URClearED

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

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Project Manager

Advisory Board Meeting - 11 October 2021

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Outline

- Project Scope and Status
- Summary of Operational Assumptions
- URClearED RWC Functional Concept
- URClearED RWC Operating Method
- Discussion Topics

Aim of URClearED Exploratory Research project

Investigate the Definition of a Remain Well Clear (RWC) Software module, integrated in a Detect & Avoid (DAA) system, for:

- a RPAS of “Certified” EASA category;
- flying IFR (Instrumental Flight Rules)
- flying into airspace classes D to G

Project Objectives (all related to Classes D to G)

- Define the operating conditions (Operational Scenarios) of a European RWC
- Propose Surveillance Sensors and Data Link performance assumptions
- Propose the functional requirements and capabilities for such RWC
- Propose operational procedures for RWC and the management of IFR RPAS flying in airspace classes D-G, including U-Space interaction
- Develop a baseline RWC prototype algorithm and related HMI to support evaluation of assumptions and requirements
- Assess and refine assumptions, requirements and operational procedures by means of Fast-Time and Real-Time Human in the Loop (including Remote Pilots and ATCOs) Simulations

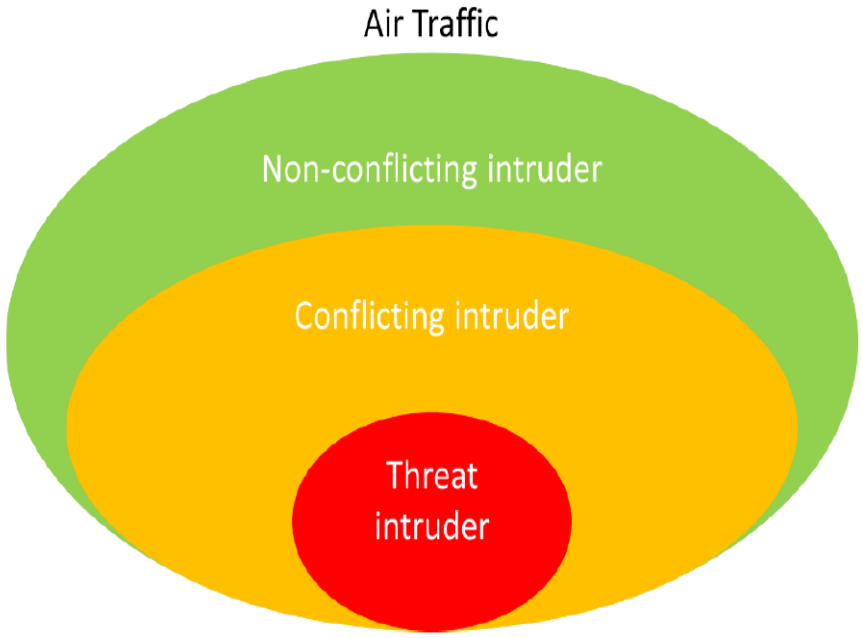
Remain Well Clear applicable definitions

REMAIN WELL CLEAR: TACTICAL LAYER OF CONFLICT MANAGEMENT

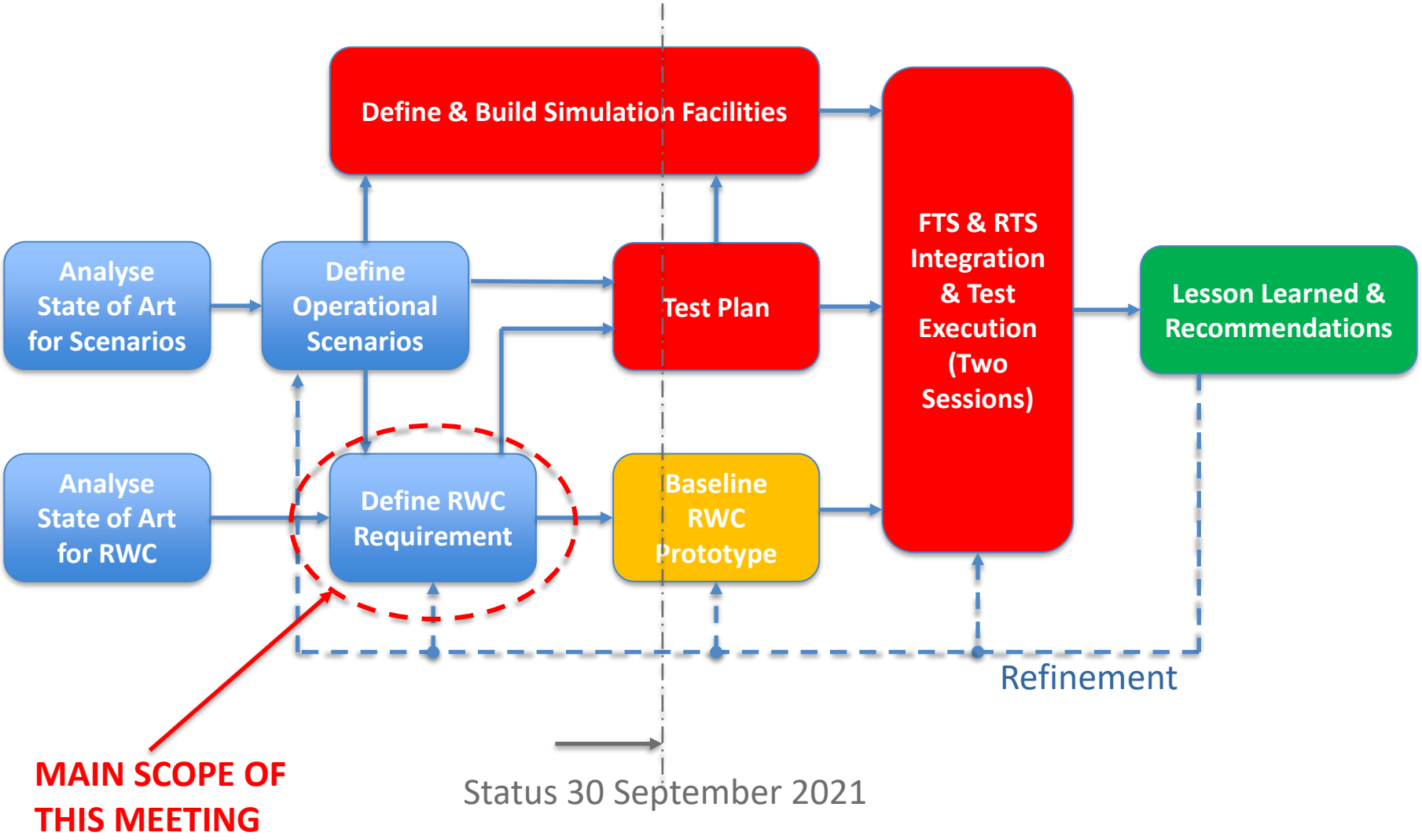
The URClearED solution is focused on the RWC function to support the remote pilot in her/his responsibilities with regards to the rule of the air "*An aircraft shall not be operated in such proximity to other aircraft as to create a collision hazard*", as stated in the ICAO Annex II, section §3.2. In this context, the RWC function will support the RPAS pilot to avoid the violation of a well-clear volume for any conflicting intruder.

Conflicting intruder: For each surrounding traffic track, a conflicting intruder is any aircraft for which it is predicted an estimated loss of well clear (LoWC) within a given look ahead time.

Well Clear Volume is a volume around each intruder that shall be not violated to avoid a Loss-of-Well Clear condition. In this context, the Well Clear Volume is quantitatively defined using horizontal thresholds, both spatial and temporal, and a vertical spatial threshold.



Project WorkFlow and Status



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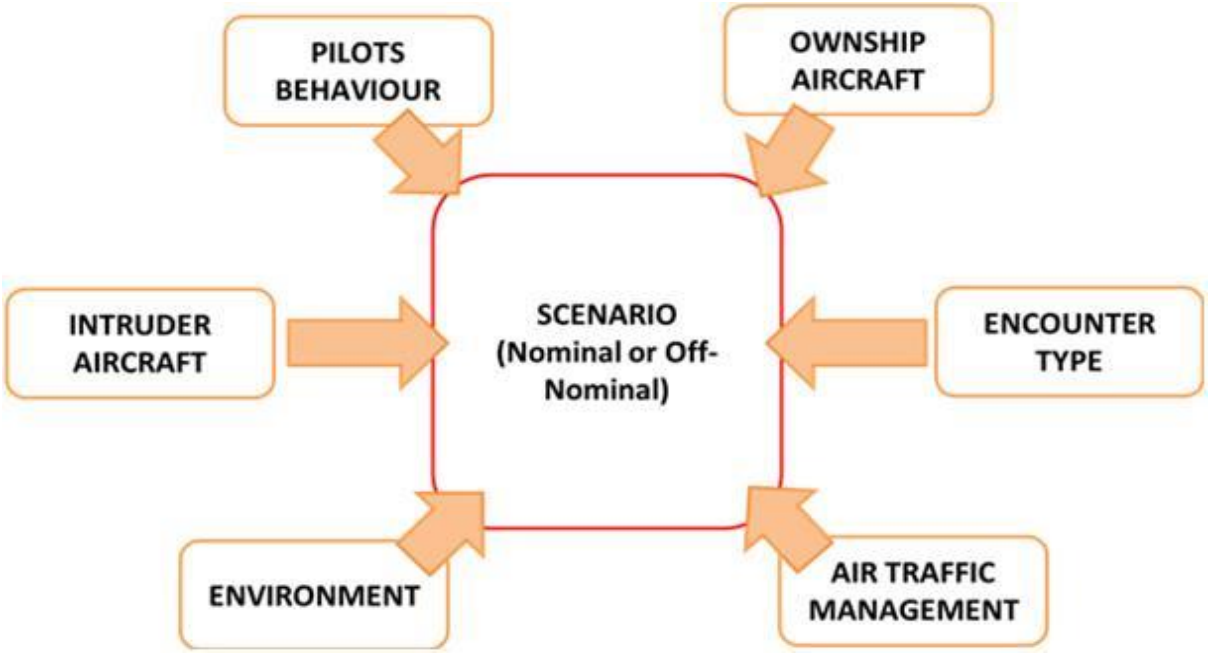
Key Elements in the Operational Scenarios

- Airspace and available Air Traffic Services.
- Ownship / Intruder performance and equipment.
- Encounter Types: geometries, speeds
- Remote Pilot Behavior



Key Elements in the Operational Scenarios

AIRSPACE: AIR TRAFFIC SERVICES

Available air traffic services, separation objectives and potential coordination with ATC depends on the type of airspace.

Airspace Class	D		E		G	
Flight Rules	IFR	VFR	IFR	VFR	IFR	VFR
Permitted	yes	yes	yes	yes	yes	yes
Speed Limitation	< 250 Kts, @ Altitudes below 10.000 feet AMSL					
ATC Clearance	yes	yes	yes	no	no	no
Air-Ground Radio Comm. Requ.	Continuous two ways	Continuous two ways	Continuous two ways	no	Continuous two ways	no
Separation minima	3 nm horizontal 1000ft vertical		5 nm horizontal 1000ft vertical		3 nm horizontal 500ft vertical	
ATC Separation Services	yes only IFR-IFR	no	yes only IFR-IFR	no	no	no
ATC Information	TFCI wrt VFR	TFCI wrt IFR and VFR	TFCI wrt VFR when possible	TFCI when possible	FIS If requested	FIS If requested

Key Elements in the Operational Scenarios

OWNSHIP PERFORMANCE and EQUIPMENT

- Fixed wing ‘certified’ RPAS from class A to E, classified based on engine type / max ceiling.
- Helicopter / VTOL : SMALL VTOL, UAM VTOL
- Operating altitude up to 18500ft
- C2 Link RLOS and BRLOS
- All RPAS Transponder Equipped, with Cooperative Sensors (ADSB-IN + Active Traffic Sensor or Interrogator) and Non-Cooperative Sensor Suite (radar, EO/IR, etc.)

C2L performances

C2 Link	Latency [s]
RLOS	1
BRLOS	2

Key Elements in the Operational Scenarios

INTRUDER AIRCRAFT PERFORMANCE and EQUIPMENT

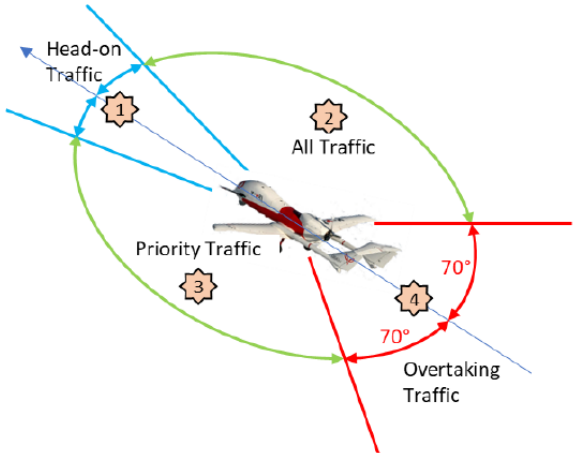
Level	Equipment	Categories	IAS [Kts]	RoC [ft/min]	Max turn rate [deg/s]	Max vert acc [g]
0	Non-cooperative	Piston fixed wing (1)	77-98	-1500/2000	6	0.25
		Piston rotary wing, glider, balloon, airship	0-98	-1200/1200	30	
1	Cooperative without cooperative traffic sensors	Piston fixed wing (1)	77-98	-1500/2000	6	0.25
		Piston rotary wing	0-102	1200/1200	30	
2-3	Cooperative with cooperative traffic sensors	Turboprop < 15000 Kg (2,3)	92-150	-3700/4200	6	0.25
4	Cooperative with ACAS	Turboprop > 5700 Kg (3,4)	110-160	-3510/3550	5	0.15
		Turbojet (6,7,9)	108-210	-4500/4650	5	0.25
		Turbine rotary wing	0-155	-2000/2000	30	0.25
		Tilt Rotor	0-275	-4100/4100		

Key Elements in the Operational Scenarios

ENCOUNTER TYPE

ENCOUNTER TYPE

Conflict Geometry	Complexity of the Encounter



Conflict Geometry (w.r.t. Ownship):

- Head On
- Lateral with Right of Way
- Lateral without Right of Way
- Overtaking

Sector	Situation description
1	Intruder approaching head-on or approximately. Both aircraft are required to give way by turning to the right.
2	Intruder converging from right sector: all intruders have the right of way, the RPA shall give way.
3	Intruder converging from left sector: the RPA has the right-of-way, except for priority intruders.
4	Intruder overtaking: the RPA has the right-of-way.

Complexity of the encounter**:**

- **Simple Pair Wise:** Straight Trajectories
- **Special Maneuvers**: CAFE' trajectories; RTCA DO 365A trajectories;
- **Multi-intruders**

Key Elements in the Operational Scenarios

REMOTE PILOT BEHAVIOUR

Monitor, verifying the state of the surrounding traffic and detecting any potential conflict situation, using the available onboard DAA equipment and associated traffic sensors.

Assess the possible RWC manoeuvre by interacting with ATCo (when available), depending on the role and responsibility in managing aircraft separation, on the airspace class and intruder type (IFR/VFR). Because the RP behaviour depends on the nature of the intruder (IFR or VFR), the RP is always responsible for assessing this info by contacting ATC, when available, or by other means.

Executes the assessed RWC manoeuvre, refers mainly to the available piloting modes for the RP, which impacts the way the manoeuvre could be executed.

Latency type	Distribution Type	Mean [s]	Std dev [s]	Bound @ 95% [s]
Initial Response	Exponential	5	5	<=15
ATC Coordination	Gamma	11	4.7	<=19.7
Execution delay	Exponential	3	3	<=9

Guendel, Kuffner, Maki, *A Model of Unmanned Aircraft Pilot Detect and Avoid Maneuver Decisions,* MIT 2017

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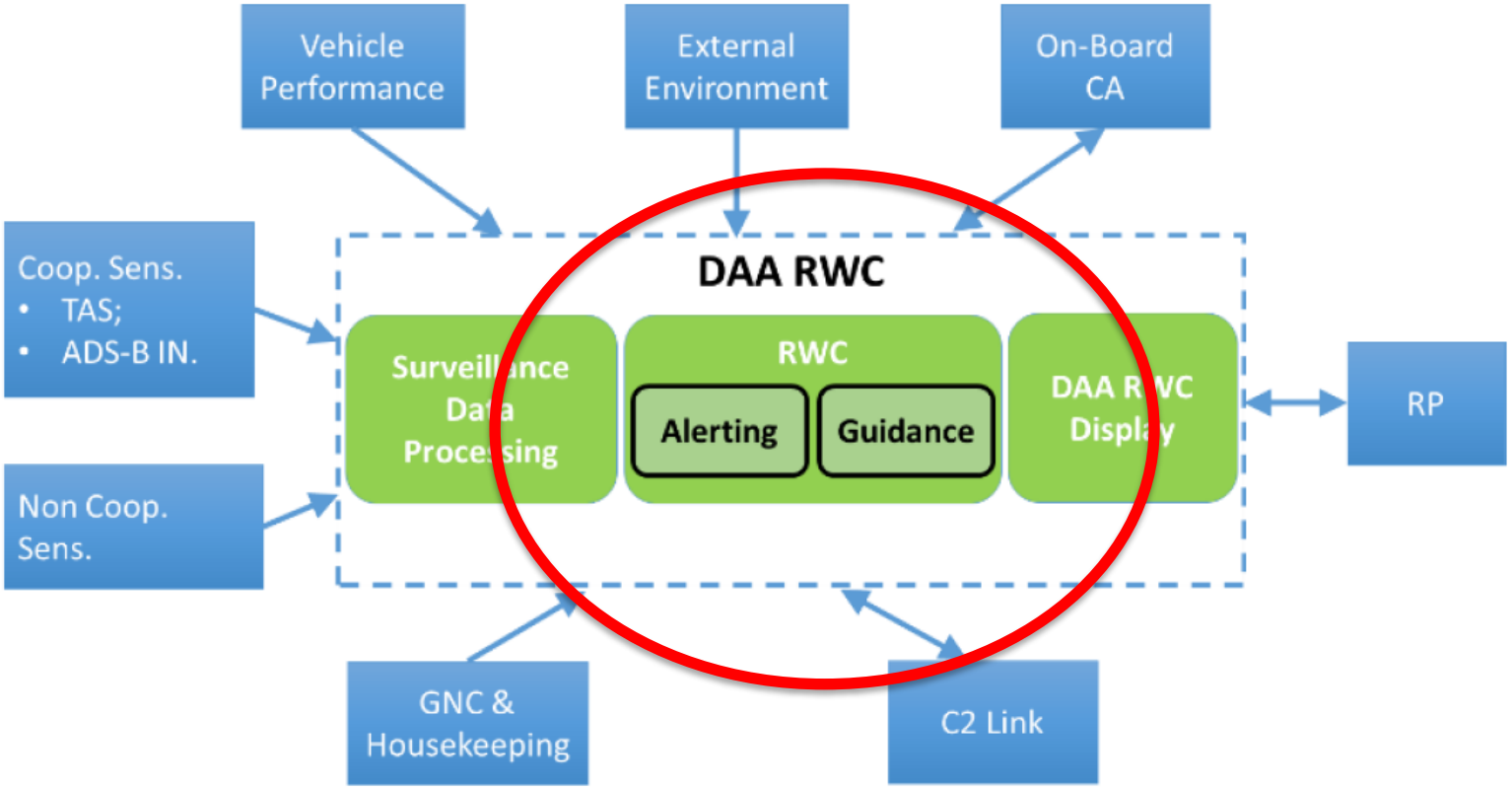
URClearED RWC Functional Concept

FUNCTIONAL CONTEXT



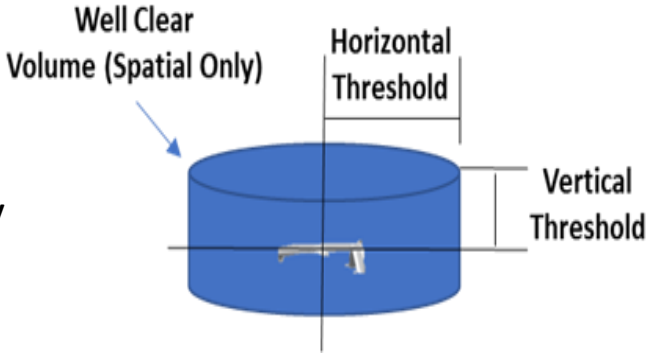
URClearED RWC Functional Concept

WELL CLEAR VOLUME

- RWC Alert and Guidance need to unambiguously define and quantify the Well Clear Volume (WCV or DAA Well Clear - DWC) to avoid
- No standard quantification exists that is generally accepted by the aeronautical community
- RTCA MOPS DO-365 (USA) quantified a WCV based on several analysis and test campaigns
- Currently, in Europe, PJ13-Sol.111 project provided bases for WCV quantification in classes A-C

PARAMETERS

- Safety Performance Figure (e.g. the maximum probability of an NMAC after an unmitigated excursion into WCV)
- Horizontal spatial threshold (TBD_HST) and optionally temporal threshold (TBD_HTT)
- Vertical spatial threshold (TBD_VST)



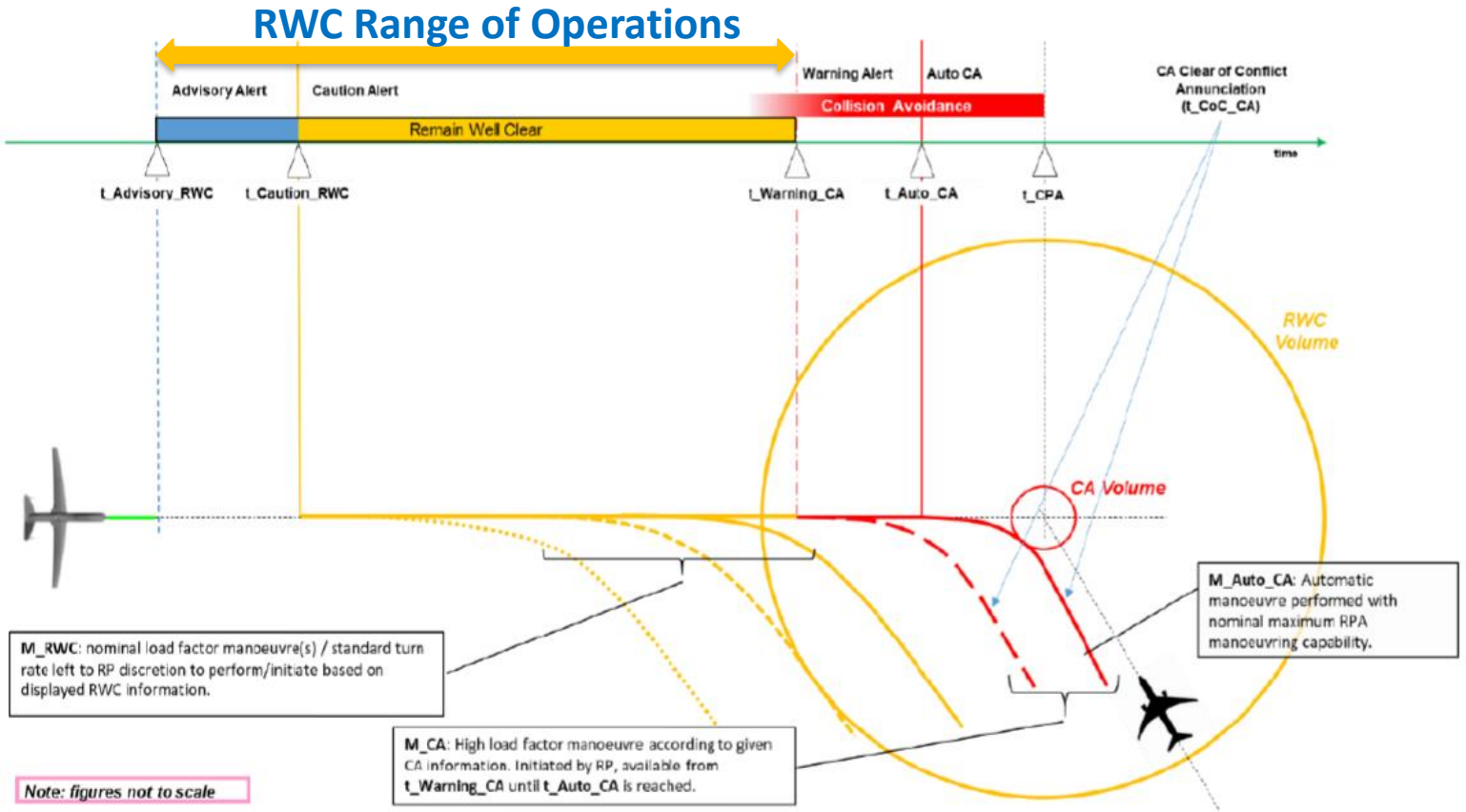
CRITERIA

- Compatibility with WCV in Classes A to C
- Differentiation by intruder type (coop., non-coop., ACAS) and Altitude
- Not Overlapping ATC in where Separation Service is provided
- Allow intruder that has only Visual Based Separation to see Ownship

URClearED RWC Functional Concept

ALERTS

The alerting functionality aims to determine whether an intruder poses enough risk to warrant an alert and, in this case, which alert priority is appropriate.



URClearED RWC Functional Concept

ALERTS

- **ADVISORY**
  - Indicating when a change in current heading/track or altitude by the ownship may immediately trigger a caution alert.
  - The RP response to an advisory level alert is to monitor the designated traffic, by assessing the overall situation of the encounter, and be aware of the risk of inducing a loss of well clear situation, due to possible future manoeuvres or mission constraints.
  - Contacting ATC in response to an advisory alert should be avoided

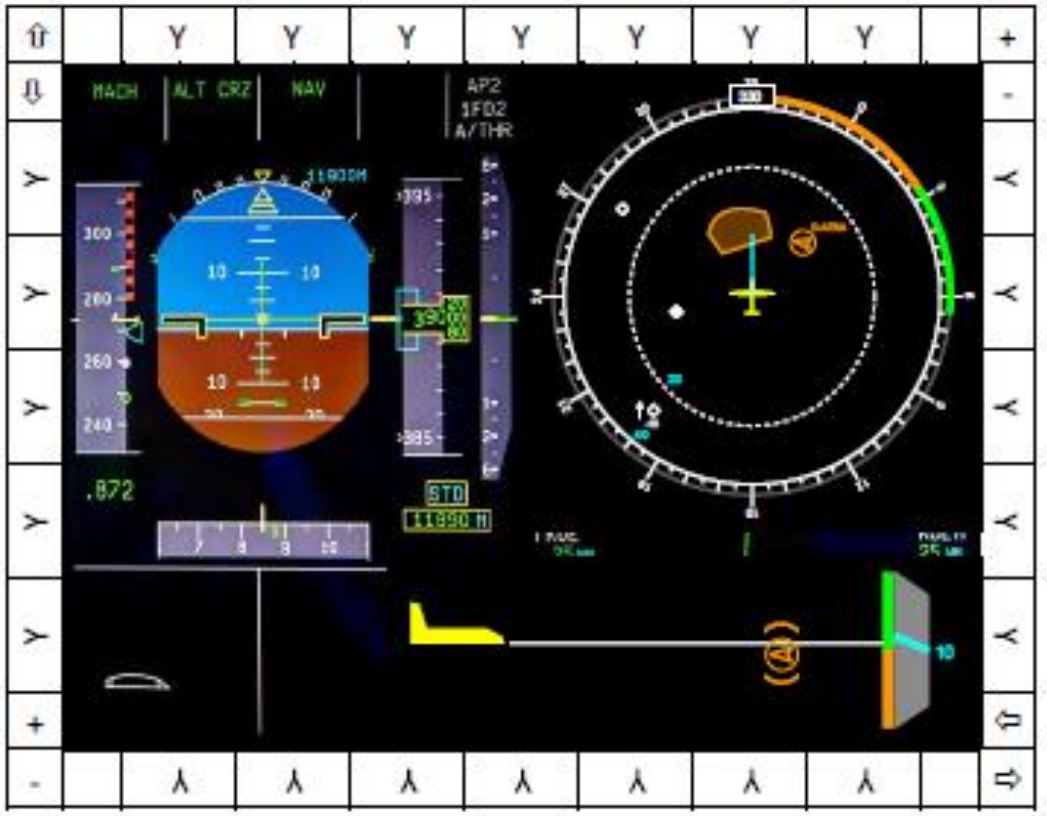
- **CAUTION**
  - Indicating a predicted (within a given look-ahead time) or current loss of well clear situation
  - This alert necessitates immediate awareness of the RP and subsequent actions
  - The RP shall determine whether a manoeuvre is needed and initiate coordination with ATC if available

URClearED RWC Functions

GUIDANCE

Provide indications to support the RP (or other involved operators of the RPAS) decisions in the resolution of a potential conflict.

- Computes the range of ownship manoeuvres that would result in an estimated loss of well clear (LoWC) within a given look ahead time.
- Maneuvers are computed only for Horizontal and Vertical Plane separately
- Horizontal maneuvers are computed in track/heading angle
- Vertical maneuvers are computed in altitude or Flight Levels



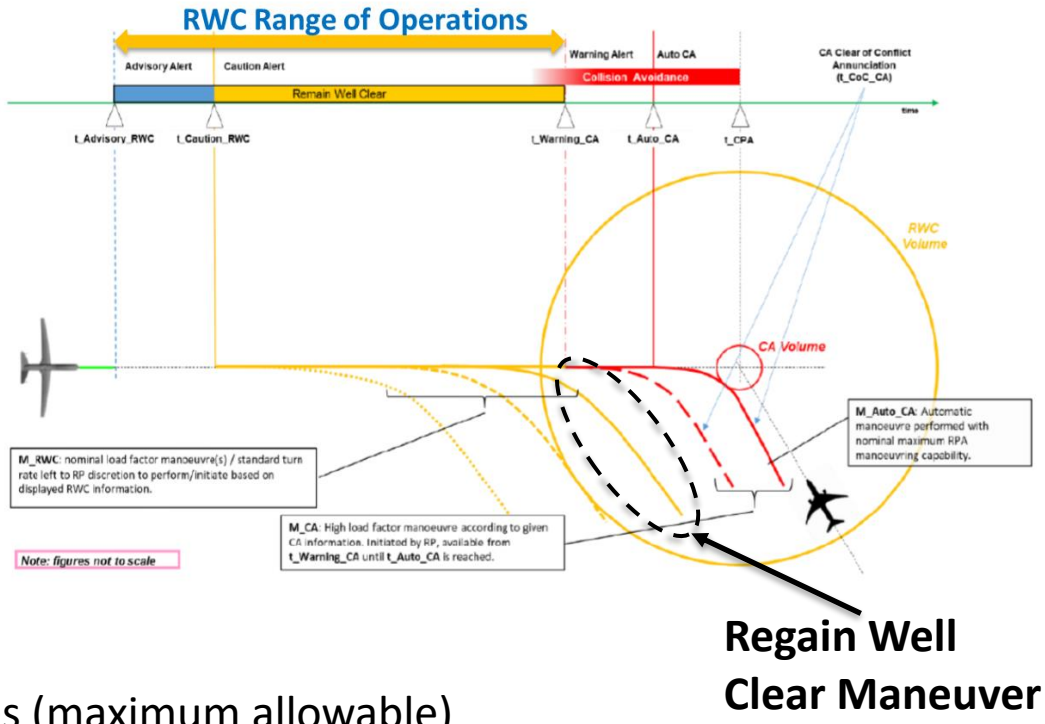
Not the Real HMI – Only for Reference

URClearED RWC Functional Concept

GUIDANCE

The guidance functionality is also in charge of **Regain Well Clear** computation

The ownship is already in the Well Clear Volume of an intruder or there is no horizontal or vertical manoeuvre that would avoid Loss of Well Clear, and no Collision Avoidance alert has been issued



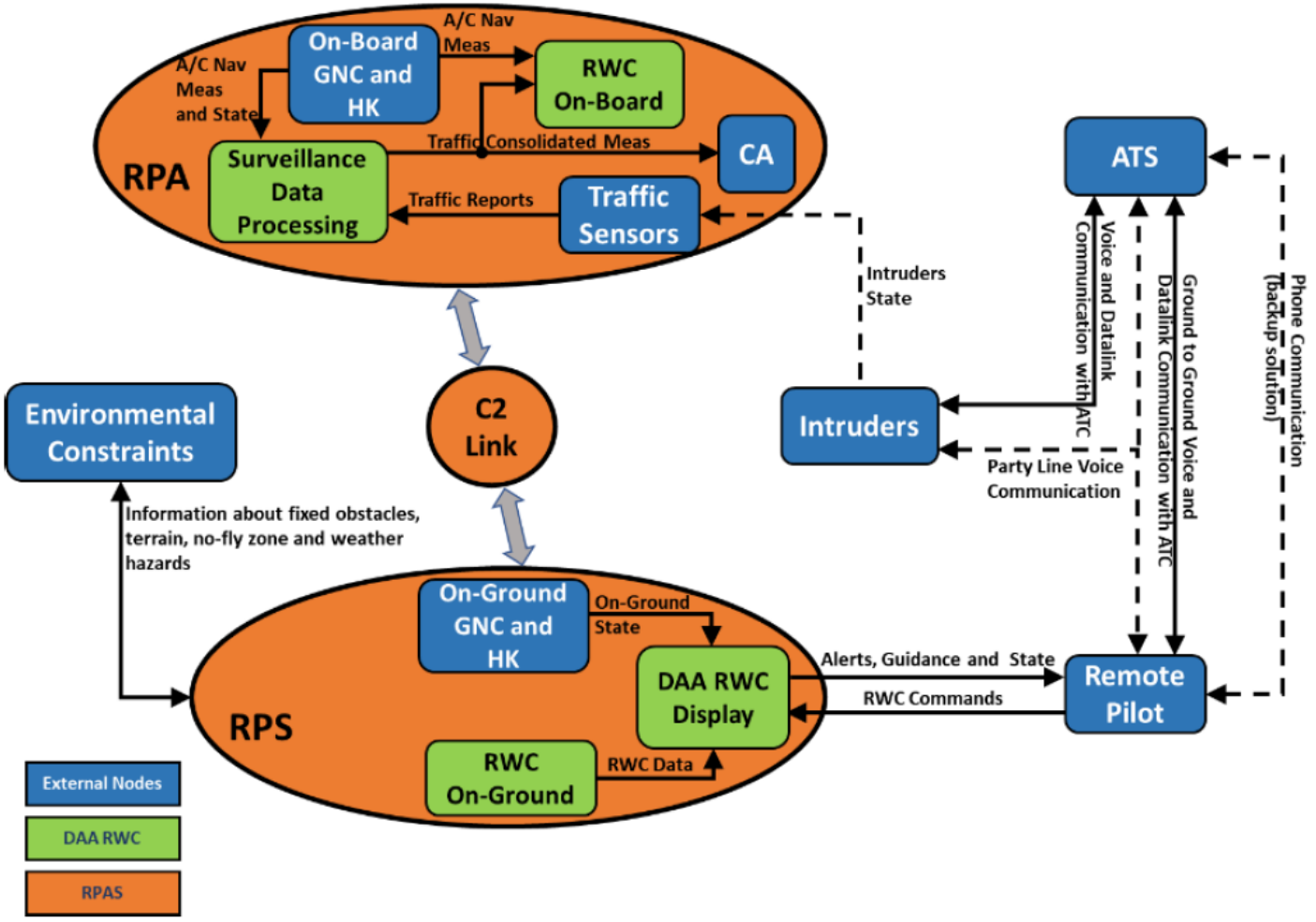
Possible Strategies

- Reduction of Well Clear Volume
- Use increased ownship performances (maximum allowable)
- Consider Blended Horizontal and Vertical Maneuvers

To Be Evaluated

URClearED RWC Operating Method

OPERATIONAL CONTEXT



URClearED RWC Operating Method

AIRSPACE CLASSES D-E

	RWC SYSTEM	REMOTE PILOT	ATCO
	Provide Info on Flight Rules/Priority →	Assess Intruder Flight Rules and Priority	
IFR Intruder	Caution Alert →	Assess Encounter Type Contact ATCO →	
	Provide Guidance Indication →	Negotiate Well-Clear Manoeuvre ↔	Negotiate Well-Clear Manoeuvre
		Execute the RWC manoeuvre	
		Request clearance to return to flight path →	Clear to return to FP

URClearED RWC Operating Method

AIRSPACE CLASSES D-E

	RWC SYSTEM	REMOTE PILOT	ATCO
	Provide Info on Flight Rules/Priority →	Assess Intruder Flight Rules and Priority	
VFR Intruder with priority	Caution Alert →	Assess Encounter Type	
	Provide Guidance Indication →	Ask an amended clearance for a RWC manoeuvre →	Clear the RWC manoeuvre
		Execute the RWC manoeuvre ←	
VFR Intruder without priority	Caution Alert →	Ask Info →	Provide Info (if available)
		Await for Intruder manoeuvre ←	
	Provide Guidance Indication →	If no VFR manoeuvre, ask clearance to manoeuvre for avoiding CA →	Clear to manoeuvre
		Execute manoeuvre to avoid CA ←	

URClearED RWC Operating Method

AIRSPACE CLASSES G

	RWC SYSTEM	REMOTE PILOT	ATCO
	Provide Info on Intruder Priority →	Assess Intruder Priority	
IFR or VFR Intruder with priority	Caution Alert →	Ask Info/Advice →	Provide Info/Advice
	Provide Guidance Indication →	Assess Encounter Type ←	
		Execute the RWC manoeuvre following the ROW rules Provide info to ATC on maneuver execution →	Monitor Maneuver
		Assess the Free of Conflict Conditions and Return to Flight Path	
IFR or VFR Intruder without priority	Caution Alert →	Assess the right of way Await for Intruder manoeuvre If no manoeuvre, ask clearance to manoeuvre	
	Provide Guidance Indication →	Provide info to ATC on maneuver execution →	Monitor Maneuver
		Execute manoeuvre Assess the Free of Conflict Conditions and Return to Flight Path	

Differences with existing operating methods

Topic	Current Operating Methods in Manned Aviation	New Operating Methods on RPAS integrated in ATM
Surveillance	Separation Management by ATC (if available) Pilot surveillance: visual or supported by ACAS and TFCI	RWC system supports surveillance by means of coop/non-Coop sensors, integrated with TFCI (when available). RWC CDTI supports situational awareness
Communication	Pilot-ATCO on VHF Radio Connection	RP-ATCO communication via G-G llink. Phone comms as backup.
Separation	Separation through ATC (when available), or through «see and avoid» pilot capabilities and RoW rules.	RWC system supports RP through Alert and Guidance functionalities. RP negotiate Well-clear manoeuvres, as provided by RWC and RoW rules. RP does never use visual separation
Situational Awareness System: Interaction with ATCO	TCAS TA. It does not require interaction with ATC	RP is assisted by RWC system. He/She is required to interact with ATC. The RWC system time range will take into account interaction with ATC. RWC alert does not interfere or superimpose to ATC instructions.

Differences with existing operating methods

Topic	Current Operating Methods in Manned Aviation	New Operating Methods on RPAS integrated in ATM
Return to Mission	The pilot requests a clearance to return to original FP, or notify it, depending on airspace class.	The pilot will wait the RWC system verify a free-of-conflict condition, then requests a clearnce for return to original FP, or notify it, depending on airspace class.
Contingency condition: Situational Awareness System Failure	TCAS failure does not compromise the operations, the pilot will monitor traffic through «see and avoid» capabilities	The remote pilot: • Inform ATC • Follow appriopriate procedures, by ATC if available or agreed contingency procedures if not, to limit the LoWC risks.
Contingency: C2 Failure	Not applicable	If C2L loss is permanent, RPA will automatically initiate agreed contingency procedures. Transponder set to ‘’Lost C2 Link’’ Code

Discussion Topics

Topic 1 – Quantitative Definition of Well Clear Volume (WCV)

The definition of Well Clear Volume (WCV) is a key element for a successful RWC system design.
In the URCLearED project, the following criteria are guiding the WCV parameter quantification:
The WCV in airspace D to G should be compatible with the WCV quantification in airspace classes A to C.
The WCV could be different based on the type of intruder, namely: non-cooperative, cooperative without ACAS and cooperative with ACAS.
WCV could be differentiated with altitude ranges.
In controlled airspace, WCV and related alerting time thresholds shall take into account that alerts to the RP shall not be issued before the ATC advisories.

1. Do you think the above criteria for quantitatively defining such volume are adequate or we need to consider also other factors?

Discussion Topics

Topic 2 – Interaction with ATC Safety Nets (STCA)

Considering the proposed RWC system requires that the Remote Pilot strictly interacts with ATCOs (in classes D and E), and that ATCOs normally can use Safety Net tools, specifically the STCA tool, for providing the Separation service:

1. Do you think that explicit interoperability, e.g. message exchange, should be implemented between STCA tool (or other ATCo tools) and the DAA-RWC?
2. In case the ATCO is responsible for providing separation, does the RWC system alert the Remote Pilot only in case ATCO lacks to act timely?
3. How long should be the time range between the STCA first activation and the RWC caution alert?

Discussion Topics

Topic 3 – Advisory Alerts

The concept of Advisory Alert is introduced just as a possibility in the ED-258, in order to eventually drive the attention of the RP to some traffic that can potentially become a conflicting intruder in the next few seconds. Following this concept, ATC shall not be contacted in case of an Advisory Alert. In the URClearED project, that concept has been retained and the RWC system is expected to emphasize traffic that, being currently the intruder not in the a Loss of Well Clear condition, it can breach the WCV in case of an undesirable manoeuvre is performed, by either the ownship or the intruder, in the horizontal or vertical plane.

1. Do you think this visual cue can be useful to the remote pilot or it might only increase the RP workload?
2. Do you consider as suitable/acceptable such criterion?

Discussion Topics

Topic 4- Regain Well Clear

There may be situations in which the ownship is already in the Well Clear Volume of an intruder or there is no horizontal or vertical manoeuvre that would avoid an imminent violation, and no Collision Avoidance alert has been issued. This can happen when:

a) the RP waited too much for performing an RWC manoeuvre
b) one of the aircraft has performed an unexpected manoeuvre while already in close range
c) a Collision Avoidance manoeuvre has been required and performed, and the Well Clear conditions have yet to be re-established.

These cases are treated within the term Regain Well Clear (or Regain DWC).

1. Do you think that a different Alert from the Caution Alert shall be generated, possibly displaying indications differently from usual guidance indication on the CDTI, for identifying such circumstance?

2. When in Regain Well Clear, the guidance algorithm shall anyway compute actionable information shall be designed. This can be done using different possible solutions, such as:

i) a reduced well clear volume,
ii) an increase of the performance at which the manoeuvre is executed,
iii) considering the possibility of performing blended horizontal and vertical manoeuvre.

Which of the above options could be the best solution from a pilot and ATC point of view?

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Thank you very much for your attention!

This project has received funding from the SESAR Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 892440

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