Certification Challenges and Opportunities for Unmanned Aircraft Systems that Employ Artificial Intelligence

Dr. Stephen P. Cook, Northrop Grumman Aeronautics Systems

ABSTRACT

"Artificial intelligence (AI) will be at the heart of most – if not all – future cutting-edge technologies in the civilian and military worlds" was a key outcome of the NATO Parliamentary Assembly's Science and Technology Committee in 2018 [1]. Indeed, the advent of automation, autonomy, and rapid technology insertions into aviation - including the introduction of AI as an autonomy enabler - provide great potential to improve performance and safety for all forms of aviation. A 2016 AIAA Roadmap for Intelligent Systems in Aerospace concluded that systems that incorporate adaptive features, such as those made possible by AI and machine learning (ML) have the potential to ". . . improve efficiency, enhance performance and safety, better manage system uncertainty, as well as learn and optimize both short-term and long-term system behaviors" [2]. Furthermore, a recent U.S. Department of Defense (DoD) study on autonomy found that, "… autonomy has the potential to deliver substantial operational value across a diverse array of vital DoD missions, and that the DoD should speed its adoption to realize the potential benefits across a diverse array of missions" [3].

However, incorporation of AI/ML into UAS and related aviation applications presents airworthiness certification challenges. NATO's leading airworthiness standard for UAS, STANAG 4671, explicitly states that it does not cover "…Non-deterministic flight, in the sense that UA flight profiles are not pre-determined or UA actions are not predictable to the UA crew…" [4]. The absence of a human pilot onboard the aircraft to provide situation awareness, avoidance of other aircraft, and contingency management means that the system must implement the functions of the pilot-in-command to a level of performance and robustness necessary to ensure the safety of other airspace users and people on the ground. Lacher et al. found that "If an autonomous system is to operate in situations where the consequences of ineffective performance could cause physical harm to persons or property (e.g., unmanned aircraft, driverless car), humans will need to have a mechanism for both establishing and maintaining trust in the perception and judgment of these systems" [5]. Further complicating the situation is that aviation regulators such as the FAA, EASA, and military regulators have discovered that technology is evolving faster than their ability to generate new regulations.

With these challenges however come exciting opportunities to shape the certification landscape to take advantage of the promise of AI. This paper will address key challenges and opportunities for certification of autonomous UAS employing AI/ML. The following sections will be expanded upon in the final paper:

<u>Software development assurance.</u> One U.S. Air Force general officer recently stated, "The B-52 lived and died on the quality of its sheet metal. Today our aircraft will live or die on the quality of our software" [6]. The primary standard used for evaluating software aspects of safety and airworthiness for civilian aircraft is RTCA DO-178C, "Software Considerations in Airborne Systems and Equipment Certification" [7]. Military airworthiness authorities sometimes use different standards for assuring software, but many of the objectives and activities are the same. While existing standards have proven effective for assuring software in today's airborne systems, the lack of repeatability of test results from software incorporating AI/ML presents a unique challenge. A 2019 Forum for Aeronautical Software report documented challenges with applying DO-178C to AI/ML, including:

Writing requirements for the software in a manner that include safety and security considerations for the intended function(s);

Understanding the role of the data inputs to the AI/ML in performance of the intended function(s) (for both the training data and the real-world data), and;

Showing that the AI/ML implementation will return solutions within accepted bounds with an acceptable level of confidence [8].

Standards organizations and airworthiness authorities are currently examining options for assuring software that includes AI/ML. The progress of these efforts will be included in the final paper.

Consensus Standard Development. One way to address standards to match the pace of technology is through use of consensus standards. The FAA stated in the Notice of Proposed Amendment to Part 23, "Incorporating the use of consensus standards as a means of compliance with performance-based regulations would provide the FAA with the agility to more rapidly accept new technology as it develops..." [9]. A recent National Research Council report cited aviation standards development of increasingly autonomous systems one of its top four "most urgent and most difficult" research recommendations [10]. ASTM International is one such standards development organization that develops consensus standards for aviation. In 2017, ASTM International established Task Group AC377 for "Autonomy Design and Operations in Aviation". As aviation proceeds into the age of autonomy, it is essential to have consensus standards to support their safe and effective use. AC377 recently published "Autonomy Design and Operations in Aviation: Terminology and Requirements Framework", a first-of-its-kind ASTM Technical Report [11]. This report proposes common terminology for use in consensus standards that address increasingly autonomous aircraft. It also proposes a novel requirements framework instead of arbitrary "levels of autonomy" to determine the appropriate level of rigor for the means of compliance to the standards. A key aspect of this requirements framework is to understand the benefits of the autonomy relative to the risks. This was inspired in part by a 2018 National Academy of Sciences report [12] that noted, "UAS operations should be allowed if they decrease safety risks in society – even if they introduce new aviation safety risks – as long as they result in a net reduction in total safety risk." A high-level representation of the requirements framework can be found in Figure 1.

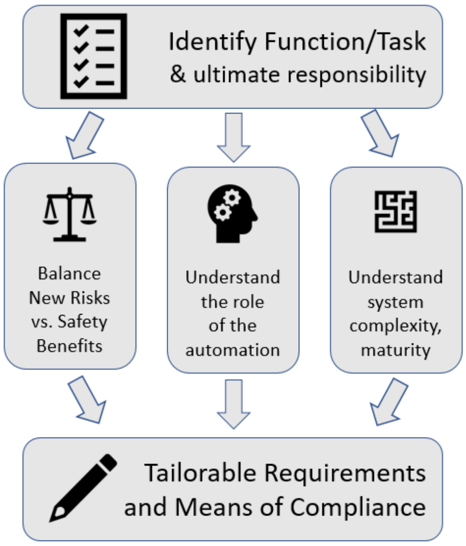

Figure 1. High-level view of requirements framework for increasingly autonomous aircraft [13].

ASTM AC377 is continuing its work and will have another technical report published in early 2020. The final paper will summarize and address the status of this ongoing work.

Policies for autonomous aircraft. The current airspace regulatory system was written at a time when it was assumed that a human pilot-in-command was onboard the aircraft. For a UAS implementing AI/ML to achieve functions normally reserved for a human pilot-in-command, it raises questions regarding the compliance to policies and regulations. The ASTM AC377 Task Group on is currently analyzing the U.S. Code of Federal Regulations to identify regulatory barriers for systems that replace traditional functions of a human pilot-in-command with automated functionality, and results from this analysis will be included in the final paper.

Run-time assurance. Since functions involving AI/ML may be too complex for current certification approaches, ASTM developed ASTM F3269, "Standard Practice for Methods to Safely Bound Flight Behavior of Unmanned Aircraft Systems Containing Complex Functions" [14]. This standard provides for the use of a trusted run-time assurance (RTA) architecture to bound the behavior of an untrusted complex function implemented in a UAS (such as one that includes AI/ML). Figure 2 shows the F3269 generic RTA architecture which bounds the behavior of a UAS containing the complex function using a pedigreed safety monitor and pedigreed recovery control functions. The F3269 standard is currently being updated by ASTM. The final paper will include a status on the updates to this standard.

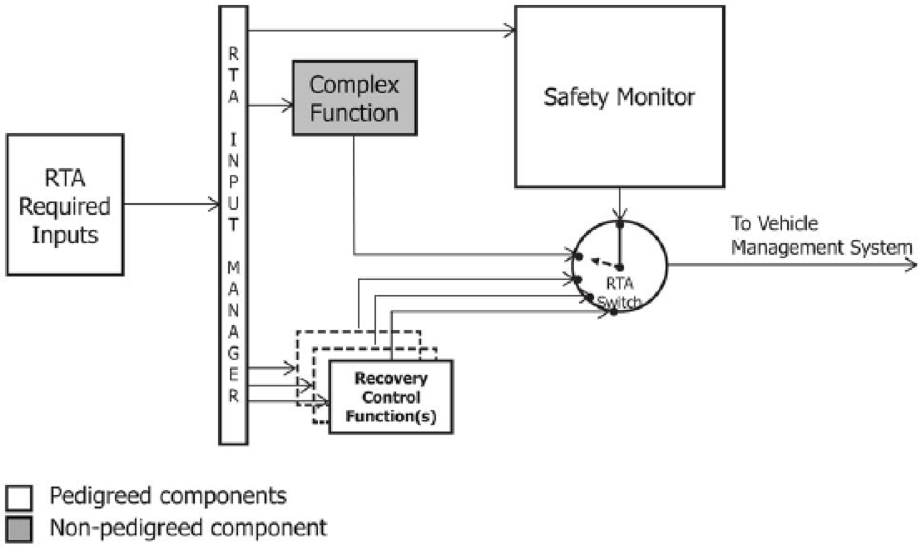

Figure 2. ASTM F3269 Generic Run-Time Assurance Architecture [14].

In conclusion, UAS that include AI/ML have tremendous promise of improved operational performance and efficiency to ensure mission success. This paper will discuss the challenges and opportunities ahead for certifying aircraft incorporating these technologies. By addressing the challenges and embracing the opportunities, NATO can ensure the timely fielding of these systems while also being confident in their safety.

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About the Author

Dr. Stephen P. Cook is the Northrop Grumman Fellow in the Northrop Grumman Office of Independent Airworthiness, where he is responsible for developing and implementing airworthiness policy and strategy across Northrop Grumman's portfolio of manned and unmanned aircraft. Dr. Cook leads the ASTM Task Group AC377 responsible for Autonomy in Aviation and also leads the airworthiness subcommittee for UAS. In a previous role with the Naval Air Systems Command, Dr. Cook chaired the Custodial Support Team for NATO STANAG 4671.