Gelada Natural Park (P.N. Serra Gelada) within the U-space boundaries.
- **Weather Conditions:** The region benefits from a mild microclimate, with minimal restrictions expected on UAS operations, except for wind gusts generated by skyscrapers.
- **Class G Airspace:** As an uncontrolled airspace, it lacks CNS services, requiring U-space services to enhance situational awareness and coordination.

Annex A.2.1.5 Identified Hazards and Risk Mitigation through U-space Services

The implementation of a U-space airspace in Benidorm introduces multiple operational challenges due to its dense urban environment, coexistence of manned and unmanned aviation, and the diversity of UAS operations. Ensuring safe and efficient UAS integration requires identifying key hazards and implementing appropriate U-space services to mitigate risks. The following table summarizes the main hazards, their associated risks, and the mitigation strategies employed:

Hazard	Details	Associated metrics	Related U-space services
High Population Density	Benidorm's urban environment, characterized by skyscrapers and tourism, increases the risk of ground impact incidents. Tall structures also contribute to GPS signal loss, communication	Number of incidents related to signal interference, frequency of navigation errors, (deviations from planned flight paths due to incorrect positioning, loss of GPS accuracy, or misinterpretation of waypoints) rate of unauthorized flight deviations.	Geo-awareness. Conformance monitoring.

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Hazard	Details	Associated metrics	Related U-space services
	disruptions, and artificial wind gusts affecting flight stability.		
Presence of Critical Infrastructure	The proximity of hospitals, ports, and schools requires geo-awareness measures to prevent unauthorized drone activity in restricted areas.	Number of incursions into restricted zones, compliance rate with geo-awareness advisories.	Geo-awareness. Conformance monitoring.
Manned Aviation Entry into Uncontrolled Airspace	Potential airspace conflicts between crewed and uncrewed aviation require Traffic Information and Network Identification services to ensure awareness and prevent collisions.	Number of airspace conflict alerts, response time to deconfliction manoeuvres, percentage of manned aircraft equipped with electronic conspicuity.	Traffic information. Network identification.
Diversity of UAS Operations	The coexistence of BVLOS, VLOS, and autonomous flights increases complexity, requiring effective detect-and-avoid capabilities. UAS Flight Authorisation services help manage operations and reduce risks.	Approval rate of BVLOS flight requests, number of detect-and-avoid activations, conflict resolution success rate.	UAS Flight Authorisation.
Urban Infrastructure Interference	Tall buildings and dense infrastructure can impact CNS performance, leading to gaps in communication and navigation coverage. Wind gusts generated by skyscrapers can destabilize drone operations. U-space services must provide real-time weather information for operational planning.	Rate of communication outages, navigation precision in dense urban areas, number of reported signal dropouts.	Geo-awareness. Conformance monitoring.

Table 79: Key Hazards and Mitigation Strategies for U-space Operations in Benidorm - Urban U-space operations in uncontrolled airspace scenario

The successful implementation of U-space services in Benidorm plays a critical role in mitigating the risks identified in the previous section. These services enhance situational awareness, improve coordination between UAS and manned aviation, and ensure regulatory compliance, ultimately enabling safe and efficient drone operations in an uncontrolled urban environment:

- **Enhancing Airspace Awareness**: Traffic Information, Geo-awareness and Network Identification services provide real-time updates on airspace activity, ensuring that both UAS operators and manned aviation pilots can detect and avoid conflicts. This is particularly important in uncontrolled Class G airspace, where manned aircraft may not always be under active air traffic control.

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- **Reducing Ground Risk Exposure**: The integration of Geo-awareness services ensures that drones operate within designated areas and avoid restricted zones such as hospitals, ports, and schools. By continuously monitoring compliance, these services minimize the likelihood of unauthorized overflights and potential ground incidents.
- **Improving CNS Performance in Urban Areas**: Urban infrastructure and high-rise buildings in Benidorm can interfere with Global Positioning System (GPS) signals and cause communication disruptions. The Benidorm U-space airspace compensates for these limitations through advanced CNS capabilities, such as redundant positioning technologies and enhanced connectivity solutions that maintain reliable tracking and navigation for unmanned and manned traffic.
- **Supporting BVLOS and High-Autonomy Operations**: The use of UAS Flight Authorisation services facilitates complex drone operations, particularly BVLOS missions, by providing pre-approved flight plans and dynamic adjustments based on real-time airspace conditions. This service is crucial for enabling scalable UAS operations in urban environments.
- **Ensuring Compliance and Operational Efficiency**: The implementation of automated compliance checks within U-space services ensures that drone operations adhere to regulatory frameworks and flight authorisations. This reduces operational delays, prevents regulatory violations, and fosters trust between UAS operators and authorities.

Despite these advantages, some challenges remain:

- **CNS limitations:** Multipath effects and signal loss in dense urban areas require improved positioning technologies.
- **Scalability:** Increasing drone traffic demands enhanced U-space infrastructure for seamless management.
- **Integration with manned aviation:** Coordination in Class G airspace remains complex, especially for emergency aircraft.
- **Regulatory evolution:** Adapting to evolving European ATM policies is essential for U-space harmonization.
- **Weather risks:** Wind gusts near skyscrapers can disrupt flights, requiring better meteorological integration.
- **Public acceptance:** Addressing concerns on noise, privacy, and security is key to community support.

Annex A.2.2 U-space BVLOS operations in low-density peri-urban and rural areas within Class-C

ÉALÚ-AER is a Digital Sky Demonstrator project that propose deploying and demonstrating an end-to-end Collins Aerospace **U-space infrastructure** to enable **UAS BVLOS operations** at the Future Mobility Campus Ireland (FMCI) vertiport next to International Shannon Airport, Ireland, which is one of the largest airports at Ireland.

Shannon connects to Limerick, which is the third largest city in Ireland, representing Limerick area, therefore, an urban area. It is connected through the Shannon River estuary, which can be considered unpopulated/sparsely populated area, making it easier to obtain Operational Authorisation over that area lowering the Ground risk for the SORA. Being the majority of the intended operation area Class-Airspace but Limerick city, make it easier to lower the Air risk, being all GA aircraft over the area identified by transponder, but make it more complex to accommodate and designate an U-space

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without affecting the existing ATM traffic, and also the equipment and performance requirements of the UASs that will be taking-off/landing at the FMCI's vertiport, will be more strict.

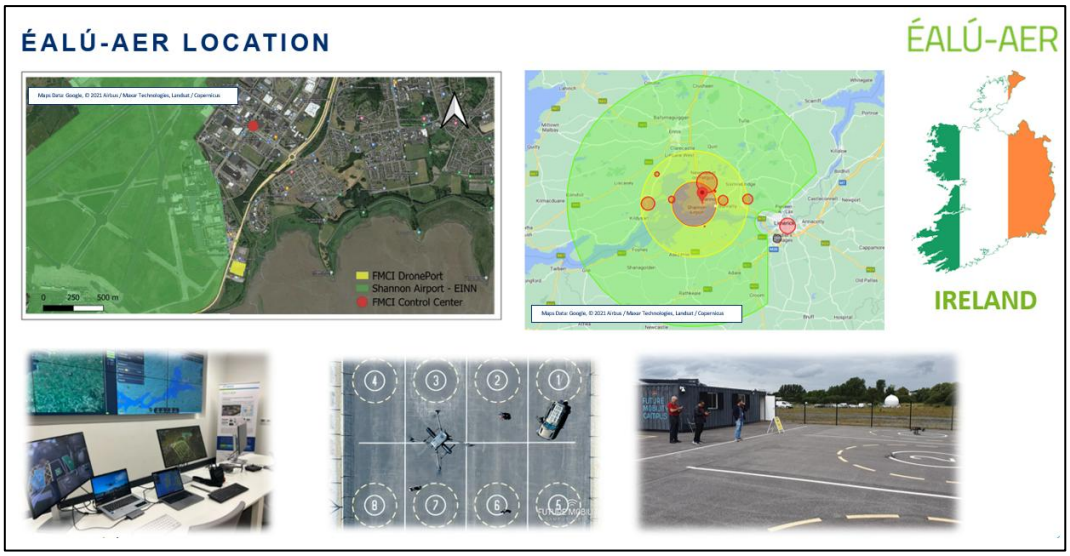


Figure 132: Aerial view of Shannon, Ireland - U-space BVLOS operations in low-density peri-urban and rural areas within Class-C

Annex A.2.2.1 Operational Characteristics

- U-space inside existing **Controlled Airspace.**
- **Transiting** actual **Class C – Class G airspace.**
- Mainly **BVLOS** Operations at **International Airport** environment.
- **Low-Density Peri-urban and Rural Areas.**
- **U-space infrastructure** available.
- **UAM** and **drone delivery** use cases.
- **Mostly Automatically flights** with varying levels of automation.

The U-space at Shannon-Limerick area is looking to enable and enhance the safety of BVLOS operations in the area and will allow for different variety of UAS models.

Due to the characteristics of the airspace in this U-space volume, it is necessary to create different areas with distinct requirements for UAS operations, as this will be more limited close to the Airport at FMCI vertiport, as well as in those areas in Limerick city where the population density is higher.

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Figure 133: Example of key routes - U-space BVLOS operations in low-density peri-urban and rural areas within Class-C

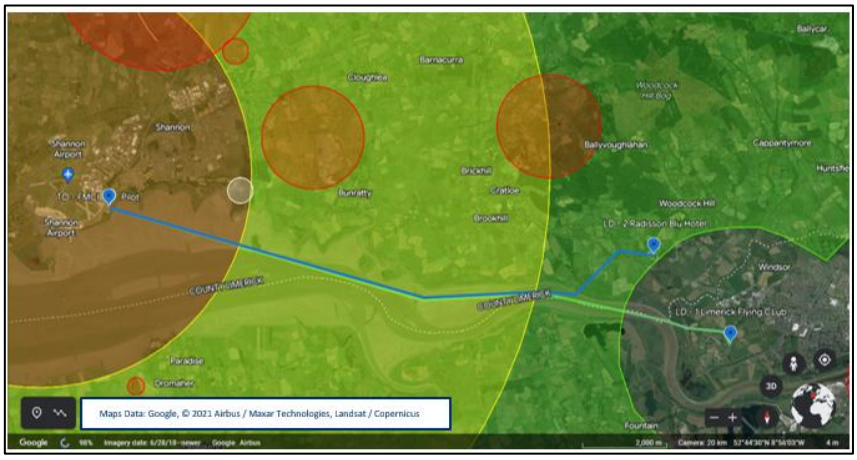


Figure 134: Transition from Class C to Class G airspace - U-space BVLOS operations in low-density peri-urban and rural areas within Class-C

The U-space infrastructure that is represented in Figure 135 comprehends:

- **Secure Backhaul Network:** AGN, to exchange secure data across systems.
- **USSP platform:** Collins Airspace Services – USS Client
- **CISP platform:** Collins Airspace Services – ATS Client
- **Ground surveillance Radar:** Skyler® Radar
- **CNPC solution as reliable C2 link:** CNPC5000 radios.

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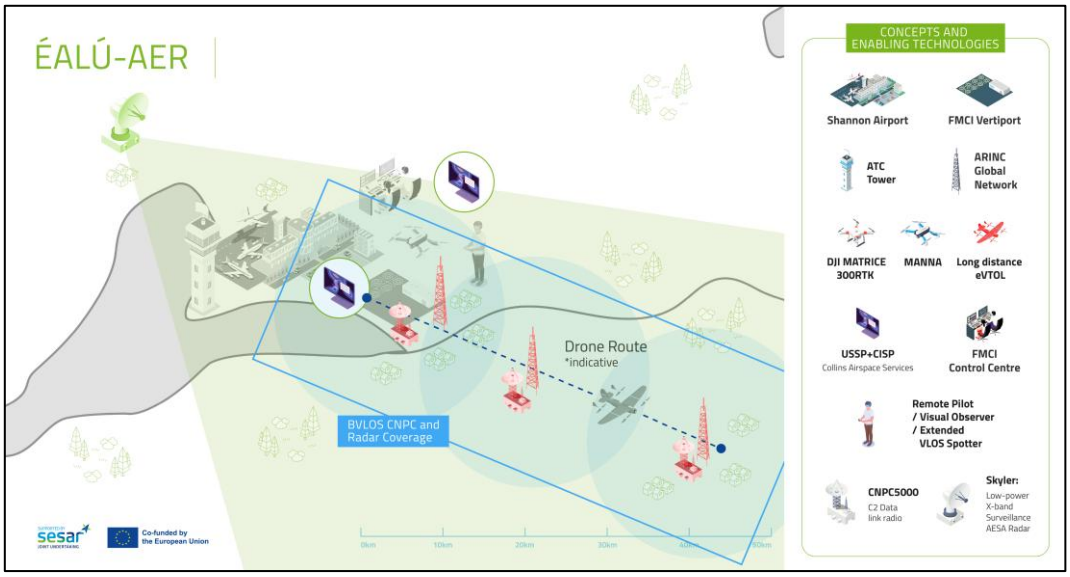


Figure 135: CNS Infrastructure Architecture - U-space BVLOS operations in low-density peri-urban and rural areas within Class-C

Annex A.2.2.2 Environmental and Regulatory Constraints

Several factors impact the operational feasibility of U-space at Shannon Area, including:

- **Class C Airspace:** It will be usual for manned aircraft to enter this U-space airspace (there are occasional VFR traffics on the area, Ryanair Pilots Training, and non-regular Police and Search and Rescue - SAR- flights) being close to the airport. In these cases, they must be equipped with e-conspicuity devices that makes them visible to other users of this airspace.
- **Weather conditions:** Between Shannon and Limerick, the weather is often influenced by Ireland's mild maritime climate. It typically features frequent cloud cover, moderate winds, and occasional rain, with visibility conditions varying due to mist or fog, especially during early mornings or after rainfall. These factors are critical for aviation, affecting take-offs, landings, and drone operations in the area, therefore, some restrictions might apply.
- **Special Natural Areas of conservation:** Lower Shannon Estuary is considered a special area of conservation (SAC 002165), therefore an appropriate screening of the special area of had been performed to determine if a full assessment is needed. With the parameters of the flights in terms of average altitude, platforms, speed, etc. This had been performed, and the conclusion was that it won't affect this area, and an appropriate assessment is not required as far as the characteristics of the flights doesn't drastically change. If dangerous-good are transported, there should follow the proper regulatory requirements.
- **Diverse Land Use:** The planned U-space covers the city of Limerick and Shannon River estuary, as well as the FMCI vertiport close to Shannon Airport. Geographically, it is a mix of periurban and unpopulated environment; with higher population density in small certain areas (Limerick city) that suddenly turns into 0 as they end along the Shannon River.

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Annex A.2.2.3 Identified Hazards and Risk Mitigation through U-space Services

Hazard	Details	Associated metrics	Related U-space services
Presence of Critical Infrastructure	The proximity of the Airport and the presence on the Controlled Airspace, requires geo-awareness measures to prevent unauthorized drone activity in restricted areas.	Number of incursions into restricted zones, compliance rate with geo-awareness advisories.	Geo-awareness
Weather Conditions	High Incidence of Wind/Rain/Fog: Frequent adverse conditions necessitating adaptive measures or operational adjustments.	Number of Flight Operations disrupted and declared emergency due to a weather forecast that wasn't accurate.	Weather Information
SID (Standard Instrument Departures) STARs (Standard Terminal Arrival Routes)	Shannon Airport handles commercial airliners, business jets, and cargo flights that follow strict SID/STAR procedures. DAR (Dynamic Airspace Reconfiguration) allows temporary restriction of UAS operations when high-density SID/STAR traffic is expected and enables strategic deconfliction by only approving drone flights that don't interfere with SID/STAR operations.	Number of Dynamic Airspace Reconfigurations for an inbound/outbound aircraft from/to Shannon Airport need to disrupt the U-space airspace.	Dynamic Airspace Reconfiguration Flight Authorisation
MAC with Manned Aviation activity	Potential airspace conflicts between crewed and uncrewed aviation require Traffic Information and Network Identification services to ensure awareness and prevent collisions.	Number of airspace conflict alerts, response time to deconfliction manoeuvres, percentage of manned aircraft equipped with electronic conspicuity.	Traffic Information Network Identification
CNS infrastructure	The requirements in the precision of the GNSS as well as C2 link reliability, requires of the proper U-space services to plan the route accordingly from the strategic phase,	Number of alerts in loss of comms or GNSS, for how much time, and average latencies. Number of detections during flight of non-	Navigation Coverage information Flight Authorisation Surveillance Data Exchange.

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Hazard	Details	Associated metrics	Related U-space services
	as well during the tactical phase to ensure the Operator is provided with the necessary link metrics. As well as the surveillance of the airspace for non-cooperative aircrafts.	cooperative aircraft by surveillance equipment.	Communication Coverage Information

Table 80: Key Hazards and Mitigation Strategies for U-space BVLOS operations in low-density peri-urban and rural areas within Class-C scenario

The success of U-space Services at Shannon Airport locations plays a critical role in mitigating the risks identified in the previous section. These services enhance the situational awareness, helping integration of BVLOS drone operations into controlled airspace environment while maintaining safety with manned aircraft movements. The U-space infrastructure described in this section plays a key role in safeguarding these BVLOS operations.

- **Improved airspace safety and conflict avoidance:** Reduces the likelihood of airspace violations, mid-air conflicts and potential disruptions to crewed aviation.
- **Enhanced BVLOS operational approval and Compliance automation:** Flight Authorisation Service automates approvals, reducing the need for manual Air Traffic Control (ATC) coordination. Faster regulatory approvals for BVLOS flights, leading to scalable and repeatable drone operations.
- **Increased operational efficiency for drone missions:** Optimizes flight planning, reducing delays and maximizing mission success
- **Lower Workload for ATC & ANSPs:** Minimizes the burden on Shannon ATC by automating UAS traffic.
- **Enabling advanced drone operations (IAM, Medical Deliveries, etc):** Supports the future integration of IAM in Shannon.

Despite these advantages, some limitations remain:

- **Coordination with ANSP and ATC:** Some services such as automated flight authorisation or dynamic airspace management, may not be available or integrated with ATM systems.
- **E-conspicuity:** Availability of e-conspicuity devices are limited yet.
- **Tactical conflict resolution:** If a manned aircraft deviates unexpectedly into U-space airspace, a drone operator may have limited time to react. Automated rerouting mechanisms are not yet standardized across different U-space implementations.
- **Data accuracy and Latency issues:** U-space services rely on various data sources (e.g. GNSS, LTE, U-space feeds), but data accuracy and latency can impact safety. There are certain limitations:
    - GPS errors or signal loss may affect drone positioning.
    - Latency in traffic updates may delay deconfliction actions.
- **U-space services cost:** Service fees for U-space access, data processing, or real-time conflict resolution could be expensive for frequent BVLOS operations.

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- **Scalability concerns:** If multiple drones operate in the same airspace near Shannon, ensuring safe separation while avoiding possible incursions and Manned aviation conflicts adds complexity.

Annex A.2.3 Dynamic U-space operations for infrastructure inspection

This scenario focuses on U-space operations for infrastructure inspection in the Port of Antwerp (Belgium), leveraging insights from the BURDI project. The Port of Antwerp serves as a key logistics and trade hub, positioned along the River Scheldt and operating as one of Europe's largest maritime gateways. Its strategic location near Antwerp International Airport (EBAW) and Hoevenen Airfield (EBHN) presents operational challenges due to the coexistence of manned and unmanned aviation, requiring advanced risk mitigation measures.

Given the complexity of this environment, ensuring safety and efficiency in UAS operations demands the integration of U-space services, coordination with aviation and port authorities, and robust monitoring systems to mitigate both ground and air risks.

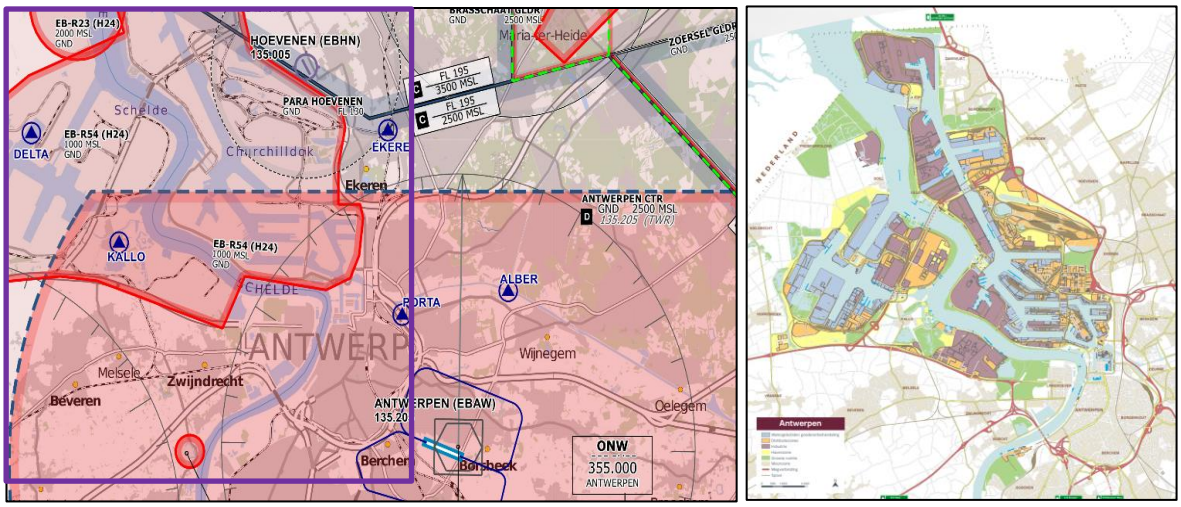


Figure 136: EBHN and EBAW next to geographical area of port, partly in CTR of EBAW. The violet rectangle frames the area of the port, enlarged in the image on the right.

Annex A.2.3.1 Operational Characteristics

The anticipated UAS operations in the Port of Antwerp include:

- **VLOS** (Visual Line of Sight) and **EVLOS** (Extended Visual Line of Sight) operations within controlled airspace.
- U-space operations requiring authorized U-plans in accordance with **SORA** (Specific Operations Risk Assessment) guidelines.

Annex A.2.3.2 Key operational characteristics

Since detailed information about the operations and environment of the **port of Antwerp** was unavailable, **an alternative approach** was taken. Data was sourced from a similar scenario with comparable requirements—the flight analyses conducted for the **port of La Spezia** (Italy) during the

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EU-funded Labyrinth project. The environments have similar characteristics apart from the size difference.

Both ports are located adjacent to their respective cities. Each features a landscape filled with obstacles such as cranes, structures, high lampposts, windmills, buildings, and stacks of containers. Additionally, both ports have moving elements, including static and rail cranes, vessels navigating the area, and birds. Notably, near the Port of Antwerp, there is a significant migration and breeding site for many waterbirds and songbirds.

The main difference between those scenarios will probably come from the weather conditions, being La Spezia more susceptible to adverse conditions since it is directly located by the sea while the port of Antwerp is in an estuary. A difference in La Spezia is that the zone around it is a very important military area (named "Prohibited area - P2 - La Spezia"), and according to the Italian legislation the civil flights are prohibited from the surface up to FL195 height. Operations shall be subject to specific authorisation according to procedures published by ENAC (the Italian Civil Aviation Authority). Due to this, a geofence was determined covering the military area, next to the port operations.

Category	Port of La Spezia	Port of Antwerp
Location	Adjacent to the city, directly by the sea	Adjacent to the city, located in an estuary
Landscape Obstacles	Cranes, structures, high lampposts, windmills, buildings, stacks of containers	Cranes, structures, high lampposts, windmills, buildings, stacks of containers
Moving Elements	Static and rail cranes, vessels, birds	Static and rail cranes, vessels, birds
Environmental Factors	Presence of seabirds	Significant migration and breeding site for waterbirds and songbirds
Weather Conditions	More susceptible to adverse conditions due to direct sea exposure	Less susceptible to adverse weather due to estuary location
Regulatory Restrictions	Located in a military area ("Prohibited area - P2 - La Spezia"), civil flights are prohibited up to FL195; operations require specific authorisation	E-conspicuity mandatory for crewed aviation flying in U-space airspace
Location	Adjacent to the city, directly by the sea	Adjacent to the city, located in an estuary

Table 81: Comparison of the Port of La Spezia and the Port of Antwerp

The following tasks were required in the **port of La Spezia**:

- **Port security:** monitor the perimeter of the port. Identify potential threats or problems on the premises.
- **Port safety:** Monitor the correct position of loads, correct mooring of vessel, loading and unloading on trains, trucks and vessels.
- **Port maintenance:** Monitoring of equipment and infrastructures.
- **Port management of traffic:** ground traffic monitoring within the port areas.

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- **Port staff training:** recording videos and images for staff training i.e., handling of load unit on cranes, controlling specific areas.
- **Control debris in water** after drag works.



Figure 137: Drone used in the flight tests in the port of La Spezia.

The drones utilized for these missions ranged from small (250g - 2kg) to medium-sized (2kg - 25kg) UAS, equipped with 5G connectivity, GPS, and GNSS for enhanced navigation and data transmission.

Annex A.2.3.3 Environmental and Regulatory Constraints

In Belgium, VFR traffic operating in U-space airspace must be equipped with e-conspicuity devices to enhance visibility and situational awareness. In the case of La Spezia, part of the port was a military zone, protected by geofencing restrictions, ensuring that drones did not capture imagery in restricted areas.

Hazard	Details	Associated metrics	Related U-space services
Low Population Density	In a port environment we suppose low population density mainly represented by port workers. This risk will vary depending on the moment of the day. In the case of La Spezia, a helmet was mandatory in some areas but not in all the port.	Density of people in area with and without helmet. The number will depend a lot of the day/hour since it will be aligned with the working activity.	Geo-awareness
CNS Limitations	Interferences to the signals could be expected in the area of the port.	Number of lost packages. Detection and response time to unauthorized incursions. Efficiency of geo-awareness systems in port environments.	E-conspicuity Network Identification
Weather and Environmental Factors	Weather might be variable due to the temperate maritime climate, with occasional rain, wind, and fog that can affect	Effects of the weather in the accuracy to follow the pre-loaded trajectory, like amount of deviation, or impact in the time of arrival	Weather Information Conformance monitoring E-conspicuity Network Identification

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Hazard	Details	Associated metrics	Related U-space services
	operations, requiring monitoring for safety.	to the points of a 4D trajectory. Impact of the weather on the operational capacity of drones	Flight Authorisation
Interaction with Manned Aviation	Given the short distance from the airport and especially the airfield, we expect a moderate probability of airspace overlap. VFR flights and SAR flights may also operate at low altitudes. E-conspicuity should be used in these situations.	Number of near-miss events (or MAC to be more conservative), Altitude separation (ft).	Collaborative Interface with ATC Network Identification E-conspicuity Traffic Information Flight Authorisation
Presence of Critical or Restricted Areas	The airport in the case of Antwerp, that will require the separation of the UAS operations, or the military base in the example of La Spezia. Besides, in a commercial port, we will find sensitive areas, for example for fuel storage.	Number of infrastructures potentially flammable in the area in case of collision, like fuel tanks or storage of chemical substances. Number of hours during which a damaged critical ground infrastructure could not provide service (estimated time to be repaired).	Conformance monitoring Geo-awareness Network Identification E-conspicuity Traffic Information
Presence of Natural or Artificial Obstacles	In a port we can find lampposts, moving cranes, cables, and frequently big birds.	Bird density	Geo-awareness

Table 82: Environmental and regulatory constraints for Dynamic U-space operations for infrastructure inspection scenario

Annex A.2.3.4 Operational Constraints and Risk Mitigation

One of the primary challenges in the **Port of Antwerp** is **airspace coordination**, given its proximity to controlled airspace and the high volume of ground and maritime operations. To mitigate these risks, U-space services will play a crucial role in:

- **Traffic Awareness**: Integration of **e-conspicuity solutions** to enhance situational awareness among manned and unmanned operators.
- **Flight Authorisation**: Implementation of **UAS Flight Authorisation Services** to ensure compliance with **U-space airspace structures**.
- **Geo-awareness and Conformance Monitoring**: Preventing unauthorized entry into restricted areas within the port.

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Since the heights of the cranes were not accurately documented, test flights in La Spezia were conducted at altitudes under 120 m, allowing assessment of camera resolution for infrastructure inspection while ensuring compliance with local aviation regulations.



Figure 138: Flight test in the port of La Spezia, Italy (Project Labyrinth, 2023). The drone appears inside the blue circle.

To mitigate these hazards, the following U-space services will be utilized:

- **Network Identification.** The drones must report their position constantly at the frequency mandated by the air authority.
- **Geo-awareness.** Providing information about the location of obstacles, expected presence of people or restricted areas.
- **Traffic Information.** Service broadcasting the presence and location of other traffic, crewed or not, tracks and expected densities.
- **Flight Authorisation.** The acceptance/rejection/modification of the U-plans will be impacted by constraints like no-fly zones or the ATC decisions with respect to the controlled areas.
- **Collaborative interface with ATC.** The mechanism to coordinate U-space operations and crewed aviation in controlled areas.
- **E-conspicuity.** In this case, the need of crewed aviation to constantly report its position (equivalent to the Network Identification for UAS) so that they can be detected and avoided while sharing U-space.
- **Conformance monitoring.** Service making use of the position reporting to check that the Unmanned Aerial Vehicle (UAV) follow their expected U-plan within a tolerated deviation. Otherwise, it would trigger the application of measures to avoid safety issues.
- **Weather information.** Will provide estimations or measurements of the weather conditions that could impact or prevent from the approval of the plan to the capability to follow faithfully the expected U-plan.

These services collectively contribute to:

- Monitoring and tracking drone operations to ensure compliance.
- Segregating UAS from crewed aviation, minimizing airspace conflicts.

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- Providing real-time notifications for airspace incursions, allowing operators to maintain safe separation distances.

Despite the implementation of these U-space services, certain **challenges** remain:

- Low-altitude flights within the port require navigation between infrastructure such as lampposts, structures, and cables, which may pose challenges for drone sensors and collision-avoidance systems.
- Dynamic obstacles, including moving cranes and ships, introduce additional risks that require adaptive flight planning and real-time situational awareness.

Annex A.2.4 Medical transport operations from suburban to urban areas

This operation represents the last part of one of the six very large demonstration conducted under the CORUS-XUAM project, designed to showcase how U-space services can support UAM operations. Before these demonstrations, a fully operational U-space infrastructure was not in place, and the project aimed to develop, test, and validate these services in real-world scenarios, demonstrating their effectiveness in integrating UAM with existing ATM systems.

The focus of the operation was last mile delivery of medical cargo from suburban to urban areas in the Apulia region of southern Italy, carrying out a BVLOS operation in controlled airspace covering 6 km.

The specific locations involved in this operation include:

- **Manduria Airfield**, located in a suburban area, is a private airfield located in Manduria. It serves as a base for general aviation, ultralight aircraft, and flight training activities. The airfield features a 900 m asphalt runway, hangars for aircraft storage, and maintenance facilities. It also supports aerial work operations, tourism flights, and pilot training programs. Positioned in the Apulia region, it plays a role in regional air mobility and aviation services.
- **Manduria "Marianna Giannuzzi" Hospital area**, located in an urban centre. The hospital does not have designated landing areas for UAVs. Therefore, for the purpose of this demonstration, a small green area near the hospital was utilized as a landing site.

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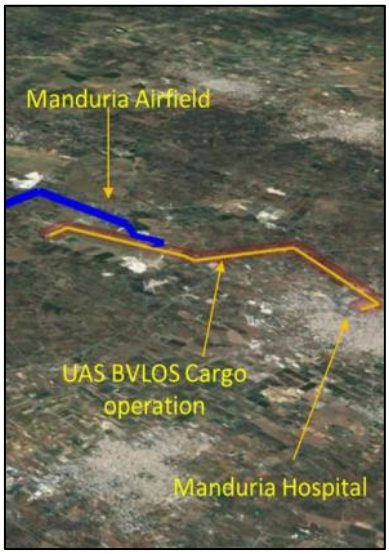


Figure 139: Last mile delivery trajectory

Annex A.2.4.1 Operational Characteristics

The UAS used for last mile delivery is the Techno Sky UAS-PPL 612 PLUS EVO XL, depicted in Figure 140. This hexarotor UAS, with a MTOM under 25 kg, was granted a Project Certification by ENAC (Italian Civil Aviation Authority) for the demonstration.



Figure 140: Techno Sky UAS: PPL 612 PLUS EVO XL

UAS characteristics are outlined in Table 83: UAS Technical Specifications. For this operation, the UAS operator and the drone were registered on the USSP platform, and upon completing the SORA assessment, the operation was authorized.

Technical Specifications	
MTOM	15 kg
Wingspan/max dimension	1.6 m
Wind resistance	12.5 m/s
Cruise speed	12.5 m/s
C2	2.4 GHz

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Technical Specifications	
Range	4000 m
Endurance	15 min
Take off	Manual (RC) or automatic

Table 83: UAS Technical Specifications

To track the UAS during the last mile delivery, the UAS Traffic Management (UTM) Box Pollicino™ was used. The UTM Box Pollicino™ is a drone tracker based on LPWAN LTE technology, which implements remote identification service over the internet network. It is the first Remote Identification device conforming to the "Manifesto" for the development of U-space services in Italy. The tracker is compliant with EU Regulation 2021/664 and can be easily configured to work with different USSPs. In the default configuration the tracking service is linked to D-flight USSP by the exploitation of d-Flight ICD for connectivity. Information was then displayed on D-flight (Italian USSP) platform, as showed in Figure 141.

A commercial drone detection system, the DJI Aeroscope, was also used during the operation to identify non-cooperative drones, integrating information into the D-flight USSP platform, to enhance situational awareness and mitigate risks from uncooperative drones.

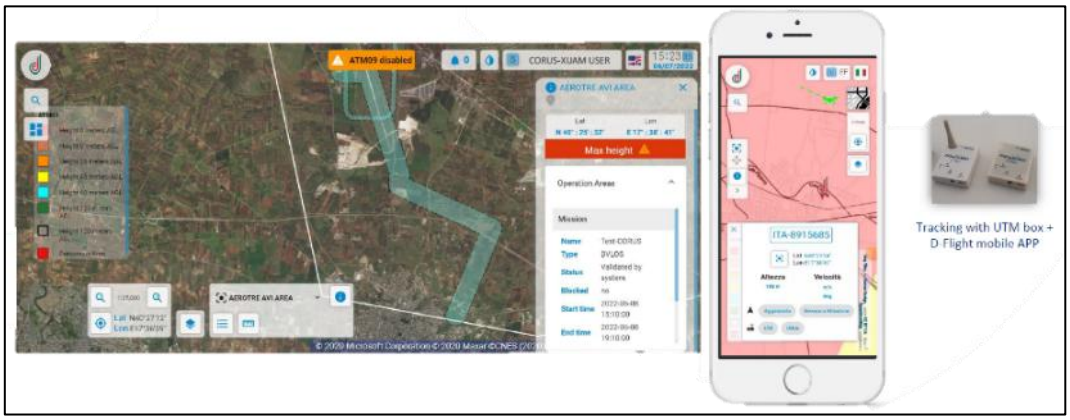


Figure 141: UAS Tracking Display on D-flight USSP Platform

The operation involved many stakeholders who collaborated for the success of the last mile medical cargo delivery, guaranteeing safety even in an urban environment. These are:

Stakeholder		Involvement
ANSP	ENAV (Ente Nazionale di Assistenza al Volo)	Involved in strategic phase for activities related to ATM (controlled airspace) and manned a/c operations in U-space (e.g. HEMS flights, VFR).
USSP	d-flight	Involved in provision of U-space services to related users in U-space.
Drone Pilot/Operator	d-flight / Technosky	Involved for the specific operation in BVLOS (last cargo delivery).

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Airfield operator	Aerotre	Involved in management of ground operations and coordination related to Manduria Airfield.

Table 84: Stakeholder Involvement in Last-Mile Medical Cargo Delivery Operations

Annex A.2.4.2 Environmental and Regulatory Constraints

The flight was conducted in controlled airspace, requiring an authorized U-plan and adherence to the SORA guidelines.

The operation took place beneath controlled airspace CTR 3 Grottaglie, as shown in Figure 142, where altitude limitations had to be strictly observed. The flight remained below 120 m in altitude, aligning with regulatory requirements.

Given the controlled nature of the airspace and the specific characteristics of the mission, a customized risk assessment was required instead of applying predefined standard scenarios. This tailored approach ensured an operational framework that effectively mitigated risks associated with urban air mobility in regulated environments.



Figure 142: Airspace CTR 3 Grottaglie

A key aspect of the risk assessment was the hospital's location in the city centre, as shown in Figure 143. This high-density urban setting necessitated a dedicated evaluation of potential hazards, particularly regarding overflight of populated areas. This consideration was fundamental to the SORA assessment, ensuring compliance with safety protocols for operations in densely populated environments.

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Figure 143: Manduria "Marianna Giannuzzi" Hospital

Annex A.2.4.3 Identified Hazards and Risk Mitigation through U-space services

The main hazards identified in this scenario are summarized in Table 85.

Hazard	Category	Details	Associated metrics	Related U-space services
High Population Density	Safety-related	Overflight of densely populated urban areas may pose risks in case of collision with buildings or critical infrastructures.	Population exposure rate, Potential impact radius in case of failure.	Geo-awareness, Conformance monitoring, Flight authorisation
Presence of Critical or Restricted Areas		Hospitals and schools can be found in the urban environment.	Number of critical infrastructures, number of affected critical infrastructures in proximity	Geo-awareness Conformance monitoring, Flight authorisation
CNS Limitations	Safety-related	Low 4G & 5G coverage in suburban areas can affect tracking capabilities. On the other hand, GNSS (e.g., GPS) can be unreliable in urban environments due to multipath effects and signal shadowing.	Dilution of Precision (DOP, both vertical and horizontal): minimum elevation, horizontal and vertical errors, maximum error estimates; Signal-to-Noise Ratio (SNR),	Geo-awareness Conformance monitoring

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Hazard	Category	Details	Associated metrics	Related U-space services
			GNSS Availability Percentage.	
Weather and Environmental Factors	Safety-related Environment-related	Adverse weather conditions like strong winds, rain, or fog can impact flight safety and energy consumption. City architecture may amplify wind hazards, which can be mitigated through wind models and static maps. This can also have effects on battery management: stability is more difficult to maintain in a windy environment; therefore, energy consumption is higher.	wind speed, turbulence index, precipitation rate, visibility range. Energy consumption variation (%), impact of adverse weather on mission success rate.	Weather information, Flight authorisation
Interaction with Manned Aviation	Safety-related	There could be potential conflicts with VFR (Visual Flight Rules) flights. Furthermore, HEMS flights could be present near the hospital and possible military helicopter activity on weekdays near the eastern side of the airfield, which could interfere with flight operations. In these cases, they should be equipped with e-conspicuity devices that makes them visible to other users of this airspace.	Traffic density (aircraft/ km²), number of near-miss events (or MAC to be more conservative), Altitude separation (ft)	Traffic Information and Network Identification services

Table 85: Key Hazards and Associated Metrics - Medical transport operations from suburban to urban areas scenario

The demonstration applied various U-space services, including network identification, geoawareness, traffic information, and flight authorisation. These services, provided by the Italian USSP *d-flight*, ensured compliance with regulatory requirements and improved operation safety.

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- **Network e-identification:** Ensures continuous processing of remote UAS identification for the entire duration of the flight (registration number, UAS ID, UAS position and direction, remote pilot position, emergency status, timestamp). This was performed using hook-on devices, plugins in Ground Control Station (GCS), networked DRI antennas, and the d-flight app.
- **Geoawareness:** Provides UAS geographical areas relevant to U-space airspace, including static, dynamic, and temporary restrictions. It supports the operator in strategic flight planning, ensuring compliance with operational constraints.
    - **Traffic information:** Provides situational awareness by delivering real-time updates on additional visible air traffic near the UAS flight's intended location or route.
      The demonstration integrated:
        - Cooperative unmanned traffic with NRIs (Network Remote Identification).
        - Manned ADS-B / FLARM traffic detected by commercial terrestrial networks (e.g., FlightAware).
    - **Manned traffic with NRI conspicuity** (pilots using the d-flight app - aviator profile).
    - **Non-cooperating local unmanned traffic** detected via commercial drone detection systems (e.g., DJI Aeroscope).
    - **Link with ATSU for coordinated operations in ATZ / CTR airspace**.
- **Flight authorisation**: Implemented in accordance with EU Regulation 2021/664, including:
    - **Flight authorisation** (request and approval process).
    - **Flight activation** (request and confirmation of active operation).
- **Other services:** To ensure safe operation in each U-space airspace, other U-space services, such as the weather information service could be implemented.

To address the hazards identified in this scenario, a series of U-space services were implemented to enhance airspace awareness, ensure regulatory compliance, and improve operational safety.

- **Enhances Airspace Awareness:** Electronic conspicuity and real-time traffic updates reduce the risk of mid-air collisions.
- **Supports Compliance & Coordination:** Facilitates adherence to regulations and seamless integration with air traffic control.
- **Improves Navigation Accuracy:** GNSS monitoring and geofencing prevent unauthorized airspace intrusions.
- **Reduces Operational Risks:** Weather services and GIS (Geographic Information System) data aid in pre-flight risk assessment and decision-making.

The following points outline the main constraints and remaining challenges that need to be addressed for the successful implementation of outer space services in this scenario.

- **Coverage Gaps:** Inconsistent 4G/5G network availability affects real-time tracking.
- **Integration with Manned Aviation:** Requires further advancements to ensure seamless coordination with VFR and commercial flights.

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- **Technological Constraints:** GNSS reliability is affected by urban environments, requiring alternative positioning methods. 5G could be a valid alternative for positioning, despite communication.

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Annex B – Application of the air risk model to the U-AGREE Manduria scenario

As a first step, in a given operations area a reduction of the air traffic database to that area needs to be applied. Figure 144 shows the Manduria area with the area of interest overlain. Figure 145 shows an exemplary dataset of an entire year (2023) restricted to the area of interest. Each cell is computed with a dimension of 50 m x 50 m. Here, an orange cell typically represents conflict probabilities in the magnitude of $4*10^{-6}$, light green is $2.5*10^{-6}$, while dark blue is $7*10^{-7}$. Note, that this graphical representation is not limited in altitude, i.e., it shows the entire range from ground to maximal altitude.

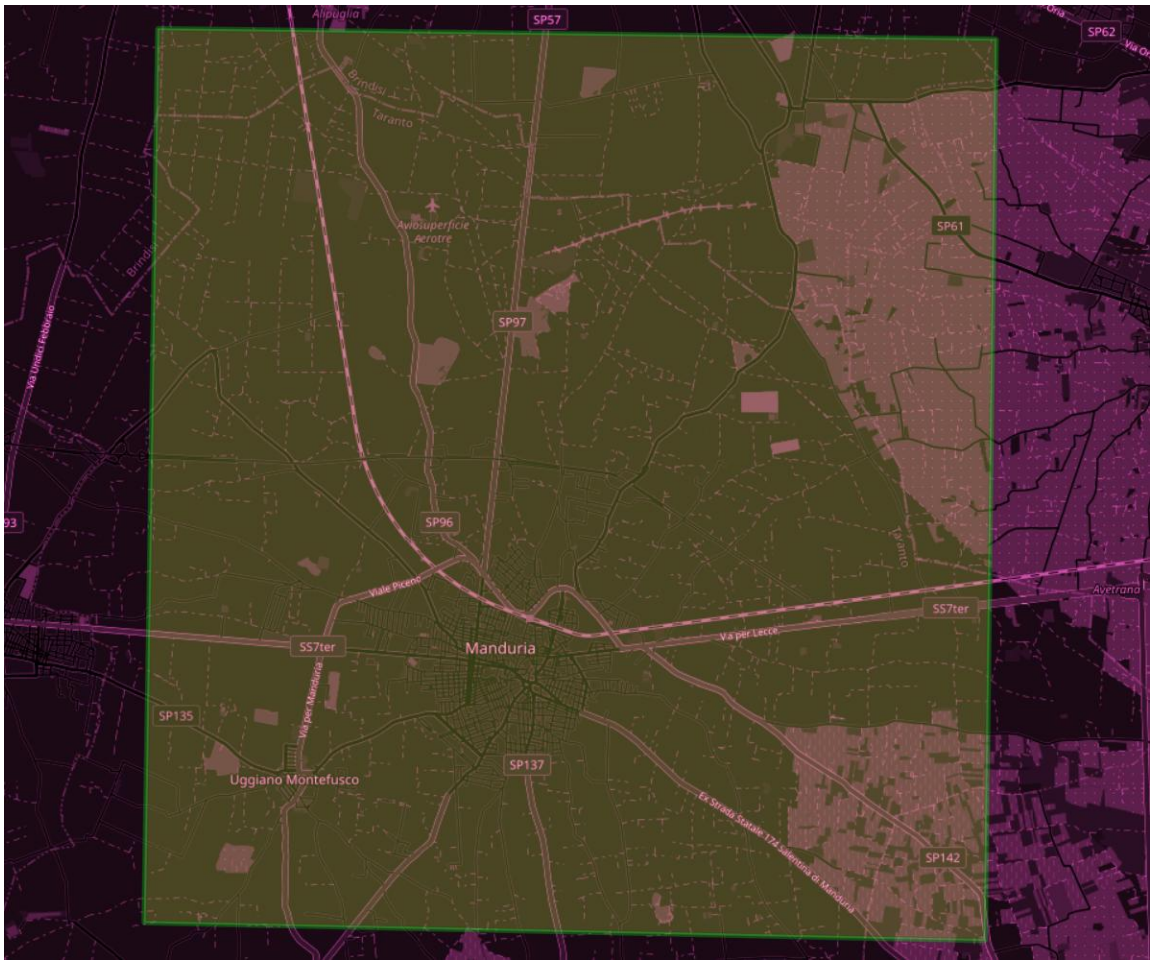


Figure 144: Surroundings of Manduria with control zone.

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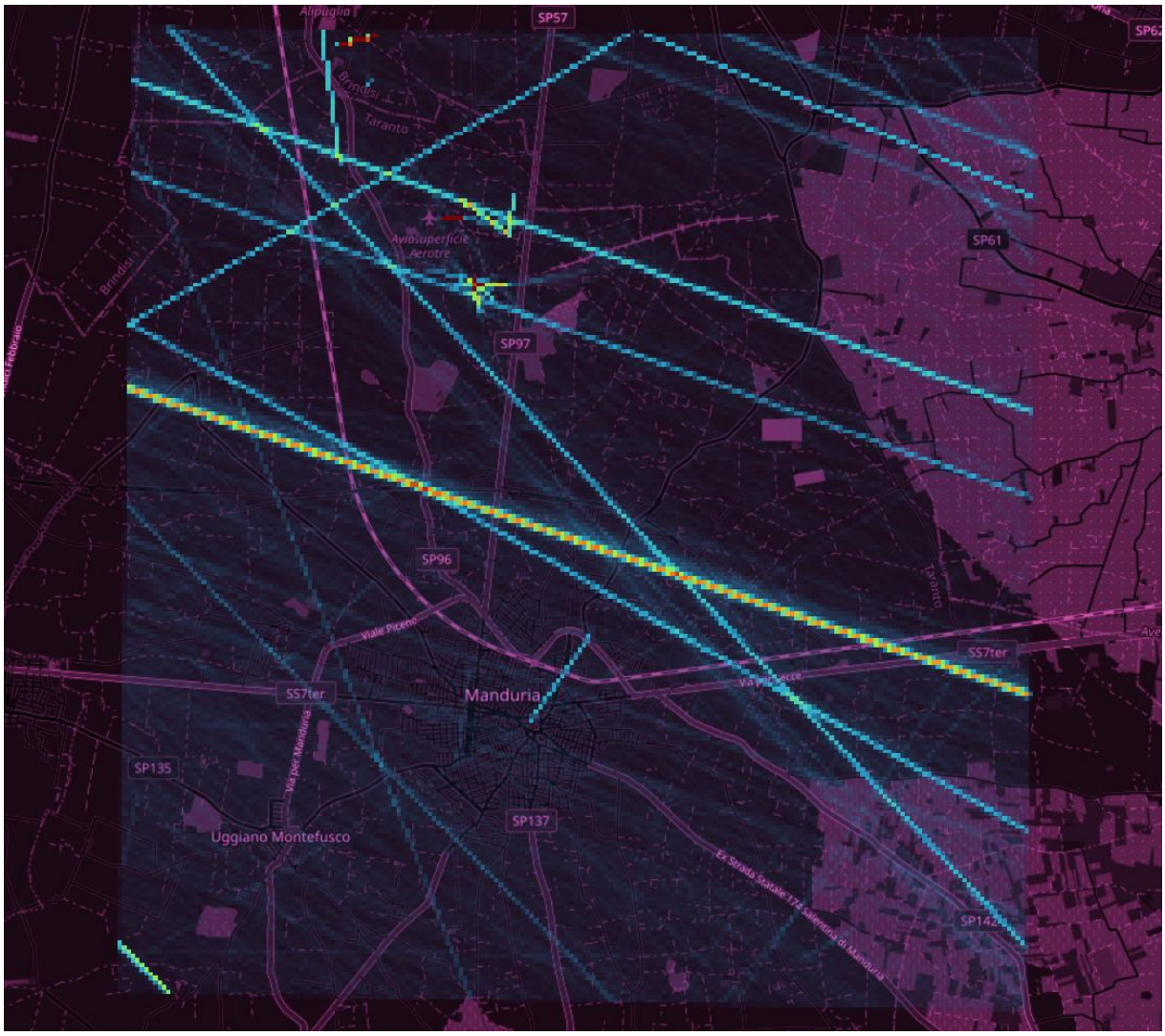


Figure 145: Local conflict probabilities for the Manduria area for an entire year.

Further, from the statistical analysis we get the following altitude distribution in the Manduria area described in Table 86. The overall number of flights in the area was 14920.

Table 86: Distribution of traffic per altitude.

Altitude	Number of aircraft
0-150 m	745
150-300 m	719
300-450 m	719
450-600 m	714
600-750 m	720
Above 750 m	14749

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We plan a mission trajectory in the altitude of 200 m, so we restrict our data to the altitude band of 150 to 250 m. Figure 146 shows the database restricted to the altitude band 150 m to 250 m. An orange cell typically represents conflict probabilities in the magnitude of $1.8*10^{-7}$, light green is $1.2*10^{-7}$, while dark blue is $3.5*10^{-8}$. One recognizes that there are a few direct approaches at local airfields present, as well as some frequently used airways. Aside from that the airspace is more or less free.

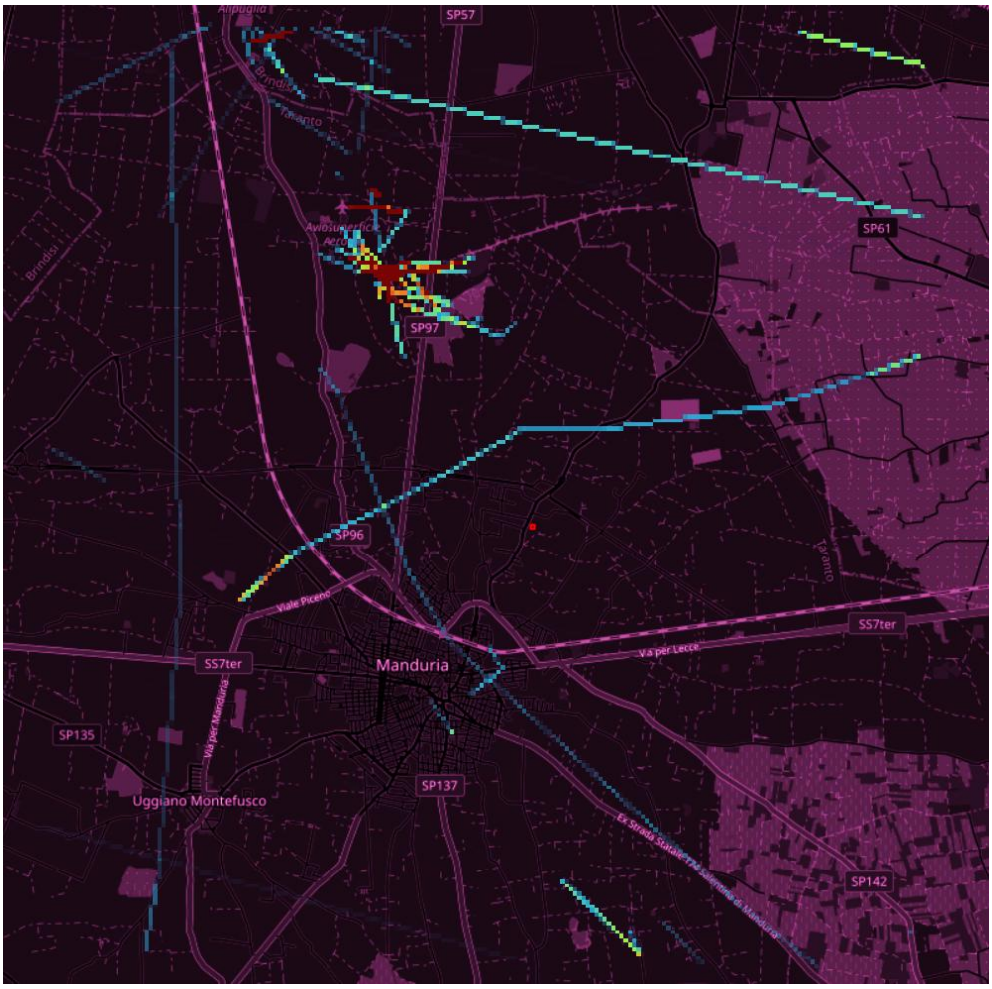


Figure 146: Conflict probabilities for the altitude band 150-250 m.

Similarly, conflict probabilities for the local population of crows were calculated. Based on model assumptions presence probabilities were calculated (see Figure 147). An orange cell typically represents conflict probabilities in the magnitude of $1.4*10^{-2}$, light green is $1.0*10^{-2}$, while dark blue is $3.3*10^{-3}$. Note that these are considerably larger presence probabilities than in the traffic distribution above.

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Figure 147: Bird conflict probabilities.

For sake of simplicity, we plan a trajectory with a constant speed of 20 m/s and an altitude of 200 m, modelling a packet delivery connecting the airfield of Aerotre Aviosuperficie di Manduria with a local logistics point (see Figure 148).

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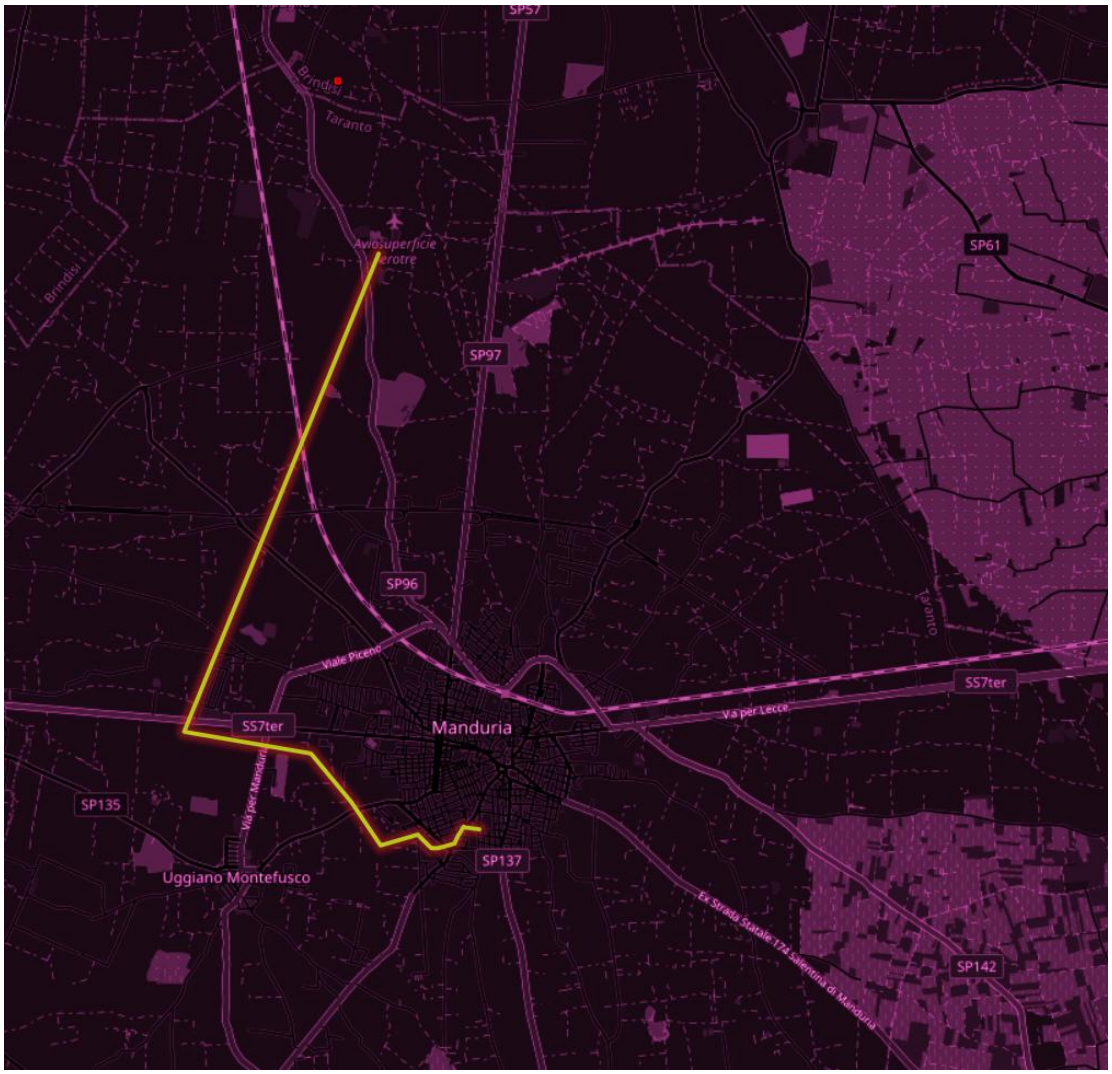


Figure 148: Exemplary mission trajectory from Aerotre Aviosuperficie di Manduria to Manduria City Center.

The example trajectory has a length of 9.3 km and an overall flight time of 467 s.

The probabilities are weighted and multiplied according to the method described. The result in this example is:

$P(T, M) = 9.23 \cdot 10^{-9}$ for the traffic conflict and

$P(T, M) = 1.35 \cdot 10^{-2}$ for the bird/wildlife conflict.

The overall risk vector of the trajectory is

1.85 [Micromort], 0.92 [Euro] for the traffic conflict and

0 [Micromort], 134.53 [Euro] for the bird/wildlife conflict.

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Annex B.1 Methodology for the wildlife presence estimation

Due to their relatively small size, limited certification standards for impact resistance — how much *bird mass* does the airframe have to be able to withstand, for instance 450 g flocking birds and 1 kg for a single bird 93 — and low-level cruising altitudes, drones are particularly vulnerable to wildlife strikes and their consequences. Therefore, realistic bird movements were considered for the use cases of Manduria. Since no complete data sets of bird movements for the location was available, exemplary realistic movement patterns were selected.

Annex B.1.1. Manduria: Daily commuting movements by crows

Many urban areas are hosts to large crow populations. The birds sleep within the city centre and perform daily commutes to feeding areas such as farmed fields or meadows. The commuting times strongly depend on daylight conditions and are coupled to twilight. The crows would fly within a narrow time window of a few minutes, loosely scattered between origin and destination (e.g. 93). This poses a high likelihood of collisions due to the high number of birds passing the airspace in a short time interval. Hence, it was identified as relevant use case, which, due to its strong predictability, can relatively easily be accounted for in flight planning.

With a visual scanning of the town centre of Manduria, 27 squares with large trees were identified as sleeping locations within the city centre. These were used to calculate the number of total birds for the simulation, which accounted to square metres of the square divided by 25 as extrapolated from own observations. This resulted in a total number of crows of 9283 which does not account to fluctuations over time.

The city is surrounded by farmed fields of which six were classified as feeding grounds. Birds were to fly between sleeping and feeding locations at random times, from the onset of civil twilight to five minutes after in the morning and from five minutes before to the onset of civil twilight in the evening, both calculated with the pyephem package 93. Thereby, each sleeping location was linked to the closest feeding location. Birds would depart from and arrive at random positions within the respective locations which resulted in individual trajectories per day. Figure 6 shows the feeding and sleeping areas identified.

The resident crows in Manduria are Hooded Crows (Corvus cornix). They were classified as medium birds according to 93 due to their average weight of 0.51 kg 93 . Travel speeds were anticipated as ranging between 9 and 11 m/s 93 . Sleeping heights in trees were randomly assigned between 70 and 80 m, flight heights between 110 and 190 m, and the feeding height at ground level of 70 m. Based on this information, trajectories were generated for each day of the year 2024.

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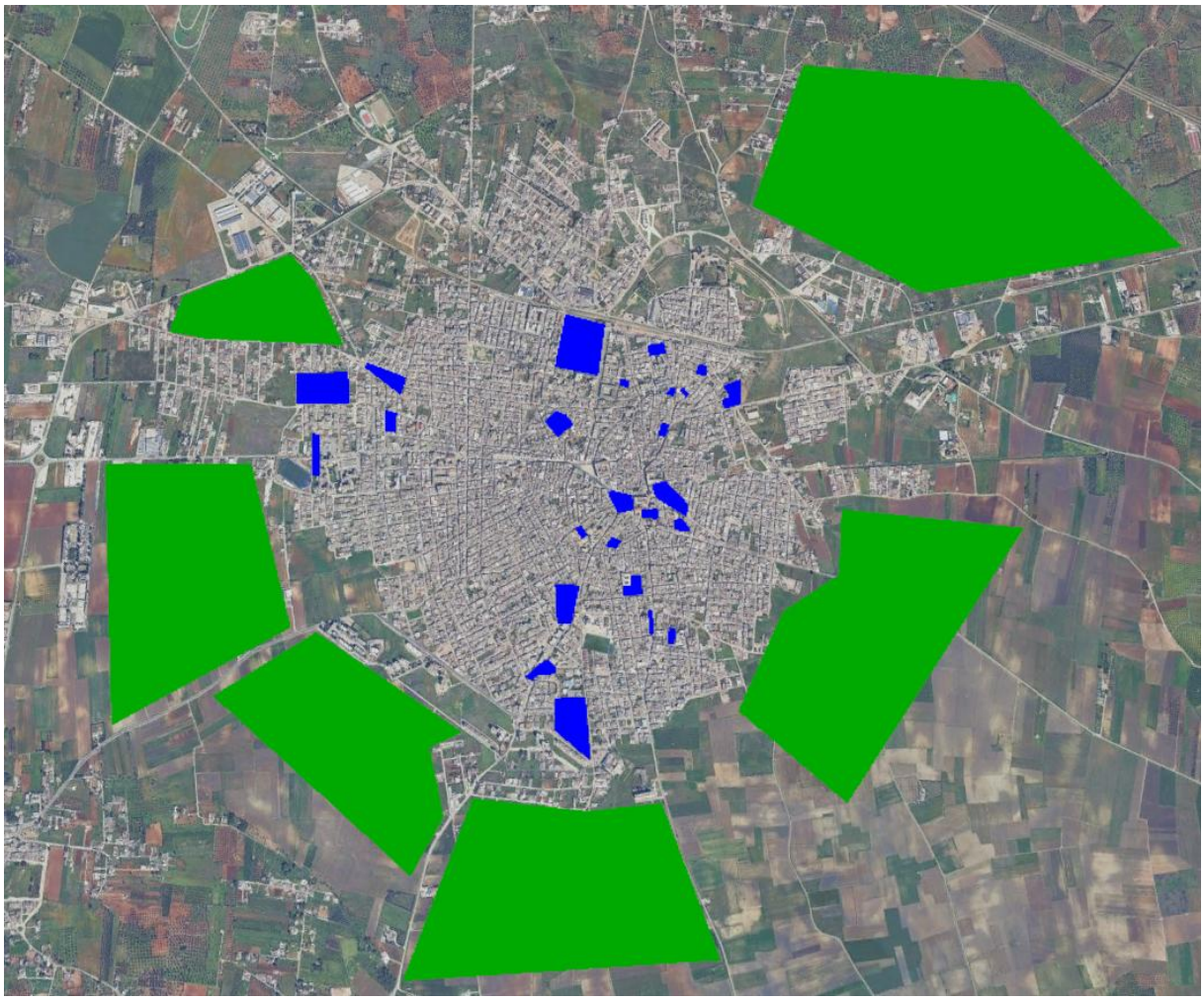


Figure 149: Sleeping (blue) and feeding (green) locations of crows

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Annex C – Safety Assessment

Annex C.1 Methodological approach and scope

Annex C.1.1 Methodological approach

U-AGREE will apply EUROCONTROL's E-SRM methodology [33] to the use cases related to the designation of the U-space services identified in deliverable D2.6 Final OSED [34] UC1 & UC2. Figure 150 illustrates the three phases that this methodology consists of:

- **Definition phase:** the first set of Safety Criteria (defined in terms of proxies related to mitigation of hazards inherent to aviation) are determined also at that stage from a preliminary safety impact assessment of the change.
- **Specification phase:** the safety specification is derived to meet the safety criteria, and the risk analysis is conducted at this stage. Safety criteria could be refined, and additional safety criteria could be identified in terms of proxies related to operational hazards following the hazard identification and analysis (HAZID).
- **Design phase:** the design phase is relative to the high-level design. The safety assessment and related assurance process will derive safety requirements covering both success and failure aspects to meet the safety specification.

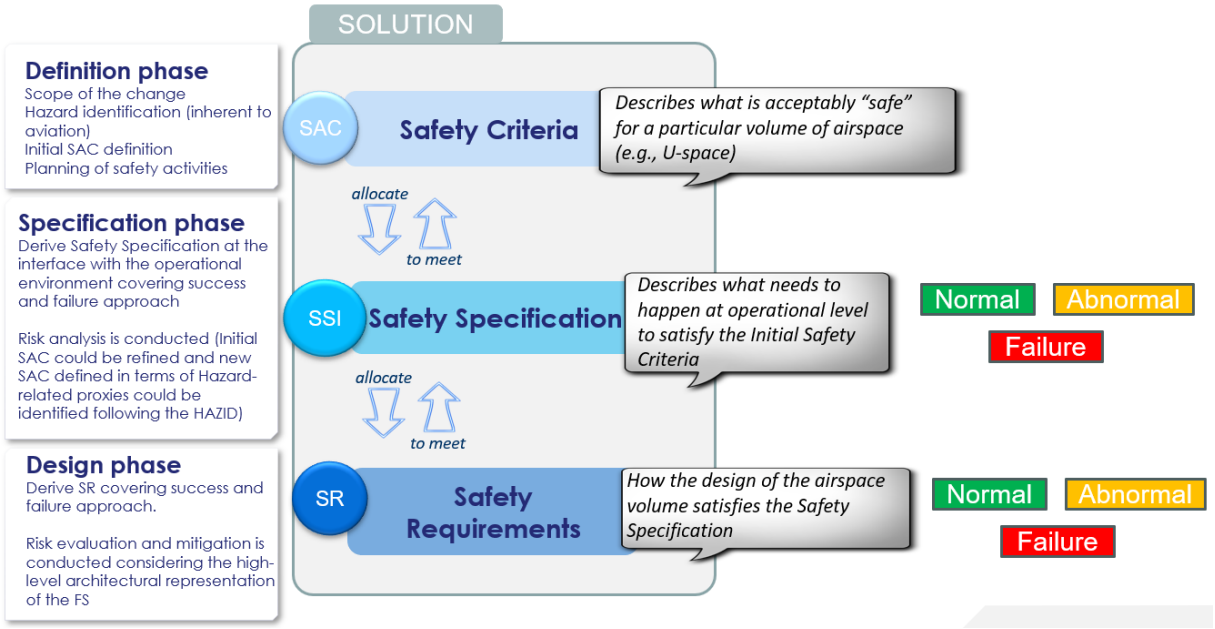


Figure 150: E-SRM method process for the safety assessment in ARA

Considering the exploratory nature of the U-AGREE project (TRL2), the safety assessment is limited to the **definition and specification phases**.

The assessment is conducted from two complementary perspectives:

- **Operating as intended**, assessing the impact of the system under normal and abnormal operational conditions, without considering system failures;

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- **Failure-based assessment**, evaluating the impact of potential malfunctions and their influence on existing and newly introduced hazards.

The safety assessment is based on Integrated Risk Models (Accident–Incident Models, AIM), as defined in the E-SRM framework. These models represent the interaction between hazards, accident precursors, and mitigation barriers. The AIMs considered in this assessment are derived from EUROCONTROL ARA guidance and adapted to the U-AGREE operational concept.

Annex C.1.2 Scope of the safety assessment

The scope of this safety assessment is defined in accordance with the change to the functional system described in Section A.1 and follows the principles of the EUROCONTROL E-SRM methodology.

The U-AGREE safety assessment is structured into three complementary exercises addressing successive stages in the development of the U-space operational concept.

The first exercise focuses on the derivation of the Safety Criteria (SAC) applicable to the U-AGREE operational concept. This assessment is based on the U-AGREE risk models and evaluates the safety implications of the identified aviation hazards independently from the deployment of mitigation barriers. Two generations of risk models are considered:

- the initial U-AGREE risk models, represented by UC1.1; and
- the final U-AGREE risk models, represented by UC2.1.

Although UC1.1 and UC2.1 rely on different modelling assumptions and levels of maturity, they follow an equivalent assessment process and are used to derive the safety criteria applicable to the corresponding stages of the project.

The second exercise addresses the introduction of the initial U-space services defined in Regulation (EU) 2021/664. These services act as mitigation barriers against the risks associated with UAS operations, particularly those related to mid-air collisions involving unmanned and manned aircraft. The assessment covers the Flight Authorisation Service (FAS), the Traffic Information Service (TIS), and the Conformance Monitoring Service (CMS), including the optional pre-alerting capability

The third exercise addresses the evolution towards advanced U-space services and final mitigation barriers defined by the U-AGREE Concept of Operations. These enhanced services provide additional risk mitigation capabilities, including support for the prevention of UAS geographical zone infringements and advanced conflict management functions.

The use cases defined in the U-AGREE OSED are employed as analytical frameworks to represent the different stages of deployment and evolution of the mitigation barriers, enabling a structured assessment of their contribution to risk reduction.

The three assessments are not independent activities but successive steps in the maturation of the same operational concept. The Safety Criteria Assessment establishes the safety criteria against which the initial barriers are evaluated, while the assessment of the initial barriers provides the reference for evaluating the effectiveness of the final barriers.

Annex C.1.3 Mapping of Safety Assessment Exercises and Operational Configurations

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Table 87 maps the operational configurations defined in the U-AGREE OSED to the three safety assessment exercises conducted within the project. The first assessment focuses on the derivation of Safety Criteria from the U-AGREE risk models and therefore does not involve mitigation barriers. The second assessment evaluates the effectiveness of the initial U-space services defined in Regulation (EU) 2021/664. The third assessment evaluates the effectiveness of the advanced U-space services introduced in the final U-AGREE Concept of Operations.

Safety assessment	Operational configuration	OSED reference	Role in the assessment
SA-0	Initial risk model	UC1.1	Derivation of initial Safety Criteria
SA-0	Final risk model	UC2.1	Derivation of final Safety Criteria
SA-1	Baseline (initial models)	UC1.1	Designation of the U-space
SA-1	Initial services – mandatory	UC1.2	Mitigated configuration (mandatory services)
SA-1	Initial services – optional services	UC1.3	Mitigated configuration (mandatory and optional services)
SA-1	Initial services – optional services	UC1.4	Mitigated configuration (mandatory and optional service)
SA-2	Baseline (final models)	UC2.1	Designation of the U-space
SA-2	Advanced services	UC2.2	Mitigated configuration

Table 87: OSED use cases definition and safety assessment

Note: Baseline configurations represent scenarios without U-space services, while mitigated configurations include progressively enhanced service capabilities acting as safety barriers.

Annex C.2 Safety assessment 0 – Safety Criteria Assessment

Annex C.2.1 Definition phase

According to the procedure sketched in Figure 150, the E-SRM definition phase consists of:

1. Scoping for the change.
2. Identifying the hazards inherent to aviation.
3. Defining initial Safety Criteria (SAC).
4. Planning of safety activities.

The next paragraphs describe how the first three steps have been addressed by U-AGREE. Given the expected project maturity, the last step is deemed unnecessary and has been skipped.

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Step #1: Scoping the change

The purpose of this safety assessment is to establish the Safety Criteria (SAC) applicable to the U-AGREE operational concept in accordance with the EUROCONTROL E-SRM methodology. Unlike the subsequent safety assessments, which focus on the evaluation of mitigation barriers, this assessment focuses on deriving the safety objectives against which those mitigation barriers will be evaluated.

The assessment is based on the U-AGREE risk models and addresses the hazards identified during the hazard identification process. Two generations of risk models are considered throughout the project:

- The Initial Risk Models, represented by UC1.1.
- The Final Risk Models, represented by UC2.1.

The Initial Risk Models are used to derive the Safety Criteria applicable to the assessment of the initial mitigation barriers, while the Final Risk Models are used to derive the updated Safety Criteria applicable to the assessment of the final mitigation barriers.

This assessment therefore provides the safety objectives that will be used in Safety Assessment 1 (Initial Barriers) and Safety Assessment 2 (Final Barriers).

Step #2: Identifying the hazards inherent to aviation.

The hazard identification process conducted within U-AGREE resulted in the identification of five hazards inherent to aviation.

Hazard ID	Description
HAZ01	UAS crash into the ground due to a loss of control
HAZ02	UAS crash into the ground due to a mid-air collision (MAC)
HAZ03	Mid-air collision between a UAS and a manned aircraft in uncontrolled airspace
HAZ04	Mid-air collision between a UAS and a manned aircraft in controlled airspace

Table 88: Hazards inherent to aviation related to the Safety Assessment 0

HAZ01 is considered outside the scope of U-AGREE because it is not directly mitigated through the provision of U-space services. The remaining hazards are retained for the derivation of Safety Criteria.

Step #3: Initial Safety Criteria (SAC) definition

The objective of this step is to establish the Safety Criteria applicable to the hazards identified in the previous step.

In accordance with the E-SRM methodology, Safety Criteria define the acceptable level of safety that shall be achieved. U-AGREE adopts Safety Criteria derived from recognised aviation Target Levels of Safety (TLS). These SACs were consolidated in the technical meeting held in Paris on the 11th April, 2025.

Ground Risk Safety Criteria

For HAZ02 (UAS crash into the ground due to a mid-air collision), the adopted Safety Criteria is:

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TLS = 1 × 10^{-7} FAT/FH

where FAT/FH denotes fatalities per flight hour.

Air Risk Safety Criteria

For HAZ03 (mid-air collision between a UAS and a manned aircraft in uncontrolled airspace), the adopted Safety Criteria is:

TLS = 1 × 10^{-7} MAC/FH

For HAZ04 (mid-air collision between a UAS and a manned aircraft in controlled airspace), the adopted Safety Criterion is:

TLS = 1 × 10^{-9} MAC/FH

These Safety Criteria constitute the safety objectives against which the effectiveness of the mitigation barriers introduced within U-AGREE will be evaluated.

Hazard	SAC ID	Safety Criteria definition
HAZ02	SAC-SA0-01	The number of fatalities because of a UAS-UAS MAC shall not exceed 1 × 10^{-7} FAT/FH.
HAZ03	SAC-SA0-02	The number of MAC between UAS-manned shall not exceed 1 × 10^{-7} MAC/FH in uncontrolled airspace.
HAZ04	SAC-SA0-03	The number of MAC between UAS-manned shall not exceed 1 × 10^{-9} MAC/FH in controlled airspace.

Table 89: Safety Criteria adopted within U-AGREE Safety Assessment 0.

The translation of these Safety Criteria into maximum allowable frequencies and scenario-specific operational objectives is addressed in the Specification Phase through the application of the U-AGREE Initial and Final Risk Models.

Annex C.2.2 Safety specification phase

Following the definition of the Safety Criteria, the Safety Specification Phase translates those criteria into scenario-specific frequencies. The new frequencies will be used during the subsequent assessment of operational and technical barriers (Safety Assessment 1 and Safety Assessment 2) as the Safety Criteria.

The purpose of this phase is not to redefine the Target Levels of Safety (TLS), but to derive measurable safety targets applicable to the operational scenarios under evaluation. To achieve this, the U-AGREE Air Risk Model and Ground Risk Model are applied to quantify the relationship between hazardous events and their associated consequences. The Air Risk Model estimates the probability of encounters and combines it with collision severity to obtain an overall air risk estimation, while the Ground Risk Model provides the means to quantify the consequences of ground impacts through casualty, sheltering and exposure analyses.

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The resulting frequencies obtained by those models establish the maximum tolerable occurrence frequencies for the hazardous events identified in the previous section, ensuring compliance with the corresponding safety criteria and Target Levels of Safety.

The derivation process is performed separately for ground-risk-related hazards and air-risk-related hazards.

Normal conditions

The purpose of this section is to present the SSIs derived for normal conditions of operation. The set of SSIs in this section specifies the desired safety behaviour of the change at its interface with the operational context, considering normal conditions. The SSI are presented in Table 90.

SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/ service ID
SSI-SA0-01	The Ground Risk Assessment shall ensure that the operational environment is represented by valid and representative population-density, building-density, sheltering and obstacle-effect assumptions.	SAC-SA0-01	UC1.1, UC2.1
SSI-SA0-02	The Ground Risk Assessment shall ensure that ground-fatality consequences are estimated using representative UAS characteristics, impact assumptions and validated Ground Risk Models.	SAC-SA0-01	UC1.1, UC2.1
SSI-SA0-03	The Air Risk Assessment shall ensure that representative traffic information and all relevant airspace-user categories are included in the assessment.	SAC-SA0-02 SAC-SA0-03	UC1.1, UC2.1
SSI-SA0-04	The Air Risk Assessment shall ensure that encounter probabilities, collision severities and resulting air-risk estimates are derived using validated Air Risk Models.	SAC-SA0-02 SAC-SA0-03	UC1.1, UC2.1
SSI-SA0-05	The Safety Assessment process shall ensure the correct allocation of applicable Safety Criteria and Target Levels of Safety to identified hazards.	SAC-SA0-01 SAC-SA0-02 SAC-SA0-03	UC1.1, UC2.1
SSI-SA0-06	The Safety Assessment process shall ensure the traceable and correct derivation of Safety Assessment Criteria from validated Ground Risk and Air Risk model outputs.	SAC-SA0-01 SAC-SA0-02 SAC-SA0-03	UC1.1, UC2.1

Table 90: safety specification for normal conditions of operation of Safety Assessment 0

Abnormal conditions

The purpose of this section is to present the SSIs derived for abnormal conditions of operation.

The SSIs in this section refer to the ability of the SESAR solution to work through (robustness), or at least recover from (resilience) any abnormal conditions, external to the U-AGREE risk models.

Identification of the abnormal conditions

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This sub-section provides the list of the abnormal conditions identified for U-AGREE that have potential relevance to the systems related to this solution. In Table 91, the abnormal conditions identified are outlined.

ABN ID	Description
ABN-SA0-01	Population exposure significantly differs from assessment assumptions.
ABN-SA0-02	Built environment significantly differs from assessment assumptions.
ABN-SA0-03	Traffic distributions significantly differ from the assessed traffic model.
ABN-SA0-04	New airspace-user categories appear.
ABN-SA0-05	Environmental or operational conditions invalidate modelling assumptions.
ABN-SA0-06	Emergency or priority operations modify traffic exposure.

Table 91: Abnormal conditions of Safety Assessment 0

Safety specification items (SSIs) for abnormal conditions of operation

This sub-section provides in Table 92 the consolidated view of the SSIs for abnormal conditions.

SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Abnormal condition ID
SSI-SA0-ABN-01	The Safety Assessment process shall identify significant deviations between the actual operational environment and the assumptions used by the Ground Risk Assessment.	SAC-SA0-01	ABN-SA0-01 ABN-SA0-02
SSI-SA0-ABN-02	The Safety Assessment process shall identify significant deviations between actual traffic conditions and the assumptions used by the Air Risk Assessment.	SAC-SA0-02 SAC-SA0-03	ABN-SA0-03 ABN-SA0-04 ABN-SA0-06
SSI-SA0-ABN-03	The Safety Assessment process shall identify environmental, operational or traffic conditions that invalidate assumptions used during risk modelling.	SAC-SA0-01 SAC-SA0-02 SAC-SA0-03	ABN-SA0-05
SSI-SA0-ABN-04	The Safety Assessment process shall support reassessment when significant deviations from the assessment assumptions are identified.	SAC-SA0-01 SAC-SA0-02	ABN-SA0-01 ABN-SA0-02 ABN-SA0-03 ABN-SA0-04

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Abnormal condition ID
		SAC-SA0-03	ABN-SA0-05 ABN-SA0-06

Table 92: safety specification for abnormal conditions of operation of Safety Assessment 0

Failure conditions

The purpose of this section is to identify the operational hazards (caused by internal failures of the SESAR solution functional system) and define the SAC in terms hazard-related proxies and additional SSIs associated to these operational hazards following the latest applicable version of guidance F and H of the E-SRM available in the programme library. The elements provided in this section complete the safety specification of U-AGREE.

Operational hazards identification

Table 93 presents the results of the Operational Hazards:

ID	Operational hazard description	Operational effects	Mitigation of effects propagation
OH-SA0-01	Ground Risk Assessment is performed using non-representative environmental data or assumptions.	Ground-fatality risk may be incorrectly estimated. Derived SAC may not be representative of the operational scenario.	Detection of invalid ground-environment assumptions. Verification of Ground Risk Assessment outputs. Independent review of Ground Risk calculations.
OH-SA0-02	Air Risk Assessment is performed using non-representative traffic data or assumptions.	Air-collision risk may be incorrectly estimated. Derived SAC may not be representative of the operational scenario.	Verification of traffic representativeness. Verification of encounter-probability calculations. Verification of severity calculations.
OH-SA0-03	Assessment assumptions are no longer valid for the operational scenario.	Ground Risk and Air Risk outputs may no longer represent actual operations.	Assessment assumption monitoring. Assessment revalidation.
OH-SA0-04	Safety Criteria are incorrectly allocated to identified hazards.	Incorrect TLS may be used. Derived SAC may not reflect the intended safety target.	Independent verification of Safety Criteria allocation. Traceability between hazards and safety criteria.
OH-SA0-05	Scenario-specific SAC are incorrectly derived.	The assessment may be performed against invalid acceptance criteria.	Independent verification of SAC derivation. Verification of inputs, assumptions and model outputs.

Table 93: operational hazards and analysis for Safety Assessment 0

Safety criteria expressed in terms of hazard-related proxies and additional SSI

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In Table 94, the SACs expressed in terms of hazard-related proxies (SAC-OH) are presented:

ID	SAC in terms of hazard-related proxy	Related operational hazard ID
SAC-SA0-OH-01	Ground Risk Assessment results shall remain representative of the operational environment.	OH-SA0-01
SAC-SA0-OH-02	Air Risk Assessment results shall remain representative of the operational environment.	OH-SA0-02
SAC-SA0-OH-03	Risk-model assumptions shall remain valid throughout the assessment lifecycle.	OH-SA0-03
SAC-SA0-OH-04	Safety Criteria shall be correctly allocated to identified hazards.	OH-SA0-04
SAC-SA0-OH-05	Scenario-specific Safety Assessment Criteria shall be correctly derived.	OH-SA0-05

Table 94: SAC expressed in terms of hazard-related proxies for Safety Assessment 0

The consolidated list of additional SSIs (functionality and performance) associated with failure conditions, derived during the operational hazard assessment addressed in the previous section is presented in the following Table 95.

SSI ID	Additional safety specification item (SSI)	Mitigated operational hazard
SSI-SA0-F-01	The Safety Assessment process shall ensure the validity and representativeness of the inputs, assumptions and outputs used by the Ground Risk Assessment.	OH-SA0-01
SSI-SA0-F-02	The Safety Assessment process shall ensure the validity and representativeness of traffic data, encounter-probability estimates and severity assessments used by the Air Risk Assessment.	OH-SA0-02
SSI-SA0-F-03	The Safety Assessment process shall identify conditions that invalidate the assumptions used during Ground Risk and Air Risk modelling.	OH-SA0-03
SSI-SA0-F-04	The Safety Assessment process shall ensure the correct allocation of Safety Criteria and Target Levels of Safety to the identified hazards.	OH-SA0-04
SSI-SA0-F-05	The Safety Assessment process shall ensure the traceable and correct derivation of scenario-specific Safety Assessment Criteria from validated risk-model outputs.	OH-SA0-05

Table 95: additional safety specification items to mitigate operational hazards and potential degraded modes for Safety Assessment 0

Annex C.3 Safety assessment 1 – Initial barriers

Annex C.3.1 Definition phase

According to the procedure sketched in Figure 150, the E-SRM definition phase consists of:

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1. Scoping for the change.
2. Identifying the hazards inherent to aviation.
3. Defining initial Safety Criteria (SAC).
4. Planning of safety activities.

The next paragraphs describe how the first three steps have been addressed by U-AGREE. Given the expected project maturity, the last step is deemed unnecessary and has been skipped.

Step #1: Scoping the change

UAS operations are conducted without the provision of U-space services. The change consists of the designation of the U-space and the roll out of the U-space services described in Reg. 664. According to the E-SRM, the ARA requires a full safety assessment, covering all the stages shown in Figure 150. However, considering that U-AGREE is indeed a SESAR U-space research project, the extent to which the E-SRM needs to be implemented depends on the expected maturity of such solution. Being an Exploratory Research project targeting a TRL2, **U-AGREE will limit the safety assessment to the definition and specification phases.**

Step #2: Identifying the hazards inherent to aviation.

U-AGREE carried out the hazard identification process (HAZID) in two stages:

1. A brainstorming process with the stakeholders gathered in the 1st U-AGREE stakeholders' workshop hosted by EUROCONTROL in Brussels on January 30th led to a first list of hazards identified in the different scenarios discussed in the meeting, compiled in Table 96 - Table 98.
2. A technical meeting of the U-AGREE team hosted by EUROCONTROL in Paris on April 11th, 2025, in which the research team assessed the hazards identified in the stakeholders' workshop and expressed them in the way hazards are described by the ICAO in the Global ATM Operational Concept (GATMOC) [35]. The resulting hazards are listed in Table 99.

Hazard ID	Description
0.1.1	High population density
0.1.2	Presence of critical infrastructure
0.1.3	Manned aviation entry into uncontrolled airspace
0.1.4	Diversity of UAS operations
0.1.5	Urban infrastructure interference (wit CNS)

Table 96: Hazards inherent to aviation identified by U-AGREE in scenario 1 (Benidorm)

Hazard ID	Description
0.2.1	High population density
0.2.2	Presence of critical or restricted areas
0.2.3	CNS limitations

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0.2.4	Weather and environmental factors
0.2.5	Interaction with manned aviation

Table 97: Hazards inherent to aviation identified by U-AGREE in scenario 2 (Manduria)

Hazard ID	Description
0.3.1	Presence of critical infrastructure
0.3.2	Weather conditions
0.3.3	Presence of SID sand STARs
0.3.4	MAC with manned aviation activity
0.3.5	CNS infrastructure

Table 98: Hazards inherent to aviation identified by U-AGREE in scenario 3 (Shannon-Limerick)

Hazard ID	Description
HAZ01	UAS crash into the ground due to a loss of control
HAZ02	UAS crash into the ground due to a MAC
HAZ03	MAC between a UAS and a manned aircraft in uncontrolled airspace
HAZ04	MAC between a UAS and a manned aircraft in controlled airspace
HAZ05	UAS infringement of a UAS geographical zone

Table 99: Hazards inherent to aviation identified by U-AGREE according to the GATMOC

HAZ01 and HAZ02 address the hazard posed by UAS operations to people on the ground, as well as to critical infrastructures. HAZ03 and HAZ04 represent the hazard UAS posed to manned aircraft. HAZ05 covers a broad range of hazards, since UAS geographical zones can be defined by a number of reasons (safety, security, environment and/or privacy). Furthermore, the relevance and severity of a geographical zone infringement depend on the purpose for which the zone has been established (e.g. safety, security, environmental protection, privacy, or operational constraints).

Since U-AGREE focuses on risks that can be mitigated by means of the provision of U-space services, HAZ01 falls out of the project's scope. In the case of the specific category, this hazard is managed by means of SORA assessments in the specific category, whereas for certified operations, the risk is mitigated through the certification process. This risk is considered negligible for operations in the open category. The risk posed by HAZ02 to HAZ05 can be effectively mitigated by using U-space serviced with a given level of performance, as will be discussed later in this document. HAZ05 remains out of scope for the initial barriers defined within U-AGREE.

Notice that there are some hazards related to weather, environment and CNS conditions that were identified during the HAZID brainstorming in the stakeholders' workshop and are listed in Table 96-Table 98, but have no associated hazard in Table 99. The reason for that is because the research team considered in the technical meeting where the conclusions of the workshop were discussed that those

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hazards were closer to abnormal conditions than to hazards inherent to the aviation. Therefore, based on this assessment, the following abnormal conditions have been identified:

Ab. cond. ID	Description
ABN-SA1-01	Adverse weather conditions affect the capability of the UAS to fly the intended trajectory.
ABN-SA1-02	Adverse communication conditions affect the capability of the remote pilot to control the UAS.
ABN-SA1-03	Adverse GNSS conditions affect the capability of the remote pilot to control the UAS.
ABN-SA1-04	Adverse communication conditions affect the capability of providing U-space services with the required performance.
ABN-SA1-05	Adverse GNSS conditions affect the capability of providing U-space services with the required performance.
ABN-SA1-06	A manned aircraft in state of emergency enters the U-space airspace.

Table 100: Abnormal conditions identified by U-AGREE

Step #3: Initial Safety Criteria (SAC) definition

U-AGREE defined the SAC for each of the hazards listed in Table 99 that were relevant to the U-AGREE project as defined in Safety Assessment 0, using the initial risk models.

Table 101 summarises the SACs defined by U-AGREE instantiated in the U-AGREE validation scenarios that are representative of the relevant sub-operating environments identified by the research team based on the outcomes of the 1st stakeholders' workshop. SACs for HAZ02 have been estimated by applying the initial U-AGREE ground risk model to these scenarios using data on population density and obstacles gathered by the U-AGREE team. For details on the implementation of the ground risk model, refer to U-AGREE deliverable D3.2 [23] and the ERP [5].

Scenario	Assoc. HAZ	SAC_ID	Description
1	HAZ02	102	The number of MAC between UAS shall not exceed $4{,}35 \times 10^{-5}$ per flight hour
	HAZ03	103	The number of MAC between UAS and manned aircraft shall not exceed 10^{-7} per flight hour
2	HAZ02	202	The number of MAC between UAS shall not exceed $1{,}5 \times 10^{-4}$ per flight hour
	HAZ03	203	The number of MAC between UAS and manned aircraft shall not exceed 10^{-7} per flight hour
3	HAZ02	302	The number of MAC between UAS shall not exceed $1{,}7 \times 10^{-2}$ per flight hour
	HAZ03	303	The number of MAC between UAS and manned aircraft in uncontrolled airspace shall not exceed 10^{-7} per flight hour

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	HAZ04	304	The number of MAC between UAS and manned aircraft in controlled airspace shall not exceed 10^{-9}per flight hour

Table 101: Initial SAC identified by U-AGREE for the relevant hazard in each scenario

Annex C.3.2 Safety specification

Identification of the changed operational activities/services.

Whenever the projected demand exceeds the baseline or the maximum peak number of simultaneous operations, mitigation measures need to be put in place to accommodate it without jeopardising safety. This first assessment for U-AGREE focuses on the mitigation of the risk by means of the provision of U-space services described in the U-AGREE barriers identification deliverables D4.1, based on Reg. 664.

Reg. 664 designates U-space services as essential enablers for the safe, secure, and efficient integration of UAS into the airspace, particularly in areas with high traffic density or complex operations. Among the services defined in the regulation, U-AGREE identified those relevant to mitigate the risk (i.e., those that can have a safety impact) in D4.1 .

- **Flight Authorisation Service – FAS –**, identified as the strategic barrier, ensures that each UAS flight is accepted and activated after performing a detection of conflict between constraints and requirements of the U-space and, with previously approved U-plans.
- **Conformance Monitoring Service – CMS – (optional)**, one of the tactical barriers, alerts the remote pilot in case the flight deviates from its intended trajectory during flight.
- **Network Identification Service – NIS –**, responsible for the exchange of Network Identification reports containing UAS state (position and velocity) and identification data among USSPs.
- **Traffic Information Service – TIS –**, the other tactical barrier, provide alerts to the remote pilot about traffic in close proximity, to help the remote pilot avoid a possible conflict between the UAS and other aircraft (manned or unmanned) in close proximity.

Given that some U-space services will be required only in case they are necessary to achieve the TLS established by the Competent Authorities, and considering that pre-alerting about imminent excursions out of the authorised 4D volume is an optional feature of the CMS, this use case unfolds in three different operational scenarios:

- No CMS
- CMS w/o pre-alerting function.
- CMS with pre-alerting function.

The paragraphs below list the safety specification items (SSI) identified for each of operational scenarios applying the specification phase defined in the E-SRM. SSIs have been defined considering the mitigation barriers' models described in U-AGREE deliverable D4.1 and taking into consideration the following assumptions:

A1. Mitigations not based on the provision of U-space services are considered out of the scope of the assessment.
A2. The simplified barriers' models set out in deliverable D4.1 are considered herein, namely:

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- Flight activation comes immediately after the flight authorisation, i.e., the continuous check of events that might cause the update or withdrawal of approved flight authorisation requests is out of scope.
- Flight authorisations are no updated or withdrawn either by the initiative of the FAS or because of a UAS operator request.
- The deactivation of the U-space airspace because of a dynamic airspace reconfiguration (DAR) is considered as an airspace constraint (i.e., a UAS geographical zone where UAS flights are not allowed). The transient state in which the DAR is implemented is considered out of the scope of the project.

A3. Flight authorisation requests are processed on a first come, first served base (i.e., no fairness rules or priority policies are applied).
A4. The traffic pattern is considered fixed regardless of the day of the week or the season. Weekly/seasonal fluctuations will be addressed in the final risk model.
A5. Temporal variations of both the ground risk and the air risk are considered out of the scope of risk model v1.
A6. Providence has been assumed equal to 10% (i.e., 10% of MAC end up in a MAC), as a conservative approach.

Assumptions A1-A3 are inherent to the limits in time and resources imposed by the nature of the project (fundamental research and outreach). Assumptions A4 and A5 are due to the specific scope of the initial version of the risk model (v1). Assumption A6 is a general assumption and will be kept throughout the project lifespan.

Normal conditions

Safety Specification Items for the Flight Authorisation and the Traffic Information Services

This section addresses the mandatory U-space services identified as mitigation barriers in the U-AGREE deliverable D4.1: **Flight Authorisation Service** and **Traffic Information Service**. Table 102 presents the SSI identified for these services under normal conditions in the identified scenarios. Note that the list in Table 102 is not exhaustive and has been developed considering the assumptions enumerated in section A3.1.

SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/ service ID
SSI-SA1-01	The drone operator shall be able to provide the U-plan to the FAS.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.2
SSI-SA1-02	The FAS shall be able to receive the U-plan information for approval from the drone operator.	SAC-SA1-102 SAC-SA1-202	UC1.2

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/ service ID
		SAC-SA1-302	
SSI-SA1-03	The FAS shall be able to assign a unique flight ID to the U-plan received.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.2
SSI-SA1-04	The FAS shall be able to file the information from the received U-plan.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.2
SSI-SA1-05	The CIS/CISP shall be able to provide to the USSP with the information from U-space (requirements and constraints).	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.2
SSI-SA1-06	The FAS shall be able to receive the information provided by the CIS/CISP.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.2
SSI-SA1-07	The FAS shall be able to assess the information received by the CIS/CISP and identify possible interactions with the U-plan being processed.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.2
SSI-SA1-08	The Flight Authorisation Exchange Service (FAXS) shall be able to provide the USSP with the flight identification and operation information from previously approved U-plans from other USSP.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.2
SSI-SA1-09	The FAS shall be able to receive the U-plans information from the FAXS from other USSPs.	SAC-SA1-102 SAC-SA1-202	UC1.2

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/ service ID
		SAC-SA1-302	
SSI-SA1-10	The FAS shall be able to assess the U-plans received by the FAXS and the ones approved by themselves and identify possible interactions with the U-plan that is being processed.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.2
SSI-SA1-11	The FAS shall be able to send the drone operator the information about the acceptance or the withdrawal of the U-plan.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.2
SSI-SA1-12	The drone operator shall be able to assess the acceptance or the withdrawal of the U-plan.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.2
SSI-SA1-13	In case the U-plan is accepted, the drone operator shall accept the terms and conditions to confirm the acceptance of the request.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.2
SSI-SA1-14	In case the drone operator accepts the terms and conditions of the acceptance of the request, the FAS shall be able to update the state of the U-plan to accepted.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.2
SSI-SA1-15	In case the U-plan has been withdrawal, the FAS shall be able to update the state of the U-plan to withdrawn.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.2
SSI-SA1-16	In case the drone operator rejects the terms and conditions of the request, the FAS shall be able to update the status of the U-plan to withdrawn.	SAC-SA1-102 SAC-SA1-202	UC1.2

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/ service ID
		SAC-SA1-302	
SSI-SA1-17	The drone operator shall be able to receive notification about the activation of the flight.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	UC1.2
SSI-SA1-18	Once in flight, the drone operator shall be able to report the position of the UAS to the NIS.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	UC1.2
SSI-SA1-19	The NIS shall be able to receive the position of the UAS during flight.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	UC1.2
SSI-SA1-20	The CIS/CISP shall be able to provide information about the aircraft in close proximity.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	UC1.2
SSI-SA1-21	The TIS shall receive information during flight about the aircraft in close proximity from the CIS/CISP.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	UC1.2

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/ service ID
SSI-SA1-22	The Network Identification Exchange Service (NIXS) shall be able to provide the information to the NIS about UAS in close proximity to the UAS.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	UC1.2
SSI-SA1-23	The NIS shall be able to receive the information from the NIXS about UAS in close proximity.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	UC1.2
SSI-SA1-24	The TIS shall be able to provide the traffic information to the UAS operator.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	UC1.2
SSI-SA1-25	The UAS operator shall be able to receive the traffic information from the TIS.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	UC1.2
SSI-SA1-26	The UAS operator shall be able to perform a manoeuvre to avoid any conflict with traffic information in close proximity.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	UC1.2

Table 102: Safety specification items for UC1.2

Safety Specification Items for the Conformance Monitoring Service without pre-alterting capability

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This section addresses the CMS when it does not feature the capability of detecting imminent infringements of the authorised 4D trajectory, which is optional according to Reg. 664. Table 103 presents the specific SSI identified for the CMS under normal conditions in the identified scenarios, while SSIs in Table 102 still apply to the other services. Note that the list in Table 103 is neither an exhaustive list and has been developed considering the assumptions enumerated.

SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/ service ID
SSI-SA1-27	The CMS shall be able to receive the U-plan information (protection volumes) to check whether there is non-conformance.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.3
SSI-SA1-28	The CMS shall be able to detect whether there is a non-conformant of the UAS predicted trajectory and the U-plan information (perform conformance monitoring).	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.3
SSI-SA1-29	The CMS shall be able to provide the non-conformance information to the Conformance Monitoring Exchange Service (CMXS).	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.3
SSI-SA1-30	The CMSP shall be able to alert the UAS operator of the non-conformance.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.3
SSI-SA1-31	The UAS operator shall be able to receive the alert about the non-conformance.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.3
SSI-SA1-32	The UAS operator shall be able to perform a manoeuvre after receiving the non-conformance alert.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.3

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/ service ID
SSI-SA1-33	The CMXS shall be able to provide the information to the USSP about non-conformant UAS.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.3
SSI-SA1-34	The CMS shall be able to receive information about non-conformant UAS from the CMX.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.3

Table 103: Safety specification items specific for UC1.3.

Safety Specification Items for the Conformance Monitoring Service without pre-alterting capability

This section CMS, including the optional capability of pre-alerting when of the authorised 4D trajectory. Table 104 presents the specific SSI identified for the CMS under normal conditions in the identified scenarios for this use case, while SSIs in Table 102 and Table 103 still apply to the other services as well as to the pre-alerting capability of the CMS. Note that the list in Table 104 is neither an exhaustive list and has been developed considering the assumptions enumerated in section A3.1.

SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/ service ID
SSI-SA1-35	The CMS shall be able to detect an imminent operation volume infringement while performing the conformance monitoring.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.4
SSI-SA1-36	The CMS shall be able to provide a pre-alerting to the UAS operator about the imminent operation volume infringement.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.4
SSI-SA1-37	The UAS operator shall be able to receive the pre-alert about the imminent operation volume infringement from the USSP.	SAC-SA1-102 SAC-SA1-202	UC1.4

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/ service ID
		SAC-SA1-302	
SSI-SA1-38	The UAS operator shall be able to perform a manoeuvre to avoid the imminent operation volume infringement.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	UC1.4

Table 104: Safety specification items specific for UC1.4.

Abnormal conditions

The purpose of this section is to present the SSIs derived for abnormal conditions of operation.

Identification of abnormal conditions

The abnormal conditions have already been identified in Table 100.

Safety specification items (SSIs) for abnormal conditions of operation

This sub-section provides in Table 105 the consolidated view of the SSIs for abnormal conditions.

SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Abnormal condition ID
SSI-SA1-ABN-01	The Conformance Monitoring Service (CMS) shall identify situations in which adverse weather conditions prevent the reliable assessment of UAS conformity with the authorised trajectory.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	ABN-SA1-01
SSI-SA1-ABN-02	The Traffic Information Service (TIS) shall identify situations in which adverse weather conditions may affect the capability of the UAS operator to maintain safe separation from nearby traffic.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	ABN-SA1-01
SSI-SA1-ABN-03	The U-space services shall identify situations in which communication performance prevents the remote pilot from exercising effective control of the UAS.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303	ABN-SA1-02

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Abnormal condition ID
		SAC-SA1-304	
SSI-SA1-ABN-04	The U-space services shall identify situations in which GNSS performance prevents the remote pilot from maintaining the UAS within the intended operational volume.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	ABN-SA1-03
SSI-SA1-ABN-05	The Flight Authorisation Service (FAS) shall identify situations in which communication degradation prevents the provision of information required to assess, authorise or activate a U-plan.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	ABN-SA1-04
SSI-SA1-ABN-06	The Traffic Information Service (TIS) shall identify situations in which communication degradation prevents the provision of traffic information with the required performance.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	ABN-SA1-04
SSI-SA1-ABN-07	The Conformance Monitoring Service (CMS) shall identify situations in which communication degradation prevents the provision of conformance monitoring information and alerts with the required performance.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	ABN-SA1-04
SSI-SA1-ABN-08	The Network Identification Service (NIS) shall identify situations in which communication degradation prevents the exchange of network identification information required by U-space services.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	ABN-SA1-04
SSI-SA1-ABN-09	The U-space services shall identify situations in which GNSS degradation prevents the provision of services with the required positioning performance.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	ABN-SA1-05

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Abnormal condition ID
SSI-SA1-ABN-10	The Flight Authorisation Service (FAS) shall consider emergency manned aircraft operations when assessing the compatibility of U-plans with operational constraints.	SAC-SA1-102 SAC-SA1-202 SAC-SA1-302	ABN-SA1-06
SSI-SA1-ABN-11	The Traffic Information Service (TIS) shall provide information concerning emergency manned aircraft that may affect ongoing UAS operations.	SAC-SA1-103 SAC-SA1-203 SAC-SA1-303 SAC-SA1-304	ABN-SA1-06

Table 105: safety specification for abnormal conditions for Safety Assessment 1

Failure conditions

The purpose of this section is to identify the operational hazards (caused by internal failures of the SESAR solution functional system) and define the SAC in terms hazard-related proxies and additional SSIs associated to these operational hazards following the latest applicable version of guidance F and H of the E-SRM available in the programme library. The elements provided in this section complete the safety specification of the U-AGREE initial barriers.

Operational hazards identification

Table 106 presents the results of the Operational Hazards:

ID	Operational hazard description	Operational effects	Mitigation of effects propagation
OH-SA1-01	Failure to identify conflicts between the submitted U-plan and applicable U-space constraints.	Unsafe operation may be authorised.	Verification of strategic conflict detection and constraint processing.
OH-SA1-02	Failure to identify conflicts between the submitted U-plan and previously approved U-plans.	Conflicting operations may be authorised.	Verification of U-plan exchange and conflict assessment.
OH-SA1-03	Failure to communicate the authorisation decision to the UAS operator.	Operational status becomes inconsistent.	Monitoring of authorisation communication.

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OH-SA1-04	Failure to activate a valid authorised operation correctly.	Operation may be conducted with incorrect U-space status.	Verification of activation workflow.
OH-SA1-05	Failure to receive traffic information from surveillance sources.	Relevant traffic remains unknown.	Monitoring of surveillance inputs.
OH-SA1-06	Failure to provide traffic information to the remote pilot.	Conflict avoidance becomes ineffective.	Monitoring of traffic-information dissemination.
OH-SA1-07	Traffic information is incomplete, outdated or inaccurate.	Incorrect avoidance actions may be taken.	Integrity and timeliness checks.
OH-SA1-08	Failure to detect a deviation from the authorised operational volume.	Non-conforming operation remains unmanaged.	Conformance monitoring performance checks.
OH-SA1-09	Failure to alert the UAS operator about a detected non-conformance.	Deviation persists and may escalate.	Alert delivery monitoring.
OH-SA1-10	Failure to exchange non-conformance information between service providers.	Shared situational awareness is degraded.	Monitoring of exchange-service availability.
OH-SA1-11	Failure to receive Network Identification information.	Loss of operational awareness.	Availability monitoring of NIS inputs.
OH-SA1-12	Failure to distribute Network Identification information.	Incomplete information available to U-space services.	Monitoring of NIS dissemination.
OH-SA1-13	Network Identification information is inaccurate or outdated.	Traffic picture becomes unreliable.	Integrity validation of NIS data.
OH-SA1-14	Failure of the Common Information Service to provide valid operational constraints.	Authorisation decisions may be based on incorrect constraints.	Validation of CIS information.
OH-SA1-15	Failure of external surveillance information supporting TIS.	Traffic information becomes unreliable.	Monitoring of surveillance-service health.
OH-SA1-16	Failure of Exchange Services supporting inter-USSP coordination.	Cross-USSP conflicts may remain undetected.	Monitoring of exchange-service integrity.

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OH-SA1-17	UAS operator fails to receive traffic information.	Conflict avoidance action is not initiated.	Notification and acknowledgement mechanisms.
OH-SA1-18	UAS operator receives traffic information but does not react appropriately.	Conflict remains unresolved.	Operator procedures and training.
OH-SA1-19	UAS operator fails to react to a non-conformance alert.	Operational-volume infringement may occur.	Operator procedures and training.

Table 106: operational hazards and analysis for Safety Assessment 1

Safety criteria expressed in terms of hazard-related proxies and additional SSI

In Table 107, the SACs expressed in terms of hazard-related proxies (SAC-OH) are presented:

ID	SAC in terms of hazard-related proxy	Related operational hazard ID
SAC-SA1-OH-01	The frequency of occurrence of failure of the Flight Authorisation Service leading to the authorisation of an operation conflicting with applicable U-space constraints shall be no greater than TBD per flight hour.	OH-SA1-01
SAC-SA1-OH-02	The frequency of occurrence of failure of the Flight Authorisation Service leading to the authorisation of conflicting U-plans shall be no greater than TBD per flight hour.	OH-SA1-02
SAC-SA1-OH-03	The frequency of occurrence of failure of the Flight Authorisation Service leading to an incorrect operational status of a UAS operation shall be no greater than TBD per flight hour.	OH-SA1-03
SAC-SA1-OH-04	The frequency of occurrence of failure of the Flight Authorisation Service leading to the incorrect activation of a UAS operation shall be no greater than TBD per flight hour.	OH-SA1-04
SAC-SA1-OH-05	The frequency of occurrence of failure of traffic-information sources leading to loss of traffic awareness shall be no greater than TBD per flight hour.	OH-SA1-05
SAC-SA1-OH-06	The frequency of occurrence of failure of the Traffic Information Service leading to unavailable traffic information shall be no greater than TBD per flight hour.	OH-SA1-06
SAC-SA1-OH-07	The frequency of occurrence of failure of the Traffic Information Service leading to inaccurate, incomplete or outdated traffic information shall be no greater than TBD per flight hour.	OH-SA1-07
SAC-SA1-OH-08	The frequency of occurrence of failure of the Conformance Monitoring Service leading to an undetected non-conformance shall be no greater than TBD per flight hour.	OH-SA1-08

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SAC-SA1-OH-09	The frequency of occurrence of failure of the Conformance Monitoring Service leading to an unreported non-conformance shall be no greater than TBD per flight hour.	OH-SA1-09
SAC-SA1-OH-10	The frequency of occurrence of failure of the Conformance Monitoring Service leading to the loss of non-conformance information sharing shall be no greater than TBD per flight hour.	OH-SA1-10
SAC-SA1-OH-11	The frequency of occurrence of failure of the Network Identification Service leading to unavailable network-identification information shall be no greater than TBD per flight hour.	OH-SA1-11
SAC-SA1-OH-12	The frequency of occurrence of failure of the Network Identification Service leading to loss of network-identification information distribution shall be no greater than TBD per flight hour.	OH-SA1-12
SAC-SA1-OH-13	The frequency of occurrence of failure of the Network Identification Service leading to inaccurate or outdated network-identification information shall be no greater than TBD per flight hour.	OH-SA1-13
SAC-SA1-OH-14	The frequency of occurrence of failure of the Common Information Service leading to the provision of invalid operational constraints shall be no greater than TBD per flight hour.	OH-SA1-14
SAC-SA1-OH-15	The frequency of occurrence of failure of surveillance services supporting the Traffic Information Service shall be no greater than TBD per flight hour.	OH-SA1-15
SAC-SA1-OH-16	The frequency of occurrence of failure of Exchange Services supporting inter-USSP coordination shall be no greater than TBD per flight hour.	OH-SA1-16
SAC-SA1-OH-17	The frequency of occurrence of failures preventing the UAS operator from receiving traffic information shall be no greater than TBD per flight hour.	OH-SA1-17
SAC-SA1-OH-18	The frequency of occurrence of ineffective operator responses to traffic information shall be no greater than TBD per flight hour.	OH-SA1-18
SAC-SA1-OH-19	The frequency of occurrence of ineffective operator responses to non-conformance alerts shall be no greater than TBD per flight hour.	OH-SA1-19

Table 107: SAC expressed in terms of hazard-related proxies for Safety Assessment 1

The consolidated list of additional SSIs (functionality and performance) associated with failure conditions, derived during the operational hazard assessment addressed in the previous section is presented in the following Table 108.

SSI ID	Additional safety specification item (SSI)	Mitigated operational hazard
SSI-SA1-F-01	The FAS shall identify conflicts between the submitted U-plan and applicable U-space constraints.	OH-SA1-01
SSI-SA1-F-02	The FAS shall identify conflicts between the submitted U-plan and previously approved U-plans.	OH-SA1-02

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SSI-SA1-F-03	The FAS shall communicate the authorisation decision to the UAS operator.	OH-SA1-03
SSI-SA1-F-04	The FAS shall ensure the correct activation status of authorised operations.	OH-SA1-04
SSI-SA1-F-05	The TIS shall identify loss of traffic-information sources.	OH-SA1-05
SSI-SA1-F-06	The TIS shall provide traffic information concerning aircraft in close proximity to the UAS.	OH-SA1-06
SSI-SA1-F-07	The TIS shall ensure that provided traffic information is accurate, complete and timely.	OH-SA1-07
SSI-SA1-F-08	The CMS shall detect deviations from the authorised operational volume.	OH-SA1-08
SSI-SA1-F-09	The CMS shall alert the UAS operator when a non-conformance is detected.	OH-SA1-09
SSI-SA1-F-10	The CMS shall exchange non-conformance information with relevant service providers.	OH-SA1-10
SSI-SA1-F-11	The NIS shall receive Network Identification information required by U-space services.	OH-SA1-11
SSI-SA1-F-12	The NIS shall distribute Network Identification information to authorised recipients.	OH-SA1-12
SSI-SA1-F-13	The NIS shall ensure that Network Identification information remains accurate and up-to-date.	OH-SA1-13
SSI-SA1-F-14	The FAS shall verify the validity of operational constraints received from CIS services.	OH-SA1-14
SSI-SA1-F-15	The TIS shall identify degradation affecting external surveillance information.	OH-SA1-15
SSI-SA1-F-16	Exchange Services shall support reliable coordination between USSPs.	OH-SA1-16
SSI-SA1-F-17	The U-space system shall confirm successful delivery of traffic information to the UAS operator.	OH-SA1-17
SSI-SA1-F-18	The U-space system shall provide traffic information in a form that supports effective operator response.	OH-SA1-18
SSI-SA1-F-19	The CMS shall provide non-conformance alerts in a form that supports effective operator response.	OH-SA1-19

Table 108: additional safety specification items to mitigate operational hazards and potential degraded modes for Safety Assessment 1

Annex C.4 Safety assessment 2 – Final barriers

Annex C.4.1 Definition phase

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According to the procedure sketched in Figure 150, the E-SRM definition phase consists of:

1. Scoping for the change.
2. Identifying the hazards inherent to aviation.
3. Defining initial Safety Criteria (SAC).
4. Planning of safety activities.

The next paragraphs describe how the first three steps have been addressed by U-AGREE Safety Assessment 2. Given the expected project maturity, the last step is deemed unnecessary and has been skipped.

Step #1: Scoping the change

UAS operations are conducted with the provision of U-space services. The change assessed in SA2 consists of the implementation of the final U-space mitigation barriers developed within U-AGREE, namely the Final Flight Authorisation Service, the Final Conformance Monitoring Service and the Tactical Conflict Prediction and Resolution Service, advancing from those defined within the Safety Assessment 1. According to the E-SRM, the ARA requires a full safety assessment, covering all the stages shown in Figure 150. However, considering that U-AGREE is indeed a SESAR U-space research project, the extent to which the E-SRM needs to be implemented depends on the expected maturity of such solution. Being an Exploratory Research project targeting a TRL2, **U-AGREE will limit the safety assessment to the definition and specification phases.**

Step #2: Identifying the hazards inherent to aviation.

The hazards identified in SA1 remain applicable to the final U-space mitigation barriers assessed in SA2. Therefore, the hazard set defined in SA1 has been retained without modification and is reused as the basis for the present safety assessment.

Step #3: Initial Safety Criteria (SAC) definition

In this exercise #02, we integrate the final risk models by defining new safety criteria.

Safety Criteria – Air Risk

From the Final Air Risk Model [12], for each pair of airspace users involved in a collision it is possible to retrieve the factor *f*, which weights ***the actual hazard to human lives***. Specifically, $f = 1$ indicates that a hull loss — and therefore fatalities — is assumed as the worst case; $f = 0$ means no risk to human life is expected from that collision pair; and intermediate values (e.g. 0.5) can be used when a hull loss is possible but unlikely, for instance substituting the actual probability of hull loss if known.

From Table 109 and Table 110 it is possible to extrapolate the values of interest for the U-AGREE project. These involve the combination of Large passenger aircraft (A) and Advanced Air Mobility (A2) with Very large drone (D4), Large drone (D3) and Medium drone (D2).

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f	A	C	G	B4	B3	B2	B1	D4	D3	D2	D1
A	1	1	1	1	1	0	0	1	1	1	0
A2	1	1	1	1	1	0	0	1	1	1	0
C	1	1	1	1	1	0	0	1	1	1	0
G	1	1	1	1	1	0	0	1	1	1	0
B4	1	1	1	0	0	0	0	1	1	1	1
B3	1	1	1	0	0	0	0	1	1	1	1
B2	0	0	0	0	0	0	0	0.5/1	1	1	1
B1	0	0	0	0	0	0	0	0	0	0/0.5	0.5/1
D4	1	1	1	1	1	1	0	0	0	0	0
D3	1	1	1	1	1	1	0	0	0	0	0
D2	1	1	1	1	1	1	0/0.5	0	0	0	0
D1	0	0	0	1	1	1	0.5/1	0	0	0	0

Table 109: Values that estimate the actual hazard to human lives given the pair of airspace users involved [12]

Class	Description	Example
A	Large passenger aircraft.	A320
A2	Advanced air mobility	prototypes
C	Small passenger aircraft.	Cessna 172
G	Glider or ultra-light aircraft.	Grob G103
B4	Very large animal.	crane
B3	Large animal.	goose
B2	Medium animal.	crow
B1	Small animal.	sparrow
D4	Very large drone.	Heron TP
D3	Large drone.	DJI FlyCart 30
D2	Medium drone.	DJI Matrice M30T
D1	Small drone.	DJI Neo



Table 110: Categories of airspace users [12]

The value of *f* extrapolated is 1, meaning that a collision between those airspace users will provoke a **hull loss**. In the absence of empirical data justifying a lower value, a fatality probability of 1 is assumed as a conservative worst case. Should future research — such as dedicated simulations or real-world test data — provide a better-grounded estimate, this assumption could be revised and the resulting safety criteria would change accordingly.

Applying this probability to the TLS, we would obtain the new safety criteria that accounts for the Final Air Risk Model:

For HAZ04 (UAS and manned aircraft conflicting trajectories resulting in a MAC in controlled airspace) the SORA air risk TLS (10^{-9}MAC/F-H) in controlled airspace will be directly applied.

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It is worth noting that, although the exercise #02 reassessment adopted an updated methodology that explicitly incorporates the fatality probability into the calculation (Final Air Risk Model), the final numerical values obtained are consistent with those derived in exercise #01. This alignment is a direct consequence of the conservative assumption f = 1, which makes the two approaches equivalent in practice.

Safety Criteria – Ground Risk

The updated ground risk safety criteria are derived by combining the outputs of the U-AGREE Final Ground Risk Model [23] with the scenario-specific characteristics of the three validation sites. The methodology followed the same approach as for exercise #01 (outlined in D2.3 Initial Concept Outline [11]) but with new assumptions related to population density distribution and sheltering.

Population density distribution

For each validation scenario, population density data are retrieved from the Copernicus Global Human Settlement Layers [24]. Differently from the initial model, that conservatively placed the entire population at ground level, population is now distributed vertically across the different floors of buildings, proportionally to the local density population and typical building height of each scenario. Building-height values were derived from assumptions made by consortium partners based on their knowledge of the regions and countries represented in the scenarios. In the absence of validated local datasets, these assumptions were considered sufficiently representative for the purposes of the study. Future activities would benefit from the use of more accurate and location-specific building-height information. The assumed floor ranges are:

Validation Scenario	Type	Number of floors in which population is distributed
Benidorm, Spain	High-rise urban environment	20 to 40 floors for the densest cells
Manduria, Italy	Peri-urban environment	5 to 6 floors
Shannon, Ireland	Urban environment	8 to 10 floors

Table 111: Population distribution per validation scenario

This vertical distribution reduces the number of people effectively exposed per floor, directly lowering the average fatalities per event with respect to the initial model. Detailed sheltering assumptions for each scenario are here provided:

Benidorm (High-Rise Urban environment)	
Population Threshold	**Assumed Number of floors**
≥ 150 people	[20-40] floors
≥ 100 people	[10-20] floors
≥ 50 people	[5-10] floors

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≥ 25 people	[3-5] floors

Table 112: Benidorm detailed sheltering assumption

Manduria (Peri Urban environment)	
Population Threshold	**Assumed Number of floors**
≥ 150 people	6 floors
≥ 100 people	[5-6] floors
≥ 50 people	[3-5] floors
≥ 25 people	[2-3] floors

Table 113: Manduria detailed sheltering assumption

Shannon (Urban environment)	
Population Threshold	**Assumed Number of floors**
≥ 150 people	[8-10] floors
≥ 100 people	[5-8] floors
≥ 50 people	[3-5] floors
≥ 25 people	[2-3] floors

Table 114: Shannon detailed sheltering assumption

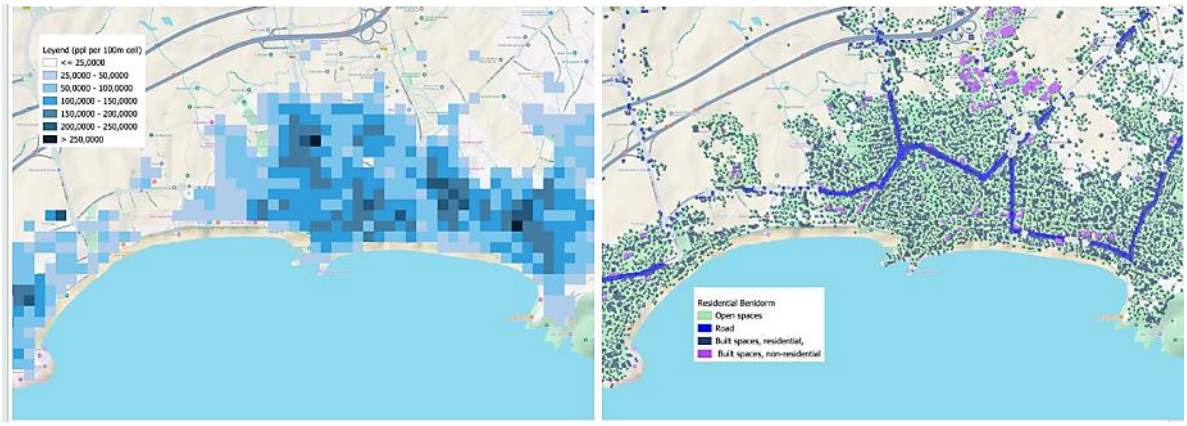


Figure 151: Benidorm population density (left) and residential map (right)

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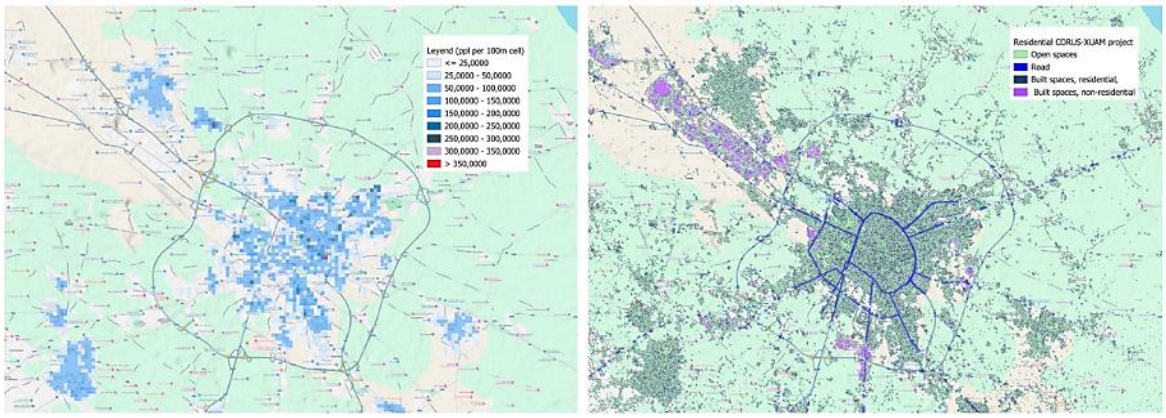


Figure 152: Manduria population density (left) and residential map (right)

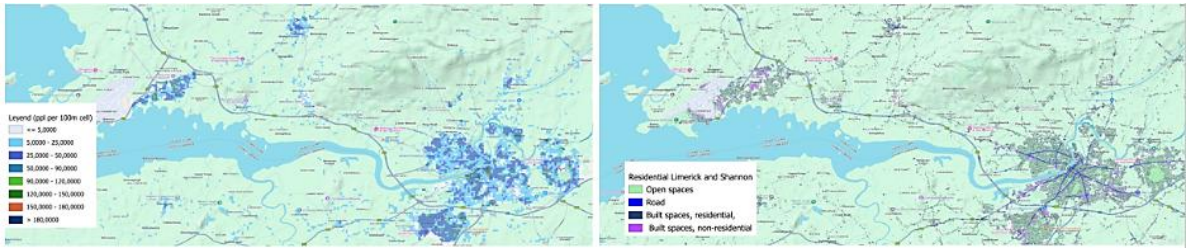


Figure 153: Shannon-Limerick population density (left) and residential map (right)

Building sheltering and the role of the Window-to-Wall Ratio

Once the UAS loses control and impacts a building, the probability of harming a person inside depends on whether the drone penetrates the building envelope. The sheltering effect — i.e., the degree of protection that a building offers to its occupants — is not uniform across building types. As detailed in the Ground Risk Model [22], different building types have structurally different facade compositions: an industrial warehouse has very few windows, while a modern high-rise office building may be almost entirely glazed. Since glass is structurally far weaker than reinforced concrete or brick the proportion of glazed surface on the facade directly governs the likelihood of penetration.

This proportion is captured by the Window-to-Wall Ratio (WWR), defined as the ratio between the window area and the total facade area. A different WWR value is assigned to each land use code, and the probability of the drone impacting each surface type (roof, opaque wall, or window) is derived accordingly, assuming an impact angle of 60 degrees for the multirotor configuration considered.

Based on 100,000 Monte Carlo simulations, the maximum MTOM guaranteeing a non-penetration probability ≥ 98% was determined as a function of the WWR. The resulting lookup table ranges from 200 kg at WWR = 1.6% to 5 kg at WWR = 14.3%, showing that the maximum allowable MTOM decreases sharply as the WWR increases.

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Multirotors only, N = 100000, simulated impact with a residential Italian MFH, roof material = "Reinforced concrete 100 mm - roof", wall material ="Unreinforced Brick - wall", windows material = "Gypsum/ fiberboard/ steel joist - roof"	
Windows to Wall Ratio (A_windows/ A_total_facade)	**Max allowable MTOM which guarantees sheltering applicability [kg]**
1,6%	200
3,2%	48,5
4,8%	9,8
6,3%	7,8
7,9%	6,6
9,5%	6
11,1%	5,5
12,7%	5,1
14,3%	5

Figure 154: Look-up table from D3.5 [22]

This table is then applied within the CasEx tool, where each cell of the operational area is assigned a land use code identifying the building typology present.

Open / Non-Built Areas

Value	Description
0	No data / Non-urban
1	Low open space / Low vegetation
2	Medium open space
3	High open space
4	Water
5	Roads / Infrastructure

Low-Density Development (Dispersed Buildings)

Value	Description
11	Dispersed residential (detached houses)
12	Rural residential
13	Suburban residential
14	Dispersed non-residential (industrial buildings, warehouses)
15	Rural non-residential

High-Density Development (Compact Buildings)

Value	Description
21	Low-rise compact residential (low-rise blocks)
22	Mid-rise compact residential
23	High-rise compact residential (skyscrapers)
24	Low/medium-rise compact non-residential
25	High-rise compact non-residential (shopping centers, offices)

Figure 155: CasEx details

For each typology, a representative WWR value is assumed based on the expected proportion of glazed surface, and the corresponding maximum allowable MTOM is retrieved from the lookup table. For example, land use codes 11, 12, 13, 14, 15 and 24 — corresponding to dispersed, industrial and low-density non-residential buildings — are expected to have a low but not minimal WWR, assumed at

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3.2%, which corresponds to a maximum allowable MTOM of 48.5 kg, rounded to 50 kg. Applying the same logic to all typologies yields the following weight limits:

Land Use Codes	Description	Weight Limit
11,12,13,14,15,24	Dispersed / Industrial / Low-density non-residential	50 kg
21,22	Compact residential (low to mid-rise)	10 kg
23,25	High-rise / Skyscrapers	5 kg

Figure 156: Weight Limits related to land use typology

Scenario-specific safety criteria

By applying the same methodology as for exercise #01 with these new assumptions related to population density distribution and sheltering, the following safety criteria related to ground risk are found:

Scenario	U-AGREE Ground Model	Average fatalities	Maximum allowable frequency/FH
Benidorm	**Initial**	2.25×10^{-3}	4.35×10^{-5}
	Final	7.11×10^{-4}	1.41×10^{-4}
Manduria	**Initial**	6.67×10^{-4}	1.50×10^{-4}
	Final	7.74×10^{-4}	1.29×10^{-4}
Shannon	**Initial**	5.88×10^{-6}	1.70×10^{-2}
	Final	1.60×10^{-5}	6.25×10^{-3}

The differences across scenarios reflect the combined effect of population density, building height, and revised sheltering assumptions.

Benidorm is the scenario in which people are most distributed across building floors due to the prevalence of high-rise buildings.

In Manduria, buildings typically reach only 5–6 floors, limiting the potential for vertical population distribution. In addition, the revised sheltering assumptions are more restrictive for some obstacle classes and do not provide a significant overall benefit. As a result, the expected fatalities are only marginally reduced, and the ground risk remains close to the initial value.

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In Shannon, higher building heights enable a greater vertical distribution of the population. However, the overall reduction in ground risk remains limited because the revised sheltering assumptions reduce the benefit associated with several obstacle classes.

Safety Criteria results

Table 115 summarises the Safety Criteria (SACs) defined for the U-AGREE validation scenarios representative of the relevant sub-operating environments identified by the research team. The SACs have been updated in SA2 using the final U-AGREE risk models developed during the project and are used as the basis for the assessment of the final U-space mitigation barriers, namely the Final Flight Authorisation Service with Strategic Conflict Resolution capabilities, the Final Conformance Monitoring Service and the Tactical Conflict Prediction and Resolution Service. The updated SAC values reflect the latest refinement of the U-AGREE risk assessment methodology and are applied to the validation scenarios considered in this safety assessment.

Scenario	Assoc. HAZ	SAC_ID	Description
1	HAZ02	SAC-SA2-102	The number of MAC between UAS shall not exceed $1{,}41 \times 10^{-4}$ per flight hour
	HAZ03	SAC-SA2-103	The number of MAC between UAS and manned aircraft shall not exceed 10^{-7} per flight hour
	HAZ05	SAC-SA2-105	The implementation of the final U-AGREE mitigation barriers shall not increase the number of UAS infringements of UAS geographical zones with respect to the baseline scenario.
2	HAZ02	SAC-SA2-202	The number of MAC between UAS shall not exceed $1{,}29 \times 10^{-4}$ per flight hour
	HAZ03	SAC-SA2-203	The number of MAC between UAS and manned aircraft shall not exceed 10^{-7} per flight hour
	HAZ05	SAC-SA2-205	The implementation of the final U-AGREE mitigation barriers shall not increase the number of UAS infringements of UAS geographical zones with respect to the baseline scenario.
3	HAZ02	SAC-SA2-302	The number of MAC between UAS shall not exceed $6{,}25 \times 10^{-3}$ per flight hour
	HAZ03	SAC-SA2-303	The number of MAC between UAS and manned aircraft in uncontrolled airspace shall not exceed 10^{-7} per flight hour
	HAZ04	SAC-SA2-304	The number of MAC between UAS and manned aircraft in controlled airspace shall not exceed 10^{-9} per flight hour
	HAZ05	SAC-SA2-305	The implementation of the final U-AGREE mitigation barriers shall not increase the number of UAS infringements of UAS geographical zones with respect to the baseline scenario.

Table 115: Initial SAC identified by U-AGREE final models for the relevant hazard in each scenario

Annex C.4.2 Safety specification

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Identification of the changed operational activities/services.

Whenever the projected demand exceeds the baseline or the maximum peak number of simultaneous operations defined for the considered U-space airspace, mitigation measures need to be implemented to accommodate the demand without jeopardising safety. U-AGREE focuses on the mitigation of risk through the provision of U-space services. While SA1 assessed the initial mitigation barriers based on the services described in D4.1 [36], SA2 assesses the evolution of those barriers towards the final U-space services characterised in Deliverable D4.2 [9]. The U-space services defined encompasses:

- **Final Flight Authorisation Service with Strategic Conflict Resolution.**
- **Final Conformance Monitoring Service.**
- **Tactical Conflict Prediction and Resolution.**

The paragraphs below list the safety specification items (SSI) identified for each of operational scenarios applying the specification phase defined in the E-SRM. SSIs have been defined considering the mitigation barriers' models described in U-AGREE deliverable D4.2 and taking into consideration the following assumptions:

A7. Mitigations not based on the provision of U-space services are considered out of the scope of the assessment.
A8. Flight authorisation requests are processed on a first come, first served base (i.e., no fairness rules or priority policies are applied).
A9. The traffic pattern is considered fixed regardless of the day of the week or the season. Weekly/seasonal fluctuations will be addressed in the final risk model.
A10. Temporal variations of both the ground risk and the air risk are considered out of the scope of the final risk model.
A11. Providence has been assumed equal to 10% (i.e., 10% of MAC end up in a MAC), as a conservative approach.

Normal conditions

Safety Specification Items for the Final Flight Authorisation Service

This section addresses the SSIs of the U-space services identified as mitigation barriers in the U-AGREE deliverable D4.2: **Final Flight Authorisation Service**.

SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/service ID
SSI-SA2-01	The Final Flight Authorisation Service shall receive and process a flight authorisation request containing the required operational information.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-105, SAC-SA2-	UC2.2

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/service ID
		205, SAC-SA2-305	
SSI-SA2-02	The Final Flight Authorisation Service shall determine whether the requested operation complies with applicable U-space requirements and operational constraints.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-105, SAC-SA2-205, SAC-SA2-305	UC2.2
SSI-SA2-03	The Final Flight Authorisation Service shall identify strategic conflicts between the requested 4D trajectory and previously authorised operations.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302	UC2.2
SSI-SA2-04	The Final Flight Authorisation Service shall determine whether the requested operation complies with applicable geographical-zone requirements and restrictions.	SAC-SA2-105, SAC-SA2-205, SAC-SA2-305	UC2.2
SSI-SA2-05	The Final Flight Authorisation Service shall determine whether the requested operation complies with applicable Dynamic Airspace Reconfigurations and temporary airspace restrictions.	SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304, SAC-SA2-105, SAC-SA2-205, SAC-SA2-305	UC2.2
SSI-SA2-06	The Final Flight Authorisation Service shall determine whether the requested operation complies with applicable airspace capacity and density limitations.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302	UC2.2
SSI-SA2-07	The Strategic Conflict Resolution function shall determine one or more conflict-free alternative trajectories when a strategic conflict is identified.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302	UC2.2

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/service ID
SSI-SA2-08	The Strategic Conflict Resolution function shall ensure that proposed alternative trajectories comply with applicable operational constraints and restrictions.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-105, SAC-SA2-205, SAC-SA2-305	UC2.2
SSI-SA2-09	The Final Flight Authorisation Service shall reassess the compatibility of an authorised operation prior to activation using the latest operational information available.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304, SAC-SA2-105, SAC-SA2-205, SAC-SA2-305	UC2.2
SSI-SA2-10	The Final Flight Authorisation Service shall identify manned aircraft activities that may prevent the safe activation of an authorised operation.	SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	UC2.2

Table 116: safety specification for normal conditions of the Final FAS

Safety Specification Items for the Final Conformance Monitoring

This section addresses the SSIs of the U-space services identified as mitigation barriers in the U-AGREE deliverable D4.2: **Final Conformance Monitoring**.

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/service ID
SSI-SA2-11	The Conformance Monitoring Service shall receive surveillance information required to monitor the execution of authorised operations.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304, SAC-SA2-105, SAC-SA2-205, SAC-SA2-305	UC2.2
SSI-SA2-12	The Conformance Monitoring Service shall determine whether an operation remains within the authorised operational volume.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304, SAC-SA2-105, SAC-SA2-205, SAC-SA2-305	UC2.2
SSI-SA2-13	The Conformance Monitoring Service shall identify non-conforming operations.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304, SAC-SA2-105, SAC-SA2-	UC2.2

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/service ID
		205, SAC-SA2-305	
SSI-SA2-14	The Conformance Monitoring Service shall provide non-conformance alerts to affected UAS operators.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304, SAC-SA2-105, SAC-SA2-205, SAC-SA2-305	UC2.2
SSI-SA2-15	The Conformance Monitoring Service shall identify imminent infringements of the authorised operational volume.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304, SAC-SA2-105, SAC-SA2-205, SAC-SA2-305	UC2.2
SSI-SA2-16	The Conformance Monitoring Service shall provide information regarding non-conforming operations to the Tactical Conflict Prediction and Resolution Service.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304, SAC-SA2-105, SAC-SA2-	UC2.2

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/service ID
		205, SAC-SA2-305	

Table 117: safety specification for normal conditions of the Final CMS

Safety Specification Items for the Tactical Conflict Prediction and Resolution

This section addresses the SSIs of the U-space services identified as mitigation barriers in the U-AGREE deliverable D4.2: **Tactical Conflict Prediction and Resolution**.

SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/service ID
SSI-SA2-17	The Tactical Conflict Prediction and Resolution Service shall receive surveillance information regarding relevant manned and unmanned traffic operating within the conflict horizon.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	UC2.2
SSI-SA2-18	The Tactical Conflict Prediction and Resolution Service shall determine predicted trajectories of relevant manned and unmanned traffic using available surveillance information.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	UC2.2
SSI-SA2-19	The Tactical Conflict Prediction and Resolution Service shall determine whether predicted trajectories will result in a loss of applicable separation minima between aircraft.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-	UC2.2

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/service ID
		SA2-303, SAC-SA2-304	
SSI-SA2-20	The Tactical Conflict Prediction and Resolution Service shall identify predicted tactical conflicts involving manned and/or unmanned aircraft within the applicable look-ahead time.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	UC2.2
SSI-SA2-21	The Tactical Conflict Prediction and Resolution Service shall incorporate information regarding non-conforming operations into tactical conflict assessments.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	UC2.2
SSI-SA2-22	The Tactical Conflict Prediction and Resolution Service shall determine conflict resolution guidance for identified tactical conflicts.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	UC2.2
SSI-SA2-23	The Tactical Conflict Prediction and Resolution Service shall ensure that conflict resolution guidance maintains the applicable separation minima.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-	UC2.2

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Use case ID & ops activity/service ID
		SA2-303, SAC-SA2-304	
SSI-SA2-24	The Tactical Conflict Prediction and Resolution Service shall provide conflict resolution guidance to affected UAS operators for tactical conflicts involving manned and/or unmanned aircraft.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	UC2.2
SSI-SA2-25	The Tactical Conflict Prediction and Resolution Service shall monitor the effectiveness of conflict resolution actions.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	UC2.2
SSI-SA2-26	The Tactical Conflict Prediction and Resolution Service shall update conflict resolution guidance when the conflict situation involving manned and/or unmanned aircraft evolves.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	UC2.2
SSI-SA2-27	The Tactical Conflict Prediction and Resolution Service shall prioritise conflict management actions associated with emergency or priority manned aircraft operations.	SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	UC2.2

Table 118: safety specification for normal conditions of the Final TCPR

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Abnormal conditions

The purpose of this section is to present the SSIs derived for abnormal conditions of operation.

Identification of abnormal conditions

The abnormal conditions identified in SA1 remain applicable to the final U-space mitigation barriers considered in SA2. Therefore, the same set of abnormal conditions is retained and used as the basis for the derivation of additional safety requirements under degraded operating conditions.

Safety specification items (SSIs) for abnormal conditions of operation

This sub-section provides in Table 119 the consolidated view of the SSIs for abnormal conditions.

SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Abnormal condition ID
SSI-SA2-ABN-01	The Final Flight Authorisation Service shall consider weather-related operational restrictions when assessing flight authorisation and activation requests.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302	ABN-SA1-01
SSI-SA2-ABN-02	The Conformance Monitoring Service shall identify deviations caused by adverse weather conditions affecting the capability of the UAS to fly the intended trajectory.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302	ABN-SA1-01
SSI-SA2-ABN-03	The Tactical Conflict Prediction and Resolution Service shall account for trajectory uncertainties caused by adverse weather conditions when assessing tactical conflicts.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	ABN-SA1-01
SSI-SA2-ABN-04	The Final Flight Authorisation Service shall detect situations in which communication conditions prevent the remote pilot from safely conducting the flight.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	ABN-SA1-02

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Abnormal condition ID
SSI-SA2-ABN-05	The Conformance Monitoring Service shall identify situations in which communication degradation affects the capability of the remote pilot to maintain conformance with the authorised trajectory.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304, SAC-SA2-105, SAC-SA2-205, SAC-SA2-305	ABN-SA1-02
SSI-SA2-ABN-06	The Final Flight Authorisation Service shall detect situations in which GNSS degradation affects the capability of the remote pilot to safely conduct the authorised operation.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	ABN-SA1-03
SSI-SA2-ABN-07	The Conformance Monitoring Service shall identify deviations associated with GNSS degradation affecting the capability of the remote pilot to control the UAS.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304, SAC-SA2-105, SAC-SA2-205, SAC-SA2-305	ABN-SA1-03
SSI-SA2-ABN-08	The Tactical Conflict Prediction and Resolution Service shall identify situations in which communication degradation affects the capability of providing tactical conflict management functions with the required performance.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-	ABN-SA1-04

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SSI ID	Safety specification item (SSI) *(functionality and performance)*	Related SAC ID	Abnormal condition ID
		SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	
SSI-SA2-ABN-09	The Tactical Conflict Prediction and Resolution Service shall identify situations in which GNSS degradation affects the capability of providing tactical conflict management functions with the required performance.	SAC-SA2-102, SAC-SA2-202, SAC-SA2-302, SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	ABN-SA1-05
SSI-SA2-ABN-10	The Final Flight Authorisation Service shall identify emergency manned aircraft activities affecting authorised operations.	SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	ABN-SA1-06
SSI-SA2-ABN-11	The Tactical Conflict Prediction and Resolution Service shall prioritise conflict management actions associated with emergency manned aircraft operations.	SAC-SA2-103, SAC-SA2-203, SAC-SA2-303, SAC-SA2-304	ABN-SA1-06

Table 119: safety specification for abnormal conditions for Safety Assessment 2

Failure conditions

The purpose of this section is to identify the operational hazards (caused by internal failures of the SESAR solution functional system) and define the SAC in terms hazard-related proxies and additional SSIs associated to these operational hazards following the latest applicable version of guidance F and H of the E-SRM available in the programme library. The elements provided in this section complete the safety specification of the U-AGREE final barriers.

Operational hazards identification

Table 120 presents the results of the Operational Hazards:

ID	Operational hazard description	Operational effects	Mitigation of effects propagation

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OH-SA2-01	An operation is authorised despite a strategic conflict with another authorised operation.	Reduced separation between aircraft and increased collision risk.	Tactical Conflict Prediction and Resolution.
OH-SA2-02	An operation is authorised despite non-compliance with geographical-zone restrictions.	UAS geographical zone infringement.	Activation checks and Conformance Monitoring.
OH-SA2-03	An operation is authorised despite an active Dynamic Airspace Reconfiguration.	Exposure of the UAS to manned aircraft operating within controlled airspace.	Tactical Conflict Prediction and Resolution.
OH-SA2-04	An operation is activated despite the presence of conflicting manned aircraft activity.	Increased risk of conflict between UAS and manned aircraft.	Tactical Conflict Prediction and Resolution.
OH-SA2-05	Strategic conflict resolution provides an unsuitable alternative trajectory.	Creation of new strategic conflicts or geographical-zone infringements.	Activation checks, Conformance Monitoring and TCPR.
OH-SA2-06	A non-conforming operation is not identified.	Degradation of traffic predictability and increased collision risk.	Tactical Conflict Prediction and Resolution.
OH-SA2-07	A non-conformance alert is not issued to the affected operator.	Continued deviation from the authorised trajectory.	Tactical Conflict Prediction and Resolution.
OH-SA2-08	Information regarding a non-conforming operation is not provided to the TCPR service.	Tactical conflicts may not be detected or correctly assessed.	Tactical Conflict Prediction and Resolution.
OH-SA2-09	A predicted loss of separation is not identified.	Tactical conflict remains unmanaged.	Operator see-and-avoid / emergency procedures.
OH-SA2-10	Conflict resolution guidance is not generated.	Tactical conflict cannot be effectively resolved.	Operator see-and-avoid / emergency procedures.
OH-SA2-11	Conflict resolution guidance is inappropriate.	Conflict geometry worsens and loss of separation becomes more likely.	Operator see-and-avoid / emergency procedures.

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OH-SA2-12	Tactical conflicts involving manned aircraft are not detected.	Increased probability of MAC between UAS and manned aircraft.	Emergency procedures and pilot collision avoidance actions.
OH-SA2-13	Tactical conflicts involving emergency manned aircraft are not prioritised.	Increased probability of conflict with emergency traffic.	Emergency procedures.

Table 120: operational hazards and analysis for Safety Assessment 2

Safety criteria expressed in terms of hazard-related proxies and additional SSI

In Table 121, the SACs expressed in terms of hazard-related proxies (SAC-OH) are presented:

ID	SAC in terms of hazard-related proxy	Related operational hazard ID
SAC-OH-SA2-01	The frequency of occurrence of failure of the Final Flight Authorisation Service leading to the authorisation of an operation conflicting with another authorised operation shall be no greater than TBD per flight hour.	OH-SA2-01
SAC-OH-SA2-02	The frequency of occurrence of failure of the Final Flight Authorisation Service leading to the authorisation of an operation conflicting with applicable geographical-zone restrictions shall be no greater than TBD per flight hour.	OH-SA2-02
SAC-OH-SA2-03	The frequency of occurrence of failure of the Final Flight Authorisation Service leading to the authorisation of an operation conflicting with an active Dynamic Airspace Reconfiguration shall be no greater than TBD per flight hour.	OH-SA2-03
SAC-OH-SA2-04	The frequency of occurrence of failure of the Final Flight Authorisation Service leading to the activation of an operation conflicting with manned aircraft activity shall be no greater than TBD per flight hour.	OH-SA2-04
SAC-OH-SA2-05	The frequency of occurrence of failure of the Strategic Conflict Resolution function leading to the generation of an unsuitable alternative trajectory shall be no greater than TBD per flight hour.	OH-SA2-05
SAC-OH-SA2-06	The frequency of occurrence of failure of the Conformance Monitoring Service leading to an unidentified non-conforming operation shall be no greater than TBD per flight hour.	OH-SA2-06
SAC-OH-SA2-07	The frequency of occurrence of failure of the Conformance Monitoring Service leading to the absence of a required non-conformance alert shall be no greater than TBD per flight hour.	OH-SA2-07
SAC-OH-SA2-08	The frequency of occurrence of failure of the Conformance Monitoring Service leading to non-conformance information not being provided to the Tactical Conflict Prediction and Resolution Service shall be no greater than TBD per flight hour.	OH-SA2-08

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SAC-OH-SA2-09	The frequency of occurrence of failure of the Tactical Conflict Prediction and Resolution Service leading to an unidentified predicted loss of separation shall be no greater than TBD per flight hour.	OH-SA2-09
SAC-OH-SA2-10	The frequency of occurrence of failure of the Tactical Conflict Prediction and Resolution Service leading to missing conflict resolution guidance shall be no greater than TBD per flight hour.	OH-SA2-10
SAC-OH-SA2-11	The frequency of occurrence of failure of the Tactical Conflict Prediction and Resolution Service leading to inappropriate conflict resolution guidance shall be no greater than TBD per flight hour.	OH-SA2-11
SAC-OH-SA2-12	The frequency of occurrence of failure of the Tactical Conflict Prediction and Resolution Service leading to undetected tactical conflicts involving manned aircraft shall be no greater than TBD per flight hour.	OH-SA2-12
SAC-OH-SA2-13	The frequency of occurrence of failure of the Tactical Conflict Prediction and Resolution Service leading to tactical conflicts involving emergency manned aircraft not being prioritised shall be no greater than TBD per flight hour.	OH-SA2-13

Table 121: SAC expressed in terms of hazard-related proxies for Safety Assessment 2

The consolidated list of additional SSIs (functionality and performance) associated with failure conditions, derived during the operational hazard assessment addressed in the previous section is presented in Table 122.

SSI ID	Additional safety specification item (SSI)	Mitigated operational hazard
SSI-SA2-F-01	The Final Flight Authorisation Service shall prevent the authorisation of operations involved in strategic conflicts.	OH-SA2-01
SSI-SA2-F-02	The Final Flight Authorisation Service shall prevent the authorisation of operations conflicting with geographical-zone restrictions.	OH-SA2-02
SSI-SA2-F-03	The Final Flight Authorisation Service shall prevent the authorisation of operations conflicting with active Dynamic Airspace Reconfigurations.	OH-SA2-03
SSI-SA2-F-04	The Final Flight Authorisation Service shall prevent the activation of operations affected by conflicting manned aircraft activity.	OH-SA2-04
SSI-SA2-F-05	The Strategic Conflict Resolution function shall prevent the generation of unsuitable alternative trajectories.	OH-SA2-05
SSI-SA2-F-06	The Conformance Monitoring Service shall identify non-conforming operations with the required performance.	OH-SA2-06
SSI-SA2-F-07	The Conformance Monitoring Service shall provide non-conformance alerts with the required performance.	OH-SA2-07

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SSI-SA2-F-08	The Conformance Monitoring Service shall provide information on non-conforming operations to the Tactical Conflict Prediction and Resolution Service with the required performance.	OH-SA2-08
SSI-SA2-F-09	The Tactical Conflict Prediction and Resolution Service shall identify predicted losses of separation with the required performance.	OH-SA2-09
SSI-SA2-F-10	The Tactical Conflict Prediction and Resolution Service shall provide conflict resolution guidance with the required performance.	OH-SA2-10
SSI-SA2-F-11	The Tactical Conflict Prediction and Resolution Service shall ensure the suitability of generated conflict resolution guidance.	OH-SA2-11
SSI-SA2-F-12	The Tactical Conflict Prediction and Resolution Service shall identify tactical conflicts involving manned aircraft with the required performance.	OH-SA2-12
SSI-SA2-F-13	The Tactical Conflict Prediction and Resolution Service shall prioritise tactical conflicts involving emergency manned aircraft with the required performance.	OH-SA2-13

Table 122: additional safety specification items to mitigate operational hazards and potential degraded modes for Safety Assessment 2

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