International Civil Aviation Organization

WORKING PAPER

ASSEMBLY — 41ST SESSION

TECHNICAL COMMISSION

Agenda Item 31: Aviation Safety and Air Navigation Standardization

AUTOMATION AND THE CHANGING ROLE OF THE PILOT

(Presented by Canada and Japan)

EXECUTIVE SUMMARY

Increasing levels of automation and the introduction of autonomous operations in aviation are changing the role of the pilot. This is evident across aviation, but particularly for Remotely Piloted Aircraft Systems (RPAS)* and for crewed aircraft. This shift is bringing economic benefit and improving the safety and accessibility of aviation, but it also impacts established aviation frameworks and definitions. This includes introducing new considerations for pilot competencies, responsibility for flight operations, decision-making authority, and liability in the event of incidents. While the focus of this paper is the pilot, it is acknowledged that automation also has impacts upon the other flight crew and aviation personnel that requires consideration.

*Please note that Canada uses the gender-neutral terminology of RPAS to refer to drones at large and in place of unmanned aircraft systems (UAS) or unmanned aerial vehicles (UAV).

Action: Recognizing potential impacts to the *Convention on International Civil Aviation (1944)* and *Annex 1 – Personnel Licensing*, the Assembly is invited to:

a) request the International Civil Aviation Organization (ICAO) to review the pilot and flight crew personnel definitions through the lens of increased automation and the changing nature of flight operations; and

b) recommend to ICAO a comprehensive review of the competencies and training required for the persons responsible for the safety of flight (e.g., pilots, flight dispatchers, etc.).

Strategic Objectives:	This working paper relates to Strategic Objectives of Safety and the Economic development of air transport.
Financial implications:	The activities referred to in this paper will be undertaken subject to the resources available in the Regular Programme Budget and/or from extra budgetary contributions.
References:	*Convention on International Civil Aviation (1944)*, and *Annex 1 - Personnel Licensing* Doc 9868, *Procedures for Air Navigation Services — Training* (PANS-TRG)

1. INTRODUCTION

1.1 In recent years, there has been a broad societal trend towards increasing levels of automation through use of new advanced technologies, such as artificial intelligence (AI) and machine-learning. This trend is evident within the aviation sector, where automation is being embedded in the operations of both crewed aircraft and Remotely Piloted Aircraft System (RPAS).

1.2 For crewed aviation, the flight deck has become increasingly automated, with a gradual move away from piloting based on "stick and rudder" skills to systems-based piloting.[1] This evolution was evident in the 1980s with the removal of flight deck engineers on airliners and many modern military aircraft, following advances in computers and technology that made the role redundant.

1.3 For RPAS, new use cases and aircraft designs are emerging that incorporate increasing amounts of automation and capabilities with respect to autonomous operations. Industry concepts of operations describe an environment where pilots are no longer flying a single RPAS instead, they are seamlessly managing a fleet of RPAS remotely or autonomously, with traditional piloting skills being completed by automated systems.

1.4 In response to the increasing automation levels, several typologies have been developed that seek to aptly define, categorize and/or describe a continuum of automation. Most notable is the work completed by SAE International[2] for the automotive sector (noting that typology has limitations and challenges especially when applied in aviation) and by ASTM International[3]. Building on this work, there is also international collaborative work between civil aviation authorities and industry stakeholders that is in its final stages, which provides a standard view on automation and autonomy for RPAS. Although some differentiation exists across the typologies, all of them describe a continuum for automation that ranges from operations being entirely manual to fully autonomous. See Appendix A for the automation scale developed through international collaboration.

1.5 Globally, flight operations are moving along the automation continuum with sustained momentum. Companies are planning for operations that are associated with high levels of automation (with certain tasks or functions being performed autonomously), and/or for operations that are fully autonomous (with no human involvement). For example, in Canada there is an opportunity for autonomous RPAS cargo delivery through use of a virtual flight management software system and a central operations control centre. Outside of Canada, companies are seen using increasingly automated and autonomous systems for delivery of goods, such as medical supplies, food and beverage, and other consumer products.

1.6 With such a dramatic shift in flight operations, the role of the pilot changes fundamentally.

[1] University of North Dakota, Determining Appropriate Levels of Automation, FITS SRM Automation Management Research, Charles L. Robertson, May 25, 2010, https://www.faa.gov/training_testing/training/fits/research/media/Det_App_Lvl_Atm.pdf

[2] SAE International, Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles, https://www.sae.org/standards/content/j3016_202104/

[3] ASTM International, TR1 - Autonomy Design and Operations in Aviation: Terminology and Requirements Framework, https://standards.globalspec.com/std/14480544/TR1
ASTM International, TR2 – Developmental Pillars of Increased Autonomy for Aircraft Systems, https://standards.globalspec.com/std/14480549/TR2
ASTM International, TR3: Regulatory Barriers to Autonomy in Aviation, https://www.astm.org/tr3-eb.html

2. DISCUSSION

2.1 Automation brings many benefits to aviation. It allows for the execution of certain tasks in a more accurate, efficient, cost-effective, and safe manner[4], with potentially less risk posed to the pilot, passengers (where applicable), and all those involved or implicated by the operation.

2.2 Automation is also making aviation more accessible; in particular, as it relates to the use of RPAS technologies. The automation embedded in RPAS has significantly lowered the costs of entry and operation for users in large part due to the pilot not needing to be on board the aircraft and the mitigation of associated risks. It is also reducing certain pilot training requirements and costs since with automation some capabilities can be infused in the system, rather than the pilot. These influencing factors can help attract a new generation of pilots, which includes people for whom mobility may be a barrier or influencing factor (e.g., persons with disabilities, persons living in remote communities, and those with caregiving responsibilities) and address anticipated future pilot shortages in traditional aviation. Where the increasingly automated flight operations are associated with lower risk profiles (e.g., no passengers on board), medical requirements may also be adapted such that it further expands the eligible pool of potential pilots.

2.3 While growing automation levels and RPAS technologies offer tremendous opportunity, they also challenge the existing frameworks and have broad-reaching consequences for the aviation system as it was developed assuming a human pilot in command of a single aircraft. Responding to this shift therefore necessitates conceptually examining the types of aircraft, operations, and tasks that will be carried out in the future, how these may integrate into the broader aviation ecosystem, and how safety and security can be maintained. Certain components may need to be reconsidered and adapted to reflect the evolving landscape.

2.4 Given the fundamental change in the role, responsibilities, and tasks that pilots will be required to perform, this will impact upon existing pilot competency requirements for licensing (as currently outlined in *Annex 1* and the *Procedures for Air Navigation Services — Training* (PANS-TRG, Doc 9868). Consistent with the anticipated use of complex automated systems, human-machine teaming, and operation of aircraft fleets, future pilots will need a high level of competency and training in areas, such as systems and operational management (including emergency response - e.g., system failure conditions), situational awareness, decision-making, and human factors. These competencies will become more important than some traditional pilot skills, such as hand-eye coordination. However, retaining traditional aviation knowledge will remain critical to ensuring safety when problems do arise and to support broader societal acceptance of the technologies.

2.5 A key consideration given the changing nature of flights and pilot tasks is where the end responsibility, decision-making authority and liability should rest. If the aircraft is being managed by autonomous systems and the pilot is no longer involved in some or all the functions (i.e., no human in the loop), should this change the established aviation constructs as it relates to responsibility for safety of the aircraft (i.e., safety of cargo and passengers on board, if any, and safety of people and property on the ground), the granting of authorities, and liability in the event of failures? For example, where an RPAS is operating autonomously and without direct human supervision would there still be a pilot considered "in command" and responsible for the safety of the aircraft? Would Air Traffic Control (ATC) communicate with a pilot or system, and who would be liable? From a legal perspective, it also poses new questions

[4] National Research Council of the National Academies, Autonomy Research for Civil Aviation: Towards a New Era of Flight, https://nap.nationalacademies.org/catalog/18815/autonomy-research-for-civil-aviation-toward-a-new-era-of

around jurisdiction in terms of where claims are filed and against who, and the adequacy of liability insurance. These are all questions that will require thoughtful consideration.

2.6 ICAO has currently defined autonomous aircraft as: "an unmanned aircraft that does not allow for pilot intervention in the management of the flight".[5] However, applying this definition to future flight operations may mean that current accountability and responsibility requirements cannot be satisfied. Responsibility for safe flight is achieved through the use of safe equipment, the knowledge and competencies of the pilots and air traffic control. This is reflected in the legal framework and definitions set out under the *Convention on International Civil Aviation (1944)* and *Annex 1- Personnel Licensing*, where pilots are presumed to be human (not machines) and issued flight responsibilities accordingly.[6] See Appendix B for applicable definitions. However, as aviation moves further along the automation continuum and contemplates operations where no human is involved, ICAO member states will need to consider how this is interpreted and whether this challenge to the framework set out in the *Convention* and *Annex 1* can be bridged by existing safety and security management constructs.

2.7 It is Canada's view that there must continue to be a person responsible for the safety of flight operations, even where they are highly automated and/or autonomous in nature. This ensures there is a person accountable for the safety of flight and aligns with the recognized Safety Management System (SMS) principles. As aviation moves towards full autonomy, the term, pilot, should however be studied, in conjunction with other terms, such as flight dispatchers, to assess their continued suitability in describing the person responsible for flight safety.

3. **CONCLUSION**

3.1 Canada and the co-sponsors of this paper recognize the shifts in the changing role and responsibilities of the pilot, competencies and training required, as well as the ongoing need to designate a person responsible for ensuring safety of aircraft operations. This designation can also aid in fostering societal acceptance and confidence in the use of automated technologies. Acknowledging the technological shift taking place and the changing roles, it is, however, necessary that the ICAO Assembly support a review of the existing definitions of pilots and flight crew personnel and consider how conceptually the definitions/terms should change as the technology evolves. This may include amendments to the *Convention, Annexes, and associated procedural documents* and guidance material to reflect the different legal landscape and evolving flight operations.

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[5] ICAO Cir 328, AN/190, Unmanned Aircraft Systems (UAS), www.icao.int/meetings/uas/documents/circular%20328_en.pdf
[6] ICAO International SARPs, Annex 1 – Personnel Licensing, Section 1.1. Definitions. page 24.

APPENDIX A

PROPOSED CLASSIFICATION FOR AIRCRAFT AUTOMATION

- **Level 0 – Manual Operation**: The crew is responsible for all functions including controlling the aircraft, evaluating and responding to the aircraft and airspace environments, communicating with external systems, and managing the aircraft when failures present themselves.
- **Level 1 – Assisted Operation**: Systems which have been automated up to this level are used to support the crew in performing the specified function.
- **Level 2 – Task Reduction:** As technology and confidence in performing tasks within a specific Operational Design Domain (ODD) are gained, automation increases to the level where a system may take over a specific task or function to help the crew focus on more mission-critical tasks.
- **Level 3 – Supervised Automation:** By expanding the capability of the automated systems to handle not only aircraft functions, but monitoring and responding to changes in the environment, the crew moves from actively managing the function to monitoring the safety and effectivity of the operational outcomes.
- **Level 4 – High Automation:** Once the technology has demonstrated the ability to perform entire tasks or functions effectively and have a robust capability to respond to their environment, the crew may trust one or more flight systems to perform their function autonomously (i.e., without human supervision).
- **Level 5 – Full Autonomy:** At the far end of the spectrum is a fully autonomous function. At this level of automation there is not only no human involvement in the function, and likely no human awareness of dynamic operational parameters affecting the functions ODD.

- **Trusted Autonomy**: As autonomy increases, the human needs to build trust in the machine and the machine needs to build trust in the human. The deployment of trusted autonomous systems results from the optimized balance of human and machine tasks with a focus on integrity metrics defined to support safe and efficient airspace operations. Trusted autonomy can be considered a pathway to progressively remove the inherent limitations of full autonomy as known today.

APPENDIX B

APPLICABLE ICAO DEFINITIONS

Annex 1: Personnel Licensing

Pilot (to). To manipulate the flight controls of an aircraft during flight time.

Pilot flying (PF). The pilot whose primary task is to control and manage the flight path. The secondary tasks of the PF are to perform non-flight path related actions (radio communications, aircraft systems, other operational activities, etc.) and to monitor other crew members.

Pilot-in-command. The pilot designated by the operator, or in the case of general aviation, the owner, as being in command and charged with the safe conduct of a flight.

Pilot-in-command under supervision. Co-pilot performing, under the supervision of the pilot-in-command, the duties and functions of a pilot-in-command, in accordance with a method of supervision acceptable to the Licensing Authority.

Pilot monitoring (PM). The pilot whose primary task is to monitor the flight path and its management by the PF. The secondary tasks of the PM are to perform non–flight path related actions (radio communications, aircraft systems, other operational activities, etc.) and to monitor other crew members.

Annex 6: Operation of Aircraft, Part 1

Flight Operations Officer/Flight Dispatcher. A person designated by the operator to engage in the control and supervision of flight operations, whether licensed or not, suitably qualified in accordance with Annex 1, who supports, briefs and/or assists the pilot-in-command in the safe conduct of the flight.

ICAO Cir 328, AN/190, Unmanned Aircraft Systems (UAS)

Autonomous aircraft. An unmanned aircraft that does not allow pilot intervention in the management of the flight.

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