



WORKING PAPER

MULTIDISCIPLINARY MEETING REGARDING GLOBAL TRACKING

Montréal, 12 May to 13 May 2014

Agenda Item 1: Explore the need and means available to track globally all airline flights

AIRCRAFT TRACKING AND LOCALISATION OPTIONS

(Presented by the European Union)

SUMMARY

This working paper provides a list of options for aircraft tracking and localisation. They are grouped in three categories: options using the COSPAS-SARSAT infrastructure, triggered tracking and continuous tracking. These options, associated to high-level objectives will need to be carefully studied as well as their limitations.

In Appendix A, some technical background information is provided on ELTs and ADS. The Appendix B, performance-based criteria are proposed. Appendix C provides a detailed table of various options compared to these criteria.

Action: The meeting is invited to take note of the options presented in this paper, the technical aspects related to them, and use these to guide future actions to be undertaken.

1. COSPAS-SARSAT INFRASTRUCTURE

Deployable recorder fitted with ELTs

1.1 ELTs were designed to locate aircraft in case of an accident and to help SAR teams to home in towards the aircraft wreckage (see Appendix A).

1.2 The option of an ELT integrated in a deployable recorder should take some time to be implemented. It has already been studied by airframe manufacturers, but should only concern new type certificates. The overall concept consists of having two combined recorders: one located in the front of the aircraft and the second in the aft position. The aft recorder would be deployable and designed to float and transmit its location thanks to an ELT. Companies such as DRS Technologies and Cassidian have

distributed deployable flight recorders for the military. This solution would address both SAR and investigation needs, and it could be made robust to intentional disconnections.

ELT activated in flight upon automatic detection of an emergency or from the ground

1.3 The option of an ELT activated in flight upon automatic detection of an emergency (before the accident), which is technically feasible (see Appendix A for new generation of ELTs) could also address the concerns of intentional disconnections. The ELT is fitted with its own battery and can transmit independently once triggered. The Triggered Flight Data Transmission Working Group has identified a number of possible triggers for an ELT activated in flight. In order to be effective such an ELT would need to be able to detect an emergency situation and start emission of a signal within a few seconds. This will only be possible when the MEOSAR (Medium Earth Orbit Search And Rescue) system is operational.

1.4 In the light of the MH370 case, it has become important that the list of triggers includes intentional disconnection events in addition to safety events. Situations, such as flight recorder disconnections, loss of communications (transponder, ADS-B signals, satellite communications, etc.) or significant change of route, should activate the ELT or the transmission of the in-flight aircraft position in a way that nobody on board can stop this alert and positioning transmission.

1.5 The main advantage of this and the previous options is that they are already supported by an ad-hoc international organisation (COSPAS-SARSAT) tasked to locate distress signals. This organisation notably uses a mix of low earth orbit, medium earth orbit and geostationary satellites, from different providers as well as the 406 MHz radio frequency. An industry standard developed by EUROCAE WG 98 / RTCA SC 229 should be ready by the end of 2016.

1.6 The Galileo MEOSAR system (and potentially new generation of GPS and GLONASS satellites) will propose a specific communication link between an ELT and the MCC (Mission Control Center) to improve the search and rescue phase (acknowledgement of distress message by the MCC) or to remotely activate the ELT. This additional service is called RLS (Return Link Service). This link will enable the ELT to be triggered from the ground by the MCC and send the aircraft position upon e.g. request of an ATC facing a non-cooperative aircraft.

1.7 The option of using new generation ELTs will greatly assist SAR and accident investigation authorities, in particular when investigating accidents over water where the aircraft wreckage is difficult to locate, and may cover the case of a non-cooperative aircraft.

2. REGULAR AND AUTOMATIC TRANSMISSION OF AIRCRAFT POSITION

2.1 The issue may also be placed in the context of a wider use of real-time flight data transmission for operational and maintenance purposes beyond emergencies.

2.2 Frequency: In 2010, the SESAR Joint Undertaking launched OPTIMI (Oceanic Position Tracking Improvement and Monitoring Initiative) as a collaborative project with air navigation service providers, airlines, manufacturers, satellite communication providers and other entities involved in the aviation sector at the European Atlantic airspace. The initiative showed that an optimum frequency of position reporting, balancing both the costs of SAR operations derived from the search area, and the operating cost of reporting, of one positioning reporting every 15 minutes. This short term solution was proposed, without prejudice to the use of the ADS-C emergency mode (see hereafter). Before the AF447

accident, Air France already had programmed its long-range aircraft to report their position every 10 minutes. The Aircraft Communication Addressing and Reporting System (ACARS) messages sent before the accident helped to reduce this uncertainty to 5 minutes, which nevertheless led to a vast search zone of 17 000 km². Therefore, it is preferable to recommend that a regular transmission is made every minute in order to achieve the proposed 6 NM accuracy. A more cost-efficient compromise could be to transmit the position every 10 minutes and trigger each minute as soon as there is an unusual change in the trajectory (important vertical speed, unusual altitude in cruise, etc.). Some triggered messaging in case of steep descent was already included in PANS-ATM.

2.3 Addressees of messages: Aircraft position messages could be transmitted in a regular and automatic manner to a number of addressees, including airlines, air traffic centres, ad-hoc services. In summary, ACARS messages are protocols that can be used between the aircraft and its airline or the manufacturers (airframe, engine) while Controller-Pilot Data Link Communications (CPDLC) provides air-ground communication for the ATC service.

2.4 Intentional disconnection: Both ADS and ACARS are on normal power bus and can be disconnected easily, on current aircraft. Making them robust to power outage and malevolent act would require costly retrofit.

2.5 Coverage: ADS has been gradually implemented in some regions of the world, notably thanks to satellite communication systems like for ADS-A/C (see Appendix A). ADS aims to provide global coverage but remains dependent on airborne equipment and ground facilities that must be supported by consistent structures. ACARS services to airlines operations centres are generally more widely available than ADS-C and CPDLC services. ACARS messages can be sent by radio or via satellite communications. However, for oceanic flights satellite communication presents an advantage. To date, two satellite constellations provide satellite communication services to aviation: Inmarsat and Iridium. In 2011 (source OPTIMI study), the vast majority of aircraft that are equipped with a satellite communication system were equipped with Inmarsat compatible equipment (Approx 2500 aircraft used SITA services over Inmarsat out of 6300 commercial aircraft fitted with Inmarsat antennae). On the other hand, the Iridium constellation is not yet certified for Air Traffic Services, which explains why less aircraft use the services provided by Iridium. Nevertheless, the Iridium constellation has a better coverage than Inmarsat as its low orbit satellites have the potential to provide services over the polar regions, which the geostationary satellites provided by Inmarsat cannot cover.

2.6 Costs: With regard to the cost of transmission of messages via the satellite communication systems, since 2009 the cost has decreased almost 90 per cent to approximately fifty cents per message (source: ICAO Discussion Paper No. 1 related to AN-WP/8697). It is likely that costs will continue to decrease, especially if special “packages” are offered in the aftermath of the MH370 accident. Regarding satellite communication ACARS messages, airlines have the choice between several service providers (FLYHT, Star navigation, etc.). For ATM, the situation is more complex and depends on the solutions provided by the air navigation service providers (ANSPs) of the geographical area. These costs for ANSPs tend to be on a fixed bandwidth and data quantity basis, whereas to the airborne user, the in-service usage cost of ADS-C and other satellite communication messages is proportional to the number of messages sent.

3. **TRIGGERING TRANSMISSION OF DATA VIA SATELLITE PRIOR TO IMPACT**

3.1 The OPTIMI project also developed ADS-C deviation alert on some specific air navigation deviations or unplanned changes. Conversely, a number of airlines have already implemented

triggered transmissions of flight deviations via their ACARS systems. ADS-C can automatically send event reports (waypoint change, vertical rate, altitude range, lateral deviation), which could be of interest in case of an unforeseen situation. However, several difficulties impede the successful automatic log-on of aircraft where these services are available. The difficulties can be technical, related to an absence of a flight plan to correlate or simply because the flight crew elects not to log-on. Finally, it is important to note that the supporting ACARS network does not guarantee the safe delivery of messages.

3.2 The loss of flight MH370 has also highlighted that the disconnection of communication systems automatically should trigger the transmission of a message to the ground.

3.3 For safety investigation and accident prevention purposes, some 'health' data could be sent (such as enhanced fault forwarding information) while the airplane is still functioning before it crashes (such system was installed on the B747-400 operated by UPS that crashed in Dubai on 3 September 2010. It successfully sent data while the aircraft was still in flight prior to the accident.

4. OTHER GNSS AIRCRAFT TRACKING SOLUTIONS

4.1 This could represent an alternative cost-effective and independent possibility: GNSS¹ aircraft tracking solutions based on devices that could be embedded in the aircraft and made of a GNSS sensor are available. Such systems can transmit the GNSS position of the aircraft to a server on ground via a communication network. The server collects the data and makes it available to aircraft operators.

4.2 For example, the company Spidertracks offers subscription for high usages where the cost of a position report is only 5 cents (sent every two minutes). This system sends the GNSS location in real-time from the device mounted in the aircraft through the Iridium Satellite Network, and displays the flight tracks on dedicated websites. This could represent a cheap solution at the condition that it can be certified and be robust to power outages and intentional disconnections.

5. CONCLUSION

5.1 Aircraft tracking and localization can be performed using different options. It is important to note their limitations and level of maturity.

5.2 The table in Appendix C summarizes the previous options, their pros and cons with a ballpark quantitative assessment of their associated costs and possible time for implementation. The table contains a number of point related to the high-level objectives: 1) the Robustness of the on-board systems to accident conditions or intentional disconnections; 2) coverage over all oceanic and remote areas; 3) conditions/frequency of transmissions to ensure a timely alert; 4) geographical accuracy and 5) multiple providers/costs. Appendix B presents the performance-based criteria that are proposed in the EASA Opinion 01/2014.

¹ Global Navigation Satellite System

APPENDIX A BACKGROUND ON ELTs AND ADS

Emergency Locator Transmitters

ELTs (Emergency Locator Transmitters) are transmitters that can be tracked in order to aid in the detection and localisation of aircraft in distress. They are radio beacons that interface worldwide with the international COSPAS-SARSAT satellite system for Search and Rescue (SAR). When activated, such beacons send out a distress signal, which, if detected by satellites, can be located by trilateration in combination with triangulation.

In the case of 406 MHz ELT which transmit a digital signal, the beacon can be uniquely identified almost instantly (via GEOSAR²), and furthermore a GPS or GLONASS position can be encoded into the signal, which provides instantaneous identification of the registered user and its location. Frequently, by using the initial position provided via the satellite system and the 121.5 MHz signal, SAR aircraft and ground search parties can home-in on the distress signals from the beacon and locate the concerned aircraft or people. ELTs are currently designed to activate automatically by shock typically encountered during aircraft crashes or manually.

In 2005, ICAO mandated that all aeroplanes and helicopters for which Parts I, II, and III of Annex 6 of the Convention on International Civil Aviation applied, be required to carry at least one ELT operating in the 406 MHz band. With a 406 MHz beacon, the position of the event can be relayed to rescue services more quickly, more reliably and with greater accuracy than with the 121.5 MHz beacons.

The COSPAS-SARSAT System has been undoubtedly helpful for Search and Rescue teams in numerous aircraft accidents on a worldwide basis. Despite these successes, the detection of ELT signals after an aircraft crash remains problematic. Several reports have identified malfunctions of the beacon triggering system, disconnection of the beacon from its antenna or destruction of the beacon as a result of accidents where aircraft were destroyed or substantially damaged. Even when the beacon and its antenna are functioning properly, signals may not be adequately transmitted to the COSPAS-SARSAT satellites because of physical blockage from aircraft debris obstructing the beacon antenna or when the antenna is under water.

At the level of the ELT, two possible improvements were identified by experts:

1. making them deployable and possibly combined with a flight recorder, or
2. Making them able to detect automatically an emergency situation and activate in flight (possibly starting the transmission of a position) before the crash impact.³

Possible improvements to the performance of 406 MHz ELTs during aircraft accidents have been impaired by some of the limitations of the current COSPAS-SARSAT LEOSAR⁴ and GEOSAR systems. These combined systems do not provide a complete coverage of the Earth at all time. As a consequence, beacons located outside the areas covered by the LEOSAR and GEOSAR satellites at a given moment cannot be immediately detected, and must continue to transmit until a LEOSAR satellite passes overhead, which can last up to 50 minutes. To improve coverage, COSPAS-SARSAT has been implementing a new MEOSAR system based on

² Geostationary SAR

³ Note that a GPS receiver does not send an accurate position until the satellite system's almanac has been received which may take up to 12 minutes. Even if the ELT's GPS was updated after manufacturing, there could be several years until it will be used and the GPS satellites orbits have most likely been changed significantly during those years. At a live test in Sweden of an ELT equipped with GPS, the first position transmitted to COSPAS-SARSAT had a faulty position of more than 800 meters. At next passage of the satellite 30 minutes later an accurate position with an accuracy of about 40 meters was transmitted (limited by the COSPAS-SARSAT position message).

⁴ Low Earth Orbit SAR

Appendix A

the use of search and rescue transponders on new GPS, GLONASS, and GALILEO satellites and accompanied by a new ground segment.

The new MEOSAR system will significantly improve the timeliness and accuracy of alerts provided by ELTs and allow for new services to be provided (e.g. return link services). In conjunction with the new MEOSAR system, COSPAS-SARSAT is developing a new second generation beacon specification.

In the aftermath of the 2009 AF447 accident, the “Triggered Transmission of Flight Data” working group had analysed the concept of triggering the transmission of flight data, which consists of detecting and using flight parameters, whether an emergency situation is upcoming. If so, transmitting data automatically from the aircraft until either the emergency situation ends, or the aircraft impacts the surface. Based on the results of the analysis, it was concluded that it is technically feasible and realistic, to reduce the search area location radius of 6 NM for 2019 by triggering transmission of appropriate data prior to impact, and/or automatically activating next generation ELTs prior to impact, and/or increasing the frequency of position reports to less than 1 minute.

The creation of specifications for second generation ELTs are required in order to ascertain if it is sufficient for application to all aircraft used in commercial operations or is under or over prescriptive.

A number of recommendations resulted from the studies. In particular it was recommended that EASA and ICAO define the regulatory requirements for new generations of ELTs.

GNSS technology allows ELTs to provide accurate accident positioning to first responders. Development of standardized GNSS requirements for use in ELTs needs to be addressed.

Improvement in technology should enable to develop specifications for next generation ELTs able to operate on 406 MHz for the homing device to support search and rescue authorities.

EUROCAE has recently established working group WG-98 (Aircraft Emergency Locator Transmitters) to develop these specifications on ELTs. It is also anticipated to use the output of the working group to update the applicable EASA European Technical Standard Order (ETSO) and Part-OPS within the revised EASA rule structure.

ADS: Automatic Dependent Surveillance

ADS stands for Automatic Dependent Surveillance. It means that the surveillance data is provided by the aircraft. There are two commonly recognized types of ADS for aircraft applications:

- ADS-Addressed (ADS-A) more commonly called ADS-Contract (ADS-C), and
- ADS-Broadcast (ADS-B).

ADS-C is based on a contractual relationship between an aircraft providing ADS information and a ground facility requiring receipt of ADS messages. ADS-C can use ACARS as the communication protocol. During flight over areas without radar coverage (e.g. oceanic), ADS-C reports can be periodically sent by an aircraft to the controlling air traffic region. This is a one to one relationship so no other aircraft in the vicinity can benefit from the transmitted information as ACARS information is not re-broadcast from ground facilities to other aircraft.

Otherwise, ADS-B is a cooperative surveillance technology for tracking aircraft. The aircraft determines its own position via GNSS and periodically broadcasts this via a radio frequency. ADS-B is one of the technologies selected as part of the Next Generation Air Transportation System (NextGen) and the Single

European Sky ATM Research (SESAR). An option is also that aircraft use other aircraft as receivers for signals, useful in situations without enough receivers on the ground.

From a dependence point of view, ADS and Secondary Surveillance Radar (SSR) have in common that they both need to cooperate with the aircraft's systems. They cannot be independent neither from the aircraft nor from the flight crew. At this stage, a technical malfunction/power loss or a voluntary disconnection will render an air traffic controller completely blind, if he does not have a backup system with primary surveillance radar (PRS) information.

APPENDIX B
EASA OPINION 01/2014 (Extracts)

The draft rules proposed by EASA Opinion 01/2014, which addressed a number of safety recommendations issued after the AF447 accident, allow that an aircraft is equipped with means for locating an accident within 6 NM accuracy as an alternative to long-range underwater locating devices. A number of criteria are also defined for this means to be considered acceptable. These criteria are used for comparing options in the table of annex 3.

CAT.IDE.A.285 Flight over water

(...)

(f) On or after 1 January 2019, aeroplanes with an MCTOM of more than 27 000 kg shall be fitted with a securely attached underwater locating device that operates at a frequency of $8.8 \text{ kHz} \pm 1 \text{ kHz}$, unless:

- (1) the aeroplane is operated over routes on which it is at no point at a distance of more than 180 NM from the shore; or
- (2) the aeroplane is equipped with an automatic means to determine, following an accident where the aeroplane is severely damaged, the location of the point of impact with the Earth's surface within 6 NM accuracy.

AMC2 CAT.IDE.A.285(f) Flight over water

AUTOMATIC MEANS TO DETERMINE THE LOCATION OF THE POINT OF END OF FLIGHT AFTER AN ACCIDENT WHERE THE AIRCRAFT IS SEVERELY DAMAGED

(a) The automatic means to determine, following an accident where the aircraft is severely damaged, the location of the point of end of flight within 6 NM accuracy should:

- (1) be operational whenever the aeroplane is airborne;
- (2) be so designed that it is very likely to work, indistinctively if the accident is survivable or not;
- (3) be robust to loss of normal electrical power on board;
- (4) not offer any control to disable it during the flight;
- (5) work at most locations on Earth, including oceanic areas and remote land areas; and
- (6) be so designed that the location of the point of impact can be determined within 6 NM accuracy and within 3 hours of the accident time.

(b) The automatic means to determine, following an accident where the aircraft is severely damaged, the location of the point of end of flight within 6 NM accuracy may use any technology. However, an automatic fixed ELT or an automatic portable ELT are not acceptable for this purpose if they are not designed to successfully emit in extreme non-survivable accident conditions or to emit upon automatic detection of an emergency situation or a situation likely to result into an accident. In addition, an automatic deployable ELT that only relies on water immersion sensors and negative acceleration sensors ('g' switches) for detecting impact with water or ground is not acceptable.

GM2 CAT.IDE.A.285(f) Flight over water

AUTOMATIC MEANS TO DETERMINE THE LOCATION OF THE POINT OF END OF FLIGHT AFTER AN ACCIDENT WHERE THE AIRCRAFT IS SEVERELY DAMAGED

(...)

(c) Examples of automatic means to determine the location of the point of impact with the Earth's surface within 6 NM accuracy are:

Appendix B

- (1) periodic transmission by the aeroplane of its latitude and longitude, from take-off to landing, at time intervals not exceeding 1 minute and to a ground infrastructure where they are stored; the transmission would be successful from most locations on Earth and robust to loss of normal electrical power on board, and there would be no control to disable the transmission in flight;
- (2) emission by the aeroplane of a signal upon detection of an emergency situation or a situation likely to result into an accident. The emission would start within seconds of detection and continue until the detection criteria have disappeared. The emission would be robust to high aircraft attitudes and to loss of normal electrical power on board and there would be no control to disable the transmission in flight. There would be reliable ground infrastructure to receive the emergency signal, store it and trigger an alert. The signal would contain position information or post-processing of the signal would allow determining the aircraft position. Examples of criteria triggering transmission are: unusual aircraft attitude, unusual airspeed or vertical speed, stall, excessive accelerations, GPWS/TAWS hard warning, ACAS/TCAS Resolution Advisory, cabin altitude warning, fire warning, multiple engine failure;
- (3) an automatic deployable flight recorder fitted with an ELT, compliant with ETSO-C123b, ETSO-C124b, ETSO-C177 or equivalent. There would be no control to disable the automatic deployment function in flight.

**APPENDIX C
DETAILED TABLE OF POSSIBLE OPTIONS IN RELATION TO KEY CRITERIA**

	TECHNICAL OPTIONS	ACHIEVED OBJECTIVES UPON COMPLETION	Requirements (Performance based)					COSTS/SIDE EFFECTS (for States and Industry)			TIMESCALE
			Coverage	Robust to power outage, upset attitudes, etc.	Robust to intentional disconnections	Geographical accuracy (6 NM)	Timely alert (3 hours)	Pros	Cons	Examples of Providers specifications	
COSPAS SARSAT infrastructure	Deployable Flight Recorder fitted with ELTs	Survivability / safety investigation / Security*	Global worldwide	Independent battery	Yes	Yes (if functional after the impact)	Yes (if functional after the impact)	Already dedicated international infrastructure	For new Type Certificates	DRS Technologies, Cassidian	LONG TERM
	On-board and Ground Triggered ELTs	Survivability / safety investigation / Security*	Global worldwide	Independent battery	Yes (could even trigger if the logic is modified in the future)	Yes	Yes	Overcomes risks of damage upon impact. Can be activated from the ground using Galileo Return Link Service	Need to be installed in a way that it cannot be switched off or disabled from the cockpit A very robust trigger logic with a comprehensive set of triggers + connection to aircraft systems need to be in place for this to be effective	EUROCAE WG98 is working on the triggering of second generation of ELTs. COSPAS SARSAT will specify ELTs and Control Center alerts management	MEDIUM TERM 2018 (on-going deployment of MEOSAR constellation) LONG TERM starting 2018 (forward fitting of new ELTs)
Triggered Tracking	On-board maintenance triggered ACARS to Airlines (including position, and Master Warning infos)	Safety investigation + enhanced maintenance	Incomplete with geostationary satellites (Inmarsat); Global with Iridium	No, signal can be lost with moderate bank angles.	No	Yes (if within a few seconds)	No unless dedicated alerting organisation within the airline	Already in use, could be encouraged on a voluntary basis. Some operators elected to embed the aircraft position when a maintenance message is send out.	A very robust trigger logic with a comprehensive set of triggers + connection to aircraft systems need to be in place for this to be effective	Several providers ARINC, SITA (FLYHT, Star navigation, etc. for Iridium). However most of today's triggers are maintenance-related.	MEDIUM OR LONG TERM FOR AN EFFECTIVE SOLUTION
	On-board and Ground Triggered ADS-C to ATC (Events reports)	Survivability / safety investigation	Incomplete (Dependent on Flight Information Regions)	No + ACARS protocol does not guarantee the deliverance of event reports	No	If sent within a few seconds	No - Emergency message depends on manual entries	A contract means direct follow up with ATC	Current system is dependent on filling a correct flight plan - Risk of non-deliverance of event reports. An ATC triggered position report may require several minutes (human + technical delays)	SITA or ARINC	MEDIUM TERM (already in place in some regions – should be extended)

	On-board Triggered HFDL(High Frequency Data Link)	Supplementary	Global but low bandwidth (sufficient for position reports)	No	No	If sent within a few seconds	No	Can be used over polar regions and is much cheaper than SatCom	Very low bandwidth and subject to atmospheric perturbations. Aircraft manufacturers could stop proposing HFDL technology on future aircraft	ARINC currently has 15 HF ground stations (HGS) available	MEDIUM OR LONG TERM
Continuous Tracking	ACARS to Airlines	safety investigation	Incomplete with geostationary satellites (Inmarsat). Global with Iridium.	No	No	If sent every minute	No unless dedicated alert system at the airline	Already in use, low cost modification for the airlines, (Air France fleet sends position reports every minute when aircraft fly below FL 150 during cruise) could be encouraged on a voluntary basis.	No oversight	Several providers ARINC, SITA (FLYHT, Star navigation, etc. for Iridium.)	SHORT TERM LONG TERM for a solution that is fully effective (that is robust to accident conditions and to intentional disconnections)
	ADS-C to ATC (Periodic reports)	safety investigation (if sent every minute)	Incomplete (dependent on FIR equipment of ATC and certification)	No	No	If sent every minute (feasibility to be confirmed)	No - Emergency message depends on manual entries	Already implemented in several Oceanic FIRs	No systematic log-on. Automatic log-on of the aircraft to ADS-C would be required. Current periodic reporting period is every 15 minutes	SITA or ARINC	MEDIUM TERM (already in place in some regions – should be extended) LONG TERM for a solution that is fully effective (robust to accident conditions and to intentional disconnections)
	HFDL (High Frequency Data Link)	safety investigation (if sent every minute)	Global but low bandwidth	No	No	If sent every minute	No	Can be used over polar regions and is much cheaper than SatCom	Very low bandwidth and subject to atmospheric perturbations Aircraft manufacturers could stop proposing HFDL technology on future aircraft	ARINC currently has 15 HF ground stations (HGS) available (single provider)	SHORT TERM LONG TERM for a solution that is fully effective (robust to accident conditions and to intentional disconnections)

	ADS-B (ground based)	Survivability / safety investigation	Line of sight with ground stations, oceanic areas are not covered	No	No	Yes (with coverage)	Yes (where there is ADS-B coverage only)	Aircraft equipped with ADS-IN can visualize other traffics	Risk of cyber-attacks, no coverage of oceanic/desert areas	Airservices Australia, FAA, Nav Canada	SHORT TERM for ground stations (without global coverage)
	ADS-B (satellite based)	Survivability / safety investigation	Global	No	Dependent on technology	Yes	Yes, with a dedicated operational alert system	Some technologies are cost efficient for airlines (no need to install additional equipment)	Risk of cyber-attacks - Risk of monopoly	Aireon (JV Iridium Nav Canada, etc.), GlobalStar, European projects	LONG TERM Iridium service announced 2018
	Other GPS aircraft tracking solutions	Survivability / safety investigation / Security* (if independent power supply)	Global (using SatCom)	No, but could be if powered independently	No, but could be if powered independently	Yes if position reports set to every minute	No unless dedicated alert system at the airline	Cheap possible solution if using existing antennas	Need to retrofit antennas – need to grant STC (Supplemental Type Certificates)	No coordinated ICAO or aviation industry standards. Already competition between providers (such as Spidertracks, DTS services, SkyTrac, etc.)	MEDIUM TERM LONG TERM for a solution that is fully effective (robust to accident conditions and to intentional disconnections)

— END —