International Civil Aviation Organization

**WORKING PAPER**

# ASSEMBLY — 39TH SESSION

## TECHNICAL COMMISSION

**Agenda Item 33: Aviation safety and air navigation monitoring and analysis**

## SURVEILLANCE OF REMOTELY PILOTED AIRCRAFT SYSTEMS (RPAS) AND CYBERSECURITY

(Presented by the Russian Federation)

**EXECUTIVE SUMMARY**

Integrating remotely piloted aircraft systems (RPAS) into the controlled airspace means that those RPAS must be surveilled by a remote pilot as well as by the ATM system. It has been shown the most acceptable surveillance method is Automatic Dependent Surveillance – broadcast (ADS-B). The lack of cyber-secure data in the ADS-B 1090 ES means that data need to be verified with secondary radar or MLat data for surveillance in the ground-based ATM system. Air-to-air surveillance verification at close range is possible only using TCAS data, which, for reasons of cost, eliminates a large class of small non-piloted aircraft from consideration. To provide other navigation services (FIS-B, DGNSS, CPDLC, AOC), several other datalinks will be needed. These liabilities disappear if we use a VDL-4 communication link. In addition, a self-organizing airborne network (SOAN) built with VDL-4 fully solves cybersecurity problems.

**Action:** The Assembly is invited to:

a) take under advisement the benefits of both a remote pilot and the ATM system using ADS-B surveilling remotely piloted aircraft systems (RPAS);
b) take under advisement that ADS-B 1090 ES data are not cyber secure and need to be verified with secondary radar or MLat data for surveillance in the ground-based ATM system and that there are no acceptable verification methods for onboard surveillance;
c) take under advisement the benefits of using the VDL-4 datalink to implement surveillance of RPAS and associated applications, including considering the potential for self-organizing airborne networks (SOAN).

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| *Strategic Objectives:* | This working paper relates to the Safety Strategic Objective. |
| *Financial implications:* | Funding from the ICAO Regular Programme Budget |
| *References:* | Doc 9924, *Aeronautical Surveillance Manual*<br>ASWG TSG WP02-27, SP-ASWG/3 WP-24 ICAO Surveillance Commission Working Papers |

[1] Russian version provided by the Russian Federation.

## 1. INTRODUCTION

1.1 When remotely piloted aircraft system (RPAS) are flown in controlled airspace, they must be accompanied by surveillance, both by a remote pilot and by various users of the ATM system.

1.2 The general position of ICAO with respect to the surveillance of any aircraft in the ground-based ATM is that the following methods and tools be used:

a) radar surveillance based on secondary radar in A/C/S modes; there has to be a transponder onboard the RPAS;

b) MLat – the use of multi-positional surveillance system (MPSN); there has to be a transmitter onboard the RPAS;

c) ADS-B using satellite navigation signals; there has to be an ADS-B Out transmitter onboard the RPAS.

1.3 RPAS must be surveilled by the ATM ground system using one of the three methods above or a combination of these methods.

1.4 The RPAS must also be surveilled by the remote pilot at the remote pilot's station (RPS).

1.5 Using equipment onboard a RPAS in the mode of a secondary radar transponder requires that the RPS have a secondary radar installed. Right now, the great majority of RPAS in the world (up to 90%) have a weight of 30 kg. In the best circumstances, the RPS rests on a small truck/van, or the remote pilot carries equipment to monitor or control the RPAS. A secondary radar for RPAS from the RPS position is not feasible for reasons of cost, size, power consumption, and other technical parameters.

1.6 A mobile RPS also precludes the possibility of using MPSN, which is a collection of time-synchronized radio receivers spaced quite far apart (15-20 km and farther).

1.7 The ADS-B is the only acceptable method of surveilling RPAS from the RPS. Meanwhile, only the ADS-B can ensure direct air-to-air surveillance. As a result, pilots achieve situational awareness. Aside from surveillance services, other air navigation services would be of interest (adjacent applications), implemented using that same datalink that provides ADS-B services. Because of mass and power constraints, it is not feasible to use a secondary radar transponder or MPSN transmitter onboard the RPAS.

## 2. DATA TRANSMISSION LINKS FOR ADS-B IMPLEMENTATION

2.1 Let's review all ICAO standardized datalinks for ADS-B. They include:

a) 1090 MHz extended squitter (1090 ES);

b) Mode 4 VHF datalink (VDL-4);

c) 978 MHz Universal Access Transceiver (UAT).

2.2 The UAT is used for regional applications in the USA. The 978 MHz frequency, pursuant to Annex 5, Vol 5, must be used not for surveillance, but for navigation. EUROCONTROL announced that the UAT datalink will not be used in the future.

2.3 At the same time, the USA and Europe, in the NextGen and SESAR programmes respectively, have announced that all aircraft must be equipped with the 1090 ES Out commercial equipment, starting in 2020. An overwhelming majority of Airbus and Boeing commercial aircraft already have the 1090 ES Out datalink as part of their onboard equipment. The ADS-B-In function is not seen as mandatory in the NextGen and SESAR programmes.

2.4 The drawbacks of the ADS-B on the 1090 ES base include the interference/saturation if there is a high density of air traffic, which causes signal layering, as signals cannot be distinguished. For these reasons, the effective range of the ADS-B is 50-70 km in zones with intensive air traffic. Since the ADS-B-In function is not mandatory, the aircraft that are sending ADS-B messages don’t have information about the condition of the broadcast and don’t know if their signal will reach airspace users.

2.5 The decisive liability of the ADS-B on the 1090 ES base is that it is transparent to unauthorized users and has no cybersecurity. When sending false ADS-B messages in the ADS-B 1090 ES framework, there is no mechanism to differentiate true ADS-B messages from false ones.

2.6 A study by Costin, Strohmeier, Lenders, Martinovic and a study by GosNIIAS (the State Scientific Research Institute of Aviation Systems) itself have demonstrated the need to make mandatory the use of secondary radar or MLat data to verify the ADS-B data as part of the1090 ES datalink in the ATM system, as indicated in the high level aeronautical surveillance document Doc 9924, and in the 2016 documents, ASWG TSG WP02-27, SP-ASWG/3 WP-24. But in this case, because of the high costs of the secondary radar and MLat, that type of ADS-B is not very efficient, and from the technical standpoint is simply unnecessary, since to determine the aircraft location in the ATM system, the SR and MLat are self-sufficient and no ADS-B is needed. In ICAO’s opinion, air-to-air surveillance data verification for the ADS-B on the 1090 ES base is possible only with the traffic collision avoidance system (TCAS) within a limited range. Meanwhile, air-to-air surveillance in particular is of the greatest interest for general-purpose aviation, helicopters, RPAS, which aren’t equipped with TCAS, that fly at low levels for which aircraft servicing using ground ATM systems is problematic, from a practical perspective – not always in demand, moreover from an economic perspective – deploying a bona fide ATM system in massive regions, where several general aviation aircraft/helicopter flights happen per week, will never pay for itself. In these regions the priority is using ADS-B-In without using an ATM system. But if aircraft surveillance data in the ATM system with ADS-B-Out 1090 ES can be verified with SR or MLat data, then air-to-air surveillance data within the ADS-B 1090 ES cannot be verified without the TCAS in principle, as confirmed by the ICAO Surveillance Commission.

2.7 In this way, deploying ADS-B 1090 ES will require keeping and further developing ground infrastructure for SR or MLat to partially solve cybersecurity issues (but then you lose the main point of introducing the ADS-B). Unwittingly we have to ask, why do we need the ADS-B 1090 ES, if it rests on the SR or MLat which handles perfectly well and cyber-safely the task of finding the aircraft in the ATM system? The ADS-B in the ATM system was conceived to replace SR or MLat because it is much less costly, more accurate, more environmentally friendly. Now it turns out that without SR or MLat, the ADS-B 1090 ES cannot live independently. The fact that TCAS is in hybrid mode - ADS-B in Stage 1 and TCAS alone in stage 2 - is not an argument. The system can operate as TCAS alone without any ADS-B, and moreover, as shown above, you cannot fully trust ADS-B-Out onboard surveillance data from other airplanes because of spoofing, which can be done easily by specially-launched RPAS, for example. And finally, the fatal question: how will remote pilots of RPAS that have a take-off mass of about 30 kg know whether ADS-B-Out signals are reliable or not? Onboard the RPAS they don't have SR, MLat, or TCAS.

2.8 Let's address the issue of how cybersecurity issues will be resolved when using VDL-4.

2.9 False ADS-B messages could be used even when VDL-4 is used; however, there is a mechanism allowed by standards that makes it possible to gauge the distance between the message's sender and recipient and that way, you can tell which ADS-B messages are legitimate.

2.10 A recipient, whether it is the ATM system or the aircraft, receives a ADS-B message from a sender and it contains the sender's coordinates. Knowing his own coordinates, the recipient calculates the distance between the sender and recipient. At the same time, the VDL-4's fundamental property is being used. As was defined in the ICAO standard, the message has a time stamp. As the sender sends the message, he inserts the highly accurate time. The recipient also tags the receipt time to the time scale. Having calculated the times when the message was sent and received and having multiplied that by the electromagnetic wave distribution speed (speed of light), the recipient calculates the actual distance measured between the sender and the recipient. If the distances between the sender and recipient calculated by different methods with acceptable accuracy are a 1-2% match, then the sender is trustworthy. If they don't match, the recipient comes to certain conclusions and informs the surrounding users that the sender isn't trustworthy.

2.11 This message verification process works on VDL-4 aircraft for air-to-ground and air-air surveillance. We assume that in the ATM ground system there is one un-serviced unit with VDL-4 for the the RPAS that interacts with the ATM system computer to computer. Data verification for ground-based surveillance is done within the actual ADS-B using VDL-4 and doesn't require SR or MLat data. Onboard surveillance for equipped aircraft are verified in a similar way; the remote pilot of the RPAS received information on the location of the non-equipped aircraft via the TIS-B function, and the location of the non-equipped aircraft is determined using the methods customary for that ATM system.

2.12 We must note that contrary to the 1090 ES datalink, which executes only one main function (surveillance), the VDL-4 datalink has many other functions, which means that the aircraft with the 1090 ES datalink and the ATM system will need to have no fewer than three additional datalinks to transmit flight information, signals about the integrity of satellite navigation signals, differential correction, point-to-point communication for pilot-dispatcher CPDLC and the airline AOC, and others. Since the VDL-4 can operate simultaneously in several frequencies, all functions are executed within one unit, weighing less than 150 g. When you use the TIS-B function, the ground-based DAA prevents collisions between aircraft equipped with VDL-4 and those not equipped with it.

2.13 Self-organizing airborne networks (SOAN) using VDL-4 are a promising area of ADS-B development. At the 12th Airborne Navigation Conference, decisions were made acknowledging that this technical solution makes sense. Aside from the robustness of function and providing surveillance when there is no direct radio line of sight between the RPAS and the RPS supported via the network of RPAS in the air, the SOAN will solve aviation security problems in a radical way. A key system and cryptography will ensure complete authentication of radio messages and prevent them from being intercepted, falsified, damaged, etc., and fully meets cybersecurity challenges.

## 3. CONCLUSION

3.1 Bearing in mind the specifics of RPAS, from the position of RPS, the most optimal would be coordinated surveillance of the RPAS by the remote pilot using ADS-B.

3.2 The 1090 ES datalink doesn't provide cybersecurity for ADS-B data. Data have to be verified in the ground surveillance system using secondary radar or MLat. There are no satisfactory tools for verifying RPAS onboard data. To implement functions like FIS-B, DGNSS, CPDLC, AOC and others, you need at least three additional datalinks.

3.3 The VDL-4 datalink as per the standard protects the aircraft location in the ground-based ATM system or during onboard surveillance within its own ADS-B. Additional aeronautical services are also implemented with VDL-4. Self-organizing airborne networks using VDL-4 have significant potential, particularly when it comes to cybersecurity.

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