NORTH ATLANTIC TREATY
ORGANIZATION

SCIENCE AND TECHNOLOGY
ORGANIZATION

AC/323(AVT-278)TP/959

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STO TECHNICAL REPORT **TR-AVT-278**

Considerations for Harmonisation of UAS Regulations for Common NATO Operating Approvals

(Considérations d’harmonisation des réglementations relatives aux UAS en vue d’autorisations d’exploitation communes à l’OTAN)

Final Report prepared by Members of the Applied Vehicle Technology (AVT) Panel AVT-278 Technical Team.

Published November 2020

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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

•	AVT	Applied Vehicle Technology Panel
•	HFM	Human Factors and Medicine Panel
•	IST	Information Systems Technology Panel
•	NMSG	NATO Modelling and Simulation Group
•	SAS	System Analysis and Studies Panel
•	SCI	Systems Concepts and Integration Panel
•	SET	Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependant Surveillance-Broadcast
AGL	Above Ground Level
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATCO	Air Traffic Controllers
ATM	Air Traffic Management
BVLOS	Beyond Visual Line of Sight
CAA	Civil Aviation Authority
CAS	Controlled Airspace
CONOPS	Concept of Operations
CTR	Controlled Traffic Region
DAA	Detect and Avoid
DNSA	Direction des Services de la Navigation Aerienne
EASA	European Aviation Safety Agency
EDA	European Defence Agency
EMAR	European Military Airworthiness Requirements
EUROCAE	European Organisation for Civil Aviation Equipment
FUA	Flexible Use of Airspace
GAT	General Air Traffic
GCS	Ground Control Station
HALE	High Altitude Long Endurance
ICAO	International Civil Aviation Organization
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
JARUS	Joint Authorities for Rule Making on Unmanned Air Systems
LDLCA	Low Density Low Complexity Airspace
MAC	Mid Air Collision
MALE	Medium Altitude Long Endurance
MDOA	Military Design Organisation Approval
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Air System
SAA	Sense and Avoid
SARPS	Standards and Recommended Practices
SESAR 2020	Single European Sky Initiative
SMS	Safety Management System

SMZ	Surveillance Mandatory Zone
SORA	Specific Operational Risk Assurance
STANAG	Standardization Agreement
TCAS	Traffic Collision Avoidance System
TMZ	Transponder Mandatory Zone
UAS	Unmanned Air System
UAS-AG	Unmanned Air Systems – Advisory Group
UTM	Unified Traffic Management
VFR	Visual Flight Rules
VLOS	Visual Line of Sight

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Considerations for Harmonisation of UAS Regulations for Common NATO Operating Approvals

(STO-TR-AVT-278)

Executive Summary

AVT-278 was initially challenged with identifying, recording and analysing the multitude of different processes used by NATO Member States to achieve UAS operations. These UAS operations were not constrained by type, e.g., Visual Line of Sight (VLOS), Beyond Visual Line of Sight (BVLOS), weight, operating altitude, range or speed. In order to evolve, focus and derive benefit from the work AVT-278 had started, the JCG-UAS asked the technical panel to answer a specific question, this was to:

> "Recommend a process for Harmonisation of RPAS Regulation to Achieve Operational (and Civil Acceptance) of NATO RPAS Operations."

By receiving national specific briefs, documenting the different Member States processes and identifying good and poor practice, themes of related processes started to emerge. It became clear that following safety and airworthiness principles, defined in current regulations for manned aviation (ICAO, EASA, FAA, Australia-CASA), as well as some of the guidance material that had already been issued for general commercial UAS operations, NATO Member States were delivering operations by following processes aligned to common airworthiness functional pillars. AVT-278 therefore identified these common-approach elements to achieving safe UAS operations, and created the '9 Considerations Framework', which, if followed by NATO Member States, would provide a methodology to gain assurance of safe and airworthy, risk based, RPAS operations, and hence operational approvals. The '9 Considerations' are described as follows:

1) That the NATO partner operates within an airworthiness framework that ensures they contract UAS capability via competent Design Organisations (DO) credentials.
2) That the NATO partner employs competent personnel and processes for the approval (airworthiness / flight envelope – Part 21J) and operation (continuing airworthiness and commanding operations (equivalent EASA/EMAR Part M/66/145/147)) of UAS.
3) That the NATO partner operates within an airworthiness framework that considers the need for Certification or compliance with appropriate standards, or a risk-based approach for UAS.
4) That the NATO partner has a method of ensuring Build Quality and maintaining that Build Quality.
5) That the NATO partner has established an operating envelope and gathered evidence to support the operating envelope of the UAS and has applied constraints/limitations where necessary and appropriate to the operation.
6) How a NATO partner has employed methods of independent scrutiny to assure the safety assessment of their UAS in the approvals process. (Usage of Independent Eyes in the Approval Process).
7) That the NATO partner employs a method for understanding, analysing and managing risk.
8) That the NATO partner provides UAS documentation, including an operator's manual, maintenance manual and other airworthiness document records.

9) That the NATO partner's UAS has technology integrated into the system that facilitates safe navigation, and separation when operating over densely populated areas and in competing airspace or can argue sufficient mitigations.

AVT-278 confirmed the validity of the '9 Considerations Framework' at the 43rd Technical Panel meeting in Slovakia on 22nd and 23rd May 2019. This report analyses the reasons behind why the individual items in the '9 Considerations Framework' are so critical for managing UAS operations and, in some cases, provides examples of methods that can be employed to achieve assurance against them. It also provides the latest subject matter expertise leadership thinking on matters such as UAS integration into non-segregated airspace.

The '9 Considerations Framework', if adopted by NATO, could provide a method for NATO Member States to assure their UAS operations into a NATO operational theatre and could also provide the method by which NATO Theatre Commanders/Administrators can assess the robustness of a Member States UAS operation. The report recommends that JCG-UAS now uses this work to provide implementation policies for NATO UAS operations, and provides a software tool to enable a means of assessment against the '9 Considerations Framework'.

Considérations d’harmonisation des réglementations relatives aux UAS en vue d’autorisations d’exploitation communes à l’OTAN

(STO-TR-AVT-278)

Synthèse

L’AVT-278 s’est initialement intéressé à l’identification, l’enregistrement et l’analyse de la multitude de processus différents utilisés par les pays membres de l’OTAN pour aboutir à des opérations utilisant des UAS. Ces opérations utilisant des UAS n’étaient pas limitées par leur type, par exemple, visibilité directe (VLOS), hors visibilité directe (BVLOS), poids, altitude d’exploitation, distance ou vitesse. Afin de faire évoluer, concentrer et tirer avantage des travaux commencés par l’AVT-278, le JCG-UAS a demandé à la commission technique de répondre à une consigne spécifique, à savoir :

> « Recommander un processus afin d’harmoniser la réglementation des RPAS pour parvenir à l’acceptation opérationnelle (et civile) des opérations de l’OTAN utilisant des RPAS ».

La réception de mémoires spécifiques nationaux, la documentation des processus des différents États membres et l’identification des bonnes et mauvaises pratiques ont fait émerger les thèmes des processus liés. Il est devenu clair qu’à la suite des principes de sécurité et de navigabilité définis par les réglementations actuelles de l’aviation avec équipage (OACI, AESA, FAA, autorité de l’aviation civile australienne) et de quelques-uns des documents d’orientation déjà publiés pour l’exploitation générale des UAS commerciaux, les pays membres de l’OTAN effectuaient leurs opérations en suivant des processus alignés sur les piliers fonctionnels communs de la navigabilité. L’AVT-278 a par conséquent identifié ces éléments d’approche commune de la sécurité des opérations avec UAS et a créé le « cadre des 9 considérations ». À condition d’être suivi par les États membres de l’OTAN, ce cadre donnerait l’assurance d’opérations de RPAS sûres et aptes au vol, basées sur les risques, et garantirait donc les autorisations opérationnelles. Les « 9 considérations » sont les suivantes :

1) Le partenaire de l’OTAN intervient dans un cadre de navigabilité garantissant qu’il obtient sa capacité d’UAS via des organismes de conception compétents, dont il peut produire les justificatifs ;
2) Le partenaire de l’OTAN emploie du personnel compétent et des processus pour l’approbation (navigabilité/domaine de vol – partie 21J) et l’exploitation (navigabilité continue et opérations de commandement, équivalents à AESA/EMAR partie M/66/145/147)) d’UAS ;
3) Le partenaire de l’OTAN intervient dans un cadre de navigabilité tenant compte du besoin de certification ou de conformité avec les normes adéquates ou d’une approche basée sur le risque pour les UAS ;
4) Le partenaire de l’OTAN dispose d’une méthode assurant la qualité de construction et maintenant cette qualité ;
5) Le partenaire de l’OTAN a établi un domaine d’exploitation et réuni des éléments à l’appui du domaine d’exploitation de l’UAS et a appliqué des contraintes/restrictions si nécessaire et de manière adaptée à l’opération ;
6) Le partenaire de l’OTAN a fait appel à des examinateurs indépendants pour assurer l’évaluation de la sécurité de ses UAS au cours du processus d’approbation (usage de prestataires extérieurs au cours du processus d’approbation) ;

7) Le partenaire de l’OTAN utilise une méthode pour comprendre, analyser et gérer le risque ;

8) Le partenaire de l’OTAN fournit de la documentation sur l’UAS, notamment un manuel d’utilisation, un manuel d’entretien et d’autres registres documentant la navigabilité ;

9) L’UAS du partenaire de l’OTAN comporte de la technologie intégrée qui facilite la navigation sécurisée et la ségrégation pendant les opérations au-dessus de zones densément peuplées et dans l’espace aérien ouvert, ou peut faire valoir des systèmes d’atténuation suffisants.

L’AVT-278 a confirmé la validité du cadre des 9 considérations lors de la réunion de la 43e commission technique en Slovaquie, les 22 et 23 mai 2019. Le présent rapport analyse les raisons pour lesquelles chaque point du cadre des 9 considérations est si important pour gérer les opérations des UAS et, dans certains cas, fournit des exemples de méthodes qui peuvent être employées pour garantir leur respect. Ce rapport expose également la pensée dominante des spécialistes à l’heure actuelle sur des sujets tels que l’intégration des UAS dans l’espace aérien non réservé.

Le cadre des 9 considérations, s’il est adopté par l’OTAN, pourrait fournir aux États membres une méthode pour assurer leurs opérations d’UAS dans un théâtre opérationnel de l’OTAN et permettre aux commandants/administrateurs de théâtres de l’OTAN d’évaluer la robustesse d’une opération d’un État membre impliquant des UAS. Le rapport recommande que le JCG-UAS utilise à présent ces travaux pour proposer des politiques de mise en œuvre destinées aux opérations de l’OTAN utilisant des UAS et fournisse un outil logiciel d’évaluation au regard du cadre des 9 considérations.

CONSIDERATIONS FOR HARMONISATION OF UAS REGULATIONS FOR COMMON NATO OPERATING APPROVALS

1.0 INTRODUCTION

1.1 Problem Statement

1) In many countries, military RPASs fly in national airspace only after obtaining special permits or approvals issued by the provider of air navigation services or by the competent authority. Only some civil and military authorities have issued airworthiness certificates for the use of unmanned aircraft. Moreover, military RPASs must have special permission to operate in foreign countries.

2) Currently, the process for approving RPAS operations between NATO members varies significantly, creating a multitude of problems for member nations involved in allied deployments and peacetime training. Additionally, the different processes place unnecessary duplication on nations seeking to export military technology or gain approvals to operate in the airspace of other allies. Presently, there are operationally approved RPAS with varying degrees of airworthiness, which are lacking a standard formal approval process, which feature non-standard organisational processes (e.g., different services, manufacturers), and where most systems in service have gradually evolved over time; these shortcoming were identified as part of the work of AVT-ET-147.

3) There is an opportunity to create a common risk-based approach for the use of military RPAS. Existing NATO STANAGs and other applicable national rules and regulations must be accounted for. This should also encourage co-operation among countries and the possibility for RPASs to operate in foreign territory.

1.2 Goal

1) To address the issue in the problem statement, AVT-278 will seek to review examples of approval processes for RPAS operations to establish best practice, with a focus on risk-based methods, to generate a common baseline for the subsequent RTG activity. The civilian world appears to be making a paradigm shift to risk-based methods (EASA Specific RPAS category, JARUS OPS Cat B), which is why AVT-278 also considers civilian approval processes as additional reference. In reference to these relatively new civilian aviation authority developments in the last 4 – 5 years, there have been similar processes applied in the military sphere for quite some time. First a list of which specific operation risk assessment processes exist needs to be gathered. Then AVT-278 will expand on this with military evidence from appropriate authorities and will assess their pros and cons with input from those experienced in risk-based UAS approval methodologies.

2) NATO will benefit from a mutually acceptable basis for this approval process allowing member states to follow legitimate steps in planning and executing successful missions – as will be evaluated by AVT-278. The aim for AVT-278 is thus:

   - To provide a recommendation for a clear and baseline equivalent level of safety to assist in obtaining operational approvals (and civil acceptance) of RPAS operations utilised by NATO.

3) At the Cologne meeting on 23rd Apr 18, the AVT Panel tasked AVT-278 members with identifying the major attributes necessary for harmonisation, by distilling knowledge gathered from cross comparison of regulatory approaches of member nations. This could then be leveraged to establish a set of harmonised NATO regulations.

4) It was decided to bring together subject matter experts from civil and military organisations to share best practice for RPAS safe operations. Presentations accounted for varied operations, environmental and other aspects that impact the safety of the operations domain. The following topics were covered:
    - Regulation: the gap between NATO international and national operations regulations.
    - Risk-based safety assessment methodology.
    - Procedures for mitigating operational risk.
    - Lessons learnt: Analysis of national/international RPAS programs Background and Justification (and relevance to NATO).

5) Moving towards a best practice approach for approving RPAS Operations would be a highly relevant contribution aligned with the objectives included in the Target of Emphasis Platforms and Materials (Unmanned Platforms) (P&M-2) and also in P&M-1 (Fast and Agile Platforms), in the Science and Technology Area – defined as one of the NATO Science and Technology Priorities.

6) It is the objective of the RTG AVT-278 to develop recommendations for a best practice approach for approving RPAS operations utilising a risk-based analysis. It will not be limited to technical airworthiness but will also account for operational, environmental and other aspects that impact the safety of the operational domain.

7) Safety is defined with respect to the potential of the system to cause the following consequences:
    - Mid-air collision with manned aircraft.
    - Harm to people.
    - Damage to property, in particular critical and sensitive infrastructure.

2.0 HARMONISATION CONSIDERATIONS AND RATIONALE

2.1 Introduction

2.1.1 Fundamentals of an Aviation Approval Framework

There is currently no consensual regulatory framework for approving UAS operations, that is directly similar to that for other systems operating in the aeronautical sector, notably for manned aircraft (ICAO, 2011 [1]).

The challenge that ICAO has so far seized, for addressing unmanned aviation, is to provide the fundamental international regulatory framework. This will be addressed through Standards And Recommended Practices (SARPs), with supporting Procedures for Air Navigation Services (PANS) and guidance material, to underpin routine operation of UAS throughout the world in a safe, harmonised and seamless manner – comparable to that of manned operations. The 2011 circular is the first step in reaching that goal.

Article 8 of the Convention on International Civil Aviation, signed at Chicago on 7 December 1944 and amended by the ICAO Assembly (Doc 7300 [2] – hereafter referred to as "the Chicago Convention") stipulates that: no aircraft capable of being flown without a pilot shall be flown without a pilot over the territory of a contracting State without special authorisation by that State and in agreement with the terms of such authorisation. The main objective of the aviation regulatory framework is to achieve and maintain the highest possible uniform level of safety. In the case of UAS, this means ensuring the safety of any other airspace user as well as the safety of persons and property on the ground.

At the military level, the International Military Aviation Authorities Conference (IMAAC) was established in 2004; where the European Military Aviation Authorities Group (EMAAG) was formed. The aim of this group is to promote safety issues, regulations and common standards in military aviation, rather than directly address airworthiness issues. In 2008, at European level, and under the auspices of the European Defence Agency (EDA), a European Military Airworthiness Authorities (MAWA) forum was set up. This forum was created to harmonise a European-wide military airworthiness certification regulatory framework. In 2005, NATO established the Joint Capability Group UAV (JCGUAV) which is organised into various subgroups and activities. These subgroups include Flight In Non-segregated Airspace (FINAS), which is comprised of specialists for defining airworthiness requirements for UAS. The most relevant product of this group was the approval of the first draft of STANAG 4671 dedicated to Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR) (DoD, 2002 [3]). This group continues to develop and refine this STANAG, as well as others relevant to UAS, such as STANAG 4703.

At a civil level, the 1944 Chicago Convention on Civil Aviation, specifically Annex 8, represents the international legal basis for all aviation (ICAO, 2005 [2]). EASA defines itself as its legal representative for civil aviation in Europe, and over the past few years has issued a set of regulations that address UAS operating requirements (EASA, 2009; EASA, 2010; EASA, 2015; EASA, 2017; EASA, 2019/945 and 947). In addition to these, there are other multinational organisations recognised as having roles relevant to this subject, namely: the European Joint Aviation Authorities (JAA), the European Organisation for the Safety of Air Navigation (EUROCONTROL) and the European Organization for Civil Aviation Equipment (EUROCAE), and the United Kingdom Civil Aviation Authority; the latter having a key role in the civil and military RPAS airworthiness certification process (EUROCONTROL, 2004 [4]). The aforementioned entities play a relevant role in the airworthiness certification process for the integration of military and civil UAS in non-segregated airspace, either in defining requirements or for overseeing their compliance in the operational phase (DoD, 2010). These processes require certain requirements to be met at the development, manufacturing and operation phase of RPAS in order to demonstrate an Equivalent Level Of Safety (ELOS) to that which currently exists for manned aviation before being inserted in non-segregated airspace.

However, each State is entitled, on the basis of existing regulations; create its own national regulation through its National Authorities. Based on this premise, AVT 278 has delivered broad research to gauge which processes member states and other entities use or are likely to use.

2.1.1.1 EASA/EDA Position

To understand the background behind most NATO Partner Nations' regulatory approaches, it is useful to understand the EASA position with regards to regulation policy on UAS.

EASA published a Policy Statement regarding the Airworthiness Certification of UAS (E.Y013-01) [5] and a number of 'Special Conditions for the Certification and Authority to Use UAS'. For example, Special Condition 1309-03 [6] refers to aspects of equipment, systems and installations design to achieve satisfactory airworthiness and safety levels. E.Y013-01, Appendix 1 provides a methodology for selecting the appropriate airworthiness code and is based upon combinations of descent scenarios and the kinetic energy expected to be released. Depending on where the chosen UAS is situated on the Appendix charts, determines the airworthiness codes to be applied and hence the level of certification. This policy still applies where appropriately determined through EASA 2019 945 and 947. Most NATO Partner Nation Military Authorities have invoked regulations that either follow the principle of this EASA Policy and Conditions for UAS, or, certainly for smaller UAS, have created alternative methods for assessing the risk of operations on a case by case basis and have issued operational approvals from delegated authorities.

EASA recognises the NATO STANAGs that apply to military use UAS and will accept these codes for a type certification basis (for civilian use), provided that:

- The applicable airworthiness code identified from application of the methodology in Appendix 1 of this policy (E/Y013-01) does not indicate that safety standards in excess of CS-23 (single engine) are required; and

- The safety targets included in the system safety assessment reflect values resulting from the application of this policy.

A key aspect of the EASA UAS Policy Statement is the objective that:

- Airworthiness standards should be set to be no less demanding than those currently applied to comparable manned aircraft nor should they penalise UAS by requiring compliance with higher standards simply because technology permits.

EDA also recognises that under certain conditions, prescription to certain standards may not be appropriate. This is covered under EMAR 21A.16B[1] [7].

Although these STANAG Certification Standards may be appropriate for larger UAS, in practice, the NATO user community are finding them less appropriate, and not easy to apply, for smaller size/weight UAS. It is here that risk-based methods have better applicability, and the JARUS SORA [8] potentially offers a methodology that could gain wide acceptance amongst National Authorities.

2.1.2 Competent Design Organisations

According to Commission Regulation (EU) 748/2012, organisations that design aircraft; changes to aircraft; repairs of aircraft; and parts and appliances need to fulfil the requirements as defined in Annex 1 (which is called “Part 21”). Such organisations need to demonstrate that they have the right organisation, procedures, competencies and resources.

In the military “world” this Commission Regulation has been reflected in the EDA Framework of EMAR Part 21 which is very similar to EASA Part 21. The framework (EMAR 21.A.14[2] [7]) refers that organisations applying for type certificate should demonstrate capability by holding a Military Design Organisational Approval (MDOA) (there are similar arrangements for production organisations). The requirements and prerequisites to achieve a MDOA are defined in EMAR Part 21 J.

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[1] EMAR 21.A.16B Special conditions [7]:

(a) The Authority shall approve any special detailed technical specifications, named special conditions, for a product, if the related airworthiness codes do not contain adequate or appropriate safety standards for the product, because:
  1) The product has novel or unusual design features relative to the design practices on which the applicable airworthiness codes are based; or
  2) The intended use of the product is unconventional; or
  3) Experience from other similar products in service or products having similar design features, has shown that unsafe conditions may develop; or
  4) Airworthiness codes do not exist for the concerned product function.

(b) The special conditions contain such safety standards as the Authority finds necessary to establish a level of safety equivalent to that established in the applicable airworthiness codes or a level of safety acceptable if airworthiness codes do not exist for the concerned product.

[2] EMAR 21.A.14 Demonstration of capability [7]:

(a) Any organisation applying for a type-certificate or restricted type-certificate shall demonstrate its capability by holding a military design organisation approval (MDOA), issued by the Authority in accordance with EMAR 21 Subpart J.

(b) By way of derogation from paragraph (a), as an alternative procedure to demonstrate its capability, an applicant may seek Authority agreement for the use of procedures setting out the specific design practices, resources and sequence of activities necessary to comply with this EMAR, under the following:
  1) Design of non-complex products or with limited scope of design activities.
  2) Starting phase toward a military design organisation approval or limited duration of design activities.
  3) Products for which the major part of the Type Design certification activities have already been accepted by the Authority concerned.

One of the main pillars of a Design Organisation is the implementation of a Design Assurance System (DAS) with Independent System Monitoring and EN ISO 9000/9100 processes. It is the organisational structure, responsibilities, procedures and resources to ensure the proper functioning of the design organisation. Design Assurance means all those planned and systematic actions necessary to provide adequate confidence that the organisation has the capability to design products, parts or appliances in accordance with the applicable Certification Specification (CS) and environmental protection requirements, to show and verify the compliance with these CS and environmental protection requirements, and to demonstrate to the Authority this compliance.

This competent design organisation is not only necessary for the initial airworthiness (e.g., military type certificate or flight release), it has the responsibility to keep the system (type design) airworthy throughout its lifecycle/operations. This shall be established by use of approved maintenance and repair procedures (continued airworthiness) in the responsibility of a Continuing Airworthiness Management Organisation (CAMO). During this lifecycle the need of a competent Design Organisation is still necessary/mandatory to cope with unforeseen problems, which are not covered within the Instructions for Continued Airworthiness (ICA). Otherwise the system would not be able to be released to service, used or operated.

It may not be feasible, or economically justified, for all designers/suppliers of UAS to achieve MDOA according EMAR Part 21 J, certainly for small UAS (sUAS). However, it would appear sensible for NATO Partner Nations to have a means to ensure acquisition of UAS capability from competent design organisations.

A competent UAS design organisation (if they are not able to comply with EMAR Part 21 J) could be defined as one, whose processes ensure consistent aerodynamic and airworthy performance, of the UAS, for a prescribed set of operational circumstances. To show this, the company should be able to demonstrate that a verification and validation process (maybe independent) as part of a quality management system is established.

Verification will check that a product or system meets a set of design specifications. It is a process that is used to evaluate whether a product or system complies with regulations, specifications, or conditions imposed at the start of a development phase.

Validation will ensure a product, or a system that results in a product, or system that meets the operational needs of the user. A set of validation requirements (as defined by the user), specifications, and regulations may then be used as a basis for qualifying a development flow or verification flow for a product, service, or system. It is a process of establishing evidence that provides a high degree of assurance that a product or system accomplishes its intended requirements. This often involves acceptance of fit for purpose with end users.

2.1.3 UAS Operations Legislation

The acquisition of a ‘fit for purpose’ UAS, with corresponding levels of reliability, safety and airworthiness is one part of the approach to safe operations. The next essential part is the method of safe operation, which starts with a competent operations authority. This contains elements of infrastructure and personnel. One key aspect of the personnel ‘Lines of Development’ is the provision of the qualified or ‘Licensed’ Remote Pilot. ICAO Circular 328-AN/190 [9] states:

- Licensing and training will be developed similar to those for manned aviation and will include both the aeronautical knowledge and operational components. Specific adjustments may be needed considering the particular and unique nature and characteristics of the remote pilot station environment and RPA applications (from both a technical and flight operations perspective, e.g., VLOS or BVLOS) as well as aircraft type (e.g., aeroplane, helicopter). In that context, qualifications for certain categories of remote crew may be significantly different from those pertaining to the traditional qualifications pertaining to manned aviation.

The competent operations authority must have means to assess, manage and sustain continuing airworthiness, which includes the training and licensing of its personnel for the full extent of the missions they could be expected to undertake. The responsibilities of the competent operations authority therefore are included as part the framework in Table 1.

2.1.4 NATO UAS Harmonised Operational Approvals Rationale

Given the evolving, but strict, regulatory landscape currently surrounding UAS, it became natural that the AVT-278 panel's logical rationale when considering a framework, that would be sufficient to support NATO Member States (MS) in achieving collaborative UAS/RPAS operations, should be based upon similar principles applied in the international aviation arena. It also became clear that civilian UAS approval processes were making a paradigm shift to risk-based methods. The panel found the logical guiding principles to be:

- Appropriate and proportionate UAS certification evidence within a risk-based construct.
- The acquisition of UAS capability from competent design organisations.
- Alignment with wider international operations legislation, whilst applying appropriate NATO specific rules.
- Ensuring personnel involved in the operations of UAS were authorised, qualified and competent.

Efforts to isolate the required correct UAS harmonisation elements led to consensus within AVT-278, in that: the derived elements should be sufficient to support NATO Command Authorities in balancing operational objectives with safety and risk management accountabilities necessary for authorising UAS/RPAS operations; and this should be in a form that is easily translatable and accepted across NATO Members States.

3.0 DATA CAPTURE PROCESS

3.1 Introduction

AVT-278's initial investigations began with an examination of NATO Member States (MS) methods for historically achieving UAS Operations Approval, which included an examination of the process for ensuring airworthiness and safety management. This commenced with a series of presentations and unguided questioning of the presented process. Gradually, it became obvious that clear themes were emerging over how the MS were achieving operational approvals – not entirely the same, not entirely different, but close enough for the AVT-278 panel to create guided questions around emerging themes. These nascent aspects became known as the '9 Items', and later the '9 Considerations'. The working group members then took the presentations, and answers provided to the unguided questions, and created a matrix of evidence. This matrix of evidence was then reconstructed to provide evidence against the '9 Considerations', with more guided questions being asked of NATO MS, where clarification or further evidence was then gathered. The results of the investigation can be found in the Enclosure.

The critical guided questions which gathered evidence for the '9 Considerations' were as follows:

1) How Does the Responsible Authority Assure Design Quality of the UAS?
2) How Does the Authority Ensure an Appropriate Level of Training for UAS Commanders / Pilots / Duty Holders, Airworthiness Authorities?
3) How Does the Authority Categorise UAS Classes?

4) Does the Authority have a method of ensuring Airworthiness by the Use of Appropriate Standards?
5) How Does the Authority Ensure that the UAS has a Proven Envelope that Meets the Operational Requirements Set by the User?
6) How Does the Authority Make Use of Independent Eyes in the Approval Process?
7) How Are Safety Management Systems Employed to Manage Risk to Life?
8) How Does the Authority Manage the Provision of Relevant Instructions to Remote Crew?
9) How Does the Authority Consider the Requirements of Solutions for Safe Separation?

3.2 Sources of Information

The analysis of the various approval processes for UAS operations was based on information gathered in essentially two ways: formal presentations made at AVT 278 meetings by Member State representatives or collected from documentation available from public sources.

Eight formal presentations to AVT-278 were provided, these were:

1) Paula Gonçalves from Portuguese Air Force in Spring 2016 at AVT-273 RSM: Approval of RPAS Operations: Airworthiness, Risked-Based Methods, Operational Limitations;
2) Guy Bodet from Belgium MAA at 41st AVT Spring Meeting, 2017;
3) Terry Martin at 41st AVT Spring Meeting, 2017;
4) Richard Adams from US Navy Airworthiness Office at 43rd AVT Panel Business Winter Meeting 2018;
5) David Guerin from OZYRPAS Consulting, at 41st AVT Panel Business Meeting, 2017;
6) Rob Jackson from General Atomics Aeronautical Systems UK Limited at 41st AVT Spring Meeting 2017;
7) Mehmet Erdem Ozet from Turkish Aerospace Industries at 42nd AVT Panel Business Meeting 2017;
8) Jamie Sayer from Unmanned Air Systems Team, UK MoD (Mini Class TAA), at 42nd AVT Panel Business Autumn Meeting 2017;
9) Joerg Dittrich from DLR, JARUS SORA Approach, 42nd AVT Panel Business Meeting 2017; and
10) Christian Grassl, Airbus Germany, German Military Approach to Airworthiness Certification of UAS, 42nd AVT Panel Business Autumn Meeting 2017.

4.0 THE NINE CONSIDERATIONS AND ANALYSIS

4.1 Introduction

Table 1 describes the ‘9 Considerations’ which complete a framework for harmonisation of NATO UAS operations. By providing solutions to these considerations the NATO Partner Nation will ensure an adequate level of safety, facilitating inclusion into a NATO collaborative UAS mission. Any gaps against the ‘9 Considerations’ would require remedial risk to be presented and argued to the NATO Command Authority.

Table 1: Framework Requirements for Harmonisation of NATO UAS Operations.

Consideration	Best Practice or Gap	Common Themes
1) That the NATO partner operates within an airworthiness framework that ensures they contract UAS capability via competent Design Organisations (DO) credentials.	The UK MAA regulations state that Organisations planning to procure small, COTS Remotely Piloted Air Systems (RPAS)… should consult with the Unmanned Air Systems Team (UAST) Type Airworthiness Authority (TAA) regarding suitability of their system prior to seeking categorisation. The UAST TAA would conduct an assurance assessment of the company involved to ensure they are a competent organisation, who comply with relevant processes – such as following the principles of a Quality Management System (QMS). (The UK approach is to assess a company once and then use many times.) For larger UAS the UK MAA regulations require the DO to have achieved the Design Assurance Organisation Scheme (DAOS) and/or the Maintenance Approval Organisation Scheme (MAOS). JARUS SORA [5] refers to the requirement for a UAS to be manufactured by competent and/or proven entity, and the level of assurance of this requirement would be dependent upon the risk class of the operation. Medium level of Integrity refers: Manufacturing procedures cover at least: • Configuration control, • Verification of incoming products, parts, materials, and equipment, • Identification and traceability, • In process and final inspections and testing, • Control and calibration of tools, • Handling and storage, • Non-conforming item control.	Nations typically insist on known QMS standards or demonstrated equivalence, up to regulatory approved credentials, via the Nation's regulator. Some nations are less concerned with standards for small, tactical UAS. Most nations refer to formal standards or methodology for configuration control. Formal processes to control configuration are laid out in higher standards or national regulation. The SORA is slightly different as it bases the extent of control on the risk (operation) of the system being assessed.

Consideration	Best Practice or Gap	Common Themes
2) That the NATO partner employs competent personnel and processes in the approval (airworthiness/flight envelope – Part 21J) and operation (continuing airworthiness and commanding operations (equivalent EASA/EMAR Part M/66/145/147) of UAS	The UK system ensures that SQEP individuals are employed in positions of authority for granting approvals and managing technical and operational risk for UAS. This includes the authorisation and maintenance of proficiency for UAS Commanders/Pilots. JARUS SORA refers to a requirement that the operator is competent and/or proven (Remote Crew Competencies). There are also elements in the JARUS SORA Annex E that would cover those Operation Safety Objectives (OSO) that the UK employ specific accountable individuals for. Therefore, the Annex E to the JARUS SORA may be the best means to ensure coherence across NATO partners approaches.	Most nations have well formulated provisions for employment of competent persons engaged in aviation operations. The UAS operation is not typically in variation to these regulations, but in the lower level of risk alleviation and discretion is introduced. The SORA introduces a method to more objectively assess these alleviations. Most nations employ methods of training for recognised qualifications, authorisations for flights and methods of ensuring competency and currency. In some nations, operator must have achieved manned aviation qualifications, depending on size and class of the UAS.
3) That the NATO partner operates within an airworthiness framework that considers the need for Certification or compliance with appropriate standards, or a determined risk-based approach for UAS.	The UK follows the MAA regulations for compliance with the Military Air Systems Certification Process (MACP). How far the UAS needs to comply with the process depends upon the weight class of the system and aggravating or mitigating factors. JARUS SORA refers to a need to develop UAS to recognized design standards, again to the extent dependent upon the risk classification. For NATO and fixed wing UAS above 150 kg – there is a standard for certification within NATO. Rotary Wing no stipulation.	Most of the nations that AVT-278 assessed are increasing UAS capability; those nations are tending to apply risk based approaches, but most start with weight when looking at applying rules and design/production assurance and operational restrictions.
4) That the NATO partner has a method of ensuring Build Quality and maintaining that Build Quality.	SMEs are familiar with the common use of ISO9001 and AS9100, AQAP standard.	Most nations employ either STANAG approach or insist on well-known equivalents. Where no compliance can be read across then risk analysis and mitigation methods would apply.

Consideration	Best Practice or Gap	Common Themes
5) That the NATO partner has established an operating envelope and gathered evidence to support the operating envelope of the UAS and has applied constraints / limitations where necessary and appropriate to the operation.	The UK uses a 'Release To Service' (RTS) process, which captures the need to justify the flight envelope / concept of use – including the gathering of independent flight trials / test and the evaluation of evidence (as necessary). The US uses a Safety of Flight process to deliver the same, or a Military Permit To Fly (MPTF). Portuguese have a Permit To Fly. JARUS also refers to OSO (Annex E) to cover tests that prove the flight envelope in all environmental conditions – Adverse Operating Conditions (OSO23).	Most nations employ a 'Service Release' process, whereby limitations and constraints have been proven and formally recorded in appropriate user guides and UAS documentation set.
6) The reasons why, and how, a NATO partner has employed methods of independent scrutiny to assure the safety assessment of their UAS in the approvals process. (Usage of Independent Eyes in the Approval Process).	More than one pair of experienced eyes on the individual Nation safety case. JARUS SORA incorporates this approach for High Levels of integrity assurance.	Most nations apply independent scrutiny at some level, increasing the level of examination depending on risk, level of complexity and the context of the UAV operation.
7) That the NATO partner employs a method for understanding, analysing and managing risk.	Maybe not common, but translatable, and would depend on the level of inferred risk to 3rd Parties. JARUS SORA methodology could be the first step in deciding if a risk calculation is necessary. Bow-Tie methodology to bring together equipment risk and operational risk. Defined Casualty Expectation (CE) rates. Calculations may not be necessary for a Certified System with a Design Safety Target, as long as they follow rules for flight in categorised airspace.	Most nations put in place a Safety Management process, which includes a method for risk assessment some are more robust and rigid than others. It appears clear that there is no one common approach.
8) That the NATO partner provides UAS documentation, including operator's manual and maintenance manual and records.	Operators' Manual should include content such as: • Training organisation; • Methods to maintain competency and currency;	There appears to be no common approach within NATO MS. See Section 3.2.8 for a complete list.

Consideration	Best Practice or Gap	Common Themes
	• Authorisations of operations; • Theatre familiarisation methods, and conduct of deployed operations; • Any special conditions, such as operating in member states territory, employment of weapons, means of maintaining safe separation; and • Environmental special conditions.	
9) That the NATO partner's UAS has technology integrated into the system that facilitates safe navigation, and separation when operating over densely populated areas and in competing airspace or can argue sufficient mitigations.	Methods to deliver the ATC live picture to the Operator and vice versa. JARUS SORA methodology may offer best practice here for calculating the risk and assurance levels required. Residual risks would require to be communicated to the in-theatre NATO Commander. Due to the significant considerations for airspace integration this Best Practice/Gap advice has been designated its own Section. (See Section 5).	Formal segregation is the typical, most common method. The only system that looks toward a more advance risk-based approach, or defines better control measures, is the JARUS SORA.

4.2 Considerations 1 – 8 of the Framework

The following paragraphs explain, in more detail, what the NATO Partner Nations' operating authority, or regulator, would be expected to consider when delivering assurance against the Framework. The explanations are not exhaustive, and the NATO Partner Nation would be expected to apply innovative thinking when assembling their case for UAS operations.

4.2.1 Critical Question for Consideration 1: How Does the Responsible Authority Assure Design Quality of the UAS?

The following aspects should form a part of the NATO Partner Nation's assurance when acquiring UAS capability:

- **Configuration Management:** Configuration of the design must be carefully controlled. The Design Organisation (DO) must satisfactorily demonstrate the involvement of SQEP Engineers, to perform airworthiness tasks, such as sentencing build standard deviations along with understanding of airworthiness implications.
- **Build Quality:** The DO must demonstrate the ability to produce Field Bulletins, Modifications, Repairs and associated safe Deviations (concessions) from the expected build standard, i.e., establish the level of confidence that the build standard accords with the design standards. This assessment will also cover the system delivery process, including the air system acceptance test and survey (an ability to produce comprehensive QA inspection and flight test).

- **Employment of Competent Persons:** Engineers, including personnel from supporting departments – competence and SQEP demonstration – show means of assessment and management.
- **Safety Management Culture:** This should be clearly described, including its validation process. The culture should include an ability to conduct Hazard Analysis. Demonstrate a Safety Management Plan and Safety Case Report construct, including Hazard Log status, and composition, and possible Loss Model development.
- **Provision of Accurate Instructions:** The development of the Engineering Aircraft Document Set (ADS) (e.g., issued as publications, such as an Operator's Manual), their validation/improvement (e.g., discoveries during trials, during maintenance activities and customer operations) and the through-life support.

4.2.2 Critical Question for Consideration 2: How Does the Authority Ensure an Appropriate Level of Training for UAS Commanders / Pilots / Duty Holders, Airworthiness Authorities?

The NATO Partner Nation should demonstrate the ability to deliver the following prerequisites when operating UAS capability:

- **Entitlement to Conduct Flying Duties:** The Operator must be in possession of a military approved UAS/RPAS pilot/operator qualification and be assessed as medically fit for duty. Must have undertaken an approved training course and be current on the type of UAS to be operated and therefore hold a Certificate of Competence for that type.
- **Authorisation of Flights:** A more senior UAS operator will be deployed to hold the position to authorise daily flights. This individual will be responsible for supervising and checking mission planning and ensuring operators maintain currency and competency for specific roles – i.e., night flying or BVLOS.
- **Risk Holders:** Duty Holders, qualified to manage risk to life, will be accountable for a NATO Member States deployed operations.
- **Continuing Airworthiness Managers:** Senior engineers will be made accountable for maintaining airworthiness of NATO Member States UAS in accordance with individual Member States' regulations.

4.2.3 Critical Question for Consideration 3: How Does the Authority Categorise UAS Classes?

The NATO Partner Nation should demonstrate the ability to categorise their UAS capability. NATO should dictate a categorisation approach, but until this is implemented it is necessary to fully understand the NATO member partner's process.

Classes and Categorisations of RPAS in National Military Regulations can be subdivided as:

- Weight-based;
- Size-based;
- Multiple-criteria-based; and
- Mitigated Risk-based.

4.2.3.1 Weight-Based Categorisation

UK MAA:

- 6 weight classes (200g, 2 kg, 20 kg, 150 kg, 600 kg and above).

- After initial categorisation, mitigating factors may be applied, resulting in a shift of the weight limits, potentially putting an unmanned aircraft into a lower category, which in some cases effectively makes this a Mitigated Risk-based classification.

Australian Defence Force:

- Using weight for small classes (200 g, 2 kg), then switching to a mitigated risk-based approach similar to JARUS SORA.

European Defence Agency (EDA):

- 3 weight categories (CAT 1 < 20 kg, CAT 2 < 150 kg, CAT III > 150 kg) – but the EDA are considering publishing a SORA methodology.

Switzerland Military:

- 4 weight categories (Micro (<300 gr); Mini (900 gr – 25 kg); Small (150 – 600 kg) and Male (600 – 750 Kg).

4.2.3.2 Size-Based Categorisation

JARUS SORA:

- 4 size classes (1 m, 3 m, 8 m, above) are used for the intrinsic, unmitigated pre-categorisation. This is however only an intermediate step, before assigning a risk-based category, as SORA is a mitigated risk-based categorisation approach.
- Makes use of the so-called characteristic dimension, which usually equals the wingspan of an aeroplane, or the size of a VTOL aircraft including its rotors.
- The SORA ground risk model ignores the actual weight of the aircraft, assuming that above quite a low threshold all direct hits are lethal to a person on the ground. As such, the actual weight is neglected, but the emphasis is put on the likelihood of hitting a person, which is somewhat proportionate to the actual size of an aircraft.

4.2.3.3 Multiple-Criteria-Based Categorisation

Belgium MAA:

- Weight, Range, Altitude, Trg (Qual) – 4 Classes:
  - (<250 g + <500 m + <150 ft + Due diligence);
  - (<5 kg + <1500 m + <300 ft + VLOS);
  - (<25 kg + <50 km + <500/1000 ft); and
  - (>25 kg + >25 km + >3000 ft).

4.2.3.4 Multiple-Risk-Based Categorisation

JARUS SORA:

- 6 categories (Specific Integrity and Assurance Levels I – VI).
- The categories are derived from independently mitigated air and ground risk assessments and are unique to each type of operation/mission.

UK MAA:

- Categories defined by weight (6 classes), but then sentenced via an inclusion of mitigating and aggravating factors.

Australian Defence Force:

- Derived categorisation from an older version of JARUS SORA (1.0).
- Six categories in the Australian Defence Specific Category.
- Mitigative measures (harm barriers) have been modified from the original JARUS SORA source.

4.2.4 Critical Question for Consideration 4: Does the Authority have a Method of Ensuring Airworthiness by the Use of Appropriate Standards?

The NATO Partner Nation should demonstrate the ability to apply and deliver appropriate standards, when required, depending on the use/risk of UAS operations.

JARUS SORA refers to a need to produce a list of adequate industry standards to be identified by EUROCAE WG105 by Sep 2019. Currently Annex E states.

National Aviation Authorities (NAAs) may define the standards and/or the means of compliance they consider adequate. The SORA Annex E will be updated at a later point in time with a list of adequate standards based on the feedback provided by the NAAs.

The German Military Aviation Authority (GMAA) uses the following standards for UAS of different types (a comprehensive list of standards used by the GMAA is included at Annex A):

MALE and EuroMALE	STANAG 4671 Ed. 3.
HALE	STANAG 4671 Ed. 3.
Tactical UAS	STANAG 4703.
Engines	CS-E Engines; FAR-33.
Propeller	CS-P Propeller; FAR-35.
In General	RTCA/DO-160; RTCA/DO-178; RTCA/DO254; MIL-STD-461; MIL-STD-704; MIL-STD-822, LTR 7030-001, LTF 1550-001.

4.2.5 Critical Question for Consideration 5: How Does the Authority Ensure that the UAS has a Proven Envelope that Meets the Operational Requirements Set by the User?

Industry data does not often stand up to independent scrutiny, e.g., claims of endurance often, in practice, drastically reduce when operating in high tempo environments, changing altitudes, waypoints etc, and using payloads. Advertised flight envelope is also affected by density altitude, temperatures and other environmental conditions. JARUS SORA High Integrity Assurance requires independent testing:

Flight tests performed to validate the procedures and checklists cover the complete flight envelope or are proven to be conservative. The procedures, checklists, flight tests and simulations are validated by a competent third party.

4.2.6 Critical Question for Consideration 6: How Does the Authority Make Use of Independent Eyes in the Approval Process?

The National Authority presenting the UAS for operation should have subjected their UAS safety assessment to independent evaluation and audit consisting of:

- Independent analysis of the data evidence supporting the Equipment Safety Assessment Report (ESAR), including, where appropriate, a qualitative assessment of UAS handling, HMI and crew workload.
- An independent process audit against the safety plan, covering such activities as the Project Safety Panel, the Project Team safety processes, the Design Organisations safety plan and record.

This independent evaluation should be proportionate to the level of risk inherent in the Class and use of the UAS. Level of independence can vary depending upon the assessed level of risk.

4.2.7 Critical Question for Consideration 7: How Are Safety Management Systems Employed to Manage Risk to Life?

The NATO Member States authority must demonstrate methods of assessing and mitigating Risk to Life during UAS/RPAS operations. Use of Bow-Ties, or other risk assessment methodologies, would be appropriate. Robust qualitative and/or quantitative methods should be utilised. Section 4.2.7.1 contains are some reasonable quantitative methods. The following example is based upon UK active methods, but these are also based upon US Armed Forces Range Commanders equation and is very similar to that equation.

4.2.7.1 The Casualty Exposure Equation – CE

CE (Casualty Exposure Factor) = PF (Probability of Equipment Failure) x PD (Population Density) x AL (Lethal Area, in the event of FIT) x PK (Probability of a Fatality) x S (Shelter factor)

Lethal Area – Aircraft-derived figure [10]:

Debris area in open areas = 1.3455 ft^2/lb MTOW

e.g., Desert Hawk III, DH3 = 1.3455/8.51 lb (3.86 kg)

= 11.45 ft^2

AL = 1.064 m^2

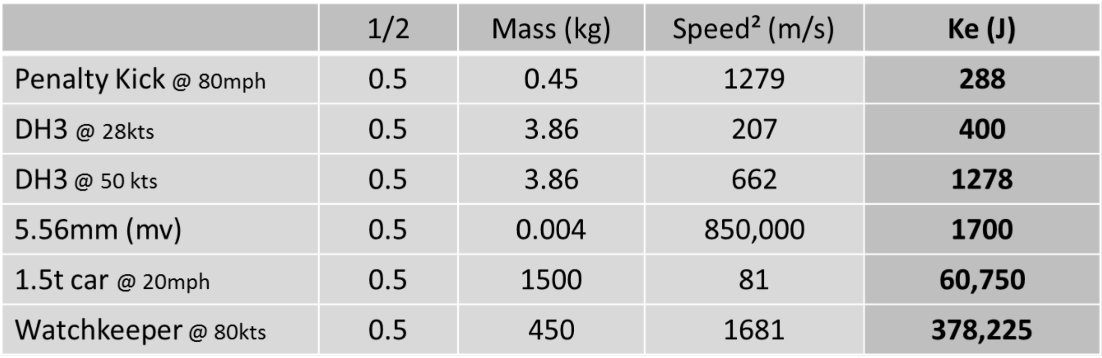
PD needs to be cognisant of the flight path of the UAS and the population density in that vicinity, rather than a general assessment of PD.

In the CE model, Kinetic Energy is not considered as a variable in its own right, it is a factor in considering PK and S.

Ke (J) = ½ x mass x $speed^2$:

Table 2 demonstrates how much energy could be transferred in specific circumstances and also demonstrates that energy is not necessarily designed to be transferred between objects, such as in a football.

Table 2: Energy Created by Moving Objects.



	1/2	Mass (kg)	Speed^2 (m/s)	**Ke (J)**
Penalty Kick @ 80mph	0.5	0.45	1279	**288**
DH3 @ 28kts	0.5	3.86	207	**400**
DH3 @ 50 kts	0.5	3.86	662	**1278**
5.56mm (mv)	0.5	0.004	850,000	**1700**
1.5t car @ 20mph	0.5	1500	81	**60,750**
Watchkeeper @ 80kts	0.5	450	1681	**378,225**

4.2.7.2 The Mid-Air Collision

Calculating the probability of a MAC on operations can be challenging and should generally be supported by intelligence to minimise the likelihood further. Airspaces should be calculated in similar ways to population density, on the ground, of the operation area and considerations should be made to a ceiling altitude with a 2D frame of reference of both the Size of Aircraft and Airspace for simplicity. The following examples are taken from academic papers on this subject and also UK approaches to describe risk when operating in non-segregated airspace:

$$\begin{gathered}\text{P\_Collision} = \\ \text{Aircraft in flight frequency} \times \text{Average duration in airspace} \times (\text{Size of Aircraft}) / \text{Airspace}\end{gathered} \tag{1}$$

A study has shown that the max air traffic density over the cities of Devils Lake and Grand Forks in North Dakota were at 625 a/c per voxel (voxel = 5000 ft x 5000 ft x 500 ft), but clearly these aircraft were not in that voxel all at the same time.

Very simply put, this results in a/c per voxel; 1 voxel = 1524 m x 1524 m x 152 m = 354 m^3 / 625 = 1 a/c per 566000 m^3.

The volume of a 737 is approximately 85 m^3. Size of a/c / airspace = 85/566000 = 0.00015. From here we can see that the probability of encountering a commercial airliner, even in reasonably high traffic densities is very low, unless you are deliberately trying to hit it.

$$\text{ARF} = \text{AST x PD x AL x PK x AS} \tag{2}$$

Where:

ARF = Air Risk Factor

AST = Agreed Safety Target (of catastrophic equipment failure). This is relevant because an equipment failure may lead to an RPAS failing to respond to commands to stay within allocated / ordered airspace.

PD = Population Density per cubic metre of airspace. This should perhaps be calculated using a ‘worst case’ figure for the crew and passengers of any aircraft with which the RPAS may realistically collide.

AL = Lethal Area. Frontal area (or volume of RPAS, multiplied by frontal area of manned aircraft). It is necessary to use cubic metres, as that is the unit of measure for airspace.

PK = Probability of fatality. Conservatively, this figure should be for the crew and passengers of the largest aircraft with which the RPAS may realistically collide (especially as we have considered that only a frontal collision would be lethal).

AS = Fraction of each RPAS operating hour in which another aircraft is expected to share same airspace as RPAS.

Example for long, thin airspace in which a heavily loaded CH-47 (30 crew and passengers) may also operate:

ARF = AST x PD x AL x PK x AS

= $(1 \times 10^{-3}) \times (30 / 4.8 \times 10^{10}) \times 16 \times 30 \times 0.1$

= 0.001 x 0.000000000625 x 16 x 30 x 0.1

= 0.00000000003

= 3×10^{-11}.

Where:

AST = 1×10^{-3}

PD = 6.25×10^{-10}). (Passengers and crew of manned aircraft = 30) / (Airspace volume = height x width x length = 600 m x 2,000 m x 40,000 m = 4.8×10^{10}) m^3)

AL = 16 m^3. Frontal area of manned aircraft is roughly equal to 16 m^3 (worked out for a CH-47 with a fuselage width of 3.78 m). It is necessary to use cubic metres as that is the unit of measure for airspace.

PK = 30. Estimate for crew and passengers of a CH47.

AS = 0.1. For the purposes of this example, I will assume that the airspace in which the RPAS will operate will be populated by a manned aircraft for 1/10th of each hour, or 0.1.

Example for a 20 km (diameter) ROZ containing a single AH64D (considered to be operating in the hover):

ARF = AST x PD x AL x PK x AS

= $(1 \times 10^{-3}) \times (2 / 9.87 \times 10^{8}) \times 72 \times 0.5 \times 0.25$

= 0.001 x 0.00000000203 x 72 x 0.5 x 0.25

= 0.0000000000183

= 1.83×10^{-11}

Where:

AST = 1×10^{-3}

PD = 2.03×10^{-9}. (Passengers and crew of manned aircraft = 2) / (Airspace volume = height x πr^2 = 300 m x ($\pi \times 10{,}000^2$ m) = 9.87×10^{8} m^3)

AL = 72 m^3. Side area of hovering AH64 is roughly equal to 72 m^3 (worked out for an AH64 with an airframe height of 3.87 m and a length of 17.73). It is necessary to use cubic metres as that is the unit of measure for airspace.

PK = 0.5. Whilst the crew of an AH-64D is 2, it is unlikely that an RPAS striking an AH64D (an armoured attack helicopter with a small cockpit area) will cause a fatality.

AS = 0.25 For the purposes of this example, it is assumed that the airspace in which the RPAS will operate will be populated by a single AH-64D for one quarter of each RPAS flying hour.

4.2.7.3 Methods of Mitigating Mid-Air Collision (MAC), Ensuring Safe Separation

Increasing the awareness capability of the UAS Remote Pilot. This relies on the Remote Pilot (RP) maintaining their own separation from other aircraft and could be facilitated by feeding in the ATC map, and communications into a headset integrated on the GCS. For BVLOS, at extended ranges, there could also be a radio receiver on the aircraft which could be fed back through to the GCS. This solution is targeting MAC events with manned aircraft on the ATC system and would be of limited use with other UAS, who are not monitoring. This approach would require a small level of aircraft radio communications understanding on behalf of the RP to implement properly.

Depending on the capability of the UAV, a possible alternative might be fitting an IFF like device to emit a signal from the GCS. IFF interrogators have an approximate range of 200NM[3]. Although the effective range could be lower, but with all likelihood it will be able to identify the UAV/GCS at a considerable range. They are also fully integrated into radar process, as it is the sole source of information for Secondary Surveillance Radar. Mode 5 Level 2 contains position and Mode 3 contains altitude data. An IFF responder could be programmed to respond with the UAV position location and be used by ATC and the interrogator to plot the position of the UAV on the ATM map. Combined with pilot radio communications being required, this could raise awareness of aircraft operating in the area for incoming air traffic. Currently a typical Mode 1-4 weighs 1.4 kg (Thales Watchkeeper) with intentions to limit any increase in size or mass with the introduction of Mode 5 (weighs 2.4 kg on Watchkeeper). This would be a significant portion of the UAV weight although feasible on the GCS of most sUAS.

> *In the future, it is expected that airborne surveillance will play a larger role in assuring safety in the Low Density Low Complexity Airspace (LDLCA) region, this being one of the main applications of electronic conspicuity. The absence of a low-cost system market has precluded any meaningful technology take-up, along with the debate about the true level of risk of mid-air collision in Class G airspace.* [11]

4.2.8 Critical Question for Consideration 8: How Does the Authority Manage the Provision of Relevant Instructions to Remote Crew?

NATO Member States UAS/RPAS Operations Instructions should include items such as:

- RPAS Qualification definitions;
- Definition of Competence in Role;
- RPAS Currency and Continuation Training;
- Theatre Familiarisation and Operational Deployments;
- Responsibilities of RPAS Captains;
- Definition and Responsibilities of RPAS Instructors;
- RPAS Pilot Medical Requirements;
- Authorisation of RPAS Personnel to Carry Out Maintenance Tasks;
- Special Flying Instructions;
- Supervision of Flying;
- Authorisation of RPAS Flights;
- Rules of the Air;

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[3] Approximate value obtained from discussions with APS Project Team in DE&S, they caveated this value saying it is dependent on terrain and placement of the interrogator as well as the altitude of the transponder.

- Emergency Procedures; and
- Flight Simulation Training Devices.

5.0 THE NINTH CONSIDERATION – AIRSPACE INTEGRATION

Critical Question for Consideration 9: How Does the Authority Consider the Requirements of Solutions for Safe Separation?

5.1 The Principles of Airspace Integration

Airspace integration will be an evolutionary process, especially as technological improvements become available and the regulatory framework changes to adapt to UAS, or has new material added. An example of the latter is that currently ICAO provides SARPs and guidance material for international IFR (and this is still focused on manned aircraft) meaning that Member States have drafted and published their own regulations to apply to small UAS operations with little consideration to standardisation across sovereign borders. This will change in future, as ICAO under direction from both the 39th session of the ICAO Assembly as well as the 12th Air Navigation Conference, has started to produce guidance for operation other than international IFR. This is seen in two groups. Firstly, the Unmanned Aircraft Systems Advisory Group (UAS-AG), which was established in 2015 to support the ICAO Secretariat in developing guidance material and expedite the development of provisions to be used by Member States to regulate (UAS). The UAS-AG has moved into its second phase, to establish a common global framework for unmanned aircraft system Unified Traffic Management (UTM), in order to allow further UTM developments to focus on better defined issues, whether technical, operational or legal. Secondly, a recently formed ICAO body is the Task Force on Unmanned Aircraft in Humanitarian Aid and Development, which will also assist ICAO in its role in harmonising UAS regulations.

To decide how integration should be approached, the first question is: does the UAS comply with all the rules of the air and would it be handled within the ATM system in a seamless manner as per conventionally piloted aircraft? [9] Even the most advance UAS do not have certified functioning TCAS/ACAS and full Detect and Avoid (DAA) (as of 2019). As full compliance is unlikely in the near term, the gaps between full compliance and the UAS operation need to be determined, and restrictions to the operation suggested or alternative means of compliance proposed, to prepare for application for operation authorisation from the CAA, and also the ANSP.

Airspace access can be divided into three areas. Segregation; Accommodation; or Integration (to different levels). As the scope of this document is on integrated operations, forms of accommodation from case by case to full integration will be discussed.

To align with the contemporary flight operations categorisation (EASA: Open, Specific, Certified) as well as to consider flight operations areas (i.e., the EUROCONTROL UAS ATM Operational Concept), further discussion is offered in this section.

To focus on the type of operation, the next step would be to specify the operational airspace. For example, whether the operation is: a Very Low Level (VLL, generally accepted to refer to not above 400 or 500 ft AGL); in controlled airspace (and therefore should operate as per the rules of the air or to an equivalence as accepted by the CAA and/or the ANSP), or is it Very High Level (for example, above FL 500) that transits to and from the HALE level bands through segregated airspace.

5.1.1 Very Low Level VLL Operations

Generally, this is typically for smaller platforms operating in airspace that is less often utilised by conventional aircraft; as it is commonly accepted, although not accurate, that VFR do not operate below 500 ft AGL due to

ICAO Annex 2. Therefore, 400 ft has been adopted by most National Authorities as the height UAS can operate to free of other constraining legislation. Albeit, clearly, without a significant nor tested buffer (100 ft). The lower airspace is often utilised by a broad range of aircraft types (gliders, parasailers, MIL, Emergency/Rescue helicopters, a broad array of drones) equipped with a range of surveillance means from none (non-cooperative) to Mode S, with either no communication capabilities, VHF or uncertified alternatives, and a cross-section of baselines for reference datum – for example in height keeping. As there are no adequate DAA or Sense and Avoid (SAA) systems (as yet) for these type of GA, alternative means to support strategic and tactical separation and collision avoidance are required. Annexes to the SORA provide excellent direction. UTM service provision will provide a range of benefits but is especially directed to provide continued safety of all air traffic. Through its tracking and location service, the UTM system could combine real time accurate locations of all UA and conventional aircraft in an airspace to mitigate the lack of DAA and provide a means to address separation and collision avoidance. The vast majority of UAS in this airspace will not be able to comply with IFR or VFR nor with the requirement of the airspace classification (i.e., Class D, etc.) and CAAs will need to provide airspace access permissions based on these facts.

5.2 Case Studies in Controlled Airspace

The ICAO RPAS Panel is progressing with its work to produce SARPs for international IFR UAS in controlled airspace. In the meantime, Member States can apply their Safety Management System (SMS) (Annex 19 and The Safety Management Manual Doc. 9859) as they see fit.

There are several projects outside of NATO AVT-278 also exploring these topics and one, EDA and EASA group that is drafting Concept of Operations (CONOPS) for the accommodation of military IFR RPAS MALE type under GAT – Airspace classes A-C, has gathered the best practices currently existing allowing RPAS flights in non-segregated airspace over Europe. Military operators have highlighted the need to have more flexibility and efficiency by enabling the en route / transit part of MALE flight outside segregated areas and the E DA/EASACONOPS aims to facilitate such RPAS transit flights in the short-term.

This section describes the operations of the General Atomics' MQ-9 in France and Italy, and the IAI/Airbus HARFANG in France.

5.2.1 Italy – Predator A and B, Global Hawk, and Hammerhead

Italy has had the Predator A since 2004 and Predator B since 2008. The Global Hawk is stationed in Sigonella air base, Sicily which is a military CTR plus controls the civilian airport Catania Fontanarossa. The Italian developed MALE RPAS Hammerhead is also undergoing flight testing here. Testing areas have been established in the surrounding sea areas to perform RPAS experimentations. The Italian Technical Airworthiness Authority is responsible for the NATO Alliance Ground Surveillance (AGS) certification and Italian Military RPAS are certified according to military certification regulation and NATO STANAGS. Operations are coordinated between civil and military ATM systems while involving segregated corridors and Temporary Segregated Airspace applying the Smart Segregation concept (corridors' – segments of Temporary Segregated Airspace dynamically opened and closed according to the RPAS flight) to provide segregation from civilian traffic an applying Flexible Use of Airspace (FUA) concepts. Segregated airspace rules are published either in the Italian AIP (when permanent) or activated through NOTAM W series (when temporary). Ground risk is considered when operating over land.

It is envisaged that the smart segregation mechanism will not be necessary once future RPAS, or current legacy RPAS, have matured their design and meet current STANAG reliability requirements. At this point nominal transit in controlled airspace is considered feasible with full airworthiness being established.

5.2.2 France – HARFANG, Reaper

France has the HARFANG UAS and Reaper at Cognac Air Force Base with operations assigned to different training areas and operational sites, in segregated airspace. However, more recently the French Air Force has carried out several experimental flights in non-segregated airspace under GAT IFR, controlled by Bordeaux ATC (civilian ATS unit/ATCOs of DSNA), in operational test areas over the Atlantic as well as the south west of France.

This is under a three phased national strategy aiming to enable MALE RPAS operations in French airspace and cross border. In January 2017, several flights of the HARFANG were conducted under Europe's Single European Sky initiative programme (SESAR 2020) accommodated by followed pre-planned flight paths, including Bordeaux approaches, meeting navigation performances of 1NM lateral and 200 ft altitude. Three flights were conducted under GAT IFR rules: the first with no chase aircraft; the second and third flights using cooperative air traffic to simulate IFR/VFR crossing – and these flights were simulated by DSNA. Next, DSNA ATCOs controlled the transit / en route phases and representative military operations conducted in segregated airspace. The flight plan departed from Cognac to Bordeaux via Toulouse and Carcassonne (where a simulated final approach has been conducted) with a 'lost link' exercise performed within the Carcassonne TMA with an extensive set of emergency procedure tests. Due to the flight altitude, the en route civil control centre was not part of the experimentation. The final stage later included some short flights in and around Cognac above FL190/FL200 and some longer flights incorporating both operational and training flights with the Reaper under civil ATCOs.

5.3 Methods (Process) and Technology to Assist Integrating UAS in Non-Segregated Airspace

Key aspects to facilitate and ensure safe separation of RPAS from other air traffic include:

- Increasing the awareness capability of the RPAS Pilot, such as feeding in the ATC map, fitting an IFF signal integrated/non-integrated with GCS, reducing distractions (BVLOS), trying to maintain situational awareness (SA) and managing overall UAS Situational Awareness (SA).
- Avoiding others by seeing and avoiding – an IFF relay from GCS, feeding flight and altitude data into the ATC picture.
- Controlled airspace in the vicinity of the UAS – a time dependant bubble.
- Different system of controlled airspace – An integrated NATO system including computer system to allow a single ATM person, in charge of small areas of airspace at low altitudes, with rules and segmentation.

The above was partially covered in the HELIOS 'Low Density Low Complexity Airspace (LDLCA) A Scoping Study', dated Dec 2013 [11]. HELIOS describes a situation where authorities protect certain Controlled Air Space (CAS) zones:

> *One option to be modelled is the possibility of varying the level of protection around aerodromes, using combinations of Controlled Airspace (Class C, D or E), Radio Mandatory Zones, and/or Transponder Mandatory Zones (TMZ) or Surveillance Mandatory Zones (SMZ). SMZ entail the use of either Mode S transponders or 1090ES ADS-B transceivers on-board the aircraft. The mandatory zone could be both radio and surveillance (known informally as a 'mandatory conspicuity zone").*
>
> *The options to be used will depend upon the potential effectiveness of the mandatory zones, which itself depends upon the take-up of the required technical solutions. In theory, reducing the size of Controlled Airspace may assist users with issues accessing CAS, since there is reduced chance they will be asked to wait or route around. The provision of a mandatory zone will act as a 'buffer zone' to the CAS, ensuring adequate protection for aircraft approaching/departing from the aerodrome.*

The HELIOS study goes on to describe how these mandatory zones could be configured, but one can see how NATO could create such TMZs/SMZs to control segregation of UAS from other airborne traffic in a collaborative operational area. Thus, the risk of MAC can be delegated to the Command Authority who can define the operational rules for particular airspace zones at a particular time. This would be defined by the JARUS SORA as 'Strategic Mitigations by Structures and Rules' (JARUS SORA Annex C, 4.3).

For larger systems and more complex UAS operations in densely occupied airspace, Sense and Avoid (or Sense and Respond) UAS process (i.e., not necessarily based upon entire technical solution) would have to fulfil the following capabilities [12]:

- Follow 'Right of Way' regulations with both Airborne and Ground traffic.
- Avoid inclement weather and retain cloud/visibility limits for flight plan.
- Respond to Aerodrome markings and pyrotechnics.
- Respond to visual signals from intercepting aircraft.
- Avoid terrain and man-made obstacles by minimum separation distances.
- Respond to pyrotechnic, smoke and emergency signals from the ground.
- Maintain separation, spacing, sequencing and visual following of traffic as directed by ATC.
- Avoid all airborne objects, including paragliders, balloons, etc.
- Operate in all lighting conditions, day and night.
- Operate in both VFR and IFR conditions.
- Respond to both cooperative and non-cooperative aircraft.
- Respond to aircraft in distress.

5.3.1 The EASA Draft CONOPS Summary Statement

The EASA draft document lists the following prerequisites for operations and includes expanded details of the more intricate areas:

- 2-way communication (VHF radio) between the Remote Pilot and the civil and military ATCO involved in the operation.
- A direct connection between the Remote Pilot and the civil and military ATCO involved in the operation. This direct connection shall be tested before each operation.
- Capability to implement all vertical and lateral instructions of ATC by the RPAS as in today's manned aviation[4].
- Navigation precision of +/- 1 NM and altitude precision of +/- 200 ft. With such navigation precision the standard separation minima of 5 nm and 1000 ft could be kept during the operation.
- Transponder mode A/C to:
    - Make the RPA a cooperative aircraft; and
    - To trigger RA manoeuvres for TCAS-equipped aircraft. The RPA itself, is not equipped with TCAS, and is not executing TCAS RA manoeuvres.

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[4] The RP shall inform the ATC unit concerned if unable, at any time, to comply with a specified rate of climb or descent. In such cases, the controller shall apply an alternative method to achieve an appropriate separation minimum between aircraft, without delay (ICAO 4444).

- Predictable behaviour in case of degraded mode (see contingency procedures below extracted from the French CONOPS). The civil/military coordination is detailed in a national CONOPS agreed by the DSAE (Military Aviation Authority) and the DNSA (ANSP) under the control of DGAC (Direction Génerale d'Aviation Civile – National Civil Aviation Authority) and in line with the national regulation.

5.3.1.1 Contingency Procedures

Abnormal and emergency situations lead to serious disruption to the ATM system and the contingency procedures relating to these situations should be carefully coordinated amongst all organisations involved in the RPAS flight.

1) C2 link failure: Three C2 link loss procedures are currently proposed. In all cases, once the C2 link loss is detected by the Remote Pilot in command, s/he will contact ATC. A direct telephone connection ensures a communication means between ATC and Remote Pilot in case of C2 link loss situations:
   - Return to base: This procedure implies an automatic return to base following the same flight route backwards, after a predefined time (1 minute). This predefined time is used to try to recover the C2 link, once the C2 link loss has been detected by the Remote Pilot.
   - Continue then return to base: This procedure implies continuing the cleared flight plan before automatically activating the return to base procedure. A specific delay can also be introduced in the turning point.
   - Continue then return to base (second option): This option is built on the previous one and has been the procedure used during the latest French operations. Depends on the following, or includes the following operational propositions:
     - The link loss is detected by the remote pilot.
     - The link loss status exceeds the established timeframe (1 min) to regain control of the aircraft.
     - The transponder squawks the emergency code 7600 (loss of communication).
     - The RPA continues the cleared flight plan until a point previously agreed/authorised by ATC.
     - Holding for 20 minutes to allow ATC coordination.
     - Direct route to home.
2) Radio/communication failure: As in the previous situation, a direct telephone connection ensures a communication means between ATC and remote pilot in case of radio failure. In this case, the mission is aborted, and the aircraft is steered towards a segregated area, following the instructions received by ATC via telephone. Depending on the location and time of the failure, the mission could be extended after consultation between military supervisors and control centres. In this case, phone connection is used as alternative means of communication between the remote pilot and ATC.
3) GNSS failure: In case of GPS signal loss, the RPAS will modify its navigation reference system from initial hybrid GPS-INS to INS only. Navigation based on radar vectors by ATC will still be possible, alongside flight by traditional map navigation.
4) Transponder failure. Upon receiving alert of a transponder failure, the mission is aborted and a return to segregated airspace is performed. When available, a primary radar is used for surveillance purposes before transferring control to military ATC.

5.3.1.2 Navigation and Surveillance

> *There is still discussion on the actual implementation environment for the core Performance Based Nav (PBN) options. In Low Density Low Complexity Airspace (LDLCA), the benefits case for very*

> *closely spaced parallel routes or for fixed radius turns may be difficult to make, particularly given the costs that may be applied to retrofit a wide variety of aircraft to be able to take advantage of the new procedures. Many of the modern avionics are able to cope with increased accuracy required from many PBN applications (RNAV1 and RNP1). This applies to GA IFR fitments, both fixed wing and rotorcraft. The capability to carry out Baro-VNAV procedures may be a greater issue for these aircraft, as certified and integrated altimeters are not standard on the GA fleet due to cost considerations. As mentioned in the previous section, the ability to revert to DME/DME based navigation may also be an issue in LDLCA due to DME coverage and fleet equipage.* [11]

CAP670 states: that for low traffic density and/or complexity areas, non-cooperative surveillance is optional. However, it is required if the hazard analysis shows that it is probable for non-transponder equipped aircraft (whether identified or not) to present a hazard to operations due to the uncertainty of their positions, which cannot be mitigated by other measures.

> *ADS-B, as a technical enabler for a safety-critical system, is currently in the midst of a transitional phase. Trust in the system is not 100%, due to known issues with installations and the properties of a single source GPS solution. The possibility of undetected errors in the position reported remains an issue. It is expected that some of these issues will be solved in the years to come, with the introduction of basic error detection internally to ADS-B OUT transceivers, and the introduction of dual GNSS solutions (i.e., Galileo). As this happens, ADS-B is more likely to be trusted as a cooperative form of surveillance, possibly even sole means, or backed up by an integrity check mechanism (e.g., reduced form of WAM).* [11]

5.4 Item 9 Summary

This section describes many techniques that could be used by the NATO Nation to make their case for safe separation in the operational airspace. The NATO Command Authority would have to review each case and assess the merits and gaps. A suggestion is that a follow-on study from AVT-278 could be tasked with creating prescribed methodology for assessment, or the assessment for Air Encounter Risk could follow the JARUS SORA methodology, which appears to be the best methodology available today, backed up with further evidence/mitigations.

6.0 FRAMEWORK ANALYSIS FOLLOW-ON ACTIVITY

6.1 Introduction

Leading on from the analysis for each Consideration in Table 1, the AVT-278 team recorded panel members' expert opinion. The '9 Considerations', to be known as the NATO Framework for approval of NATO UAS Operations, requires the following subsequent activity.

6.1.1 Consideration 1 Analysis: "That the NATO Partner Operates Within an Airworthiness Framework That Ensures They Contract UAS Capability with Competent Design Organisations (DO) Credentials"

For follow-on activity post this technical report, NATO needs to create a means of assessment to ensure that Member States and Partner Nations deliver assurance for 'the employment of competent UAS Organisations via National Regulations.'

This needs to be combined with Item 3 – the level of assurance on a competent Design Organisation is directly related to the Class/Category; i.e., for EASA defined 'Open' Class the assurance would be minimal, but we suggest still needs assessment by a competent national authority.

An issue was debated – in that a partner may not want to make an assessment of a Design/Production company in the lower levels of the Categorisation/Class. This would be a gap that would need an additional means of mitigation/argument by a competent authority.

6.1.2 Consideration 2 Analysis: "That the NATO Partner Employs Competent Personnel and Processes in the Approval (Airworthiness / Flight Envelope – Part 21J) and Operation (Continuing Airworthiness and Commanding (Equivalent EASA/EMAR Part M/66/145/147)) of UAS"

For 'Means of Assessment against the Framework', follow-on activity needs to deliver expected levels of training of certain individuals with important roles. MS must establish an Airworthiness Authority – an individual accountable for managing the Safety of the UA system and a Duty Holder (operator) accountable for managing the risk of operations. For smaller systems – an accountable individual (operator) must be identified. There is sufficient justification for this to become NATO policy for UAS.

6.1.3 Consideration 3 Analysis: "That the NATO Partner Operates Within an Airworthiness Framework that Considers the Need for Certification or Compliance with Appropriate Standards, or a Determined Risk-Based Approach for UAS"

The Framework will steer towards appropriate determinations of the use of standards. This will include an assessment of Class/Categories against a set of specific set of characteristics and operational circumstances. This report does not recommend a specific MS methodology, but rather asserts that a risk-based approach to UAS Classification is the most suitable approach.

6.1.4 Consideration 4 Analysis: "That the NATO Partner has a Method of Ensuring Build Quality and Maintaining that Build Quality"

AVT-278 believes the Framework insists on known QMS standards or equivalents, i.e., ISO9001 (see Annex A for a list of appropriate standards).

6.1.5 Consideration 5 Analysis: "That the NATO Partner has Established an Operating Envelope and Gathered Evidence to Support the Operating Envelope of the UAS and has Applied Constraints/Limitations Where Necessary and Appropriate to the Operation"

The Framework stipulates the requirement to support operational use with appropriate test evidence against the flight envelope – JARUS SORA Annex E offers best practice.

6.1.6 Consideration 6 Analysis: "The Reasons Why, and How, a NATO Partner has Employed Methods of Independent Scrutiny to Assure the Safety Assessment of their UAS in the Approvals Process. (Usage of Independent Eyes in the Approval Process)"

The Framework insists on the Nation having subjected safety cases to independent scrutiny, which could be the Nations' regulator.

6.1.7 Consideration 7 Analysis: "That the NATO Partner Employs a Method for Understanding, Analysing and Managing Risk"

AVT-278 recommend a set of safety equations to record the Risk to Life (RtL), e.g., CE (Casualty Exposure Factor) = PF (Probability of Equipment Failure) x PD (Population Density) x AL (Lethal Area, in the event of FIT) x PK (Probability of a Fatality) x S (Shelter factor) – and a similar methodology for calculating Air Encounter Risk. It would be useful if the NATO Nations were using the same equation. See Section 4.2.7.

6.1.8 Consideration 8 Analysis: "That the NATO Partner Provides UAS Documentation, Including Operator's Manual and Maintenance Manual and Records"

See Section 4.2.8 for a complete list.

6.1.9 Consideration 9 Analysis: "That the NATO Partner's UAS has Technology Integrated into the System that Facilitates Safe Navigation, and Separation when Operating Over Densely Populated Areas and in Competing Airspace, or Can Argue Sufficient Mitigations"

JARUS SORA is the best place to start the process for calculating your Air Encounter Risk and therefore implement mitigation strategies to handle the residual risk. Some mitigation strategies/methods are included in this report in Section 5.0.

7.0 SUMMARY AND COMMON THEMES

7.1 Analysis of the Common Themes

Today, most NATO MS would recognise the elements in the 9 Considerations Framework but would not have common aligned processes. In a NATO collaborative UAS mission scenario, this would make it very difficult for Command Authorities to compare operational approval approaches, risk management processes and therefore overall mission risk. This would make it difficult to have one streamlined method of gaining NATO collaborative UAS mission approval and operating collaboratively. By adopting the 9 Considerations Framework and providing a common set of NATO Policy and Rules, NATO could establish a simple means of assessing a NATO MS approach to UAS operations approval and therefore swiftly facilitate collaborative missions.

8.0 FURTHER WORK AND POTENTIAL NEXT STEPS

8.1 Next Steps

AVT-278 has delivered a 9 Considerations Framework that, if utilised by NATO Member States, would deliver means to ensure safe and airworthy operation of UAS within a risk-based approach assessment of individual UAS operations. The approach covers Categories/Classes of UAS and the operational environment and the likelihood of risk for safe ground separation and safe separation of other airborne assets. NATO technical leaders now need to decide whether to automatically adopt this approach via the delivery and execution of UAS policies, or to suggest this methodology to NATO Member States via an Implementation Notice; therefore seeking comment on the idea of implementing the 9 Considerations Framework approach.

It is strongly recommended that the technical UAS panel 'Flight in Non-Segregated Airspace' (FINAS) is engaged to take this work forward in whichever guise the NATO technical leaders decide. It is easy to see that the 9 Considerations Framework could be developed to include means of assessment for NATO Member States UAS Operations submission to NATO. The 9 Considerations Framework could be delivered via a Spreadsheet/Database model, which could include a 'Spiderweb Chart' to score a NATO Member State's submission; the NATO Member State would score itself based upon a set of criteria, this would then be assessed via the NATO Operation assurance service, for accuracy and coherence with the expected assurance expectation. It is strongly recommended that NATO exploits the 9 Considerations Framework to deliver this means of assessment via a software model.

AVT-278 has delivered a risk-based safety assessment method for operational airworthiness and certification requirements for UAS/RPAS and recommendations for clear and baseline equivalent levels of safety to assist in obtaining operational approvals of UAS/RPAS operations utilised by NATO. This concludes the work of AVT-278.

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 Recommendations

Following the investigation, the AVT-278 report recommends the following:

I. The JCG-UAS uses this work to provide implementation policies for NATO UAS operations, and provides a software tool to enable a means of assessment against the 9 Considerations Framework. There is an opportunity to create a common risk-based approach for the use of military RPAS, the existing NATO STANAGs and other applicable national rules and regulations must be accounted for. This could then be leveraged to establish a set of harmonised NATO regulations.

II. For This purpose, the competent operations authority must have means to assess, manage and sustain continuing airworthiness, which includes the training and licensing of its personnel for the full extent of the missions they could be expected to undertake;

III. The NATO Partner Nation should provide solutions to the ‘9 Considerations’, and that will ensure an adequate level of safety, facilitating inclusion into a NATO collaborative UAS mission. Any gaps against the ‘9 Considerations’ would require remedial risk to be presented and argued to the NATO Command Authority.

IV. The design configuration must be carefully controlled.

V. The Design Organisation (DO) must satisfactorily demonstrate the involvement of SQEP Engineers, to perform airworthiness tasks, such as sentencing build standard deviations along with understanding of airworthiness implications. The DO must demonstrate the ability to produce Field Bulletins, Modifications, Repairs and associated safe Deviations (concessions) from the expected build standard, i.e., establish the level of confidence that the build standard accords with the design standards. This assessment will also cover the system delivery process, including the air system acceptance test and survey (an ability to produce comprehensive QA inspection and flight test).

VI. The Safety Management Culture should be clearly described, including its validation process. The culture should include an ability to conduct Hazard Analysis and demonstrate a Safety Management Plan and Safety Case Report construct, including Hazard Log status, and composition, and possible Loss Model development.

VII. The Member States must establish an Airworthiness Authority – an individual accountable for managing the Safety of the UA system and a Duty Holder (operator) accountable for managing the risk of operations. For smaller systems – an accountable individual (operator) must be identified. There is sufficient justification for this to become NATO policy for UAS.

VIII. The Entitlement to Conduct Flying Duties by the Operator must be through the possession of a military approved UAS/RPAS pilot/operator qualification and by an assessment as medically fit for duty. Must have undertaken an approved training course and be current on the type of UAS to be operated and therefore hold a Certificate of Competence for that type.

IX. The NATO Partner Nation should demonstrate the ability to categorise their UAS capability.

X. The NATO Partner Nation should demonstrate the ability to apply and deliver appropriate standards, when required, depending on the use/risk of UAS operations.

XI. The National Authority presenting the UAS for operation should have subjected their UAS safety assessment to independent evaluation and audit consisting of:

- Independent analysis of the data evidence supporting the Equipment Safety Assessment Report (ESAR), including, where appropriate, a qualitative assessment of UAS handling, HMI and crew workload.
- An independent process audit against the safety plan, covering such activities as the Project Safety Panel, the Project Team safety processes, the Design Organisations safety plan and record.
- This independent evaluation should be proportionate to the level of risk inherent in the Class and use of the UAS. Level of independence can vary depending upon the assessed level of risk.

XII. The NATO Member States authority must demonstrate methods of assessing and mitigating Risk to Life during UAS/RPAS operations. Use of Bow-Ties, or other risk assessment methodologies, would be appropriate. Robust qualitative and/or quantitative methods should be utilised. In Section 4.2.7 are some reasonable quantitative methods.

XIII. The NATO Member States UAS/RPAS Operations Instructions should include items such as: RPAS Qualification definitions; Definition of Competence In Role; RPAS Currency and Continuation Training; Theatre Familiarisation and Operational Deployments; Responsibilities of RPAS Captains; Definition and Responsibilities of RPAS Instructors; RPAS Pilot Medical Requirements; Authorisation of RPAS Personnel to Carry Out Maintenance Tasks; Special Flying Instructions; Supervision of Flying; Authorisation of RPAS Flights; Rules of the Air; Emergency Procedures and Flight Simulation Training Devices.

XIV. Regarding the Airspace Integration, as full compliance with all the rules of the air is unlikely in the near term, the gaps between full compliance and the UAS operation need to be determined, and restrictions to the operation suggested or alternative means of compliance proposed.

XV. A follow-on study from AVT-278 should be tasked with creating prescribed methodology for assessment of Mid-Air Collision Risk, or the assessment for Air Encounter Risk could follow the JARUS SORA methodology, which appears to be the best methodology available today, backed up with further evidence/mitigations.

XVI. NATO should create a means to assess that ensures that Member States and Partner Nations deliver assurance for ‘the employment of competent UAS Organisations via National Regulations’.

XVII. A follow-on activity to deliver expected levels of training of certain individuals with important roles.

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ANNEX A – LIST OF UAS STANDARDS USED BY THE GERMAN AVIATION AUTHORITY

General Regulations

ARP 4754: Certification Considerations for Highly Integrated or Complex Aircraft Systems.

ARP 4761: Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne System and Equipment.

UAS Regulations

SAE ARP 94910 (12/2012): Specification Guide for Flight Control Design, Installation and Test of Military Unmanned Aircrafts.

Software, Electronics and Electrical Installations

MIL-STD-1521B: Technical Review and Audits for Systems, Equipment and Computer Software.

RTCA/DO-330: Software Tool Qualification Considerations.

RTCA/DO-331: Model-Based Development and Verification Supplement to DO-178C and DO-278A.

RTCA/DO-332: Object-Oriented Technology and Related Techniques Supplement to DO-178C and DO-278A.

RTCA/DO-333: Formal Methods Supplement to DO-178C and DO-278A.

RTCA/DO-248C: Final Report for Clarification of DO-178B "Software Considerations in Airborne Systems and Equipment Certification".

RTCA/DO-200A: Standards for Processing Aeronautical Data.

STANAG 3659: Forderungen an Masseverbindungen für metallische Luftfahrzeuganlagen (Requirements for Earth Bondings for Metal Aircraft Systems).

SAE AS50881: Wiring Aerospace Vehicle.

DIN EN 2282: Eigenschaften der elektrischen Stromversorgung von Luftfahrzeugen (Aircraft Electrical Power Supply Properties).

Environment and EMC

MIL-STD-810 or STANAG 4370: Environmental Testing.

AECTP-200: Environmental Conditions.

MIL-STD-461: Requirements for the Control of the Electromagnetic Interference Characteristics of Subsystems and Equipment.

MIL-STD-464: Electromagnetic Environmental Effects Requirements for Systems.

STANAG 3614: Electromagnetic Environmental Effects (E[3]) – Requirements for Aircraft Systems and Equipment.

ED 91: Aircraft Lightning Zoning Standard.

Fuel, Hydraulics and Landing Gear

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EASA ED 2012/019/R: Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Part-SPA.

ICAO Annex 10 Volume 1: Radio Navigation Aids.

STANAG 4533: Precision Approach and Landing System (PALS) – Transition Strategy.

STANAG 4550: Local Area Differential GPS (DGPS) for Military Precision Approach.

Commission Regulation (EC) 29/2009: Requirements on Data Link Services for the Single European Sky.

Commission Implementing Regulation (EU) 1079/2012: Requirements for Voice Channels Spacing for the Single European Sky.

EASA CS-ACNS: Airborne Communications, Navigation and Surveillance.

ETSO-2C169a: VHF Radio Communications Transceiver Equipment Operating within the Radio Frequency Range 117.975 to 137 Megahertz.

EUROCAE ED-23C: Minimum Performance Specification for Airborne VHF Receiver – Transmitter Operating in the Frequency Range 117.975 – 137.000 MHz.

Flugsicherungsausrüstungsverordnung (Air Traffic Control Equipment Orders), FSAV, 2004.

ETSO-2C128: Devices That Prevent Blocked Channels Used in Two-Way Radio Communications Due to Unintentional Transmissions.

Commission Implementing Regulation (EU) 1207/2011: Requirements for the Performance and the Interoperability of Surveillance for the Single European Sky.

Commission Regulation (EU) 1332/2011: Common Airspace Usage Requirements and Operating Procedures for Airborne Collision Avoidance.

ETSO-C-145c: Airborne Navigation Sensors Using the Global Positioning System Augmented by the Satellite Based Augmentation System.

ETSO-C196a: Airborne Supplemental Navigation Sensors for Global Positioning System Equipment Using Aircraft-Based Augmentation.

ETSO-C112d: Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment.

ETSO-C166bA1: Extended Squitter ADS-B and TIS-B Equipment Operating on the RF of 1090 Megahertz (MHz).

RTCA DO-229D: Minimum Operational Performance Standards for GPS/WAAS airborne Equipment (including Appendix R – Requirements and Test Procedures for tightly integrated GPS/INS Systems).

RTCA DO-236B: Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation.

RTCA DO-283A: Minimum Operational Performance Standards for Required Navigation Performance for Area Navigation. The compliance of the Flight Management / Flight Guidance System of the UAS has to be demonstrated against RTCA DO-236B und DO-283A.

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14. Abstract

AVT-278 were challenged with identifying and analyzing the multitude of different processes used by NATO to achieve UAS operations. These UAS operations were not constrained by type, e.g., Visual Line of Sight, Beyond Visual Line of Sight, weight, operating altitude, range or speed. To derive benefit from the work AVT-278 had started JCG-UAS asked the technical panel to answer a specific question: Recommend a process for Harmonization of RPAS Regulation to Achieve Operational (and Civil Acceptance) of NATO RPAS Operations.

By documenting Member States processes, and good/poor practice, themes of related processes started to emerge. It became clear that following safety and airworthiness principles, defined in current regulations (ICAO/EASA/FAA/CASA) for manned aviation, as well as guidance material issued for general commercial UAS operations, Member States were delivering operations by following processes aligned to airworthiness functional pillars. AVT-278, therefore identified common elements to achieving safe operations, and created a '9 Item Framework', which, if followed by Member States, would provide methodology to gain assurance of safe and airworthy, risk based, RPAS operations.

The 9 Item Framework, if adopted, could provide a method for Member States to assure their operations for NATO operational theatres and could also provide the method by which Theatre Commanders/Administrators can assess the robustness of a Member States UAS operation.

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