Final Report

MALE-Type RPAS Accommodation Study

EDA CALL REFERENCE: 17.CPS.OP.017

Doc. Ref: SIRENS/2018/FR

Issue 08 – 1st March 2019

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Abstract

Team SIRENS was set up to deliver this project and to provide long-term support to EDA and EASA on the journey towards the routine and seamless flying of RPAS in European airspace alongside manned aviation. The team is built on a philosophy of open and collaborative behaviours, working with all stakeholders to support this final goal via an iterative and collaborative approach and has all the necessary tools, expertise and resources to support the EDA's strategic objectives within the 2020-2025 time period.

The study outcomes represent a vital step on this journey and can be used to assist the EDA in developing regulatory frameworks and enabling technologies to make RPAS operations in non-segregated airspace alongside manned aviation an everyday occurrence.

The study has developed an enhanced Aviation Systems Safety Case Assessment Methodology and tested it in a series of simulation runs using experienced pilots and Air Traffic Controllers in a comprehensive and established ATM Simulation environment using Implementation scenarios, developed from the original Generic MALE RPAS Accommodation, as the backdrop to the simulation runs.

The results of the study will be widely disseminated amongst the European stakeholder community and used to inform other initiatives to help meet EDA's long-term strategic objectives.

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Document History

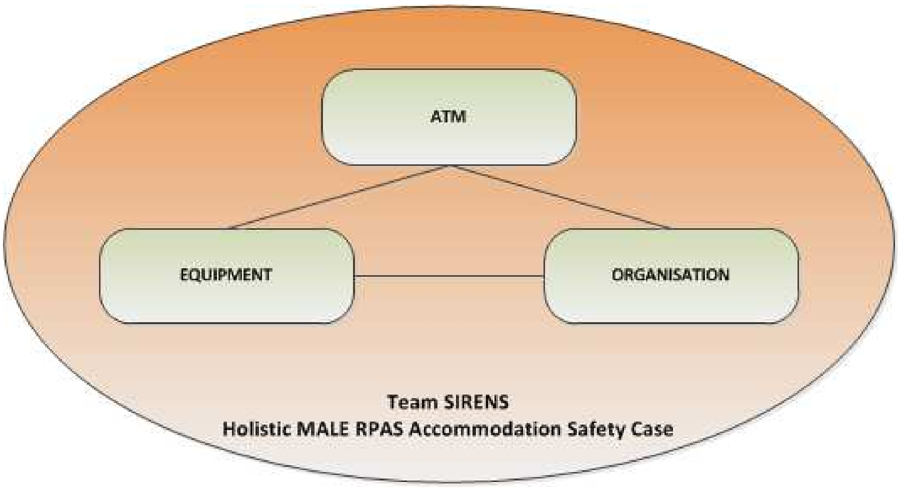
Issue	Date	Reason for change
Draft 01	1st November 2018	Initial draft for internal review
Draft 02	6th December 2018	Internal comments for final update
Issue 01	7th December 2018	Issue 01 for release to EDA
Issue 02	14th January 2019	SIRENS update incorporating EDA feedback and comment
Issue 03	18th January 2019	SIRENS update incorporating EDA feedback and comment
Issue 04	21st January 2019	SIRENS update incorporating EDA feedback and comment
Issue 05	25th January 2019	SIRENS update incorporating EDA feedback and comment
Issue 06	29th January 2019	Final version following EDA Webex Feedback
Issue 07	18th February 2019	Additional clarification on the holistic ASSC
Issue 08	1st March 2019	Standard disclaimer & study abstract added

Number of pages: 41

Executive Summary

Team SIRENS set out in January 2018 to further develop the concept of MALE-type RPAS Accommodation into European skies alongside manned aviation aiming to facilitate the move from 'accommodation' of these platforms towards their final 'integration' into the airspace. This will minimise the consequential impact upon other airspace users and ensure Air Traffic Management becomes seamless and routine whilst always being demonstrably safe.

The study produced and exercised a holistic Air Systems Safety Case (ASSC) methodology based on an assessment of the SESAR Safety Reference Materials (SRM)[1] alongside operational experience, stakeholder (expert) feedback and current best practice across three top-level functional 'pillars' as illustrated below:

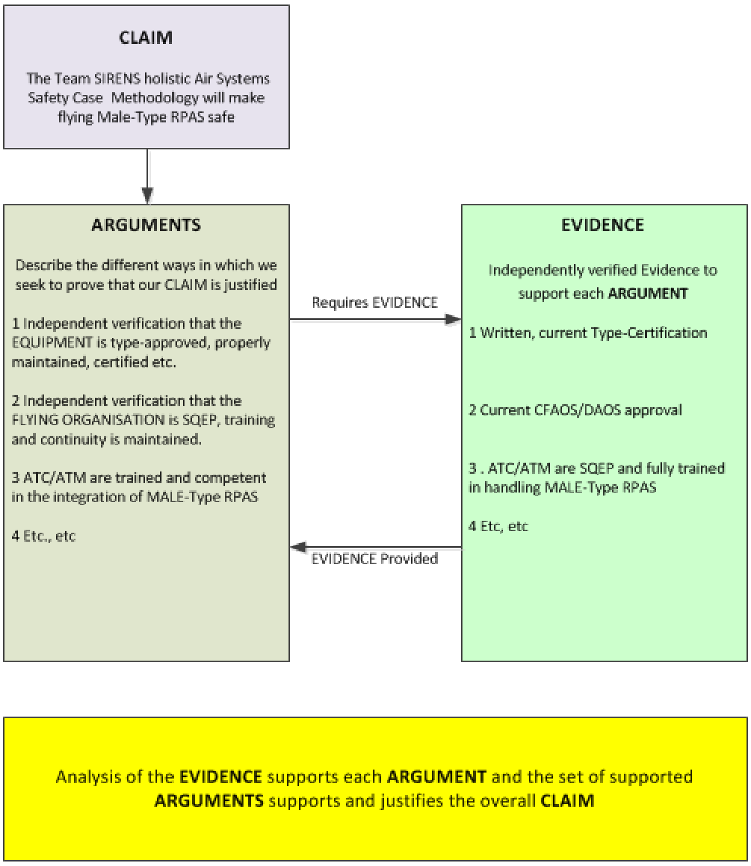


The study also expanded the Generic MALE-type RPAS accommodation scenario supplied in the EDA call for tender into a number of agreed Implementation Scenarios which were used to provide context and a backdrop to a Simulation Campaign used to test the developing Safety Case Methodology. Key stakeholders were engaged and invited to provide inputs and feedback throughout the study. A Dissemination workshop was held at Eurocontrol Headquarters where conclusions and recommendations were presented, discussed and reviewed in open forum.

Air System Safety Case Methodology

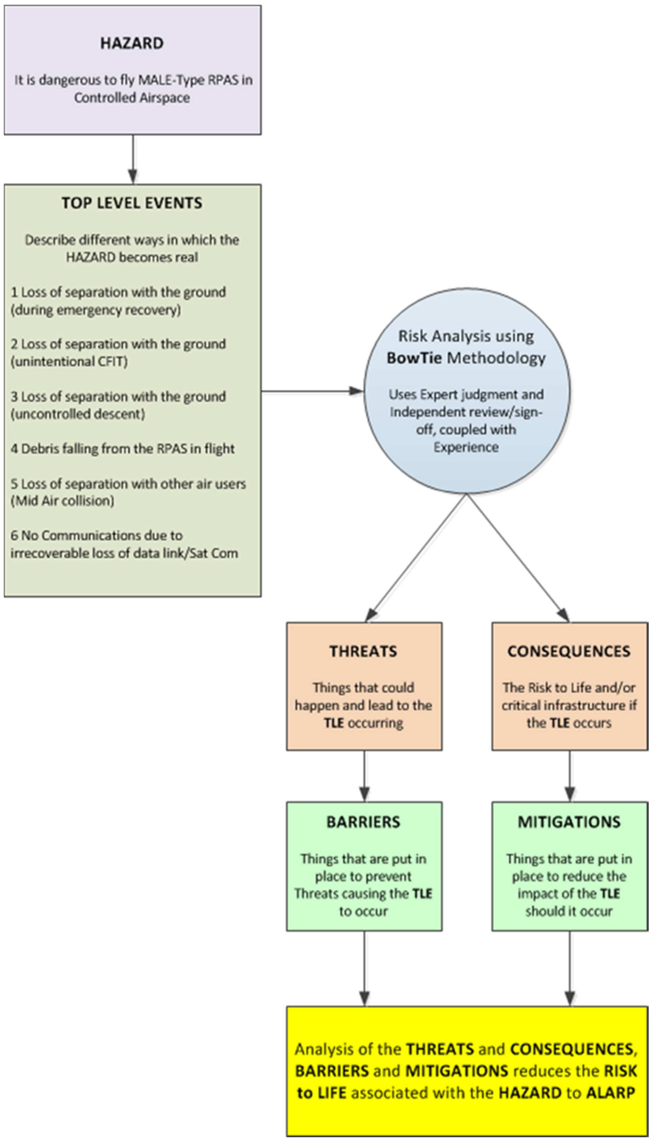
The methodology developed was used to assess the top-level **"Claim"** that it will be ***safe to fly a MALE-type RPAS within the context of the two Implementation Scenarios***. This "Claim" is supported by "Arguments" which are encapsulated in the Hazard (Risk) Analysis and presented using the BowTie methodology. Each "Argument" is independently assessed and only accepted as proven given compelling documentary "Evidence".

[1] SRM was considered for this holistic Air Systems Safety Case (ASSC) methodology but compliance was not demonstrated.



"Arguments"[2] were provided in the form of high-level safety statements such as: "*All ATCO's will be Suitably Qualified Experienced Persons (SQEP)"* and *"The RPAS has the correct type-certification and will be properly maintained"*. These were supported at a more detailed, lower level by the results of conducting a Hazard Analysis (using the BowTie methodology) which was designed to identify circumstances or events that would undermine or challenge the "**Claim"**. Each Hazard is characterised by one or more **"Top-Level Events"** (TLEs) the occurrence of which would potentially lead to a **"Consequence"** which is usually a **"Risk to life".** Each TLE is devolved into a series of ***"Threats"*** which could individually cause the TLE to occur and each threat is analysed in order to identify one or more "***Barriers*"** that would eliminate or minimise the ***probability of occurrence*** of the threat resulting in the TLE. The consequence of a TLE resulting in a risk to or loss of life is analysed and mitigated by identifying further barriers that aim to reduce the ***impact*** of the TLE.

[2] "Arguments" are developed by first decomposing the Hazard into a number of Top Level Events (TLE) that could cause the Hazard to occur.



The whole thread through the Risk Analysis from “Threat” to “Barrier” to TLE to “Mitigation” to “Consequence” represents an “Argument” that the RTL is reduced to “As Low As Reasonably Practicable” (ALARP). The outcome of this analysis results in the generation of an overall Air Systems Safety Case (ASSC) encapsulating: ***“Evidence”*** to support the ***“Arguments”*** to prove that the original ***“Claim”*** is justified.

Another key part of proving each ***“Argument”*** is to ensure that each of the identified ***“Threats”*** are real and that the ***“Barriers”*** are sufficient, either individually or collectively, to reduce the risk of the consequences occurring to ALARP. This verification exercise was undertaken using a series of Real-Time Simulations conducted under the team SIRENS Simulation campaign.

Originally, the study expected to include Quantitative Analysis to help quantify and rank hazards both before and after mitigation strategies (barriers) were identified and applied. This activity was discussed in depth and team SIRENS demonstrated that its use added little value to the study since the numbers needed to populate the bow-tie models were somewhat speculative without an adequately-defined MALE-type RPAS and a clear indication of its true performance parameters sufficient to draw meaningful and useful metrics. Notwithstanding this observation team SIRENS recognises that external barriers (such as the ATC being able to mitigate the consequential impact of a particular hazard) could be partially quantified using statistics and/or simulation without dependency on the RPAS performance characteristics. This rationale was accepted and backed-up by EUROCONTROL experts at the Dissemination Workshop.

The ASSC developed is considered as a good starting point for the next stage of migrating from accommodation towards integration as it provides a sound baseline and lays the foundation of a credible methodology on which to build in subsequent studies, simulation and demonstration activities. There is also potential to augment the safety assessment methodology to accurately determine the impact of the layered approach to conflict management (i.e. strategic; tactical and collision avoidance) when applied to MALE-type RPAS accommodation use cases.

1 Introduction

1.1 Document Purpose

This document is the Milestone deliverable (D4) Final Report for the MALE-type RPAS Accommodation Study (Ref: 17.CPS.OP.017) let by the EDA to Team SIRENS at the Project Launch Workshop held at EDA HQ in Brussels on January 11th 2018.

This document is a summary report designed to give the reader a concise understanding of the overall aims of the study, the conclusions reached and the recommendations made by Team SIRENS. The detail of how the study was conducted and how the conclusions and recommendations evolved are to be found in the aforementioned deliverable documents (D1, D2 and D3) as previously submitted to EDA and updated incorporating invaluable stakeholder review and feedback.

The study was conducted according to the flow depicted in Figure 1:

1.2 Study Background

The EDA have embarked on a long-term strategy to enable the integration of RPAS into European skies alongside manned aviation and this study forms an important part of the initial work programme aimed at achieving that goal – more information may be found at:

https://www.eda.europa.eu/what-we-do/activities/activities-search/remotely-piloted-aircraft-systems---rpas/

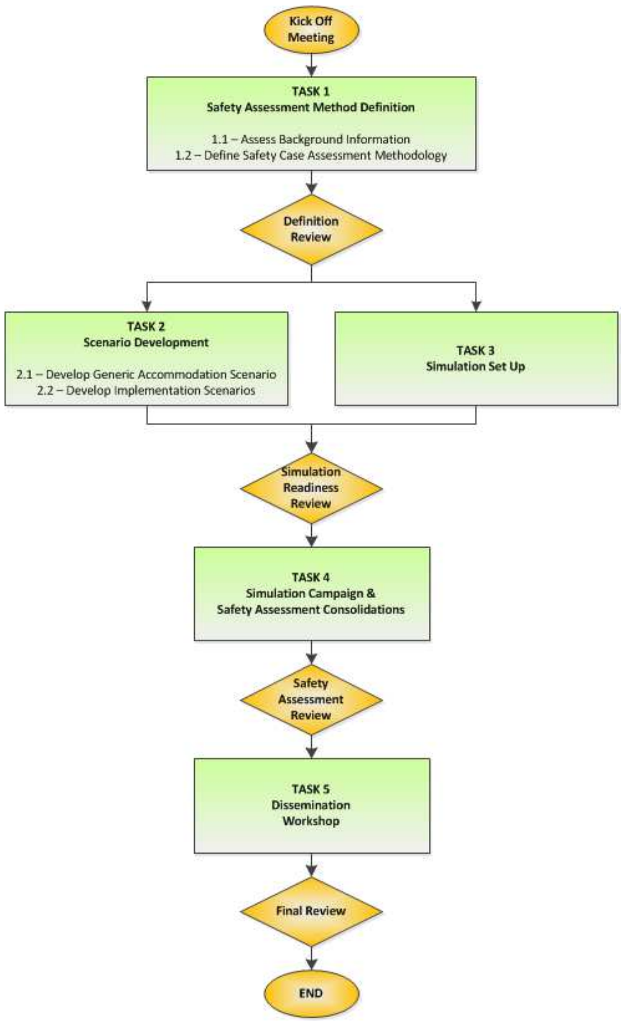


Figure 1 – Study Flow

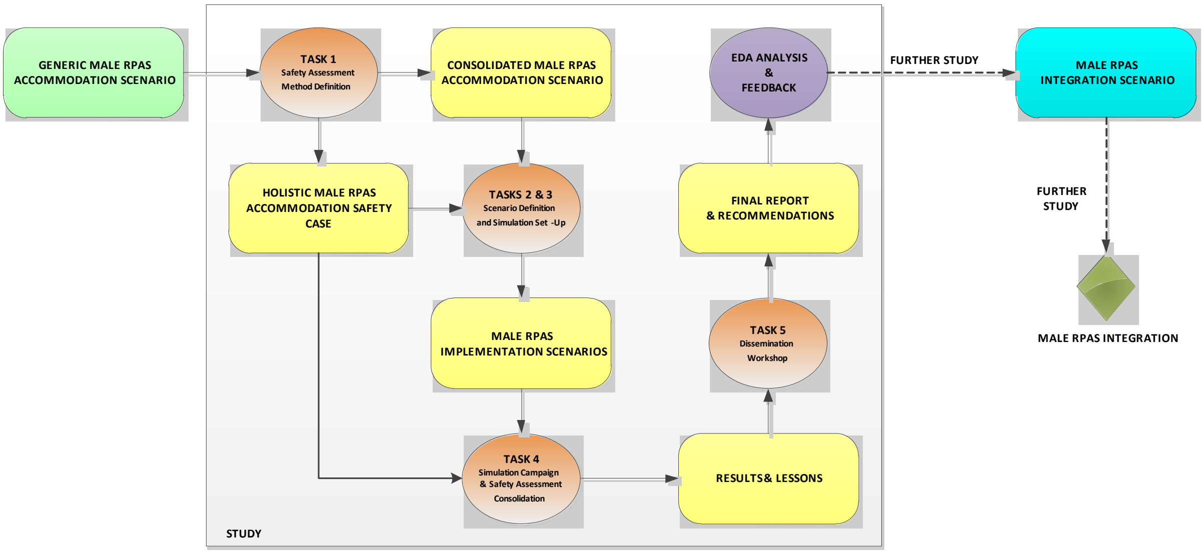


Figure 2 – Study Linkage

1.3 Overview of the Study Tasks & Deliverables

1.3.1 Task 1 – Safety Assessment Method Definition

This task took the BowTie ASSC methodology employed on a Military, Tactical RPAS and developed it into the holistic ASSC - for MALE-type RPAS - for use throughout the remainder of the study; the main update task was to include the key Air Traffic Control safety elements crucial to RPAS accommodation in non-segregated airspace and paving the way for subsequent integration.

The conduct and outcomes of this Task are captured in the D1 deliverable.

1.3.2 Task 2 – Scenario Development

This task developed the Generic MALE-type RPAS Accommodation scenario baseline defined in the original call for tender into two discrete Implementation Scenarios which were used to provide context and background to the Simulation Campaign conducted in Task 4.

The conduct and outcomes of this Task are captured in the D2 deliverable.

1.3.3 Task 3 – Simulation Set-Up

This task developed the detailed ‘runs’ and simulation environment set-up to be used throughout the Simulation Campaign for the purposes of testing aspects of the holistic ASSC methodology.

The conduct and outcomes of this Task are captured in the D2 deliverable.

1.3.4 Task 4 – Simulation Campaign & Safety Assessment Consolidation

This task executed the simulation 'runs' and assessed the results against the backdrop of the ASSC when applied to the agreed Implementation Scenarios.

The conduct and outcomes of this Task are captured in the D3 deliverable.

1.3.5 Task 5 – Dissemination Workshop & Final Report

This task conducted the Stakeholder Dissemination Worksop at EUROCONTROL Headquarters in Brussels and produced this report in cognisance of stakeholder comments, observations and feedback.

2 Study Overview

2.1 MALE-TYPE RPAS Accommodation and Integration

There are many activities being conducted worldwide under the auspices of a number of bodies (including EDA, SESAR; JARUS; EASA; ICAO etc.) whose common aim is to work towards the full and seamless integration of RPAS alongside manned aviation '**as if**' the RPA was conventionally manned, thus with no significant impact on normal air traffic management or other airspace users. In order to realise this objective a number of significant technological, regulatory and societal barriers must be overcome – an interim solution is the use of special procedures to enable 'constrained' RPAS operations to accommodate platforms in mixed traffic environments. A number of definitions have been developed with the premise that 'accommodation' is a series of incremental steps that will eventually lead to full integration subject to suitable enablers and safety mitigations being established and agreed in close association with regulatory bodies.

Integration may be defined as the state where RPAS and conventional manned aviation are considered, managed and controlled in a similar manner, without ATM being impacted by the difference (essentially location of the Pilot) or incurring additional workload burden. Team SIRENS believes, that RPAS will need to be distinguished from manned aviation by some type of notification (e.g. flight plan or unique call sign) so that ATCOs are aware of the difference in pilot situational awareness (the RP being remote without the possibility of exhibiting intuitive behaviours nor looking out of the window[3]) and in the potential mitigation response to a lost-link hazard event resulting in compromised situational awareness[4].

RPAS **Accommodation** is defined by the International Civil Aviation Organisation (ICAO) as "*the condition when an RPAS can operate along with some level of adaptation or support that compensates for its inability to comply within existing operational constructs".* The "existing operational constructs" are not yet specified for RPAS operation and until new operational constructs are in place, including the regulatory framework and required technology, all RPAS operations in European airspace will have to accept a certain degree of **segregation** from other manned and unmanned aircraft. Regulatory frameworks and operating procedures will be required to support routine RPAS operations (possibly as enablers to accommodation) - these will be developed so as not to disrupt current operations nor add additional burdens to traditional manned aviation. Some recommendations and procedures may have a minor impact on manned aviation and air traffic procedures though this has yet to be fully assessed.

The ERSG Regulatory Roadmap definition of Accommodation is:

'Accommodation' means limited RPAS access to non-segregated airspace via special procedures and mitigations. These include permits to fly, restricted airworthiness certification processes and the use

[3] Unless a forward-looking camera system is installed on the RPA and even these have limitations, currently.
[4] Some RPAs climb to try to re-acquire the C2 link others may return to a previous 'good' position. Team SIRENS recommends that these behaviours become 'normalised' through regulation so as to reduce the burden on ATM.

of airspace to segregate RPAS operations from manned operations. Such operations are considered on a case-by case basis to ensure that today's non-standardized RPAS performance and operational features do not adversely affect safety or efficiency. As RPAS research, rulemaking, and policy developments enable an increase in integrated operations, the need for accommodation will decline significantly

The diagram below (Figure 3) illustrates a potential overall roadmap for MALE-type RPAS Accommodation from full segregation, through a number of accommodation steps to full integration where RPAS are treated in the same way as 'normal', manned aviation (notwithstanding the discussion above).

Accommodation also encompasses (starts with) full segregation, which is the current approach adopted by most European nations. However, this imposes severe restrictions for operations and training purposes and there are therefore several on-going initiatives to enable (one or a number of) more flexible accommodation scenarios to be defined, particularly the use of an iterative approach to enable RPAS to operate under Instrument Flight Rules (IFR) in non-segregated airspace in specific flight phases of the operation.

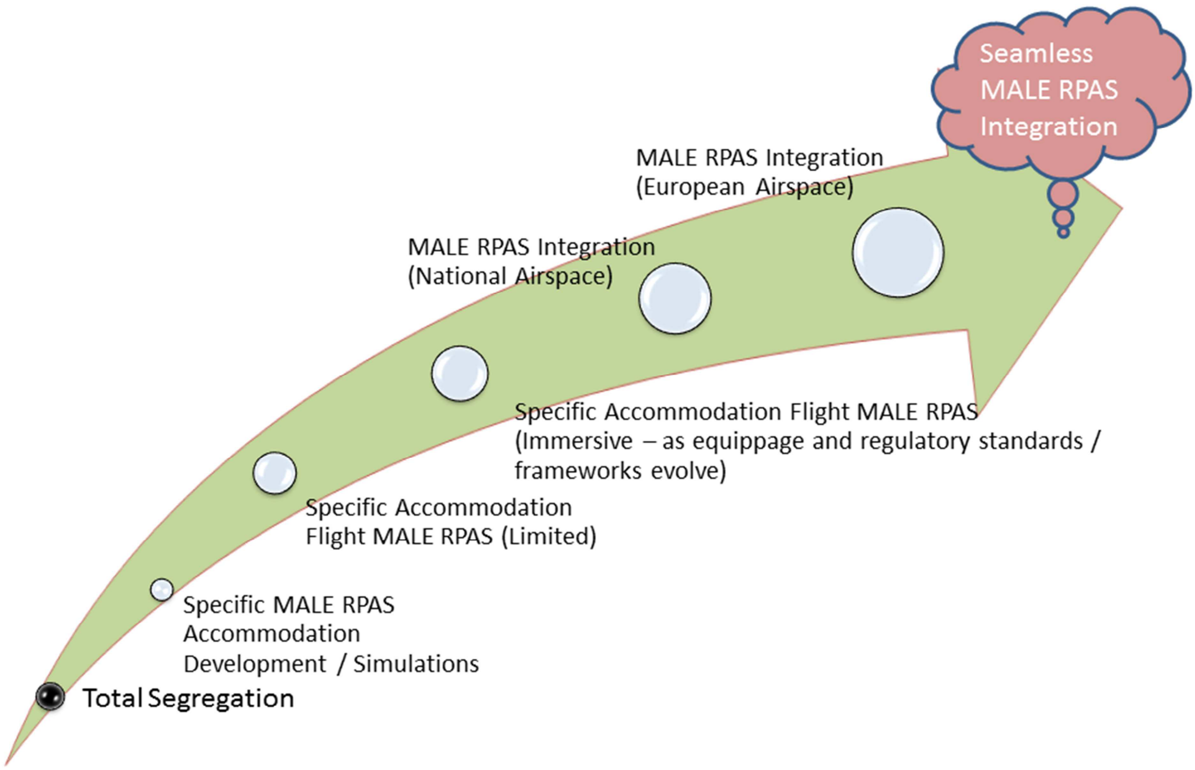


Figure 3 – MALE-type RPAS Accommodation roadmap

Military operators are currently the main stakeholders involved in enabling RPAS operations in the conventional ATM system[5] (i.e. excluding U-Space and small RPAS operations likely to operate in very low level airspace). Military RPAS are expected to be amongst the earliest adopters of IFR[6] RPAS operations involving civil Air Traffic Control and, as such, they are expected to pave the way to enable these kinds of operations between 2020 and 2030. Opportunity was given to discuss operational experience and lessons learnt by the French Air Force who have acquired a wealth of knowledge in MALE-type tasks over several years, (please see D1, Section 3.2 for further details). The study also used the ongoing accommodation of the Global Hawk UAS into European skies as important background – this case is summarised in D1, section 3.3.

2.2 Safety Case Assessment Methodology

2.2.1 Overview

Starting from an Equipment and Organisational perspective, team SIRENS developed a holistic Air Systems Safety Case Methodology by integrating Air Traffic Management best practice to generate the holistic ASSC as shown below in Figure 4.

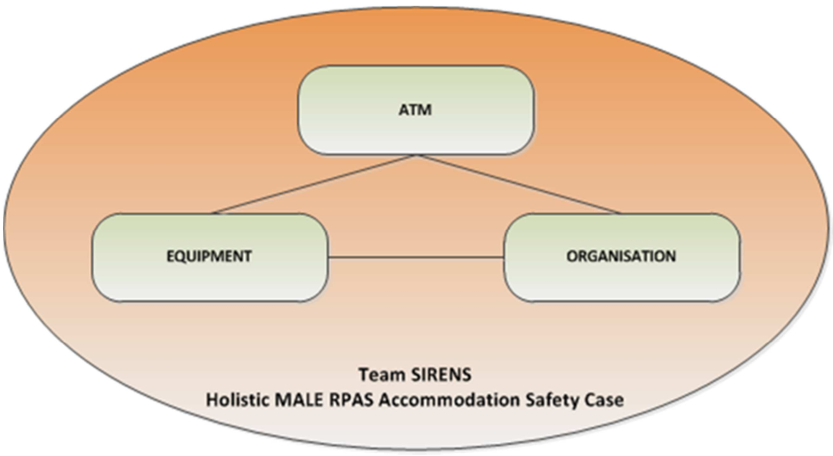


Figure 4 - Holistic ASSC

The Hazard Analysis process underpinning this approach is encapsulated in the BowTie methodology. Pictorially, a top-level BowTie model may be summarised as per the illustration below.

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[5] However team SIRENS believe that commercial freight organisations are, or will also be, key stakeholders in this area alongside other commercial and governmental operations such as agricultural surveying; homeland security; maritime surveillance; environmental monitoring; and numerous other potential applications.

[6] Instrument Flight Rules (IFR) are rules which allow properly equipped aircraft to be flown under instrument meteorological conditions (IMC), i.e. when flying and navigation based on outside visual reference is not safe or possible. IFR flight depends upon flying by reference to instruments in the flight deck, and navigation is accomplished by reference to electronic signals.

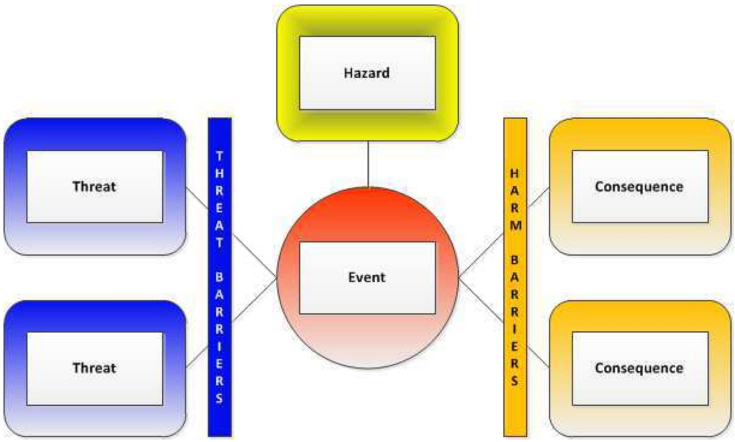

Figure 5 - Simple Bow Tie

Each identified 'Hazard', marked in rectangular yellow & black stripes is characterised by one or more 'Top Level Events (TLE)' marked in red & orange circles in Figure 6 below. Each TLE may be caused by one or more 'Threats' (blue rectangle) placed to the left and if the TLE occurs it may lead to one or more 'Consequences' (red rectangle) placed to the right. Each 'Threat' may be prevented or each 'Consequence' mitigated by one or more 'Barriers' (grey and white vertical rectangle) placed between the Threat and the TLE or between the TLE and the Consequence.

Threat barriers may also be dependent upon some other action or threat also known as an 'Escalation Factor' – these are shown in yellow rectangles. Similarly, each mitigation barrier may lead to a further 'Escalation Factor' or Consequence and these are shown in the vertical rectangles below.

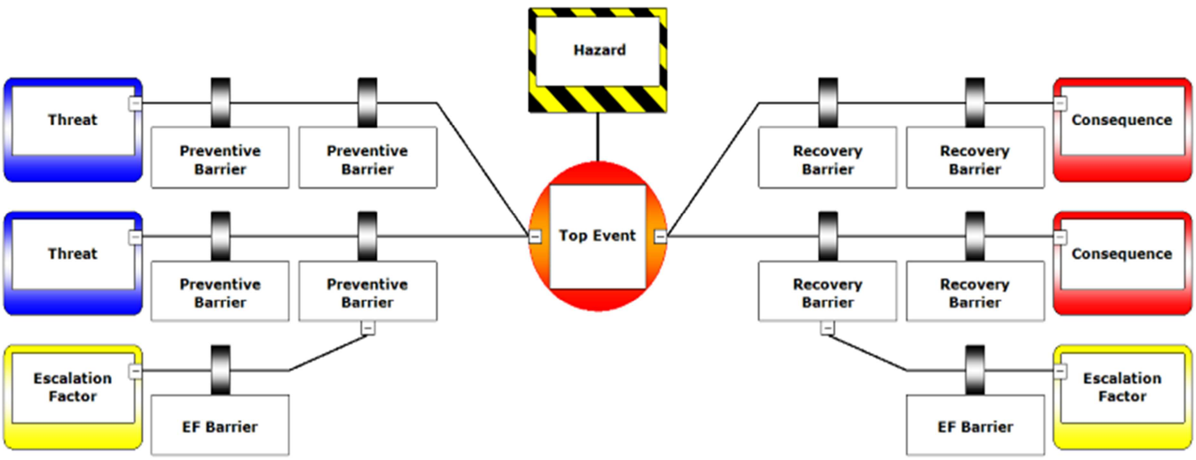

Figure 6 - Extended Bow Tie

Threats were identified across all three pillars of the ASSC: Equipment (something might malfunction); Organisation (someone might make a mistake in the flying or maintenance of the system) and ATM (an ATCo might expect unrealistic behaviour or performance characteristic from an RPA if not properly aware or briefed).

2.2.2 Detailed Risk Assessment

Team SIRENS applied the Bow Tie Methodology as their Risk Assessment and Mitigation Methodology, see the visual representation in Figure 7. This included threats that could cause the Top Level Event (TLE) to occur, which in turn may lead to a Hazard. Similarly, barriers (or controls) are identified which serve to mitigate and protect against the threats which could result in the increased Risk to Life (RtL). Consequences are also identified to understand the level of RtL which could result from the Hazard.

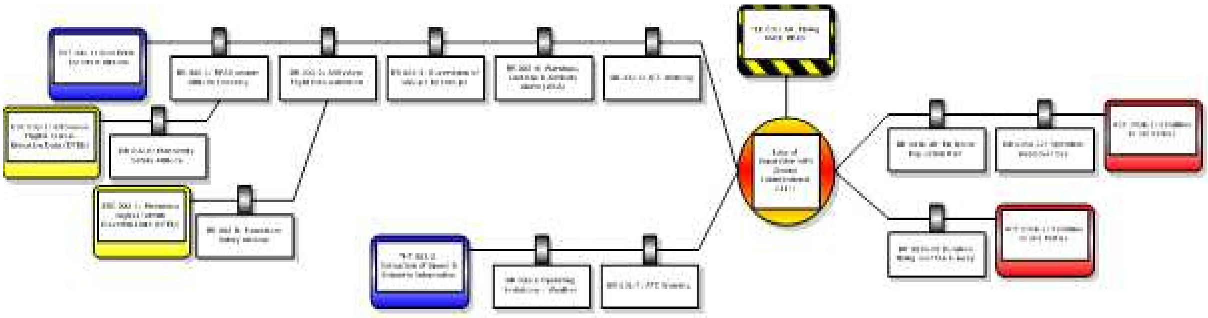

Figure 7 – Populated Bow Tie for 'Loss of Separation with the Ground (Unintentional CFIT)

The BowTies are analysed using a semi-quantitative analysis approach whereby Layers of Protection Analysis (LOPA) techniques are used for analysing and assessing Barriers & Controls. LOPA uses an order of magnitude approach to evaluate the adequacy of existing or proposed layers of protection against known hazards.

In the Task 1 Report (D1) Team SIRENS addresses MALE-Type RPAS accommodation into European skies and considers the RtL associated with the following Hazards;

- Airborne Risk to Life:
    - Loss of separation with other airspace users leading to mid-air collision, this includes cleared airspace boundary proximity violation
- Ground Risk to Life:
    - Equipment failure leading to uncontrolled decent
    - Equipment failure leading to falling debris
    - Mid-air collision (as above)

Team SIRENS assumes that the RPAS pilot manoeuvres his RPA by remote control, using vectors received from an ATCO, leading to the following assumptions:

- The RPAS pilot has limited means to directly interrogate and interact with other airspace users in the controlled airspace. In addition to the ATC primary surveillance radar the MALE-type RPAS platform is likely to incorporate some CNS equipage based on ADS-B transponder or similar 'broadcast/receive' technologies to share positional information that may be used by other suitably equipped aircraft to provide improved situational awareness and support the principles of self-separation. Though several advanced transponder based technologies are available and are currently being trailed in unmanned aircraft, there is still a pressing need to develop and agree a set of common procedures and performance standards. The availability of non-cooperative sensing techniques (such as optical or radar) will eventually contribute to the situational awareness picture compilation and enable RPAS to detect non-equipped air traffic which may have inadvertently entered the controlled airspace (or possibly to mitigate against situations whereby the RPA may have strayed outside controlled airspace – such as in emergency conditions forcing diversion into Class G airspace). It is assumed that necessary procedures and equipment standards to support Non-Cooperative Detect and Avoid (DAA) will not be readily available within the 2020-2025 timeframe.

- ATC detects and vectors all aircraft in controlled airspace;
- RPA will require a 'person in-the-loop' to ensure 'appropriate' avoidance manoeuvres are authorised and implemented in cognisance of emergent rules of the air and other considerations such as weather, airspace structures and proximate traffic. Work continues to develop 'appropriate' manoeuvres for RPAS in a similar manner to extant TCAS standards exist for manned aviation; however it is essential that a harmonised approach is agreed.
- DAA is not included in the team SIRENS simulations as it is considered (that for accommodation of few RPAS into controlled airspace) the ATM organisation Standard Operating Procedures (SOP's) are capable of providing appropriate separation assurance with manned aircraft. However, to facilitate progression from accommodation of few RPAS to full integration of multiple RPAS in controlled airspace, the introduction of a certified and capable DAA system will be necessary.

2.2.3 Threats and Barriers[7]

Further analysis the Threats leads to one or more possible actions to mitigate the consequences of these threats for the two Top Events. The Threats and mitigation measures lead to elements that need to be included in the simulations, hence in the Implementation Scenarios. The list of Threats is indicated in Table 1, together with the proposed mitigation measures and elements to be included in the simulations. Individual Threats are numbered in the table below; these numbers can be further subdivided if several mitigation actions and/or several situation elements are possible.

Table 1 –Threats and barriers to be exercised for MALE-type RPAS integration in European skies

#	Threat	Mitigation	Simulation event
1-1	ATC is unable to detect the RPA or the other airspace user.	If RPA visible to ATC on primary radar, ATC can ask to squawk IDENT to check functional status of the equipment. Else the pilot has to report the RPA position to ATC or ATC	RPA visible on primary radar: not simulated in SIRENS because procedure for RPA is the same as for manned aircraft, and hence there are no specific issues to simulate.
1-2			RPA not visible on primary radar:

[7] All Threats & Barriers assessed are of an operational nature. The threats identified are considered as the operational means by which the Hazard would occur.

#	Threat	Mitigation	Simulation event
		instructs RPAS pilot to leave controlled airspace.	simulated in SIRENS.
2a-1	ATCo is unable to communicate with the pilot of the RPAS or the other airspace user.	RPAS pilot and ATC may communicate by telephone.	RPAS pilot phones ATC: simulated in SIRENS.
2a-2			ATCo phones RPAS pilot: simulated in SIRENS.
2a-3			If ATCo and RPAS pilot unable to communicate by telephone: this is not simulated in SIRENS because then the 'lost comm' procedures of manned aviation apply, and hence there are no specific issues to simulate.
2b		Other airspace user: The pilot of a manned aircraft squawks 7600 and follows a prescribed 'lost comms' procedure.	Not simulated in SIRENS because manned aircraft is beyond scope of SIRENS.
3-1	The pilot of the RPAS or the other airspace user does not maintain separation.	ATC monitors the flights of individual aircraft and issues vectors before separation is compromised.	ATC anticipation of potential loss of horizontal separation is simulated in SIRENS.
3-2			ATC anticipation of potential loss of vertical separation is simulated in SIRENS.
4a	The pilot of the RPAS or the other airspace user is unable to manoeuvre his RPA/aircraft.	The RPAS is equipped with a dual C2 link for the manoeuvring of the RPA.	Single C2 link failure is simulated in SIRENS.
4b		If both C2 links are lost, the RPA is equipped with an on-board system to automatically fly a predetermined procedure.	Dual C2 link failure is not simulated in SIRENS because already demonstrated in CLAIRE.
4c		The pilot of the manned aircraft may issue a mayday call and squawk 7700.	Not simulated in SIRENS because manned aircraft is beyond scope of SIRENS.
5	Loss of performance.	Abort mission and return, divert or perform an emergency landing.	No specific role for ATC, ATC asks pilot about his intentions, and facilitates (re)routing. Not simulated in SIRENS because procedure for RPAS is the same as for manned aircraft, hence no specific issues to simulate.
6	Loss of manoeuvrability.	Inform ATC about the reduced manoeuvrability.	Not simulated in SIRENS because RPAS can still perform manoeuvres.
7	RPAS pilot wishes to deviate from assigned route.	ATC assigns route that does not conflict with the routes of other aircraft.	Request of RPAS pilot for rerouting is simulated in SIRENS.
8	RPAS unable to navigate to waypoint	ATC provide RPAS pilot with vectors.	Simulated in SIRENS.

#	Threat	Mitigation	Simulation event
	because GPS unable to determine position.		
9	The RPAS experiences an issue for which ATC support is requested.	Depends on the issue and on how RPAS is designed to deal with it.	Simulated in SIRENS.

This way, using the BowTies method, a number of events are found that one-on-one is a translation of the mitigation measures to the Threats identified. The events will now be included in the SIRENS-simulations in order to evaluate the corresponding Threat. In the next section, a number of scenarios will be elaborated, based on these events.

2.3 Accommodation Scenarios

The **generic accommodation scenario** flight profile is described in detail in D2 and is illustrated below:

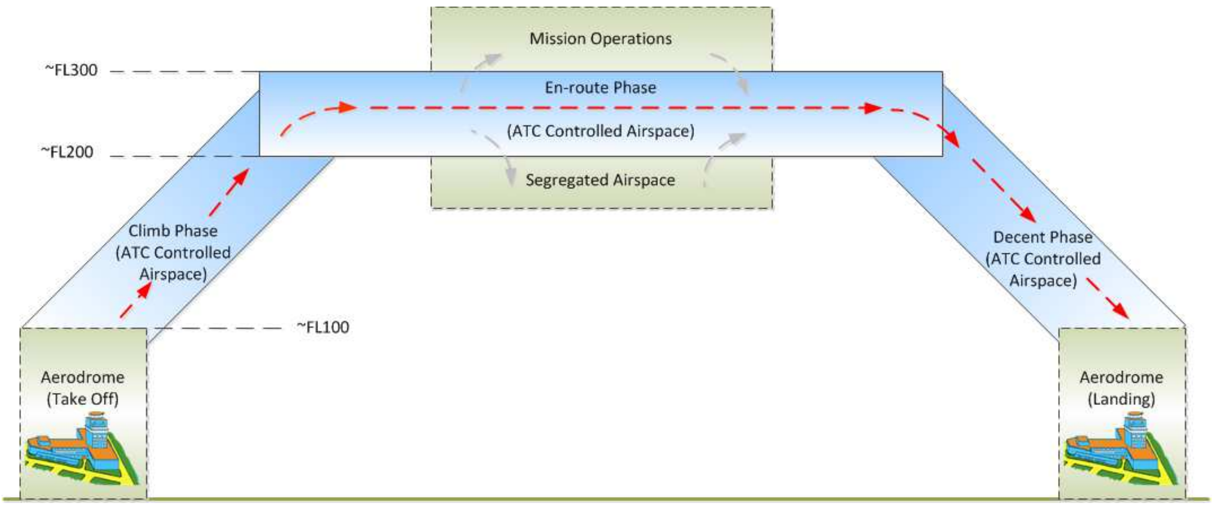

Figure 8 – Flight Profile for the Generic RPAS Accommodation Scenario

As illustrated, the generic accommodation scenario requires the partial use of segregated airspace under the control of ATM/ATCO and is a good start point to explore the issues of ground and air risk. In order to further develop the concept of 'Accommodation' it will be necessary to determine suitable measures to allow MALE-type RPAS to share controlled airspace with manned aviation and progressively overfly more densely populated areas and occupy more complex and congested airspace.

In general terms, air risk relates to dangers to or from other air traffic and ground risk relates to danger to people, property, infrastructure and/or the environment caused by an RPA equipment failure in the air which may lead to a crash or debris falling onto the ground below.

In Task 2, the generic accommodation scenario was developed by introducing elements of complexity to form the 'consolidated' generic accommodation scenario, elements of which were then selected for simulation in the implementation scenarios. Examples of complexity elements include but are not limited to:

- Use of Civilian aerodromes
- Relaxing the limitations placed upon air traffic assumptions by including operations in non-segregated airspace – such as complex airspace structures and areas of heightened traffic densities
- Developing the assessment of Ground risk to include flight over more densely-populated areas and closer to critical infrastructures
- Widening the operational time windows to include peak times and uncertain traffic flows
- Demonstrating the ability to cope with environmental impacts such as adverse weather
- Including a Statement of Assumptions relating to regulation and certification (of people, systems, equipment and support services)
- Adding an analysis of the use of platform equipage options (such as Detect and Avoid and consideration of more sophisticated CNS capabilities)

The following set of assumptions emerged from the analysis of the Generic Accommodation - Scenario; these provide the basis for quantitative analysis to undertake a risk assessment. Other assumptions may be introduced into the assumptions register to support this approach – these may include factors such as platform performance data; applicable flight rules, ATC interaction and more complex encounter types:

a) RPAS is Certified
b) Remote Pilot is trained /Suitably Qualified & Experienced Personnel (SQEP) and licenced/approved
c) Mission Objective Operations take place in Segregated Airspace
d) SATCOM is used for BLOS/BVLOS
e) Ground communications are in place for back-up between ATCO and GCS however routine communications will be via normal VHF radio
f) RPAS will execute a standardised and predictable protocol for lost-link behaviour.
g) RPA is capable of supporting the operating requirements of the proposed flight profiles in terms of Performance, Communications and Visibility to ATC. Necessary equipage includes availability of Mode-S Transponder; VHF Radio (relay) as well as mandatory CNS equipage
h) DAA capability is currently not available due to immature enabling technologies, operating protocols and performance standards
i) The RPAS will navigate based on GNSS rather than by using conventional navigation aids.

The **Implementation Scenarios** took the generic accommodation scenario and refined it (constrained it) by locating them in specific airspace; defining the time of day to be used; the ground population density to be over-flown and the air traffic densities to be encountered and the method of navigation.

The RPAS will be operating from Rotterdam/The Hague airport (EHRD) in The Netherlands. This airport is located to the south of the larger airport of Schiphol (EHAM) and, although in principle strategically separated, traffic of both airports may interact.

The RPAS scenarios are based on two flight plans:

Flight plan #1:

DEPT: EHRD DEST: EHRD ALTN: EGMD F240 N0170
REFSO – Z291 – ODROP – STAY1/0300 – SONOG – M183 – REDFA – DCT – MASOS
STAYINFO1/RACETRACK BETWEEN ODROB AND SONOG

Flight plan #1 is for an aerial surveillance mission in the London FIR (Flight Information Region), above the North Sea, just west of the border between UK and NL airspace.

Flight plan #2:

DEPT: EHRD DEST: EHRD ALTN: EHKD A030 N0170
COSTA – DCT – DIBRU – STAY1/0300 – VALKO – DCT – ROT
STAYINFO1/RACETRACK BETWEEN STD AND HSD

Flight plan #2 is for an aerial surveillance mission above the North Sea along The Netherlands coastline; in flight this mission will be re-tasked for a mission in the London FIR, just west of the border between UK and NL airspace in an area different from the area for flight plan #1.

Both flight plans included 3 hours of airborne surveillance but for the simulation runs only a few orbits were flown.

2.4 Simulation Campaign

Based on the Implementation Scenarios, a number of Simulations ‘runs’ were designed to test key points in the application of the ASSC to the scenarios in order progress the overall study aims.

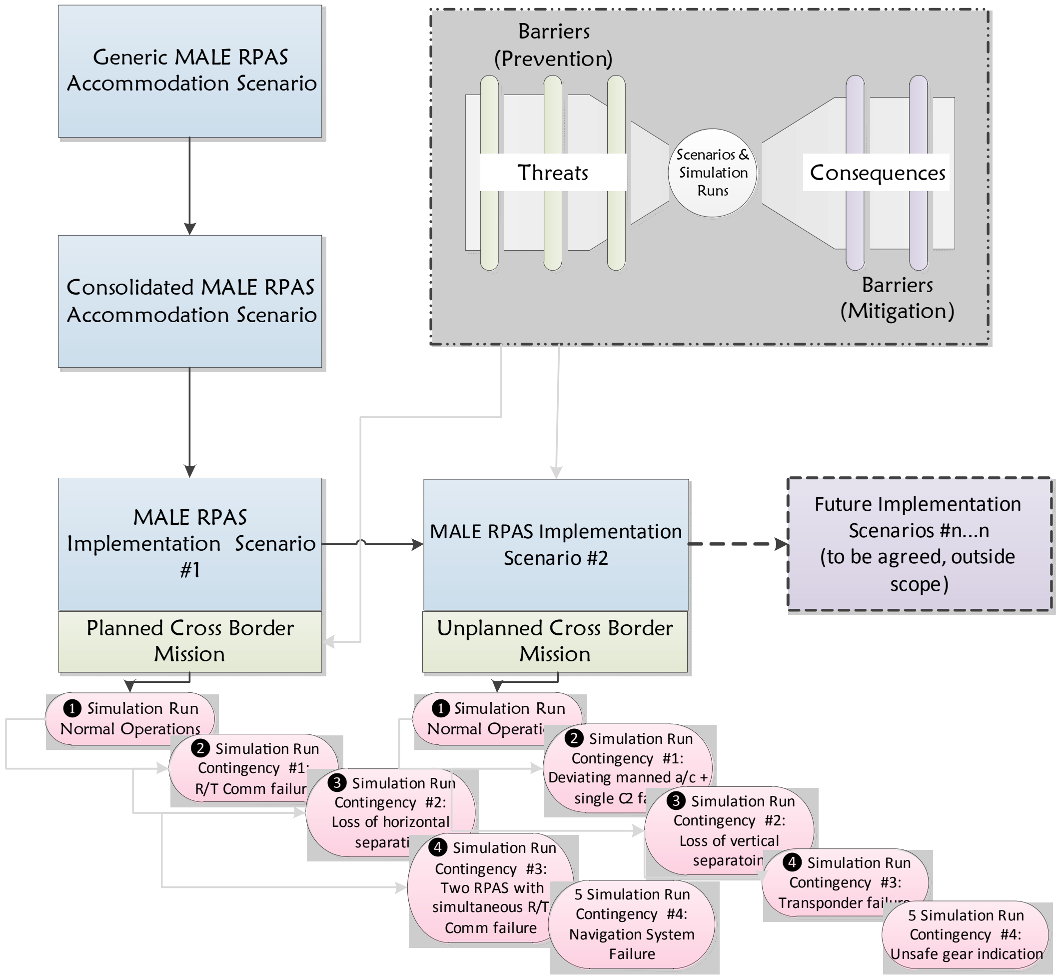

Figure 9 - Simulation Campaign Overview

The details of the Simulation runs conducted can be found in D2, section 3.6.

2.5 Developed Air Systems Safety Case

2.5.1 Top-Level ASSC

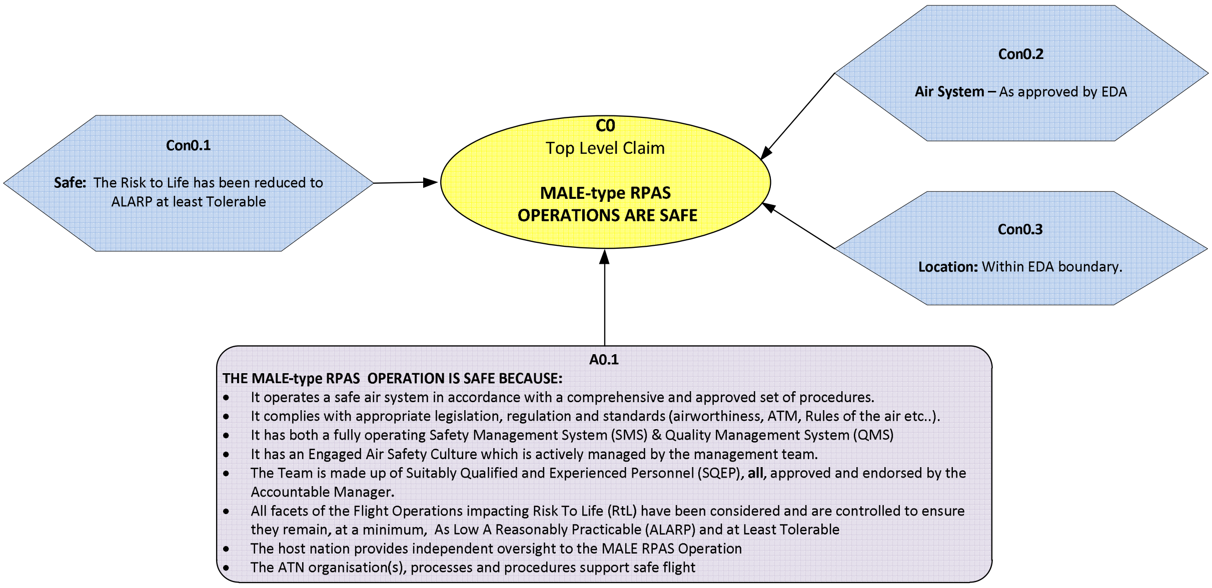

Figure 10 - Top Level Safety Case Claim

The top-level claim is that the planned MALE-type RPAS flight operations are safe because:

- The Risk to Life has been reduced to 'As Low As Reasonably Practicable (ALARP) and at least Tolerable ' by:
  - Ensuring the MALE-type RPAS 'Equipment' is safe
  - Ensuring that the MALE-type RPAS Operators are safe, and
  - Ensuring that the ATM organization, processes and procedures, support safe flight

2.5.2 ASSC Development

The Claim; Argument; Evidence methodology which has been used to develop the ASSC is more fully described in section 3.1.1 of this report. Each of the three sub-claims (see above paragraph) is hierarchically devolved to greater levels of detail which is ultimately captured using a number of BowTie models. This has been expanded in Figure 12 and Figure 13 to illustrate the Claim-Argument-Evidence (CAE) Safety Case as it develops. Figure 12 expands the top-level safety claim shown in Figure 10 to indicate how the structure will support the top-level safety claim. Figure 13 expands a specific element of the diagram in more detail to illustrate how; typically the ATM evidence would be included in the umbrella of the Air System Safety Case (ASSC) safety artifacts.

The diagram in Figure 11 - Nomenclature for CAE Diagrams details the nomenclature used in the CAE diagrams to allow the reader who is unfamiliar with these terms and diagrams, to better understand the ASSC.

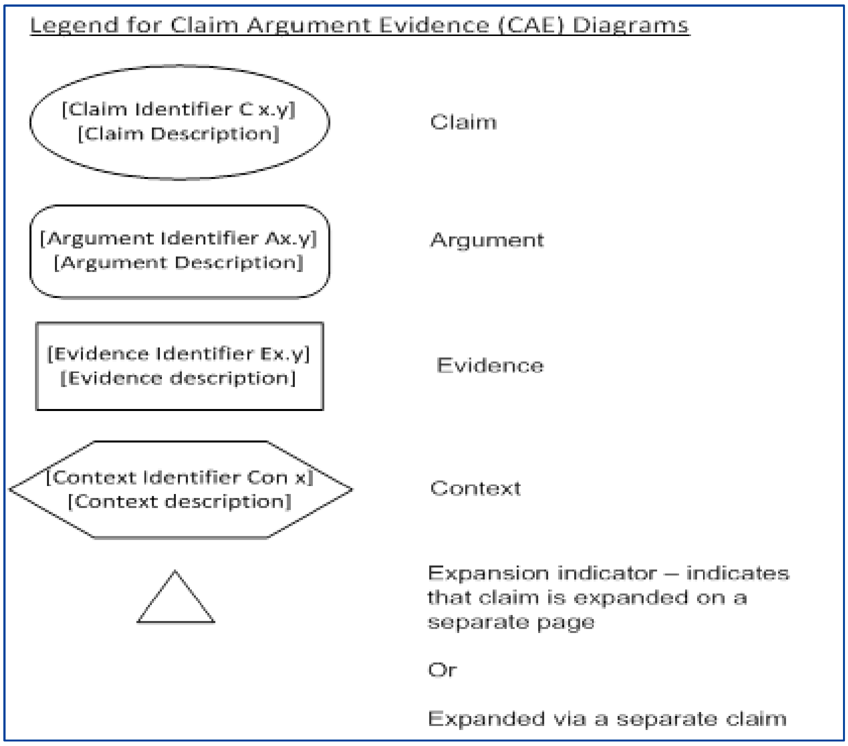

Figure 11 - Nomenclature for CAE Diagrams

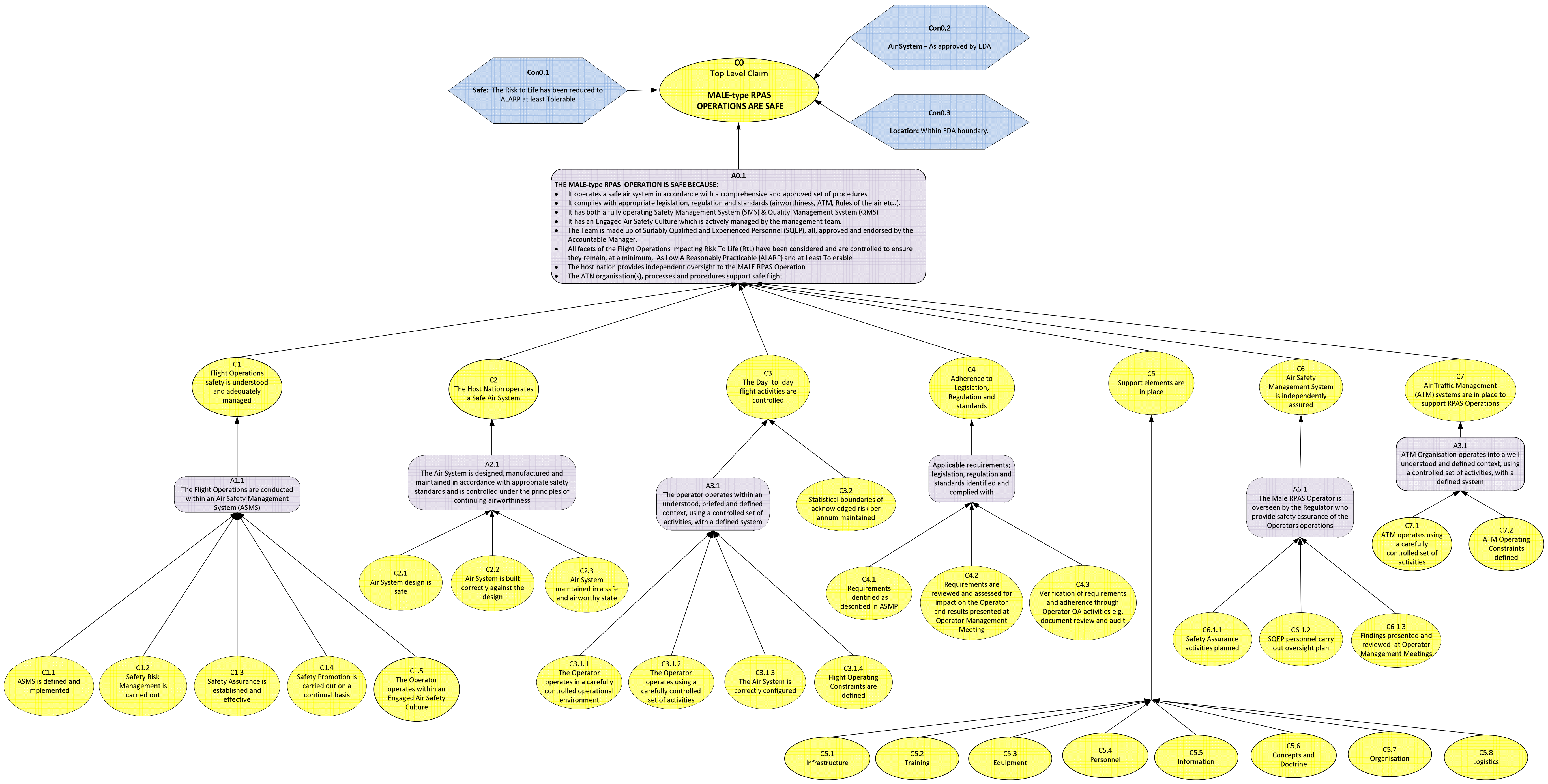

Figure 12 - Expanded Air Systems Safety Case

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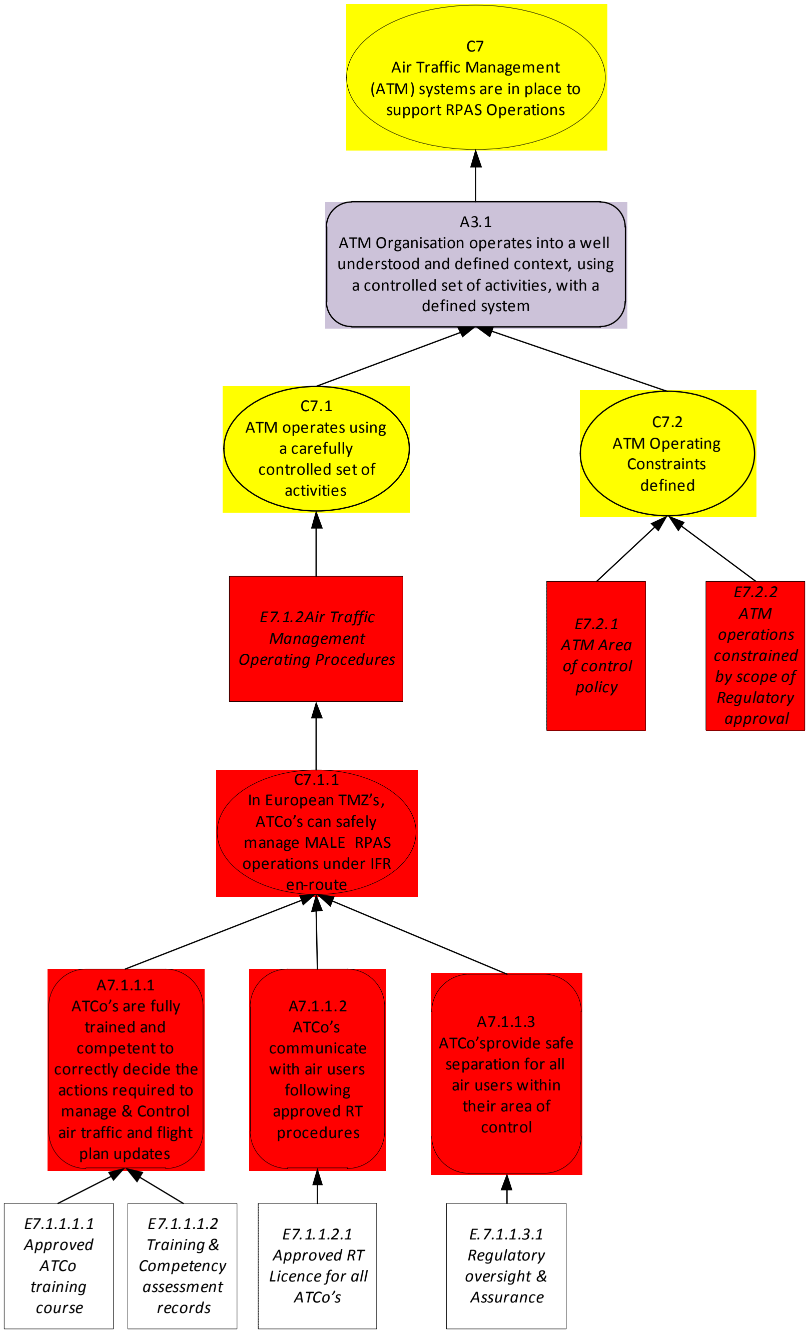

Figure 13 - Further Expansion to include ATM considerations

Whilst it was the intention to conduct a quantitative analysis within the BowTies it was not possible to give an accurate quantitative analysis due to the generic nature of the study. No specific MALE-type RPAS was used and assumptions over Human factors issues were not able to be sensitised to the platform and operating areas.

2.5.3 ATM Organisation & Separation Provision

To gain access to controlled airspace pilots are required to obtain permission from Air Traffic Controllers (ATC) in the first instance, thereafter aircraft are mandated to follow ATC instructions and rules-of-the-air - except in emergency situations. Furthermore and subject to submission and acceptance of an appropriate flight plan, aircraft will only be admitted into controlled airspace if they are equipped to a certain standard enabling controllers to provide separation assurance services and flight crews to maintain separation from other proximate aircraft and provide positional information to others.

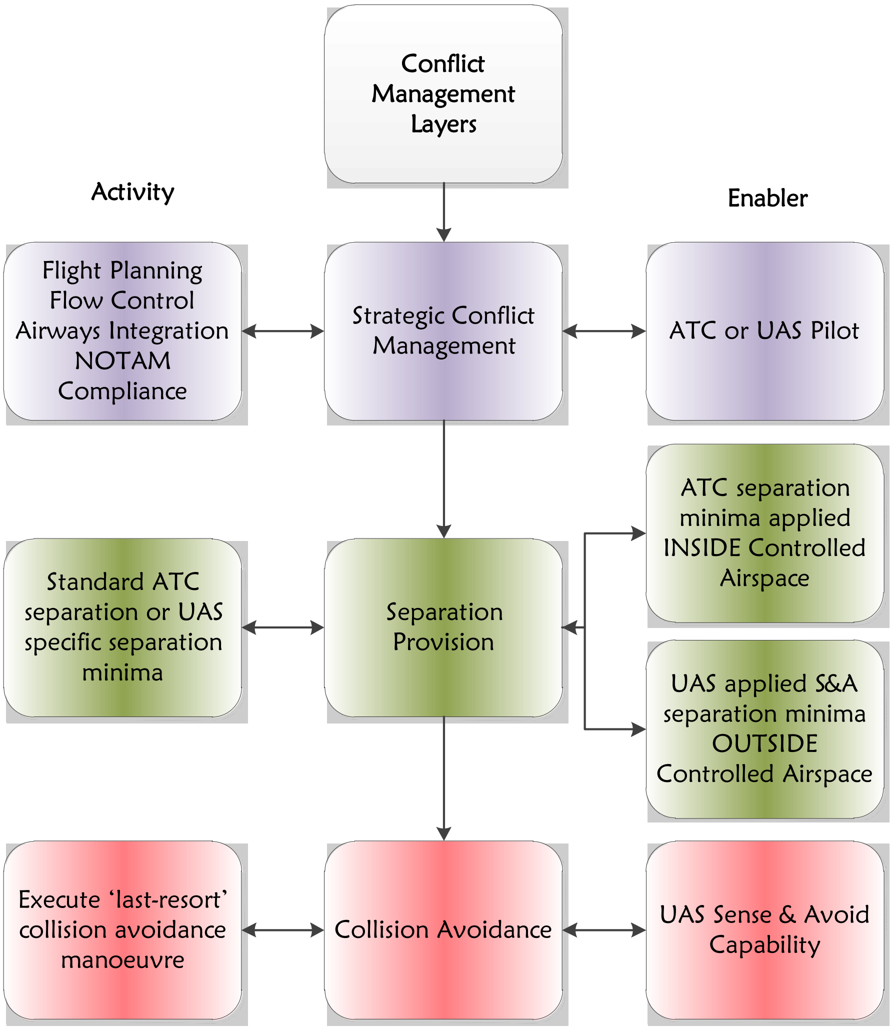

Figure 14 – Conflict Management Layers

In general terms a layered approach is used to support conflict management requirements – this concept incorporates strategic flight planning; application of air traffic management services to achieve separation minima and also collision avoidance in situations where no ATC services are present or there has been a loss of separation for some reason. The layered conflict management approach for RPAS is illustrated above.

2.6 Stakeholder Engagement

The stakeholder community was principally identified and engaged by the EDA to ensure member states were afforded fair opportunity to assess and critique the documentation and reports produced by Team SIRENS. Raw stakeholder feedback and recommendations were compiled onto a common spreadsheet template whereby each data item which was individually reviewed prior to telecon or face-to-face meetings attended by EDA; EUROCONTROL and other subject matter experts. Individual comments were discussed and, where appropriate, actions recorded for inclusion in updated 'final' documents. This process proved an effective and efficient means of gathering invaluable feedback, adding value and providing a forum in which to debate topics of interest throughout the study.

The Dissemination Workshop was used to share the study methodology and outcomes with a broad cross-section of representatives from several European member states. The opportunity to review bow-tie model illustrations during a 'walk-around' provided a means in which to gather feedback in a more face-to-face manner. Encouragingly, no contentious issues were reported and comments were generally very positive.

3 Study Conclusions

3.1 Safety Case Analysis Conclusions

3.1.1 Claim, Argument, Evidence

Underpinning the application of the Air Systems Safety Case analysis methodology derived in D1, to the Implementation Scenarios developed in D2, team SIRENS make the following ***Claim"*** in support of the overall objectives of this study: ***It will be safe to fly a MALE-type RPAS from Rotterdam under Netherlands ATC out over the North Sea towards the UK, crossing the border into UK airspace and handing over ATC to UK ATCOs; for the MALE-type RPAS to then conduct a Military ISR Mission in UK airspace and when complete, returning back into Netherland airspace under Netherlands ATC to return to base in Rotterdam.*** Note that this analysis does not include take-off and landing or ground operations which fall outside the scope of this study phase.

Clearly this claim covers many and varied aspects but is supported by a number of "***Arguments"*** that apply to each scenario in support of the claim and refer back to the holistic ASSC shown in Figure 4.

In terms of '**Equipment'** (by which we mean the RPAS 'system'), we argue that flying either of the two ***Implementation Scenarios*** (as described in D2 and Section 2 of this document) will be safe because the RPAS has type certification, it is maintained by Suitably Qualified Experienced Persons (SQEP) under a strict set of rules, procedures and supervision and that the correct flight permit has been granted by the relevant authorities. In detail, the Air system design is safe because:

- The Design organisation are appropriately trained, assessed & approved
- Air System – Type approval certificate/Flight permit/release to service (military)
- Equipment – Robust qualification/testing process
- Approved Maintenance provider – Licenced Engineers etc…
- Continued Airworthiness oversight is provided by the organisation

In Terms of the 'Operating Organisation' we argue that flying either of the two ***Implementation Scenarios*** will be safe because the organisation operates in a highly regulated industry. This means that all processes & procedures carried out are strictly-controlled requiring many different levels of approval before any flying operations are conducted. In detail, the Operating Organisation is safe because:

- Operators & Maintainers are appropriately trained, assessed & approved.
- Terms Of Reference (TORs) are in place for all staff and the Staff are suitably Qualified & Experienced
- The organisation is compliant to appropriate Regulations
- Risk to Life (RtL) is understood and managed within the organisation
- Appropriate processes are in place to support the claim the Operational Organisation is safe.

In terms of '**Air Traffic Management**' we argue that flying either of the two ***Implementation Scenarios*** will be safe because the ATCOs are SQEP and they follow strictly enforced and supervised procedures. In detail, the Air traffic Management Organisation is safe because:

- Air traffic controllers are appropriately trained, assessed & approved.
- Standardised Air Traffic Management processes are used.
- The ATM organisation is compliant with appropriate regulations including any additional RPAS Accommodation procedures. In short, RPAS accommodation will not negatively impact the ATC capability to deliver Air Traffic Services to any proximate manned aircraft flying in the vicinity of MALE type RPAS. The ATC is expected to deliver appropriate and safe services to MALE type RPAS.

3.1.2 Methodology

The methodology developed can be used to produce a, holistic Air Systems Safety Case. However, the level of detail is currently somewhat generic and so in future it would need to be made 'specific' to a platform being flown and the host nations' regulations and requirements in order to support live flying of RPAS accommodation flights.

3.2 Simulation Campaign Conclusions

The following conclusions were derived from analysis of the simulation results and of the questionnaires formally completed by the participants during the campaign.

3.2.1 Participant Workload

Team SIRENS found that the ATCO participants were able to predict potential 'loss of separation' events between aircraft represented in the Simulation runs some time before they would occur and instigate avoidance procedures well in advance. This begs a numbers of questions:

- What happens as the level of proximate air traffic increases?
  - At what point would 'normal' ATCOs start to miss spotting and dealing with potential conflicts?
  - Is there a point where the level of traffic is so high that the ATCOs could get overwhelmed and this Barrier begins to fail?
  - What then is the potential for the hazard to occur leading to consequential risk to life?
- What happens if there are more RPAS for the ATCOs to manage? At what point would the same set of issues outlined above start to occur?
- What happens if RPAS pilots begin to fly more than one Aircraft each? Does their ability to liaise with ATC diminish and at what point does this represent a failure of the Barrier leading to the occurrence of the TLE/Hazard?
- What happens if all of these situations occur?

In addition, it was thought that additional manpower (resources) may be required to help deal with RPAS emergencies:

- In most ATC centres, the operational air traffic controllers are supported by an assistant who provides provide basic support and can also take a role in situations that require more attention. These assistants will be able to deal with MALE-type RPAS emergency situations and ensure sufficient measures are implemented to avoid conflicts with other traffic.

Other workload issues that arose included:

- Dutch controllers were not familiar with the UK airspace which influenced their capability to handle the traffic efficiently but on the other hand it caused them to be very busy thus making the RPAS integration more stressful. This was a consequence of the fact that the ATCO participants in the Simulations were Dutch.
- In the event of a Transponder failure additional resources may be required to help handle the situation. This could be mitigated by the use of additional surveillance equipment such as ADS-B.

3.2.2 Back up Communications Procedures

In the Simulation runs a back-up communications set-up was used whereby the ATCOs could talk to the RPAS Pilots via a dedicated phone line in case of emergency (i.e. in case of radio relay failure on-board the RPA). This was considered a reasonable measure with the following caveats:

- A good communications procedure needs to be established for the use of back up phone line. This includes several important considerations such as how to routinely identify the pilot’s phone number by ATC (and vice versa); maintenance of communications with other air traffic and workload implications
- The phone procedures take some familiarisation effort, after some time using the phone, it became easier to use
- Is it considered necessary to keep the phone line open or could it be closed after each clearance and read back as necessary?
- If R/T failure is one direction, only from pilot to controller, it may be decided to cancel the need for read back
- A secondary frequency may be required for radio and/or data-link communications back up

3.2.3 Route Awareness

As RPAS are accommodated alongside manned aviation the ATCOs need to gain confidence that the RPAS will behave as expected. To help gain this level of confidence the ATCOs will need “good briefing on planned RPAS routes”. This is really to ensure that RPAS flights are planned in the same way and to the same level of detail as manned flights are today. The illustrations below depict the airspace used to support the simulation events with the Amsterdam and London Flight Information Regions.

3.2.4 Dual- RPAS flying & Communications Failures

In future it is conceivable that an RPAS Pilot may take control over more than one RPA (for example, an in-service UK tactical UAS is designed to allow the single ‘UAV Pilot’ to control up to three airborne UAVs simultaneously, although this action has not as yet been undertaken). This situation was simulated during the Simulation campaign in order to present a new and difficult situation to all participants, in particular since they were challenged with simultaneous loss of communications to both RPAs. In the relevant simulation run both the ATCOs and RPAS Pilot coped well and made the following observation:

- When two RPAS simultaneously have a loss of R/T voice communications with the same controller and are flown from one GCS and by one pilot and the pilot can separate these RPAs, then for the controller (ATCO) the situation would be equivalent to the loss of R/T voice communication of one RPA.

3.2.5 Navigation System Failures

Specific conclusions arising from the examination of the effect of a failure in the RPAS navigation system include:

- Should this be a pan-call? In the discussion, the tendency was no
- It may be decided to define standard phraseology for this (or use “unavailable RNAV”, which is standard ICAO terminology
- The RPAS pilot shall inform the controller about the consequences of a failure on the performance of the RPAS, not on the failure itself.

3.2.6 Overall Safety and Control

In general, the ATCOs were satisfied that they retained a level of control over the airspace and its proximate traffic with a MALE-type RPAS present, with the following specific observations:

- The level of control that the air traffic controllers indicated in the simulations was reasonably low in some of the runs. These were the runs where controllers used the phone connection the first time. Later on in the simulations the phone connection between the controller and the ground control pilot became a more standard a part of their working procedures.
- The concerns on safety of the situation correlate with the answers on the level of control the air traffic controllers experienced. The same applies for their ability to plan and organise the work as they wanted.

  The impact of the MALE RPAS that controllers indicated on situation assessment and on their workload was mostly concerned with the need to give the RPAS a different route and the effect of its slow (slower) speed.

Therefore we conclude that the accommodation of MALE-type RPAS as demonstrated in the simulation runs conducted under this study does not compromise ATCOs ability to maintain safe skies.

3.2.7 The ‘Impact’ of RPAS Accommodation

The participants were questioned about the overall impact of accommodating a MALE –type RPAS in the scenarios and their conclusion was that the RPAS had no significant impact on ATCO workload or scenario complexity. The only thing that was noted to be different from “normal” traffic was the way the RPAS was routed.

There were times during the simulation runs (particularly when positional information was compromised) where the ATCOs were not aware of or familiar with the remaining RPAS capabilities and it took them a few iterations to become comfortable with the ability of the RPAS to navigate as expected.

In circumstances where controllers were not initially familiar with RPAS capabilities it is considered advisable to ensure capabilities are provided as part of the flight plan.

4 Dissemination Workshop Comments

The following notes were taken at the Dissemination workshop and represent both the informal minutes of the meeting and a summary of the comments raised and subjects discussed:

4.1 Workshop Highlights

- The workshop was held in the CASTOR Meeting Room at EUROCONTROL HQ with more than 30 attendees from several member states.
- The EDA Project Officer in charge of the study introduced the Workshop highlighting the key objective 'to determine an expedient and safe way to operate initial military MALE-type RPAS in European Airspace.'
- The Stakeholder Consultation Group (comprising personnel from all member states as well as interested agencies including EUROCONTROL; EASA; EDA and OCCAR) was thanked for its support over the past 10-months. There is widespread interest in the study with over 200 comments, corrections and questions raised and considered within the documents published to date.
- The EDA Generic Accommodation Scenario was used as the basis for the study – this was developed to include 'an area of missions' in segregated airspace during the en-route phase. This approach was questioned (i.e. 'why segregated airspace') EDA responded that it was necessary to pursue 'quick wins' in the short-term.
- The EUROCONTROL Safety expert provided a briefing highlighting the importance of considering both NORMAL operations as well as CONTINGENCY situations – many participants supported the assertion that manned/unmanned aircraft differences are relatively low in normal flight conditions but this is not the case in emergency circumstances.
- EUROCONTROL Safety expert highlighted that team SIRENS had considered NORMAL operations; ABNORMAL operations (degraded performance caused by external issues such as weather, GNSS problems etc.) as well as FAILURE conditions – mitigation approaches were generally considered as 'resilient'. One observation was that the study (and future activities) should continue to focus on NORMAL flights to establish the strongest possible set of 'benchmarks'
- The Holistic Safety Case considered the three primary areas of Flight Operations; Airworthiness and Air Traffic Control. The collective decision to undertake a qualitative assessment (expert judgment) of the safety case was seen as the correct approach rather than attempt a quantitative approach at this very early stage.
- EUROCONTROL Safety expert suggested that it may be beneficial to use the EUROCONTROL Mid Air Collision integrated risk model in order to standardize the qualitative and quantitative safety impact assessment associated to RPAS accommodation.
- EASA shared many of the observations raised by EUROCONTROL and noted that the SPECIFIC operations model is most closely aligned to the study approach – at least at this early stage. This model calls for the completion of an operational risk assessment for particular operation whereas OPEN is limited to VLOS and sUAS situations and CERTIFIED is pushing beyond

Accommodation towards Integration – rulemaking in this category is less mature but may become more relevant in the future.

- EASA provided an update of the European regulatory framework explaining that the OPINION was published by EASA on 6.02.2018 as Implementing Act and Delegated Act. After other rounds of meetings and consultations the IA and DA have been published by the EC in October and should be formally adopted in April 2019
- SPECIFIC operations may also be articulated as a set of Standard Scenarios under declaration, published as part of the Rule, or, for inherent higher risk scenarios, under authorization, published as AMC (Acceptable Means of Compliance)

4.2 Summary Observations:

- Detect & Avoid remains an important topic but the audience understood (agreed) why it was deemed 'out of scope' due to immature performance standards and lack of operating procedures.
- Differing levels of CNS and RPAS platform performance need to be considered when developing standardized scenarios – team SIRENS was asked to confirm performance envelopes used during the simulation runs.
- Outcomes and Conclusions from study need to be shared with the regulatory authorities following completion of the Final Report.
- Many participants commented that the study was interesting and provided the basis for further work – esp. considering limited budgets. Strong consensus was reached regarding additional work to consider additional Implementation Scenarios, wider SCG participation and inclusion of additional dimensions such as political, societal and regulatory aspects.
- SIRENS approaches regarding DAA and Qualitative Assessments were supported by the audience.
- NLR provided a video of the simulation events.

5 Recommendations

5.1 MALE-type RPAS Performance criteria

Team SIRENS recommends that a standardised set of minimum MALE-type RPAS performance characteristics are developed and agreed to aid ATM and to set the benchmark for type-certification for Integration into European Airspace alongside manned aviation. For example these should specify a minimum climb rate which will allow ATCOs to position the RPAS in such a way as to ensure swift compliance with anticipated separation directives. Similarly a minimum descent rate, transit speed, loiter direction & radius (in the event of Loss of datalink) and manoeuvrability characteristics should also be considered to ensure safe separation is maintained even in adverse environmental conditions. It may be that MALE-type RPAS become classified into a range of 'classes' as it is recognised that performance and equipage attributes vary enormously within the MALE-type RPAS classification thresholds.

5.2 Fully Integrated Air Systems Safety Case Methodology

Team SIRENS recommends that a further study programme is conducted to ensure that the Safety Case Methodology, as proposed in this study, is complete and fully exercised by integrating the three primary safety attributes of Equipment; Organisation and Air Traffic Management. In addition to a more immersive Simulation Campaign, the proposed methodology should be subject to further examination by independent experts outside of Team SIRENS in each of the three areas.

5.3 Complete Hazard Analysis

Team SIRENS recommend scenarios to fully test the Safety Case Methodology and ensure study completeness. This wide ranging hazard analysis may also include additional hazards and inputs from the EDA and wider community of experts supporting the study. This treatment will need to cover elements excluded from this study such as: take-off and landing, ground operations, en-route exercises and flight over densely populated areas.

5.4 Accommodation Scenario Development

Team SIRENS recommends that the "Consolidated Generic Accommodation Scenario" be further developed to accommodate the lessons from this study aiming at turning it into an 'Integration Scenario' involving a heterogeneous set of MALE-type RPAS with differing performance characteristics.

This scenario also needs to be expanded to cover issues including:

- Flight over populated areas

- The utility of 'Detect And Avoid' technology additions
- Quantitative analysis (this will require the selection of a 'specific' RPAS instance in order to be able to define meaningful metrics and performance figures to support the analysis).

5.5 Live Flying

Upon completion of the aforementioned recommendations Team SIRENS recommends that the Safety Case Methodology developed in this study is exercised to the next level by applying it to a live flying RPAS exercise. This should be conducted opportunistically to reduce costs and to achieve flights as quickly as possible. Ideally these flights should be performed using a MALE-type RPAS in European airspace but benefit would still be gained from using other RPAS types and making use of segregated airspace to de-risk exercises and refine initial operating procedures. Once safety case methodologies are successfully applied to low-risk and non-complex operations it will be possible to make the transition to address more-demanding conditions within Controlled Airspace – this may include simple to complex airspace structures; quiet to congested airspace and even optimal to demanding environmental conditions.

Annex A Acronyms and Abbreviations

ALARP	As Low As Reasonably Possible
AMC	Acceptable Means of Compliance
ANSP	Air Navigation Service Provider
ASSC	Air Systems Safety Case
ATC	Air Traffic Control/Controller
ATCO	Air Traffic Control Officer
ATI	Air Traffic Integration
ATM	Air Traffic Management
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CAE	Claim, Argument, Evidence
CLAIRE	CiviL Airspace Integration of RPAS in Europe
CNS	Communication, Navigation & Surveillance
DAA	Detect and Avoid
EASA	European Aviation Safety Agency
EDA	European Defence Agency
ERSG	European RPAS Steering Group
FL	Flight Level
ICAO	International Civil Aviation Organization
IFR	Instrumental Flight Rules
ISR	Intelligence, Surveillance and Reconnaissance
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
LOPA	Layers Of Protection Analysis
LOS	Line of Sight
MALE	Medium Altitude Long Endurance
NLR	Netherlands Aerospace Centre
R&D	Research & Development
RPAS	Remotely Piloted Aircraft Systems

RtL	Risk to Life
SCG	Stakeholder Consultation Group
SERA	Standardised European Rules of the Air
SESAR	Single European Sky ATM Research
SQEP	Suitably Qualified & Experienced Personnel
SRM	SESAR Safety Reference Material
sUAS	Small UAS
UAS	Unmanned Aircraft System
VLOS	Visual Line of Sight