State of the Art of Airworthiness Certification

John E Mayer
47123 Buse Rd
Building 2272 Room 253
Patuxent River, MD 20670
USA

john.e.mayer1@navy.mil

ABSTRACT

The paper describes the current state of Unmanned Aircraft Systems (UAS) standards in NATO. Background on how the work was undertaken, the participation and the content of the standards are detailed. The objective for the paper is to broaden the understanding of what is available and how the standards are based on current national experience. Detail is provided on how the four airworthiness standards evolved in terms of the different classifications of UAS adopted to help reduce the challenge to individual segments to match the notional NATO UAS classifications. The limits of the range of information included in the standards are described as well as the purpose and methods for the individual documents. A way ahead is proposed to continue to focus expertise on the elements that must be addressed to continue to use these standards as one part of the integration of UAS in non-restricted airspace.

1.0 INTRODUCTION

The NATO UAS Airworthiness standards represent 15 years of work by NATO military and acquisition experts, based on academic and national UAS platforms experience, to meet the requirement for UAS airworthiness standards. The paper reviews how the enterprise to develop the standards was undertaken, the participation and the evolution of the concept over the last 15 years. Airworthiness standards with respect to UAS design, even when that includes the extended systems, only addresses one part of the goal to integrate UAS across military and national regulations. This paper addresses the aspect of UAS airworthiness development where the gap between NATO standards and present military regulations has been narrowed considerably. The work completed to date by the NATO UAS airworthiness development group, will provide a basis to meet the full potential for deployment of UAS to support their national and NATO military missions.

2.0 BACKGROUND

Additional work on the particulars for how the standards are applied to UAS in acquisition and production, as well as the science to support modelling and testing for compliance, will still be needed. The work from the JCGUAS, which includes 22 countries, and several hundred participants including the standards development groups, has provided a way forward for UAS airworthiness with these standards. Nations and industry are employing the standards which have led to additional discoveries based on their experience. Those seeking to use the standards either as the tool for acquisition and design, or for the means to link the actualization of the standards through scientific methods to accomplish compliance, should start by having an appreciation of the content of the individual standards. The three ratified standards to date total 569 pages. One additional standard is in draft and follow on editions of each of the three ratified standards are in development. The paper highlights the need and the origin, the nature of the experience, and examples of key aspects of the contents to engender additional participation in the airspace integration of UAS, and in particular the development of UAS airworthiness design standards.

3.0 APPLICABILITY

These standards are developed under the doctrine of state (or public) aircraft. The International Convention on Civil Aircraft (ICAO) establishes two categories of aircraft: civil and state. As public aircraft are operated by governments for safety, security, and welfare of the public, the convention acknowledges that standards for such aircraft are not subordinate to civil standards and may be established independently under the self-certification authorities of government. These airworthiness standards for UAS are developed to apply to military aircraft only as a type of public aircraft. Any similarity of these standards to civil standards is one of convenience to government authorities, not subordination.

Further, the standards should apply a qualitative level of safety that would enable unmanned systems to fly with the same level of acceptance afforded similar performing manned systems. Such an outcome would provide unmanned system the same flexibility and freedom of navigation in civil airspace that a manned aircraft, on a similar mission, is allowed.

4.0 THE DEVELOPMENT OF THE NATO UAS AIRWORTHNESS STANDARDS

Joint Capability Group Unmanned Aircraft Systems (JCGUAS) was formed to achieve advances in capability development and interoperability among UAS. Within JCGUAS is the Flight in Nonsegragated Airspace

(FINAS) subgroup. Within FINAS the Airworthiness team has compiled the NATO Airworthiness standards over the last 15 years. The work was undertaken, as a NATO acquisition group, to provide the standards that can be used by governments and industries to design, build and subsequently test UAS to achieve the goal of flight in nonsegragated airspace.

While flight in military operations on the battlefield and restricted airspace was the initial approach to operate UAS, it was quickly realized that these limitations provide great restrictions on the use of UAS. UAS, like other types of military aircraft, must often transit and train in civil airspace in the course of normal operations. Indeed, some military missions such as surveillance may be conducted entirely in civil airspace. All military manned aircraft work best when they are able to integrate fully with civil aircraft. Hence, UAS working in combat areas need to work as well to allow all the users in the airspace to have a coherent set of expectations for safety and performance. The participation for the development of the standard was largely with government representation. Edition 1 of STANAG 4671 was taken forward based on work by France to create a national UAS airworthiness standard and included coordination with European participation during development. FINAS undertook the task of creating the first NATO UAS airworthiness standard and Edition 1 of STANAG 4671 was completed. Continued inputs by nations in JCGUAS lead to the achievement of Edition 2 of the standard. This edition accomplished the task of resolving more than 50% of the national exceptions listed as comments accompanying national ratifications when Edition 1 was ratified.

At the same time as Edition 2 was in development, JCGUAS completed a rudimentary classification of UAS as an aide to participants in naming the types of UAS covered in a variety of standards. The initial resolution of classes of UAS lead to a training standard for qualifications and highlighted the need for additional airworthiness standards to cover the smaller subsets of the UAS types not readily covered in STANAG 4671 which covered the largest types of UAS.

Three different countries, US, France and Italy, provided the leadership for the development of STANAGs 4671, 4702 and 4703. These multinational development groups served as a gathering point to pool the experience on platforms and operations to bring to the standards. The standards represent the collection of the best data and resources from all the nations working in NATO JCGUAS.

5.0 UAS CLASSIFICATIONS

The NATO airworthiness standards include top level reviews for technical airworthiness intended for four different subsets of UAS classifications. The UAS classifications are based on a NATO classification guideline document that was completed to enable an organized structure to differentiate among the notional classes of UAS. This grouping was largely used to assist in the development of a variety of UAS related standards where the size scale and wing type of the aircraft can be a factor in determining discrete values in the standard. The first UAS airworthiness was for fixed-wing military UAS with a maximum take-off weight between 150 and 20,000 kg, or Class II and III in the table below. While STANAG 4671 clearly applies to the larger aircraft sizes, there is ongoing discussion within the airworthiness development group if the lower threshold should be set at 600kg in the future for this standard. The challenge has been found to implement the precepts of STANAG 4671 to an aircraft scale as small as 150kg to be able to gain airworthiness certification on this size of UAS. The remaining 3 NATO airworthiness standards are 4702 (for rotary wing), 4703 (for light UAS) and still to be ratified 4746 (for small VTOL UAS). Once STANAG 4671 was completed, the airworthiness standards development group was able to decide on the next increment for airworthiness standards development required in order to eventually address all the UAS from the NATO UAS classification guideline. The importance of the classification guideline is that a notional division of the types of UAS was required in order to segment the airworthiness certification task in manageable sections both for development and for application. The NATO UAS classification Guideline accomplished this. The development of the airworthiness standards may choose to adjust from this guideline in the future, but for now these are the boundaries that guide the development of the NATO UAS airworthiness standards.

UAS CLASSIFICATION TABLE						
Class	Category	Normal Employment	Normal Operating Altitude	Normal Mission Radius	Primary Supported Commander	Example Platform
Class III (> 600 kg)	Strike/ Combat*	Strategic/National	Up to 65,000 ft	Unlimited (BLOS)	Theatre COM	Reaper
	HALE	Strategic/National	Up to 65,000 ft	Unlimited (BLOS)	Theatre COM	Global Hawk
	MALE	Operational/Theatre	Up to 45,000 ft MSL	Unlimited (BLOS)	JTF COM	Heron
Class II (150 kg -600 kg)	Tactical	Tactical Formation	Up to 10,000 ft AGL	200 km (LOS)	Bde Com	SPERWER
Class I (< 150 kg)	Small (>15 kg)	Tactical Unit	Up to 5,000 ft AGL	50 km (LOS)	Battalion Regiment	Scan Eagle
	Mini (<15 kg)	Tactical Sub-unit (manual or hand launch)	Up to 3,000 ft AGL	Up to 25 km (LOS)	Company Squad Platoon Squad	Skylark
	Micro** (<66 J)	Tactical Sub-unit (manual or hand launch)	Up to 200 ft AGL	Up to 5 km (LOS)	Platroon, Section	Black Widow
* Note: In the event the UAS is armed, the operator should comply with the applicable Joint Mission Qualifications in AP XXXX (STANAG 4670) and the system will need to comply with applicable air worthiness standards, regulations, policy, treaty and legal considerations.						
** Note UAS that have a maximum energy state less than 66 Joules are not likely to cause significant damage to life or property and do not need to be classified or regulated for airworthiness, training, etc. purposes unless they have the ability to employ hazardous payloads (explosive, toxic, biological, etc.).						

Table 1-1: UAS Classification

6.0 THE AIRWORTHINESS STANDARDS

The three ratified UAS airworthiness standards include 589 pages. This represents a substantial body of work completed and ratified by NATO nations. These documents provide the source of information to carry the process forward. While UAS are aircraft, they have distinctive features including control stations off board the aircraft that could be in the air or on the ground and the reliance for the most part on data links as a factor in reliability. During the development of the standards the subject matter experts arrived at conventions for what could and would not be included in the UAS airworthiness standards. Across the standards there is a common set of attributes that are not included. These exclusions and the rationale for this decision are provided below. This is followed by a summary of the scope of the three ratified standards and well as a description of the one remaining standard within development.

6.1 Elements not included in the UAS Airworthiness standards.

Among the NATO UAS airworthiness standards there are 16 items that are not addressed and are listed below:

Exceptions from the UAS Airworthiness Standards
• Control station security, • Security of the command and control data link from wilful interference, • Airspace integration and segregation of aircraft (including “sense and avoid”), • The competence, training and licensing of UAS crew, maintenance and other staff, • Approval of operating, maintenance and design organizations, • The type of operation, • Vehicle Management and Navigation requirements, • Frequency spectrum allocation, • Noise, emission, and other environmental certification, • Launch/landing equipment that is not safety critical and which does not form part of the Type Certification Basis, • Operation of the payload (other than its potential to hazard the aircraft), • Carriage and release of weapons, pyrotechnics and other functioning or non-functioning stores designed for release during normal operations, • Non-deterministic flight, in the sense that UAS flight profiles are not pre-determined or UAS actions are not predictable to the UAS crew, • Sea-basing, • Piloting from an external or internal control box, • Supersonic flight.

Table 1-2: Exceptions from UAS Airworthiness Standards

These areas are subject to other forms of approval. These were not areas that lend themselves to a determination by the subject matter experts within the standards development groups. These areas are not excluded from the completion of UAS airworthiness certification; however for the current editions of the standards these represent limits in the standards development as well as areas covered by other sources.

Sense and Avoid (SAA) is a separate key capability for UAS. The derivation and definition of SAA capability across the classes of UAS remains outside the scope of these standards. The standards for what would be required for SAA have not been defined in a shared way to enable a common standard. A series of technologies, demonstrations and research and development efforts are ongoing in this field among several of the classes of UAS. Once SAA requirements have been clarified based on current research, tests and trials additional standardization can be achieved in the definition of UAS airworthiness related to systems and capabilities that will support SAA on UAS.

The NATO standards may not be sufficient for the certification of UAS with unconventional, novel or extremely complex features. Additionally, the standards may not be sufficient for UAS with a design performance significantly different from that of General Aviation. Nevertheless, the standards may have significant value for assessing all or parts of such systems for Certifying Authorities and the use for these requirements as a basis for certification of these systems within their national regulatory framework.

6.2 Scope included in the UAS airworthiness standards

6.2.1 STANAG 4671 (Document Link: ../zpublic/stanags/current/4671efed02.pdf)

STANAG 4671 has no release restrictions and is available to the public on the NATO website. The document includes 230 pages and the effort was lead by United States. The document is in the 2nd Edition and the promulgation date was February 2017. The standards group is completing working Edition 3 which is expected to begin the ratification process by 2018.

Purpose for STANAG 4671
"This document contains a set of technical airworthiness requirements intended primarily for the airworthiness certification of fixed-wing military UAS with a maximum take-off weight between 150 and 20,000 kg that intend to regularly operate in non-segregated airspace. Certifying Authorities may apply these certification requirements outside these limits where appropriate. These requirements represent the minimum applicable requirements to meet the safety objectives defined by paragraph 1309 and it's associated AMC. It may be augmented by additional Special Conditions (i.e. additional airworthiness requirements) required by individual Certifying Authorities. USAR is intended for application by Certifying Authorities within each country's relevant national regulatory framework."

Table 1-3: Purpose for STANAG 4671

Using the form and structure of CS-23 served to provide a familiar template for military engineers build a NATO standard. NATO was not beholden to the levels of robustness of CS-23, yet in the initial drafting STANAG 4671, the standard presented for what is a minimally-manned standard that began a benchmark for UAS as a generally accepted level of safety.

Method for STANAG 4671
"Whilst military aircraft are not specifically required to comply with civil airworthiness regulations as agreed in the ICAO[1] Convention on International Civil Aviation (Article 3), the paper highlights the utility to correspond as closely as practicable to a comparable minimum level of airworthiness for fixed-wing aircraft as embodied in documents such a EASA[2] CS-23 (from which USAR is derived) and 14 CFR[3] Title 14 Part 23 whilst recognizing from military experiences that there are certain unique features of UAS that require modification to those civil airworthiness requirements and/or the addition of new individual requirements or new subparts. Civil codes were utilized as the foundation for USAR because they represent the minimum airworthiness requirements for flight in non-segregated airspace with minimal or no restrictions. Additionally, many military fixed-wing UAS have flight profiles similar to that of General Aviation, making the selection of civil airworthiness codes a practical starting point. "

Table 1-4: Method for STANAG 4671

Going forward, there are continued benefits from a collective effort to update the present airworthiness standards. Foremost is the best use of data from UAS in service that has been developed and shared in an effort for resolution of the remaining issues as well as improvements to the comprehensiveness of the standards. We have already seen early applicable of STANAG 4671, Edition 1, in the manufacturing community with General Atomics, Thales, and Israel Aerospace Industries (IAI). Further application of the standards by the manufacturing community will also bring discovery in the development of the airworthiness standardization process. While civil recognition was not sought, the work of the NATO was honoured in 2009 by EASA welcoming applicants to apply STANAG 4671 as a basis for certification.

6.2.2 STANAG 4702 (Document links: ../zpublic/stanags/current/4702efed02.pdf and ../zpublic/ap/prom/aep-80 edb v1 e.pdf)

STANAG 4702 has no restrictions and is available to the public on the NATO website. The document includes 246 pages and the effort was lead by France. The document is in the 1st Edition and the recent promulgation date was October 2016.

Purpose for STANAG 4702
"These requirements may not be sufficient for the certification of rotary wing UAV Systems with unconventional, novel or extremely complex features. Additionally, USAR-RW may be insufficient for rotary wing UAV Systems with a design usage spectrum significantly different from that of General Aviation. Nevertheless, the USAR-RW may have significant value for assessing all or parts of such systems and Certifying Authorities are encouraged where appropriate to use these requirements as a basis for certification of such systems within their national regulatory frameworks. Rotorcraft UAV Systems (including block upgrades to legacy systems) designed prior to the approval of this document may not comply with these requirements. Appropriate standards and airworthiness certification for these systems for flight in non-segregated airspace, many of which are consistent with this document, are the responsibility of each Certifying Authority."

Table 1-5: Purpose for STANAG 4702

Method for STANAG 4702
"This document is an airworthiness code derived from EASA CS-27 amendment 2 requirements supplemented by elements from STANAG 4671 Edition 2 (airworthiness requirements for fixed wing military UAV Systems) depending upon which code provided the best starting point from which to tailor based upon considerations such as weight, performance, system complexity or specific applicability to rotorcraft UAV."

Table 1-6: Method for STANAG 4702

6.2.3 STANAG 4703 (Document Links: ../zpublic/stanags/current/4703efed02.pdf and ../zpublic/ap/prom/aep-83 edb v1 e.pdf)

STANAG 4703 has open distribution and is available to the public on the NATO website. The document includes 111 pages and the effort was lead by Italy. The document is in the 1st Edition and the recent promulgation date was October 2016.

Purpose for STANAG 4703
"This document contains the minimum set of technical airworthiness requirements intended for the airworthiness certification of fixed-wing Light UAS with a maximum take-off weight not greater than 150 kg and an impact energy greater than 66 J (49 ft-lb) that intend to regularly operate in non-segregated airspace. The lower limit is established according to available blunt trauma studies showing that below this level it is reasonably expected that a fatal injury should not occur if the UA strikes an unprotected person. It is recognized that 66 J is a conservative value based on current research that will be reviewed after further investigation. For UAS below the 66 J impact energy threshold, it is reasonable that a number of requirements can be relaxed. Specific airworthiness requirements must be agreed with the Certifying Authority on a case-by-case basis. Annex J of this document provides applicable guidelines that are not limited to fixed wing aspects."

Table 1-7: Purpose for STANAG 4703

Method for STANAG 4703
"Due to the large variety of possible configurations and technology in this category of UAS and the fact that many of these systems are architecturally simple, this STANAG has been developed with the following objectives: - Require no more than the minimum amount of certification evidence that is needed to substantiate an acceptable level of airworthiness; - Address all design attributes which may endanger safety; - Be flexible by being non-prescriptive, in order not to limit the design solutions (i.e., address issues instead of prescribing solutions). It has been considered that a pure complete traditional prescriptive set of airworthiness codes (e.g., CSs, FARs) could not fulfil this objective, and could not be derived from existing civil or military regulations applicable to manned aircraft. Therefore, a hybrid approach has been established, which combines a set of conventional airworthiness code requirements with other types of qualitative criteria aimed to achieve a high level of confidence that the type design is airworthy (e.g., through process evidence or design criteria). Creating this hybrid approach, the top-level starting point is the set of the Military Essential Requirements for Airworthiness. This STANAG also establishes means to comply with each of these mandatory minimum essential requirements in order to obtain a Type Certificate (or equivalent document) for UA with Maximum Take Off Weight of 150 kg, or less, for flight in non-segregated airspace."

Table 1-8: Method for STANAG 4703

There are a preponderance of UAS flight hours conducted with the UAS described in this standard. While not Remotely Piloted Aircraft Systems (RPAS), in the sense they are operated by a rated aviator, none the less they can share the same airspace as larger unmanned and manned aircraft assuming they meet other essential requirements for interoperability that are beyond the scope of airworthiness. For the military these small UAS frequently operate in areas with manned helicopters, various branches of law enforcement, and public safety applications such as search and rescue. This is in addition to the burgeoning commercial applications.

As stated in each of the airworthiness standards, when practical, all rely on information in STANAG 4671 as it can apply to each class of UAS. Then for particular groupings, like this one, the extra measures are carefully weighed and addressed in the text. A standard too stringent for practical applications is simply ignored and regulators/industry are left with no options to guide the continued development of principles across the community. A great deal of effort based on extensive national experience fed into the development of the standard and in a way that each of the standards can be complementary.

6.2.4 STANAG 4746

STANAG 4746 is focused on Light Rotary Wing UAS Systems Airworthiness Requirements. This document, in initial development now, will contain the minimum set of technical airworthiness requirements intended for the airworthiness certification of light rotary-wing UAS with a maximum takeoff weight not greater than 150 kg and impact energy greater than 66 joules (49 ft-lb) that intend to regularly operate in non-segregated airspace.

7.0 WHAT IS MISSING?

While the title of this paper is State of the Art of Airworthiness Certification, the current state of the art for UAS must continue to be advanced for the integration of UAS in the airspace of today and the future. While these documents took a decade to complete based on the work of NATO and partner nations, they remain as the starting point having been promulgated in their current form in the last 6 months. Remaining is the work by nations to include these standards in current UAS programs as widely as possible and in all future UAS programs. The science to test to these standards, the broad acceptance to the range of the content, and the continued work to bring back the national experiences to update these standards based on their active use in the mainstream procurement of UAS, will be needed in the near term. Accompanying the 1st Edition of 4671 were hundreds of exceptions by nations on specific elements that accompanied their national ratifications. By the current 2nd Edition these national exceptions were cut by more than half as nations saw the way to pool their understanding of how these standards would be applied. Edition 3 of 4671, which is now in the final stages of completion, will add an additional measure of experience based on the lessons learned from the earlier versions and based on measures that have come into better understanding based on a more complete examination of the current technology developments. STANAG 4671 addresses the larger classes of UAS, as that was seen as the more substantial requirement for the integration of long distance flights and to be more fully integrated with airspace at higher operating altitudes. File and Fly was a goal, just like with manned aircraft. However, it was quickly realized by the subject matter experts in UAS airworthiness development that smaller classes of UAS comprise the majority of total flight hours and had unique considerations that must be addressed separately due to their size and therefore, additional airworthiness standards were completed. Each of these four UAS airworthiness standards will benefit greatly from their application in national programs. Industry has a key role in providing its experience base from the assembly and testing of these unmanned aircraft. A number of industries have taken the lead to employ these standards even before the final promulgation. Their actions provided them a head start for UAS certifications and improved options for cost effective applications of the standards in the UAS designs.

8.0 CONCLUSION

The three NATO Airworthiness STANAGs: 4671, 4702 and 4703, together, cover the range of the classes of UAS in use today and for the foreseeable future. These three standards mirror in their document structure, civil standards, using the format and approach to highlight those elements included in a UAS that would not be included under the current airworthiness documentation as it has been written for manned aircraft. This work, based on the operational experience of NATO and nations working with NATO, completed the bridge regarding the gap between existing regulations and those standards needed to design, acquire, build and operate UAS in non-restricted airspace. National participation came from the highest levels. The next challenge is the broad use of these standards, continuing to pool the lessons learned and sharing testing concepts to help prove the standards on UAS. Airworthiness standards are only one component to be used to complete integration of UAS in non-restrictive airspace, but an important tool that can be used today. Aspects of the Airworthiness standards that are not included in the standards are excerpted from the three documents and listed in the paper. These areas have been excluded at this point given there is not a ready way to determine these impacts or values and the fact that these do not cover useable cases in the near term. The standards are open for update and improvement. The groups continue to work for the subsequent editions within the NATO JCGUAS subgroups. The objective is to employ what is available today and understand the rigors that were applied in the development of the standards. Broad acceptance through widespread use of the standards is expected. The continued use of science from the groups who are capable of undertaking this work, to refine the constructs and applications of specific elements of the standards, will remain an important component to continue to add to the utility of the standards.