



International Civil Aviation Organization

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WORKING PAPER

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REMOTELY PILOTED AIRCRAFT SYSTEMS PANEL (RPASP)

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Autonomy and Automation

(Presented by Jay Shively)

SUMMARY

A significant level of debate and confusion has surrounded the meaning of the terms “autonomy” and “automation”. Automation is a multi-dimensional concept, and we propose that RPAS automation should be described with reference to the specific system and task that has been automated, the context in which the automation functions, and other relevant dimensions. In this paper, we present a definition of “automation”. We recommend that autonomy and autonomous operations are out of the scope of the RPAS panel. WG7 proposes to develop, in consultation with other workgroups, a taxonomy of “Levels of Automation” for RPAS.

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Priority: routine

2. INTRODUCTION

The current description of “autonomous aircraft” and “autonomous operation” as specified in the RPAS manual coupled with the declaration that these are out of scope inadvertently eliminates lost link operations from the purview of this panel. Working group 7, Human In The System (HITS), propose definitions of “autonomous” and “automated” that clarify the distinction between these two concepts and make it clear that lost link operations are within the scope of the panel.

3. DISCUSSION

3.1 The *RPAS Manual on Remotely Piloted Aircraft (RPAS)* (Doc 10019) contains the following descriptions:

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

“Autonomous Operation: An operation during which a remotely piloted aircraft is operating without pilot intervention in the management of the flight.”

Furthermore, the manual does not contain a definition of “automation”.

3.2 In section 1.5.2.b, the *RPAS Manual on Remotely Piloted Aircraft (RPAS)* restricts the scope to exclude “autonomous aircraft and their operations ...” Lost link operations, by definition, are operating without pilot intervention (i.e., pilot out of the loop, section 2.13). Therefore, based on the descriptions (section 2.1) and the restriction in scope, lost link operations are excluded from the RPAS panel scope. However, these operations are discussed in chapters 4, 8, 9, 10, 11 and 14 of the RPAS Manual.

3.3 Automated or automatic operations can best be discussed with reference to levels of automation. Levels of automation (LOA) have been discussed with respect to general human-automation interaction since the late 1970s. Sheridan and Verplank (1978) defined ten levels, from fully automated to fully manual. Many other conceptualizations of LOA have been proposed, however they have received criticism for being overly simplistic and/or not useful as design guidance. Various LOA descriptions have been refined and adapted for specific applications. For example, U.S. National Highway Transportation Safety Administration (2016) adopted a LOA taxonomy developed specifically for automobiles by SAE (2016). There are many points of view with respect to RPAS relevant to this discussion and therefore it is proposed that an RPAS working group be established to adapt/define LOA specific to RPAS and ICAO.

3.4 Multi-dimensionality: A source of much confusion and miscommunication is the practice of referring to an RPAS (as a complete entity) as automated or autonomous. RPAS, like all aviation systems, have numerous capabilities; navigation, communication, caution and warning systems, etc. Further, each of these capabilities is (from a human operator point of view) a collection of tasks, each of which may have a different level of automation. For example, an RPA performing waypoint to waypoint navigation may be said to be performing at a certain level of automation. However, the communication may still be performed manually. To refer to this RPA as either manual or automated is imprecise and misleading.

Further, RPAS may employ different levels of automation for the same task in different contexts. For example, an RPA may navigate with a level of automation in the cruise phase of flight, but may be manually controlled during take-off and landing. In fact, many RPA are operated in this way.

In addition, Parasuraman, Sheridan and Wickens (2000), have posited that automated tasks may have different stages corresponding to stages of human information processing (e.g. information acquisition, information analysis, decision and action) and that the LOA may vary across stages.

3.5 There are numerous definitions of automation and autonomy. For example, the US Air Force Research Laboratory has clarified the distinction between automated and autonomous systems.

They note that automated systems tend to perform a limited set of actions and that these are typically well-defined tasks that have predetermined responses. On the other hand, autonomous systems “have a set of intelligence-based capabilities that allow them to respond to situations that were not pre-programmed or anticipated in the design (i.e. decision-based responses). Autonomous systems have a degree of self-government and self-directed behavior ...” (AFRL, 2014)

These definitions are consistent with the common distinction between deterministic and nondeterministic systems. The behaviour of a deterministic system can be predicted by the designer if the inputs to the system are known. A nondeterministic system may exhibit behaviour that cannot be predicted on the basis of the inputs alone and may involve concepts such as artificial intelligence or machine learning (Bhattacharyya et al., 2015; Rierson, 2013).

Table 1 outlines how the concepts of automation and autonomy could be applied to systems on board an RPA, taking into account the important consideration of pilot intervention as expressed in the definitions in section 2.1. It should be noted that the table considers automation and autonomy at a system level, not at the level of an entire RPA. Furthermore, we assume that by definition, all “Remotely piloted” aircraft have a functioning control link during normal operations, enabling the pilot to send commands to some (but not necessarily all) on-board systems and receive information from the airborne platform. It can be seen that an on-board system controlled by deterministic software is considered to be under the control of automation. This is true when the pilot can intervene (case 1) and when the pilot cannot intervene either due to a loss of link (case 2) or a design decision (case 3). It is expected that case 3 might be relevant to tasks such as engine fuel metering, but not to complex tasks such as navigation. A system that utilizes nondeterministic software, but retains the ability of a pilot to intervene (case 4) is best described as human/autonomy teaming. An example is a system that analyses information and then offers at set of options to the pilot. Cases 5 and 6 represent hypothetical autonomous systems. In each case, the system is under the control of nondeterministic software. In case 5 pilot intervention is not possible due to a lost link. In Case 6, the designers built a nondeterministic system and made no provision for pilot intervention in its operation.

Table 1. A typology of automated and hypothetical autonomous on-board systems.

	Ability of pilot to intervene		
	1. Pilot is informed and can intervene	2. Pilot cannot intervene due to lost link	Pilot cannot intervene due to deliberate design decision
3.5.1.1.1.1.1			
3.5.1.1.1.1.2			
3.5.1.1.1.1.3			
System characteristics			
Deterministic system that behaves in a predictable manner using pre-set rules. Will always produce same output given same inputs.	3.5.1.1.1.1.4	3.5.1.1.1.1.6	3.5.1.1.1.1.8
	3.5.1.1.1.1.5	3.5.1.1.1.1.7	3.5.1.1.1.1.9
	(1) Automation	(2) Automation	(3) Automation

Nondeterministic system that behaves in a manner that cannot be reliably predicted. Over time, may produce different outputs given same inputs.	3.5.1.1.1.1.10	3.5.1.1.1.1.12	
	3.5.1.1.1.1.11	3.5.1.1.1.1.13	3.5.1.1.1.1.14
	(4) Human/autonomy teaming	(5) Autonomy	(6) Autonomy

3.6 Table 1 makes it clear that deterministic systems continue to be automated systems during lost link events, and do not become “autonomous”.

3.7 Given these descriptions, it is proposed that the systems and subsystems of a current RPAS will be operated in either manual or automated modes and that by design each element of the system may operate at different levels of automation depending on the context. It is not anticipated that in the short term, any element of an RPAS operating in civil airspace can be considered to be autonomous given current technologies, and social, ethical and legal concerns. WG7 therefore recommend that autonomy and autonomous operations are beyond the scope of the RPAS panel.

3.8 Summary

We propose the following for the ICAO RPAS panel:

3.8.1 Describe the RPAS automation with respect to the specific system, tasks and context and/or other relevant dimensions.

3.8.2 Autonomy and autonomous operations are beyond the scope of the RPAS panel.

3.8.3 The term automation (or automated) should be used to describe systems that are under the control of deterministic algorithms performing well-defined tasks that have predetermined responses.

3.8.4 Workgroup 7 (Human in the System) will, in consultation with other Workgroups, adapt or define relevant and specific levels of automation (LOA).

3.9 References

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3.10 ACTION BY THE RPASP

3.11 The RPASP is invited to:

- a) note and review the contents of this working paper;
- b) endorse the proposed line of action in paragraphs 2.8; and
- c) agree that WG7 continue its work on this proposal, with a view to finalization during the next meeting of the RPASP.

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