sesar
JOINT UNDERTAKING

URClearED
A Unified Integrated Remain Well Clear Concept in Airspace Classes D-G

URClearED

Federico Corraro (PM) and Partners
Final Event, Rome, 03/04 November 2022

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Summary

- Project Scope
- Functional & Operational Context
- Project's Achievements
- URClearED Remain Well Clear Solution
- Validation Results
- Conclusions & Recommendations

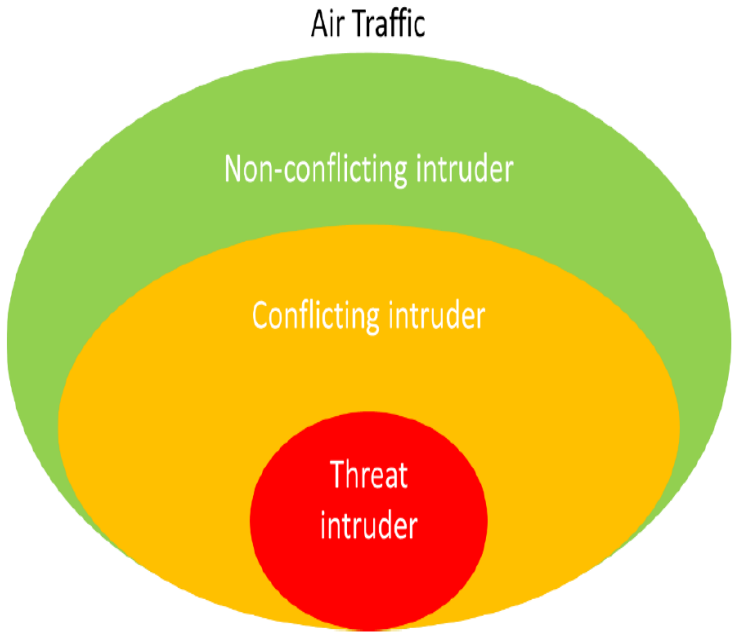
Project Scope

URClearED
A Unified Integrated Remain Well Clear Concept in Airspace Classes D-G

sesar JOINT UNDERTAKING

IFR (CERTIFIED) RPAS INTEGRATION IN ATM

- Seamless integration of a certified Remotely Piloted Aircraft Systems (RPAS) in non-segregated airspace is one of the major objectives for the worldwide civil aviation system.
- The development of a **Detect And Avoid** (DAA) system is widely recognized as a primary need for the RPAS integration in the unsegregated airspace.



REMAIN WELL CLEAR (RWC)

Investigate the Definition of a Remain Well Clear (RWC) function as integrated in a Detect & Avoid (DAA) system, for unmanned air vehicles (any class and type) flying IFR (Instrumental Flight Rules) into European airspace classes D-G

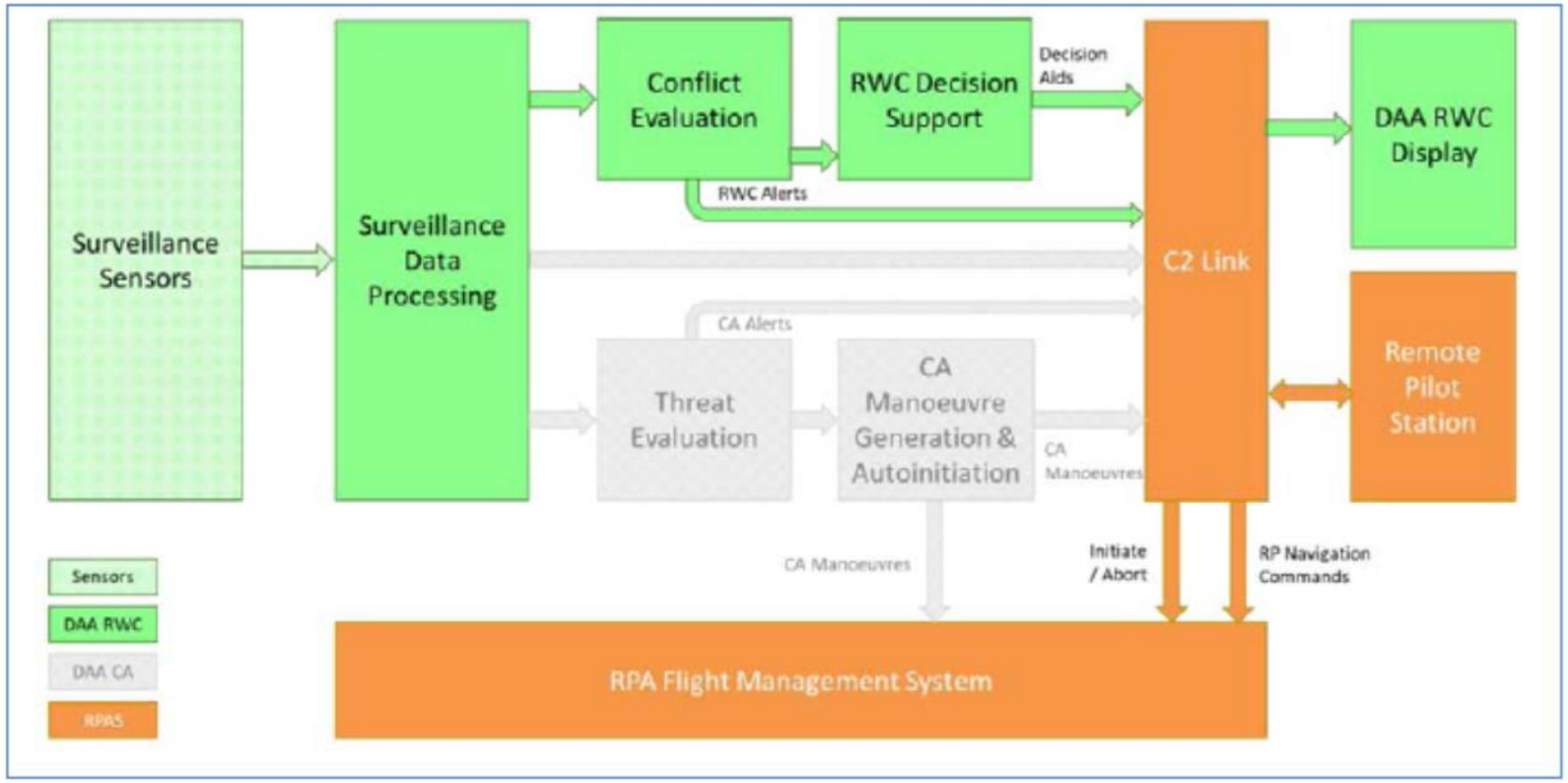
Functional Context (in a DAA System)

URClearED
A Unified Integrated Remain Well Clear Concept in Airspace Classes D-G

sesar JOINT UNDERTAKING

EUROCAE DAA OSED ED-258

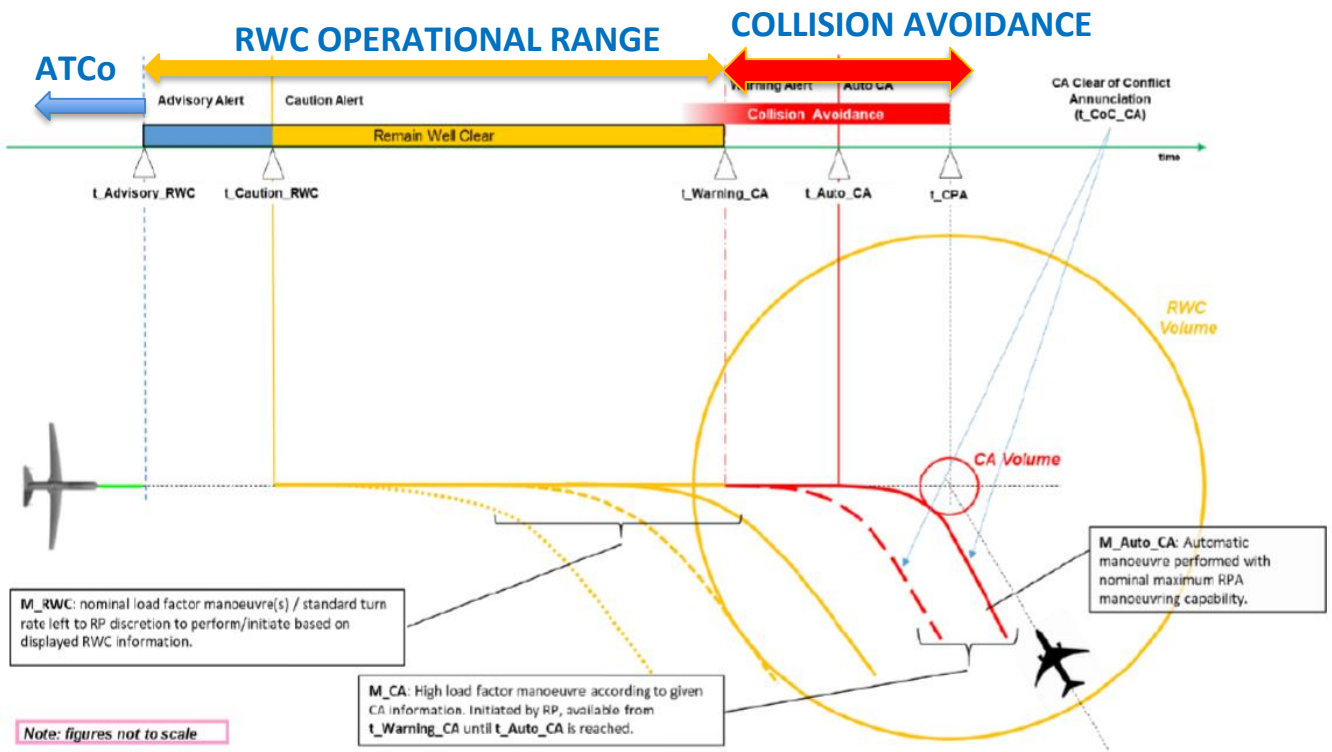
- Cooperative & not cooperative (no trasponder) Surveillance sensors
- Surveillance data fusion and processing common to both RWC and Collision Avoidance
- Conflict evaluation for alerting the pilot



- RWC decision support for assisting the Remote Pilot in taking decisions on maneuvering
- Dedicated RWC Display for traffic situational awareness, alerts and guidance indications

Operational Context (Airspace D to G)

- Cooperative and Not Cooperative (no Transponder) and IFR/VFR air traffic
- Separation Service by Air Traffic Controllers only for IFR-IFR encounters (D and E)
- Only Traffic Information for any A/C in Class G (uncontrolled airspace)
- VFR A/C (typically not cooperative) need ATC clearance only in Class D
- Close to U-SPACE / VLL Traffic
- Some differences between European countries



Remain Well Clear Timeline

Project Objectives vs. Achievements

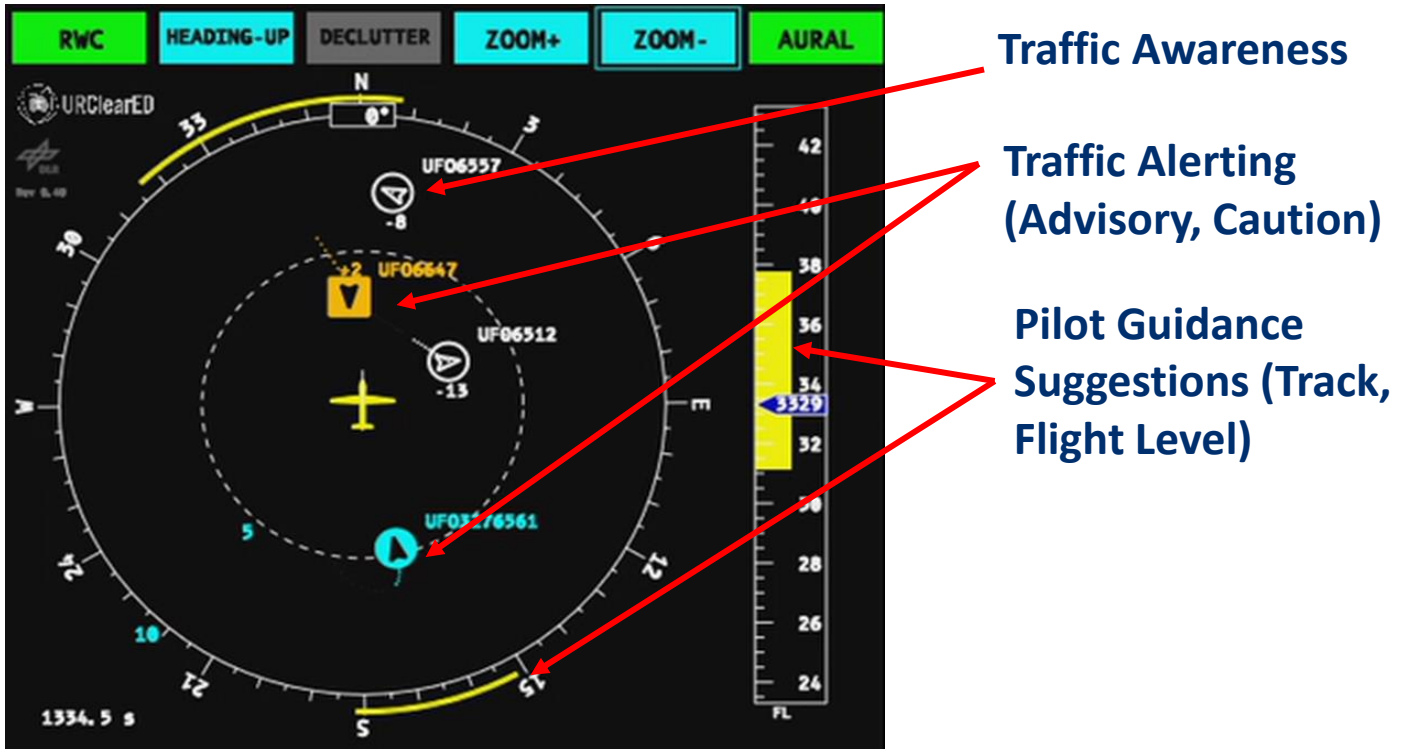
URClearED
A Unified Integrated Remain Well Clear Concept in Airspace Classes D-G

sesar JOINT UNDERTAKING

• Define the operating conditions (Operational Scenarios) of a European RWC	→ **Achieved**	
• Propose the functional requirements and capabilities for such RWC	→ **Achieved**	
• Propose Surveillance Sensors and Data Link performance assumptions	→ **Partial**	Surveillance Sensor Accuracy verified only in RTS
• Develop a baseline RWC prototype algorithm and related HMI to support evaluation of assumptions and requirements	→ **Achieved**	
• Perform Fast-Time and Real-Time Human in the Loop (including Remote Pilots and ATCOs) Simulations	→ **Achieved**	
• Analyse procedures for the management of IFR RPAS flying in airspace classes D-G, including U-Space interaction	→ **Partial**	Procedures Modifications and Full Validation (contingencies & UTM) to be completed
• Disseminate the findings to the relevant stakeholders	→ **Achieved**	2 Workshops + 2 Open Days

URClearED Remain Well Clear Solution

- Dedicated Analyses for quantifying Well Clear Volumes independent from airspace classes (can be related to SESAR PJ13 sol.111)
- Alerting times for avoiding Loss of Well Clear without interfering with ATC and STCA settings (65s to 85s to well clear violation)
- Key Differences with USA RTCA DO-365
  - Advisory Indications for covering maneuvering intruder aircraft
  - Only Caution Alerts, no Warning Alerts
  - Slightly Different Well Clear Volumes
  - Alerting times to allow interoperability with ACAS equipped intruders

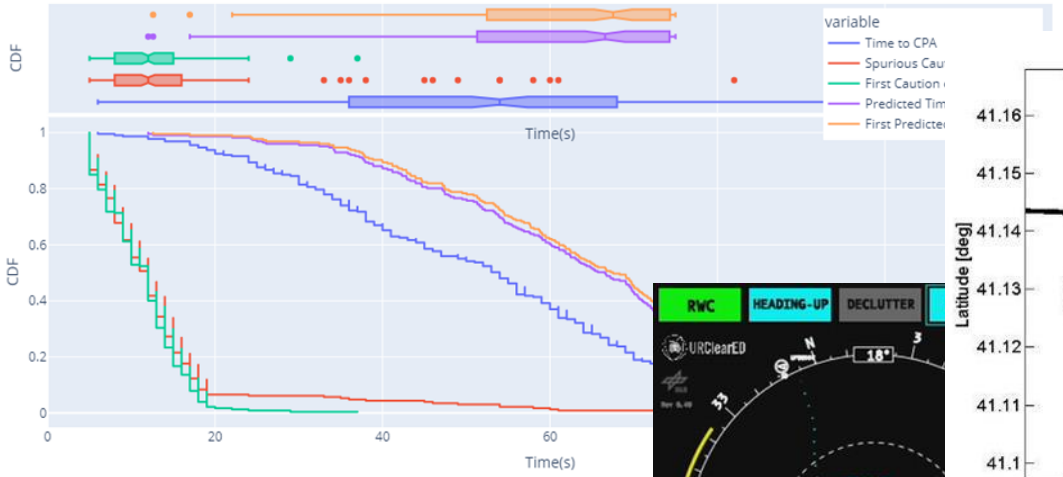


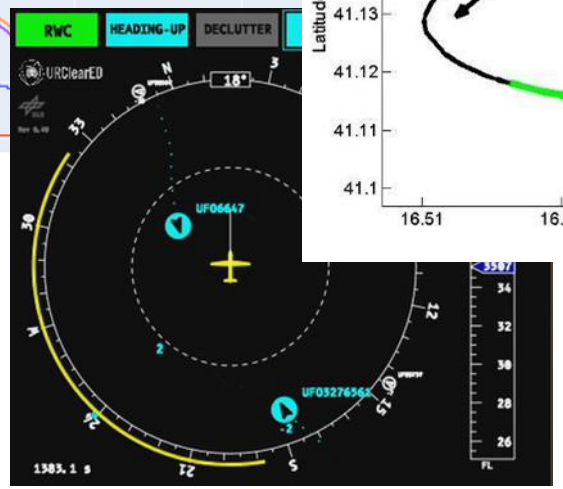
RWC Main Functions & Display

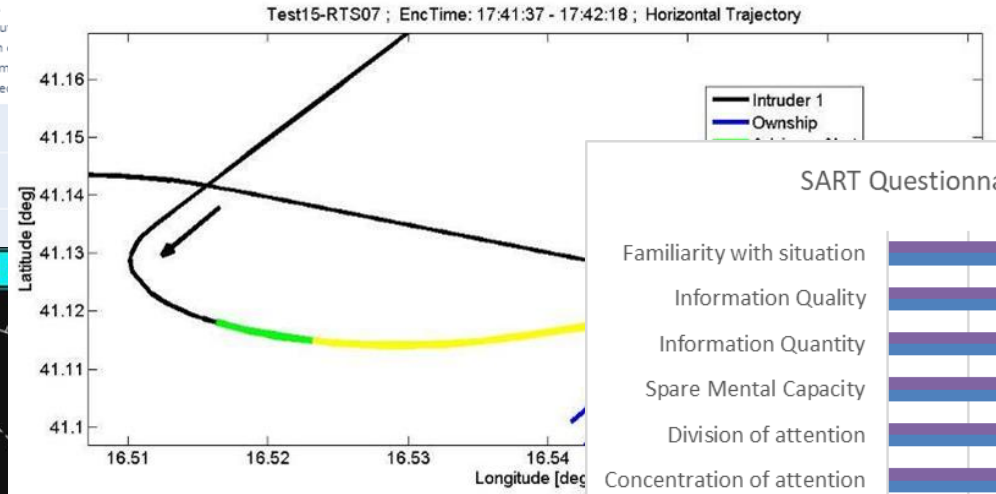
- First attempt to perform validation with the European Encounter Model in airspace classes D to G
- Simple HMI for Pilot readability and easy training
- Guidance Suggestions in terms of Conflict Bands always of the same color (yellow)

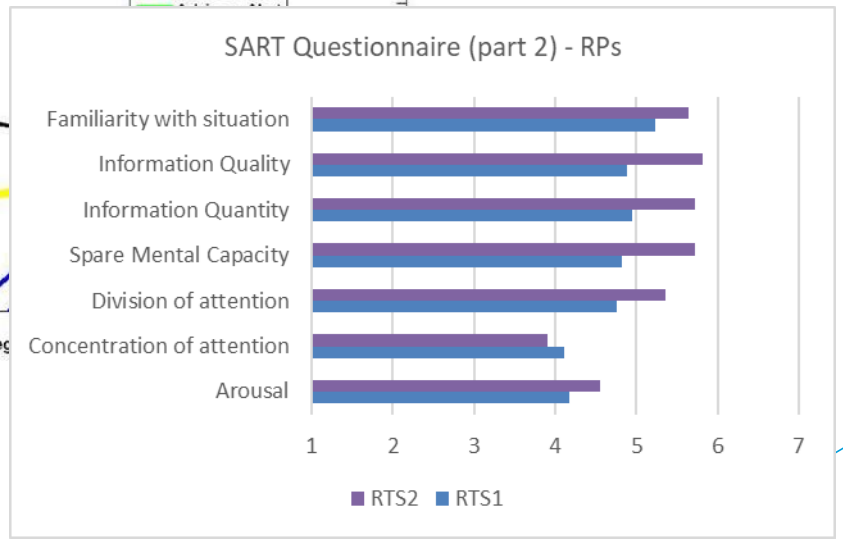
Validation Results

- Fast Time Simulation Key Results
- Real Time Test Campaign Data Analysis Assessment
- Real Time Test Campaign Human Performance Assessment









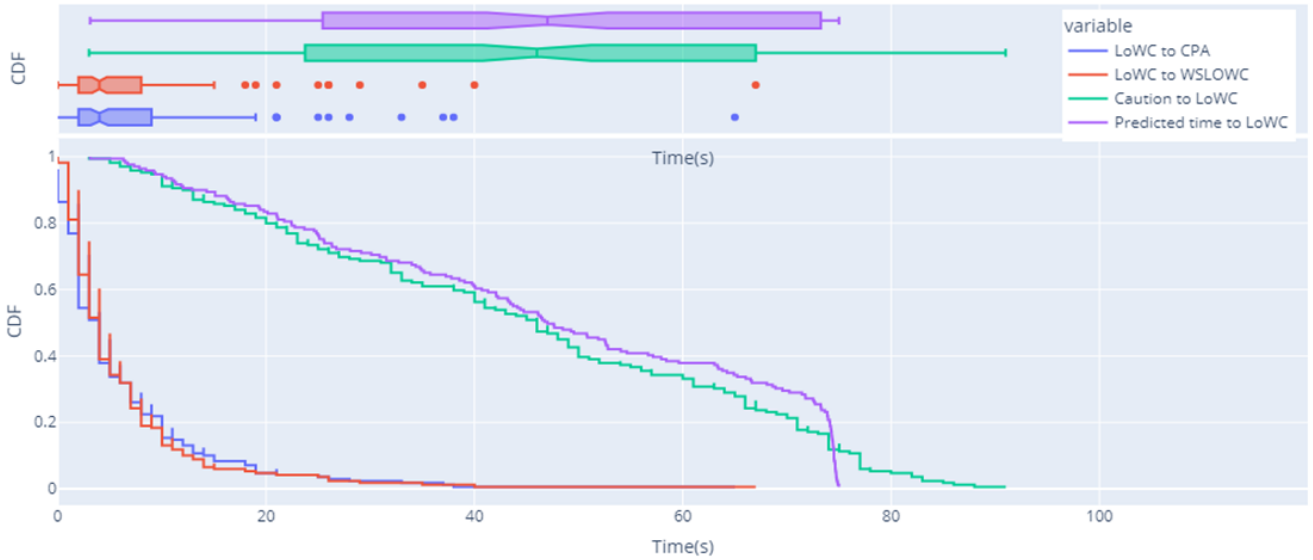
FTS Validation – Strategy and Objectives

Validation Strategy

- Explore different WC Volumes focusing on key time and distance metrics.
- Open-loop encounter evaluation in two consecutive steps:
    1. Uniformly distributed encounters with both ownship and intruder performing straight trajectories.
    2. Selection of encounters from the European CAFÉ encounter model (CRÈME) that best fit the type of encounters that are possible in the airspace classes D to G. Several hundred thousands of simulations performed.

Analysis Objectives

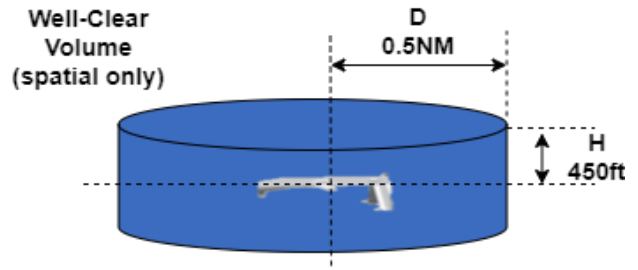
1. RWC Nominal Performance:
    - Caution Alerts and LoWC Analysis
    - Advisory Alerts Analysis.
2. Collision Avoidance Interoperability.
3. ACAS Interoperability.
4. Separation Interoperability.
5. See and avoid Interoperability.



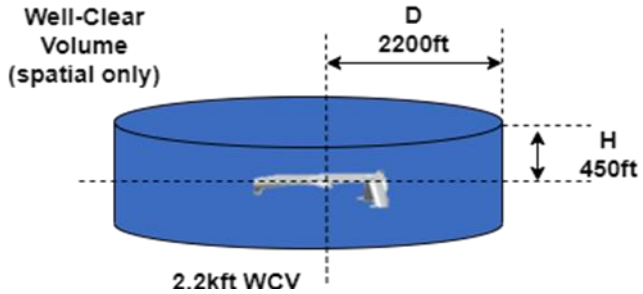
Sample of Results for Probabilistic FTS Analysis with CREME

FTS Validation – Key Conclusions

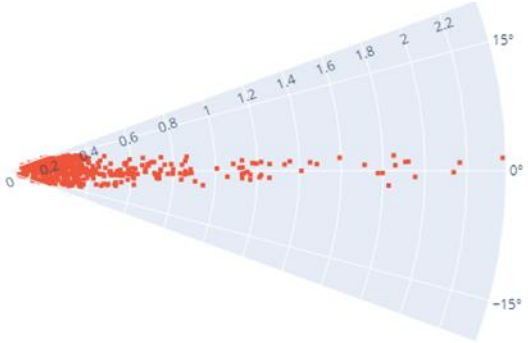
- Different Well Clear volume (WCV) quantifications and alert timings should be settled for encounters below and above 10.000 ft and for each class of intruders: Non-Cooperative, Cooperative without ACAS and Cooperative with ACAS.
- For encounters except the ones with Cooperative ACAS equipped A/C, a Caution Alert between 65 s (for non-coop) to 85 s (for coop) from violation of the WCV is compatible with sensor/visual ranges.
- Margins to manoeuvre when the encounter is with straight or low manoeuvring trajectories is 40s, on average.
- Using the CREME model, in 30% of encounters with manoeuvring aircraft the RWC cannot alert the pilot in time
- A relevant number of encounters needs a broader elevation range than ±15deg, especially when the conflict is detected for the first time at ranges close enough to lose well clear
- Margin between the ATCO intervention (with or without STCA) and the Caution Alert activation is, on average, about 20s (>100FL) and 15s belc



Typical Cooperative WCV



Typical Non-Cooperative WCV



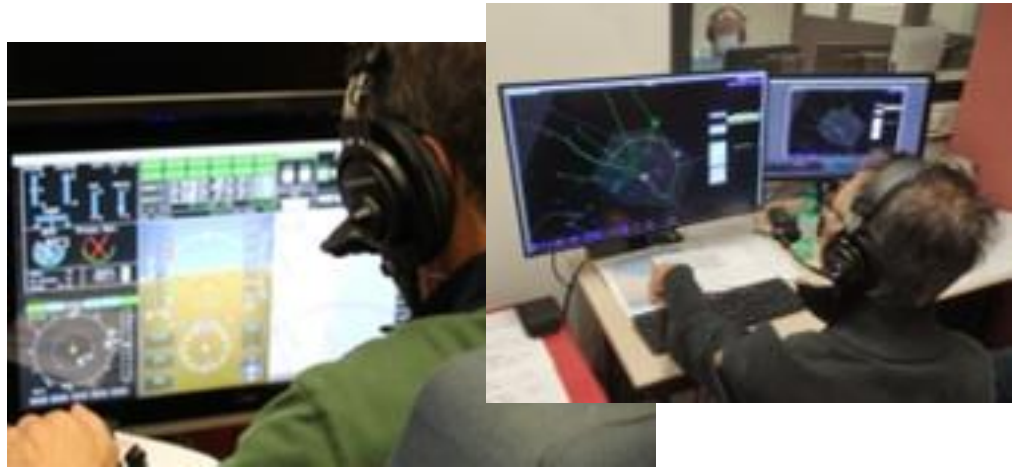
Non-Cooperative Elevation Distribution

Real Time Simulations – Overview

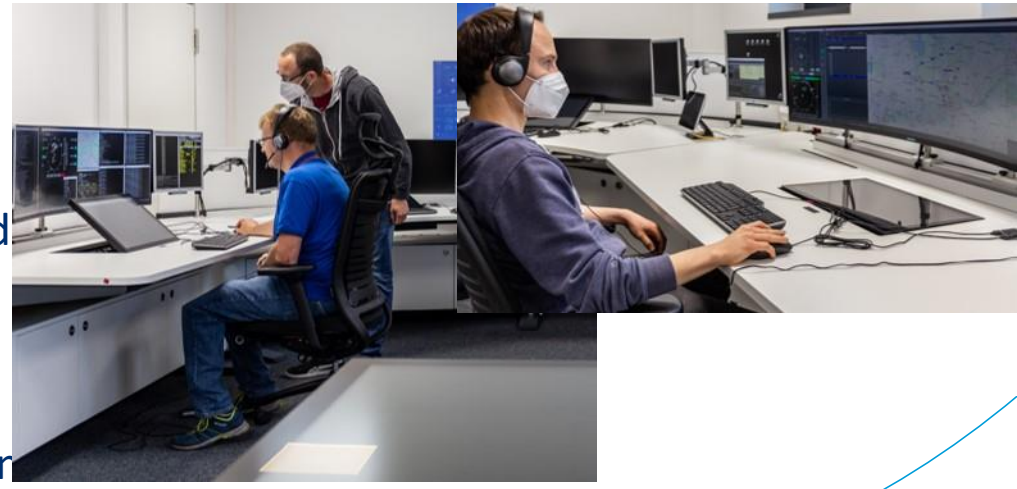
URClearED
A Unified Integrated Remain Well Clear Concept in Airspace Classes D-G

sesar JOINT UNDERTAKING

- **2 RTS test campaigns c/o CIRA**
  - Operational scenarios located in Italy (Bari, Brindisi and Grottaglie airports)
  - TUAV and MALE fixed wing RPAS as ownship
  - 5 ATCOs (4 Italian and 1 from Switzerland), 3 UAV pilots, 3 human factors experts and 8 CIRA system and avionic engineers.
  - **71** encounter conditions distributed over 28 Runs, with an average test run duration of about 30 min, resulting in almost **15 hours of RTS**



- **1 RTS test campaign c/o DLR**
  - Operational scenarios located in Germany and Czech Republic, (Lower Saxony near Bremen, at Prague Airport, between Mannheim and Frankfurt, in Hannover, and near Greifswald).
  - A generic light MALE UAV, a UAM vehicle similar to a Volocopter 2X and a smaller multicopter drone, as ownships
  - 7 UAV pilots, 2 ATCOs, 2 human factors experts and 3 test engineers from DLR.
  - **70** encounter conditions, one for each test run, with an average test run duration of about 10 min, resulting in around **12 hours of RTS**



RTS – Data Analysis Results 1/2

URClearED
A Unified Integrated Remain Well Clear Concept in Airspace Classes D-G

sesar JOINT UNDERTAKING

- **The measured RWC alert timing** was sufficient to coordinate with the ATCO, if needed, and to avoid the loss of well-clear for all type of intruder equipment, encounter geometries, and tested airspace classes. The few LoWC events in nominal conditions occurred mainly in in encounters with maneuvering and non-cooperative intruders.
- **The measured impact on RWC performances of traffic sensor measurements errors**, was limited to very rare cases when there was a temporary unwanted flickering of the RWC alerts. LoWC conditions were induced by the intrinsic field of view limitations of non-cooperative traffic sensors.
- **The measured performance of the RWC system during RTS**, is not compromised by the C2 link delay in line-of-sight (LOS) and beyond-line-of-sight (BLOS) conditions.

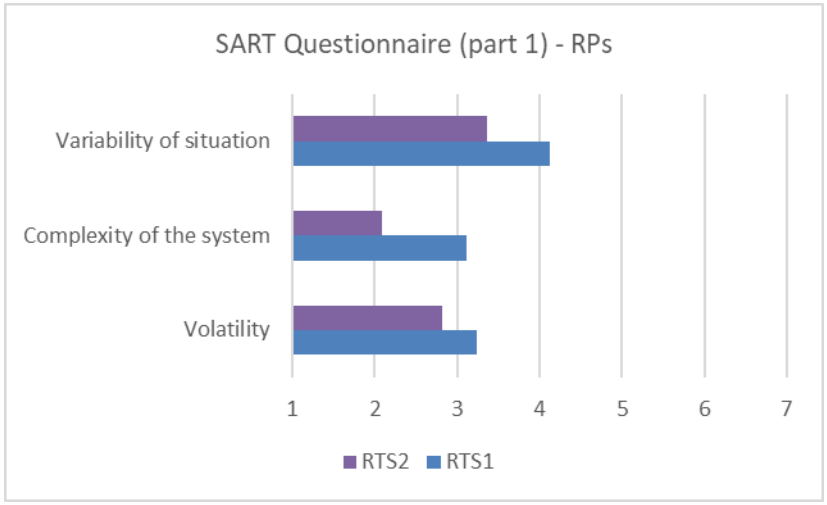
- When **comparing with DO-365A compliant RWC system**, differences were noted in some situations in which only DO-365A RWC alerted, and when a Warning alert may have provided the pilot with a sense of urgency to maneuver, allowing loss of DWC to be prevented

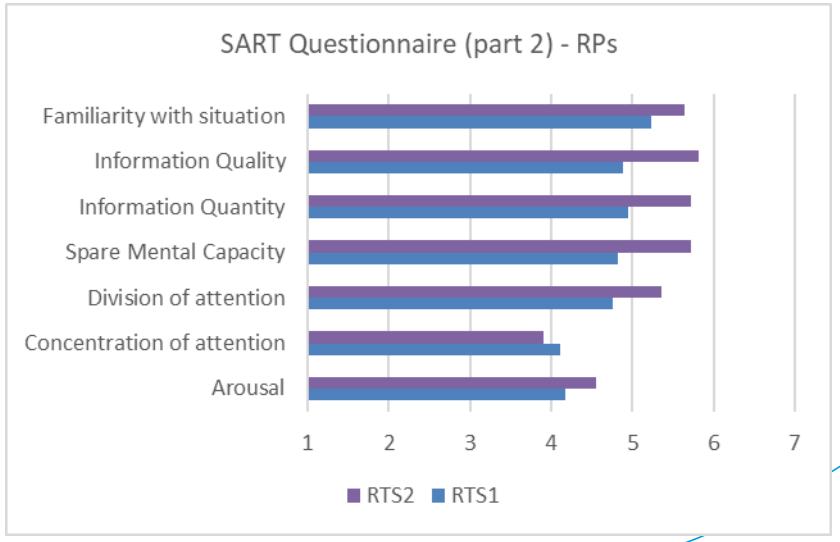
RTS – Data Analysis Results 2/2

- **In all the cases in which no LoWC has occurred in encounters with ACAS equipped intruders**, the time interval from the caution alert activation up to the execution by the RP of the well-clear maneuvers did not trigger the RA activation.
- **In airspace classed D-E, the measured ATCO separation provisions were well in advance with respect to the RWC caution alert activation**. The RP initiated the action before asking the clearance, only in a few cases in which the high-density traffic delayed the ATCO actions or in encounters with non-cooperative intruders not visible on the CWP.
- **During encounters with VFR intruders**, the Caution Alert activation always occurred below the threshold of 5NM, giving the possibility to the intruders to visual detect the RPAS and operate a separation manoeuvre. In the cases in which the manned aircraft did not separate, the RP had the time to execute a well-clear manoeuvre

RTS – HP Assessment Overview

- The applicable validation objectives are those concerning **Human Performance, Acceptability and Safety**, that can be evaluated by using ATCO and Remote Pilot comments and suggestions, collected during test debriefings and derived from specific questionnaires
  - Specific Standard Questionnaires
    - SART –> Situation Awareness
    - Bedford Scale -> Workload
  - Over the shoulder observation
  - Debriefings -> after each run and after each RTS
  - Post-Run and Post-RTS Specific questionnaires
- The impact of RWC on Safety **is intended as RP/ATCO perceived level of safety** and it has been done only **in nominal conditions**, due to the limited number of test in contingency situations
- **Challenges**: 2 Parallel RTSs, high number of variables involved, need to induce error situations (especially in Class D and E), differences between RTS#1 and RTS#2/3





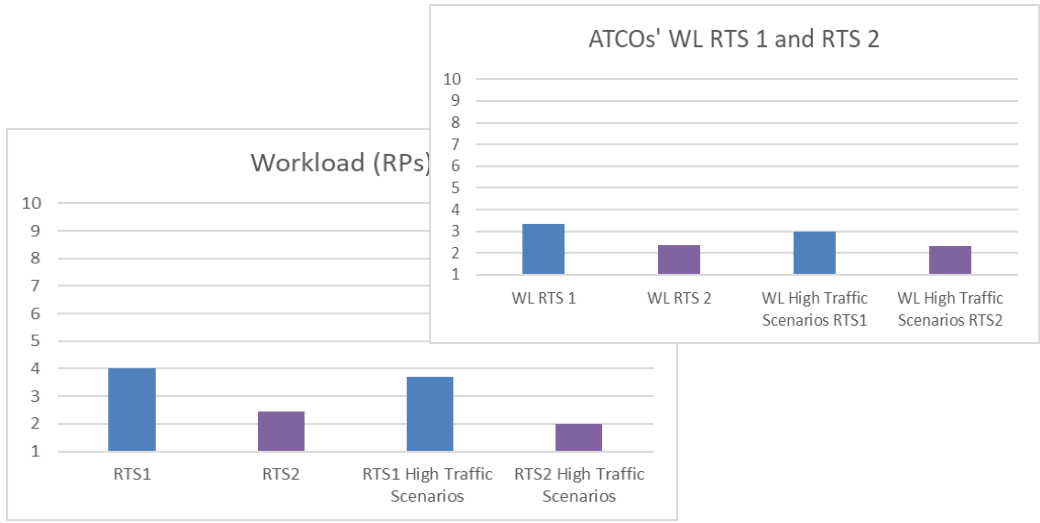
RTS – HP Assessment Results 1/3

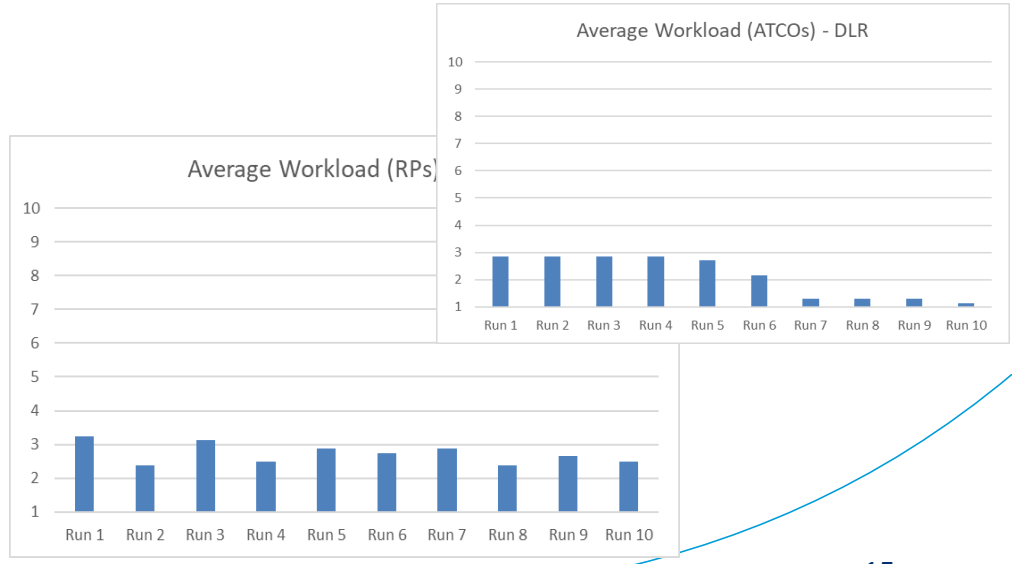
A. All test RPs, reported that the RWC provides **good situational awareness**, coherent with the actual traffic dynamical evolution, and provides **added value** with respect to the ATCO information in all airspace classes D-E-G.

B. Both RPs and ATCOs did not perceive **any changes in their role and responsibilities** in relation to the RWC module compared to current operations in all the airspace classes D-E-G.

C. The tasks of the ATCOs did not change with the introduction of the RWC module, and the **overall level of workload of ATCOs remained acceptable** also considering high traffic scenarios.

D. In airspace classes G the ATOCs proposed that the **Traffic Information (TFCI) should inform** the other manned aircraft, mainly VFR, **that there is a RPA in the area**.





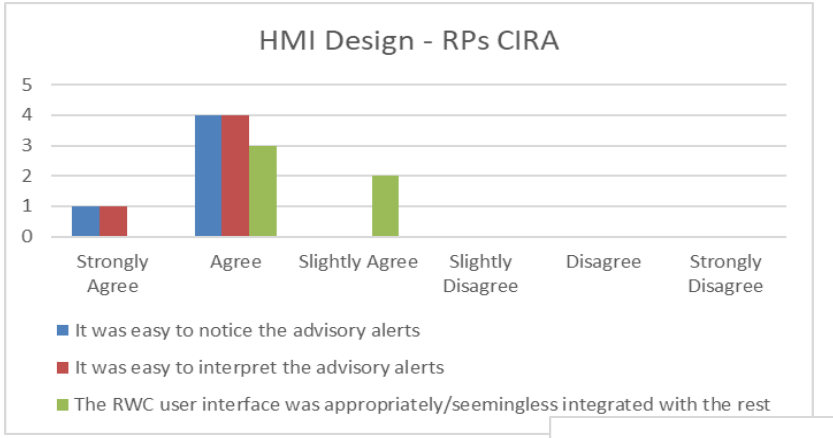
RTS – HP Assessment Results 2/3

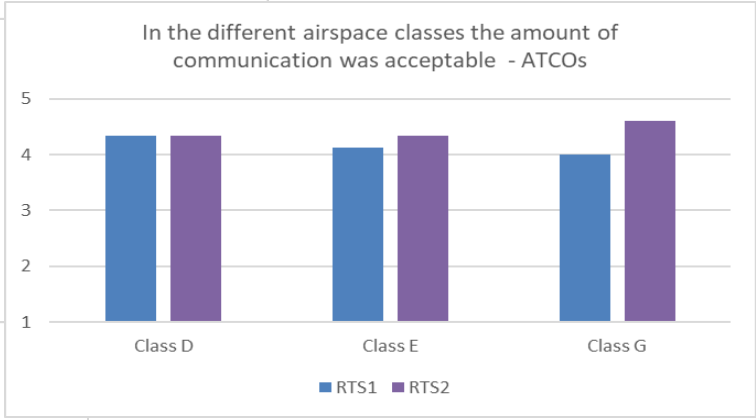
E. The RPs answers concerning the **RWC HMI returned positive results**, especially for the ease to notice and interpret the RWC alerts

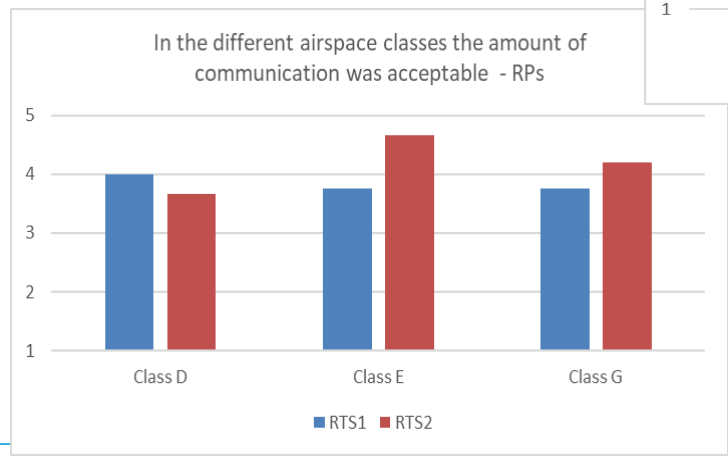
F. Team communication was positively evaluated by the RPs, with no significant difference between airspace classes D-E-G.

G. RPs and ATCOs acceptability of the concept depended on the timing of the alerts of the RWC module.

H. Both ATCOs and RPs recommended **the preventive definition of specific RWC user procedures and related training activities.**







RTS – HP Assessment Results 3/3

I. In general both RPs and ATCOs judged that RWC can **increase flight safety** and can help avoiding traffic disruptions due to collision avoidance activation, not only in class G, but also in class D and E where VFR aircraft without transponders can be present.

J. The **RPs' evaluations of the perceived level of safety** returned mixed results, depending on the different type of intruders, level of traffic (i.e., high, medium, low), airspace classes, evaluated. For this reason, a more intense and structured RTS campaign should be performed in future activities.

K. The **ATCOs evaluation of the perceived level of safety** shows a lower variability in the results compared to those of the RPs, with in general a higher perceived level of safety

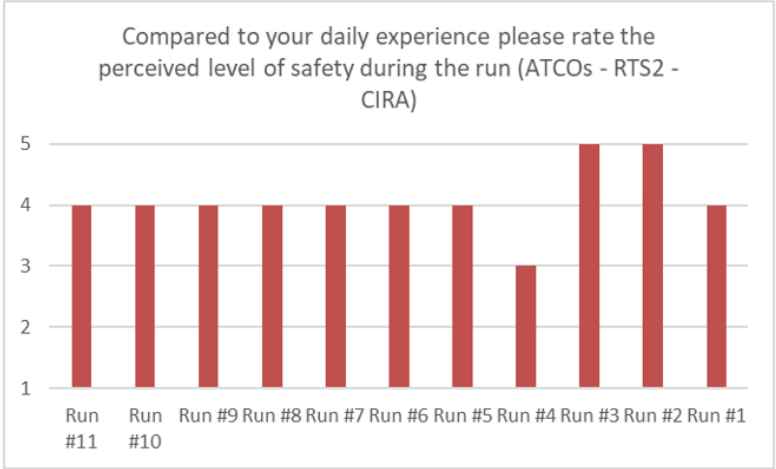
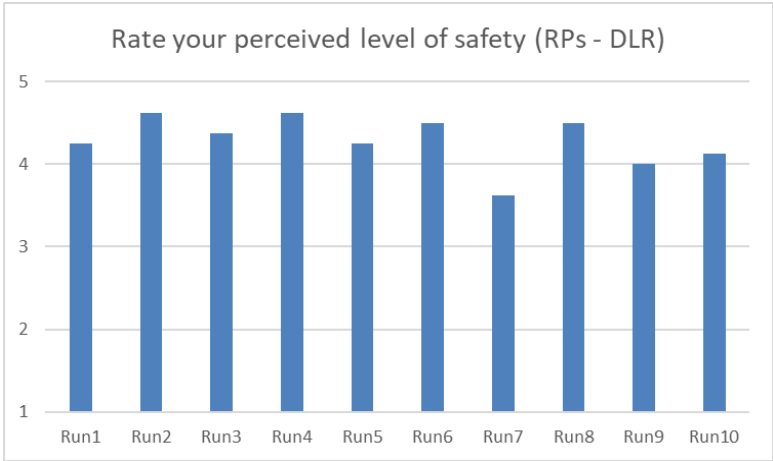


Figure 65 - Perceived level of safety by ATCOs (1: Very Low; 5: Very High)



Conclusions

- The proposed **URClearED RWC solution for IFR RPAS in airspace D to G can effectively support the integration in the civil ATM**, but an operational distinction between controlled airspace (D and E) and uncontrolled one (G) shall be clearly defined and the solution for D/E shall be merged with the one proposed in other SESAR industrial projects for airspace A to C (PJ13)
- Both the **RPs and ATCOs did not perceive any changes in their role and responsibilities** in relation to the RWC module compared to current operations in all the airspace classes D-G
- The **key Safety Benefits** (evaluated only qualitatively by the data analysis and RP/ATCo judgments) are related to avoiding traffic disruptions due to collision avoidance activation in airspace D to G and in avoiding that in such conflicts situations an ACAS-equipped intruder issues a Resolution Advisory alert
- The URClearED **RWC alerts do not normally interfere with the ATC separation services,** so it does also not increase ATCOs workload. However:
    - **Evaluation of nuisance alerts** shall be performed especially when in TMA
    - The **risk that a RP calls ATC or maneuvers in controlled airspace D-E before calling ATC**, cannot be neglected and shall be minimized with detailed operational procedures and training
- **Small operational differences with US DO-365A RWC solution** that, however, suggest some means to indicate to the RP the urgency of performing some actions

Recommendations

- **Operational and Technical**
  - Advanced surveillance sensor filtering, account for field of view limitations of non-cooperative sensors
  - Alerting function to account for intruders' manoeuvrability and detection of airspace using the flight plan
  - Provide indications to RP of the urgency of maneuvering for avoiding LoWC
  - Definition of detailed operational procedures and of RP training requirements
  - Interaction with UTM needs defining and developing
- **Validation**
  - Develop a European uncorrelated encounter model to be used for validation in uncontrolled airspace
  - Develop a standardized Pilot Model for Closed Loop FTS and nuisance alerts evaluation
  - Safety and Risks: perform larger and structured RTS campaigns for evaluating suitability in all airspace, TMA, contingency situations, multiple and maneuvering intruders, STCA compatibility, etc.
  - Evaluation of Security Risks (ADSB-IN surveillance sensor, RPAS C2 link)
- **Standardization**
  - Develop a unique European standard (at least OSED and MASPS) for all airspace with clear operational distinctions between controlled (A to E) and uncontrolled airspace G

sesar
JOINT UNDERTAKING

URClearED
A Unified Integrated Remain Well Clear Concept in Airspace Classes D-G

THANK YOU FOR YOUR ATTENTION

EUROPEAN PARTNERSHIP

Co-funded by the European Union