International Civil Aviation Organization

Twenty Fourth Meeting of the Communications/ Navigation and Surveillance Sub-group (CNS SG/24) of APANPIRG

Web-conference, 30 November – 4 December 2020

Agenda Item 2: Review outcomes of APANPIRG/RASG Chairpersons review, APANPIRG/30 meeting, 40th Session of ICAO Assembly, ATM Sub-group and other major meetings relevant to CNS Sub-group

CNS SYSTEMS RESILIENCE AND GNSS INTERFERENCE

(Presented by the Secretariat)

SUMMARY

This paper presents the outcomes of working papers A40-WP/82, A40-WP/352 and A40-WP/188, and the action required by State Letter Ref.: AN 7/5-20/89 on the issues related to the evolution of CNS systems and the associated threats and vulnerabilities, with particular regard to satellite-based CNS systems, such as GNSS.

1. INTRODUCTION

1.1 The Council, at the ninth meeting of its 220th Session on 22 June 2020, agreed with the proposal to bring to the attention of States the actions agreed by the 40th Session of the Assembly (24 September - 4 October 2019) with regard to communications, navigation, and surveillance (CNS) systems resilience and mitigation of harmful interference to global navigation satellite system (GNSS).

1.2 A State Letter with Ref.: AN 7/5-20/89 and **Subject**: *Strengthening of communications, navigation, and surveillance (CNS) systems resilience and mitigation of interference to global navigation satellite system (GNSS)* was circulated to States on 28 August 2020, and proposed required action by States on the aforementioned issues.

2 DISCUSSION

2.1 Assembly working papers A40-WP/82, A40-WP/352 and A40-WP/188, presented respectively by Finland on behalf of the EU and its Member States, by Saudi Arabia and jointly by the International Federation of Air Traffic Controllers' Associations (IFATCA), the International Federation of Air Line Pilots' Associations (IFALPA) and the International Air Transport Association (IATA). The papers identified issues related to the evolution of CNS systems and the associated threats and vulnerabilities, with particular regard to satellite-based CNS systems, such as GNSS.

2.2 They highlighted, in particular, the impact from harmful interference to GNSS on the safety and efficiency of aircraft and ATM operations, and identified the need to strengthen the

protection of GNSS signals from harmful interference and degradation of performance through actions by States and ICAO in coordination with industry.

2.3 The Assembly noted the essential commonality of purpose among the three papers and agreed with the proposals contained therein (*Assembly Fortieth Session, Technical Commission Report*, Doc 10137, A40-TE, 30.15 refers). The attachment to the State Letter compiles the proposals that are relevant for action by States. In summary, they include: reinforcing CNS system resilience to interference, preventing the use of illegal interfering devices, increasing collaboration with radio regulatory and enforcement authorities, reinforcing civil-military coordination to address interference risks associated with GNSS testing and conflict zones, increasing coordination between aviation and radio-regulatory authority and military, retaining essential conventional navigation infrastructure for contingency support in case of GNSS outages, and developing mitigation techniques for loss of services.

2.4 In particular, all three papers stress the importance of applying the GNSS radio frequency interference mitigation plan outlined in the ICAO *Global Navigation Satellite System (GNSS) Manual* (Doc 9849). The framework recommended to implement the mitigation plan includes a continuous three-step process, comprising threat monitoring, risk assessment and deployment of mitigation measures. Checklists of preventive and reactive measures aimed at mitigating the interference risk, as far as practicable, are also provided with the State Letter.

3. ACTION BY THE MEETING

3.1 The meeting is invited to

a) Note the information contained in the attached three A40 working paper and the State Letter;

b) Note the criticality of the issue and the importance of action by States to address it by making use of the ICAO guidance provided in Doc 9849, *Global Navigation Satellite System (GNSS) Manual* and by taking any other measures as appropriate.

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Tel.: +1 514-954-8219 ext. 6717

Ref.: AN 7/5-20/89

28 August 2020

Subject: Strengthening of communications, navigation, and surveillance (CNS) systems resilience and mitigation of interference to global navigation satellite system (GNSS)

Action required: Note the criticality of the issue and the importance of action by States to address it by making use of the ICAO guidance provided in Doc 9849, *Global Navigation Satellite System (GNSS) Manual* and by taking any other measures as appropriate

Sir/Madam,

1. I have the honour to inform you that the Council, at the ninth meeting of its 220th Session on 22 June 2020, agreed with the proposal to bring to the attention of States the actions agreed by the 40th Session of the Assembly (24 September – 4 October 2019) with regard to communications, navigation, and surveillance (CNS) systems resilience and mitigation of harmful interference to global navigation satellite system (GNSS).

2. The agreed actions were pursuant to proposals contained in Assembly working papers A40-WP/82, A40-WP/352 and A40-WP/188, presented respectively by Finland on behalf of the EU and its Member States[1], by Saudi Arabia and jointly by the International Federation of Air Traffic Controllers' Associations (IFATCA), the International Federation of Air Line Pilots' Associations (IFALPA) and the International Air Transport Association (IATA). The papers identified issues related to the evolution of CNS systems and the associated threats and vulnerabilities, with particular regard to satellite-based CNS systems, such as GNSS. They highlighted, in particular, the impact from harmful interference to GNSS on the safety and efficiency of aircraft and ATM operations, and identified the need to strengthen the protection of GNSS signals from harmful interference and degradation of performance through actions by States and ICAO in coordination with industry.

[1] Austria, Belgium, Bulgaria, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom.

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3. The Assembly noted the essential commonality of purpose among the three papers and agreed with the proposals contained therein (*Assembly Fortieth Session, Technical Commission Report*, Doc 10137, A40-TE, 30.15 refers). The attachment to this letter compiles the proposals that are relevant for action by States. In summary, they include: reinforcing CNS system resilience to interference, preventing the use of illegal interfering devices, increasing collaboration with radio regulatory and enforcement authorities, reinforcing civil-military coordination to address interference risks associated with GNSS testing and conflict zones, increasing coordination between aviation and radio-regulatory authority and military, retaining essential conventional navigation infrastructure for contingency support in case of GNSS outages, and developing mitigation techniques for loss of services.

4. In particular, all three papers stress the importance of applying the GNSS radio frequency interference mitigation plan outlined in the ICAO *Global Navigation Satellite System (GNSS) Manual* (Doc 9849). The framework recommended to implement the mitigation plan includes a continuous three-step process, comprising threat monitoring, risk assessment and deployment of mitigation measures. Checklists of preventive and reactive measures aimed at mitigating the interference risk, as far as practicable, are also provided.

5. May I request that you note the criticality of the issue and the importance of action by States to address it by making use of the ICAO guidance provided in Doc 9849, and by taking any other measures, as appropriate.

Accept, Sir/Madam, the assurances of my highest consideration.

Fang Liu
Secretary General

Enclosure:

Actions agreed by the 40th Session of the Assembly to strengthen CNS systems resilience and mitigate interference to GNSS

ATTACHMENT to State letter AN 7/5-20/89

Actions agreed by the 40th Session of the Assembly to strengthen CNS systems resilience and mitigate interference to GNSS

From *A40-WP/82,* States are urged to:

"1) transition from a CNS system-based concept towards secure CNS services, mainly based on a satellite-based infrastructure while addressing its resiliency to interference through independent minimum operational networks based on ground and/or airborne components;
2) apply necessary measures to avoid the commercialisation / proliferation and the use of illegal transmitters such as jammers which may impact satellite-based CNS systems;
3) ensure, considering that the use of radio frequency spectrum by aeronautical safety services requires special measures, close collaboration between aviation authorities, service providers, radio regulatory and spectrum enforcement authorities to ensure that this spectrum is free from harmful interference;
4) reinforce civil-military collaboration regarding global navigation satellite system (GNSS) testing and other activities, which may impact satellite-based CNS systems, with the air navigation services provider (ANSP) responsible for the affected airspace; and
5) consider, when assessing the interference risks associated with conflict zones, that the use of satellite-based CNS systems can potentially be impacted beyond that zone."

From *A40-WP/352,* States are urged to:

"1) assess the likelihood and effects of global navigation satellite system vulnerabilities in their airspace and apply, as necessary, ICAO mitigation methods;
2) provide effective spectrum management and protection of global navigation satellite systems (GNSS) frequencies to reduce the likelihood of unintentional interference or degradation of GNSS performance; and
3) cooperate for design, development and realization of Ground and on-board mitigation techniques of GNSS loss of service;"

From *A40-WP/188,* the Assembly is invited to:

"a) to implement appropriate mitigation measures as contained in the *Global Navigation Satellite System (GNSS) Manual* (Doc 9849) as a matter of high priority and to report progress and any difficulties to ICAO;
b) to recognize the unintended impact of harmful interference to civil flight operations and to exercise caution to the maximum extent possible to protect the safety of civil aircraft during military exercises and operations;
c) to establish and ensure appropriate frequency regulations are in place and maintained to protect allocated GNSS frequencies from harmful interference in line with ITU Radio Regulations;
d) to ensure that contingency procedures are established in coordination with air navigation service providers and airspace users and that essential conventional navigation infrastructure, such as Instrument Landing System (ILS), are retained when operationally beneficial; and
e) to support the multi-disciplinary development of alternative positioning, navigation and timing (APNT) strategy and solutions to complement the use of GNSS in aviation in coordination with ICAO and airspace users."

— END —

International Civil Aviation Organization

A40-WP/82
TE/17
23/7/19

WORKING PAPER

ASSEMBLY — 40TH SESSION

TECHNICAL COMMISSION

Agenda Item 30: Other issues to be considered by the Technical Commission

INTERFERENCE-RESILIENT SATELLITE-BASED CNS SYSTEMS

(Presented by Finland on behalf of Member States of the European Union[1], the other Member States of the European Civil Aviation Conference[2]; and by EUROCONTROL)

EXECUTIVE SUMMARY

The air traffic management/ communications, navigation, and surveillance (ATM/CNS) systems are evolving and so are the associated CNS threats and vulnerabilities. While satellite-based CNS systems take a growing part in the overall ATM system, the occurrences of interferences against those systems have significantly increased. CNS resiliency to interference needs to be addressed at global level with a holistic approach, ensuring an efficient and coordinated evolution between the infrastructure architecture, new technological capabilities, operational procedures, radio regulatory authorities and civil-military coordination.

Any lack of resiliency to interference needs to be compensated and can use a combination of an independent minimum operational networks (MON), based on ground and airborne components and air traffic control (ATC) procedural methods, which provide contingency of the CNS services in case of satellite-based service unavailability.

In addition, both the on-board and ground segments of the satellite-based CNS systems need to be adapted to potentially increasing threats by developing interference detection and reporting capabilities and mitigation measures to ensure flight safety. Combined with an appropriate legal framework, it will allow for the relevant authorities to act upon harmful interferences caused by illegal transmitters or other sources of electromagnetic radiation and avoid the proliferation and the use of such illegal transmitters. A civil military coordination should facilitate the sharing of relevant information with airspace users either during civil or military testing activities or when flying in the vicinity of a conflict zone.

[1] Austria, Belgium, Bulgaria, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom.

[2] Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Georgia, Iceland, Republic of Moldova, Monaco, Montenegro, North Macedonia, Norway, San Marino, Serbia, Switzerland, Turkey and Ukraine.

Action: The Assembly is invited to:

a) urge States to:
   1) transition from a CNS system-based concept towards secure CNS services, mainly based on a satellite-based infrastructure while addressing its resiliency to interference through independent MON based on ground and/or airborne components;
   2) apply necessary measures to avoid the commercialisation / proliferation and the use of illegal transmitters such as jammers which may impact satellite-based CNS systems;
   3) ensure, considering that the use of radio frequency spectrum by aeronautical safety services requires special measures, close collaboration between aviation authorities, service providers, radio regulatory and spectrum enforcement authorities to ensure that this spectrum is free from harmful interference;
   4) reinforce civil-military collaboration regarding global navigation satellite system (GNSS) testing and other activities, which may impact satellite-based CNS systems, with the air navigation services provider (ANSP) responsible for the affected airspace; and
   5) consider, when assessing the interference risks associated with conflict zones, that the use of satellite-based CNS systems can potentially be impacted beyond that zone.

b) direct ICAO to develop guidelines and best practices for use at the State, regional and global levels to mitigate safety risks related to any civil or military GNSS testing activities or other activities which may impact CNS systems (e.g. intentional jamming); and

c) call upon industry standardization bodies and industry to develop appropriate interference detection, mitigation and reporting capabilities for both the on-board and ground segments of the satellite-based CNS systems, in order to ensure higher CNS resiliency.

Strategic Objectives:	This working paper relates to Strategic Objectives of Safety and Air Navigation Capacity and Efficiency.
Financial implications:	The activities referred to in this paper will continue subject to the resources available in the 2020-2022 Regular Programme Budget and/or from extra budgetary contributions
References:	A32-19, A32-20, A39-11 Appendix F

1. GLOBAL CNS RESILIENCY

1.1 The traditional communications, navigation and surveillance (CNS) system, which is currently organised around the 3 C, N and S pillars, relies on the logic that while one pillar can have a complete failure, the two others enable, as a minimum, the safe landing of aircraft. Resulting from the transition to performance-based concepts and the introduction of global navigation satellite system (GNSS) as an integral enabler in multiple areas of CNS, the traditional, single system CNS safety concept needs to evolve.

1.2 An integrated CNS concept is being developed to manage this CNS concept evolution and to address the existing and upcoming CNS challenges: global CNS resiliency is to be achieved by defining a future CNS infrastructure based on two layers:

a) a backbone of recently standardised or being standardised and global technologies, mainly satellite-based (including satellite communication (SatCOM), GNSS, automatic dependent surveillance — broadcast (ADS-B) and ADS-B satellite-based), supporting resilient CNS services, complemented by

b) a minimum operating network (MON) composed of legacy ground and/or airborne components (e.g. inertial reference system(IRS)) independent from the backbone which provide continuity of the CNS services in case of satellite-based CNS service interruptions.

1.3 Any lack of resiliency to interference needs to be compensated. This compensation can be built with a combination of an independent MON, based on ground and airborne components and ATC procedural methods, which provide contingency of the CNS services in case of satellite-based service unavailability.

2. CNS INTERFERENCE, DETECTION AND REQUIRED ACTIONS

2.1 Interference can degrade civil satellite-based CNS signals (e.g. GNSS) and services which are the main enablers of integrated CNS, and in some cases results in unusual system behaviour. Satellite signals are by nature very weak when they arrive at the receiver and thus vulnerable to interference, both natural or artificial, intentional (including jamming and spoofing) or unintentional. The subsequent discussion illustrates the issues already encountered by navigation, being the first CNS domain moving to satellite-based services. However, surveillance and communication may suffer from comparable threats with a need to define actions to address CNS as a whole.

2.2 The aviation community is well-aware of the threats due to the proliferation of interference capable equipment including portable electronic devices (PEDs), personal privacy devices (PPDs), incorrectly operated GNSS repeaters, miss-operated test equipment and the foreseeable proliferation of sophisticated spoofing devices in the future. Improved protection against such interference is under consideration in the development of next-generation avionics and CNS system standards.

2.3 An increasing number of partial or complete loss of GNSS services are reported by pilots (several hundred of occurrences with interruption from generally 10 to 20 minutes were reported by 60 airlines in 2018). This represents a significant increase compared to previous years. The International Air Transport Association (IATA) member airlines and other aircraft operators are experiencing and reporting unavailability of GNSS equipment on a regular basis today. In most cases, the likely cause was ground-

originated jamming. So far, no spoofing event was identified. A limited number of those events were caused by low power PPDs. Whilst illegal, these devices intend to jam GNSS signals only closely around the user, but might still interfere with aircraft or airport ground-based augmentation system (GBAS) and ADS-B ground stations at close distance. Several occurrences have been reported among which the majority were encountered during the en-route phase of flight, in areas where political tensions prevail. In some cases high power jammers have been used, impacting a large volume of airspace.

2.4 Once the degradation of GNSS performance is recognised, the consequences may differ from case to case. In some most severe cases, not only the required navigation capability is affected, but the airplane may experience terrain avoidance and warning system (TAWS) errors, and trigger sudden "'terrain-pull up" warnings, including during instrument landing system (ILS) approaches. This could lead to inappropriate action by flight crews.

2.5 Finally, it shall be noted that the aforementioned interference impacts may be in many cases reduced within States which have set-up simultaneously: 1) an efficient spectrum regulation policy, involving civil aviation, to alleviate the impact of unexpected interference events; and 2) a civil aviation coordination mechanism with State military authorities.

2.6 In the future, technical means should be deployed to detect and identify areas of frequent interference, so that operational and technical mitigations can be put in place in advance, and that negative impacts on safety related to the aircrew “surprise” effect can be alleviated. It is not expected that ground-based interference estimation systems alone be either practical or efficient: aircraft are in an ideal position to assess interference areas in real-time. Airborne technical means should be developed to e.g. detect interference on-board and broadcast a position message at the start and end of the detected interference event. These positions would then be used by the ground-based systems to locate more precisely the interferer.

2.7 Given the global nature of aviation operations, it is desirable that States ensure that a radio frequency interference risk mitigation framework, including agreements, processes and equipment capabilities for mitigation actions, are in place, tested and exercised regularly. For GNSS, a radio frequency interference (RFI) mitigation plan is described in the ICAO *Global Navigation Satellite System (*GNSS) Manual (Doc 9849). Such framework should be built on the International Telecommunication Union’s (ITU) radio regulations, which includes provisions for the prevention and removal of radio interference, whether between radio services or countries, between frequency assignments, or from other sources of electromagnetic radiation. At national level, radio-regulatory authorities are normally responsible for radio spectrum inspection and compliance functions which should enable the identification and measurement of interfering signals, the verification of proper technical and operational characteristics of radiated signals, and the detection and identification of illegal transmitters. If a safety service is affected, urgent action shall be taken.

2.8 Identification of an interference source can be a difficult and often time-consuming activity. Some States have found that, when aviation stakeholders assist the national radio-regulatory authority in local detection actions, resolutions are more time-effective. States are encouraged to continue to report their experiences to the spectrum and frequency working groups in ICAO to ensure knowledge sharing and establishment of best practices.

3. GNSS AND OTHER TESTING ACTIVITIES AND NEED FOR AN ENHANCED CIVIL/MILITARY COORDINATION

3.1 As stated above, statistical data[3] established based on ATM incident and voluntary reporting in European Civil Aviation Conference (ECAC) airspace and neighbouring airspace are showing a significant increase in the number of global positioning system (GPS) outage reports. While further investigations of the reported GPS failures cannot confirm military activities as causes of the outages with certainty, this nonetheless remains probable for cases near zones of conflict. Therefore, it is appropriate to reiterate that States should use caution when conducting civil and military GNSS and other testing activities which could contribute to operational impact on aviation CNS systems. Airspace users should be informed accordingly.

3.2 Many States have already put in place efficient civil-military processes to coordinate testing activities, in particular in the context of military exercises. Considering the potential negative impact of GNSS testing on the safety of flights, States are strongly encouraged to further enhance civil-military coordination related to GNSS and associated testing[4]. States should therefore strive to establish through the involvement of both civil and military stakeholders, at State, regional or global level guidelines and best practices sharing for any civil or military GNSS testing activities.

4. CONFLICT ZONE MANAGEMENT

4.1 With increased reliance on digital and space-based CNS services, interference to such services (regardless of the origin of such interference) is becoming more operationally relevant. While closure of airspace due to conflict causes a re-routing of air traffic around that zone, interference to CNS services can extend to regions far outside of the closed airspace. Therefore States are urged when assessing the interference risks associated with conflict zones to consider that the use of satellite-based CNS systems can potentially be impacted beyond that zone.

— END —

[3] EVAIR Safety bulletin, https://www.eurocontrol.int/library?f%5B0%5D=product%3A989 and ECR (European Central Repository for accident and incident reports in aviation).

[4] For the military, GNSS testing can occur during exercises or military operations/equipment in areas near conflict zones. For civil purposes, such testing is typically conducted to further develop vulnerability mitigation measures in order to improve the resiliency of GNSS to interference.

International Civil Aviation Organization

A40-WP/188[1]
TE/74
5/8/19

WORKING PAPER

ASSEMBLY — 40TH SESSION

TECHNICAL COMMISSION

Agenda Item 30: Other issues to be considered by the Technical Commission

AN URGENT NEED TO ADDRESS HARMFUL INTERFERENCES TO GNSS

(Presented by the International Federation of Air Traffic Controllers' Association (IFATCA), the International Federation of Air Line Pilots' Associations (IFALPA) and the International Air Transport Association (IATA))

EXECUTIVE SUMMARY

The global navigation satellite system (GNSS) provides essential position and timing information supporting flight and air traffic management (ATM) operations. A significant number of reports have been received on harmful interference to GNSS. Under their obligations to ICAO, the International Telecommunication Union (ITU) and the international aviation community, States are invited to adopt and implement measures to manage and reduce the operational impact from harmful interference to GNSS, as it can adversely affect the safety and efficiency of aircraft and ATM operations.

Action: The Assembly is invited to:

a) to implement appropriate mitigation measures as contained in the *Global Navigation Satellite System (GNSS) Manual* (Doc 9849) as a matter of high priority and to report progress and any difficulties to ICAO;
b) to recognize the unintended impact of harmful interference to civil flight operations and to exercise caution to the maximum extent possible to protect the safety of civil aircraft during military exercises and operations;
c) to establish and ensure appropriate frequency regulations are in place and maintained to protect allocated GNSS frequencies from harmful interference in line with ITU Radio Regulations;
d) to ensure that contingency procedures are established in coordination with air navigation service providers and airspace users and that essential conventional navigation infrastructure, such as Instrument Landing System (ILS), are retained when operationally beneficial; and
e) to support the multi-disciplinary development of alternative positioning, navigation and timing (APNT) strategy and solutions to complement the use of GNSS in aviation in coordination with ICAO and airspace users.

Strategic Objectives:	This working paper relates to the Safety and Economic Development of Air Transport Strategic Objectives.

[1] Arabic, Chinese, English, French, Russian and Spanish versions provided by IATA.

Financial implications:	Failure to mitigate effectively the harmful interference to GNSS would prevent the full continuation of safety and efficiency benefits of GNSS-based services. The cost impact of implementing the mitigation measures being suggested by ICAO would be minimal for all stakeholders as compared to the cost of accidents or significant disruption of flight and ATM operations.
References:	Annex 10 — *Aeronautical Telecommunications,* Volume I — *Radio Navigation Aids* Doc 9849: *Global Navigation Satellite System (GNSS) Manual* Doc 10007, *Report of the Twelfth Air Navigation Conference (AN-Conf/12),* Recommendations 6/7, 6/8 Doc 10022, *Assembly Resolutions in Force (as of 4 October 2013),* Resolution A37-11 Doc 10115, *Report of the Thirteenth Air Navigation Conference (AN-Conf/13),* Recommendations 2.2/1 Assembly/39-WP/118 – *Impact to Flight & ATM Operations from Harmful Interference to GNSS* *Radio Regulations, Edition of 2016,* International Telecommunication Union

1. INTRODUCTION

1.1 The global navigation satellite system (GNSS) includes satellite constellations, infrastructures and augmentations which provide position and timing information for aircraft and air traffic management systems. GNSS constellations which are recognized by ICAO include the US. Global Positioning System (GPS), the Russian GLONASS, the European Galileo and the Chinese BeiDou.

1.2 Flight and ATM operations utilizing GNSS have resulted in substantial efficiency and safety benefits. On safety, GNSS is a main technical enabler for approach with vertical guidance in line with *Assembly Resolution A37/11* effectively mitigating the risk of controlled-flight into terrain (CFIT). For efficiency, GNSS contributes to the United Nations' Sustainable Development Goals by making it possible for aircraft to navigate and fly enhanced, more efficient air routes. Regarding capacity, GNSS is also the primary technology supporting performance-based navigation (PBN) operations which enhance airspace capacity through enabling safe reductions of aircraft separation minima.

1.3 With its proven benefits, GNSS has its vulnerabilities. AN-Conf/12 in 2012 recognized that very low strength of GNSS signals received from satellites makes GNSS vulnerable to interference and other effects that have the potential to affect multiple aircraft over a wide area. The sources of GNSS vulnerabilities include unintentional interference, intentional interference, effects of the ionosphere, solar activity (space weather) and others.

1.4 The concern over harmful interference to GNSS has also been documented by *AN-Conf/12 Recommendation 6/8* where, in planning for mitigation of GNSS vulnerabilities, States were recommended to:

a) assess the likelihood and effects of global navigation satellite system vulnerabilities in their airspace and apply, as necessary, recognized and available mitigation methods;

b) provide effective spectrum management and protection of GNSS frequencies to reduce the likelihood of unintentional interference or degradation of GNSS performance;

c) report to ICAO cases of harmful interference to global navigation satellite system that may have an impact on international civil aviation operations; and

d) develop and enforce a strong regulatory framework governing the use of global navigation satellite system repeaters, pseudolites, spoofers and jammers.

1.5 The 2012 ICAO High-level Conference on Aviation Security also recognized the significance of this issue and recommended that ICAO intensify efforts to develop guidelines on the prevention and appropriate response to aviation security threats such as GNSS jamming and spoofing.

2. IMPACTS ON FLIGHT AND ATM OPERATIONS

2.1 GNSS is the main source of aircraft position information driving the aircraft navigation system and is important for safety and efficiency of flight. GNSS provides aircraft position input to pilot navigation display (ND), an important function during reduced visibility conditions.

2.2 *GNSS beyond Navigation*: In addition to aircraft navigation, GNSS is a main component of various essential communication, navigation and surveillance (CNS) and flight safety/control systems. GNSS is used to provide timing signal to some satellite communications avionics which are essential for operations in oceanic and remote airspaces. It is the sole aircraft position source to automatic dependent surveillance – broadcast (ADS-B). Some business aircraft are using GNSS as a reference source for aircraft flight control and stability systems. Particularly noteworthy, GNSS is a necessary component of an aircraft terrain awareness and warning system (TAWS) - a mandatory aircraft safety system implemented to alert pilots of upcoming terrain.

2.3 *GNSS in ATM/ATC Operations:* With on-going worldwide deployments of ADS-B, harmful interference to GNSS will adversely impact ATM and air traffic control (ATC) operations. Once GNSS signals are compromised, a degradation or complete interruption of ADS-B surveillance service will consequentially occur as ADS-B requires aircraft position input from GNSS.

2.4 Since the last ICAO Assembly, IATA has received from various airlines and airspace users an increasing number of reports of harmful interference to GNSS. During one recent incident, it was reported that a passenger aircraft flew off course during a period of GNSS jamming and nearly crashed into a mountain. Fortunately, an alert RADAR controller intervened, and the accident was averted.

3. SOURCES OF HARMFUL INTERFERENCE TO GNSS

3.1 Unintentional interference to GNSS signals can arise from several sources. A non-exhaustive list would include very high frequency (VHF) communications, television signals, certain RADARs, mobile satellite communications, military systems, microwave links, GNSS repeaters and certain systems on-board aircraft.

3.2 However, more concerning cases of recent harmful interference to GNSS being reported are likely caused by intentional interference sources, such as “GNSS jammers or spoofers”. Some equipment being used in some military operations and activities has been reported to interfere with specific GNSS signals and have the coverage radius of more than 300 NM. While some of these military activities were well coordinated with relevant aviation authorities, there have been a significant number of cases where the coordination was less successful - resulting in civil flight operations being interrupted without airspace users being appropriately notified.

3.3 The airline industry welcomes the efforts by some States and air navigation services providers (ANSPs) in informing airspace users regarding the use of GNSS jammers during military operations and exercises. Nevertheless, States are strongly urged to recognize the unintended impact of such interference and to exercise caution in order to minimize their effect on civil aviation. Recognizing the importance of national security needs, IATA stands ready to support coordination efforts with States.

4. GNSS RADIO FREQUENCY INTERFERENCE (RFI) MITIGATION PLAN

4.1 ICAO has developed a GNSS RFI mitigation plan as a part of the *GNSS Manual* (ICAO Doc 9849). The mitigation plan describes a list of preventive and reactive measures aimed at mitigating the interference risk as far as practicable. The framework recommended by the mitigation plan includes a continuous three-step process of 1) monitoring threats; 2) assessing risks; and 3) deploying mitigation measures. The plan also explains the need to inform airmen in the event of GNSS outages and the necessity to train airspace users and air traffic controllers to be able to recognize interference events and to react appropriately.

5. PROTECTION OF GNSS THROUGH EFFECTIVE SPECTRUM MANAGEMENT AND REGULATIONS

5.1 ICAO AN-Conf/12 recommends that States provide effective spectrum management and protection of GNSS frequencies to reduce the likelihood of unintentional interference or degradation of GNSS performance. The following ICAO Air Navigation Conference in 2018 also reemphasized this critical issue in *AN-Conf/13 Recommendation 2.2/1* recommending that States engage in the spectrum regulatory process to ensure the continued necessary access to and protection of safety-critical aeronautical communications, navigation, and surveillance (CNS) systems.

5.2 Through several State Letters and Electronic Bulletins, ICAO has continued to highlight the essential role of States in ensuring protection of GNSS signals from interference, which can be achieved through cooperation of national aviation and telecommunication authorities in the introduction and enforcement of appropriate regulations controlling the use of the radio spectrum.

5.3 Noting the importance of safety-of-life applications using GNSS, radio frequency spectrum allocations for GNSS signals are globally harmonized and legally protected under the Radio Regulation of the International Telecommunication Union (ITU). Article 4.10 of the Radio Regulations states that ITU member States recognize that the safety aspects of radio navigation and other safety services require special measures to ensure their freedom from harmful interference and that “it is necessary therefore to take this factor into account in the assignment and use of frequencies.”

5.4 As radio frequency spectrum is a very limited resource with competing demands and interests, it is essential that State aviation and telecommunication authorities work closely together to ensure that aviation and the travelling public are well served by effective spectrum management and State regulations. In coordination with ICAO, IATA will continue engaging in this important strategic topic at global, regional and national levels to provide a necessary foundation for sustainable air transport growth while balancing other societal demands and public interests.

6. ROLES OF CONVENTIONAL NAVIGATION AIDS AND PROGRESS FOR ALTERNATIVE POSITION, NAVIGATION AND TIMING (APNT) SOLUTIONS

6.1 *Need for Contingency Procedures and Infrastructures:* Whilst today many aircraft navigate primarily using GNSS in all phases of flight, some conventional navigation aids still play a

major role supporting flight operations, particularly when GNSS signals are compromised. Interruptions of GNSS services often result in operational disruptions and have recently led to cancellation of flights.

6.2 During critical operations like approach and landing, it is very important that alternative navigation aids are readily available to flight crews to continue the operations while maintaining the safety of flight. Lessons learned from interference cases at major airports, including those servicing capital cities, have shown that instrument landing system (ILS) will be preferred and often required by flight crews whenever they perceive that the performance of GNSS shown in the cockpit is in question.

6.3 From these lessons learned, ANSPs are therefore invited to assess carefully the possible impacts of harmful interference to GNSS in coordination with State safety regulators and airspace users while developing their rationalization strategy for conventional navigation aids. The *Strategy for Introduction and Application of Non-Visual Aids to Approach and Landing* attached to ICAO Annex 10 suggests the continuation of ILS operations at the highest level of service.

6.4 *Global Strategy for Future APNT:* In the longer term, acknowledging the fundamental limitations of satellite navigation systems (e.g., low strength signals) and the economic consequences of interrupted airline operations for the travelling public and the global supply chain, States are invited to provide more robust support for the development of a global strategy for Alternative Position, Navigation and Timing (APNT) solutions and infrastructures in coordination with ICAO and the aviation community as requested by *AN-Conf /12 Recommendation 6/7d*. This APNT strategy should aim to maintain flight safety and an acceptable level of efficiency of air navigation services to the maximum extent possible in the event of prolonged GNSS signal outages or interferences. Noting the ubiquitous use of GNSS in various CNS/ATM applications and increasing challenges in the global frequency spectrum environment, an integrated, multi-disciplinary CNS approach - taking into account frequency spectrum efficiency and existing and potential avionics capabilities - should be used when defining this APNT strategy.

7. CONCLUSION

7.1 GNSS has resulted in substantial safety, efficiency and capacity benefits and is a necessary cornerstone of daily flight and ATM operations. Effective mitigations of harmful interference to GNSS will ensure that these benefits continue, and will help prevent interruptions of flights - resulting in better punctuality of global trade and enhanced satisfaction of the travelling public.

7.2 IATA commends ICAO for its on-going efforts on this critical issue, including the establishment of the GNSS RFI mitigation plan, and reiterates a strong concern regarding on-going harmful interference to GNSS. On behalf of the global community of airlines, IATA respectfully invites the Assembly to urge States to adopt and implement measures to manage and reduce causes and impacts of the interference.

— END —

International Civil Aviation Organization

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WORKING PAPER

ASSEMBLY — 40TH SESSION

TECHNICAL COMMISSION

Agenda Item 30: Other issues to be considered by the Technical Commission

TOWARDS GNSS RESILIENCE TO SUPPORT SUSTAINABLE IMPLEMENTATION OF ASBU MODULES

(Presented by Saudi Arabia)

EXECUTIVE SUMMARY

The sixth edition of the *Global Air Navigation Plan* (GANP) has defined a global technical level (level 2) the technical global which includes an updated draft of the aviation system block upgrades (ASBUs) framework. The ASBU modules/elements covering information management, operational performance, communications, navigation, and surveillance (CNS) technology and services are heavily relying on Global Navigation Satellite System (GNSS) either for positioning, navigation or timing (ANT) and can be impacted directly or indirectly from any loss of GNSS services.

The Assembly Resolution A32-19 defines a Charter on the rights and obligations of States relating to GNSS Services. However, this resolution is not covering obligations to protect GNSS signals and mitigate in appropriate manner GNSS vulnerabilities through appropriate level of cooperation and planning.

Action: The Assembly is invited to:

a) urge States to:
   1) assess the likelihood and effects of global navigation satellite system vulnerabilities in their airspace and apply, as necessary, ICAO mitigation methods;
   2) provide effective spectrum management and protection of global navigation satellite systems (GNSS) frequencies to reduce the likelihood of unintentional interference or degradation of GNSS performance; and
   3) cooperate for design, development and realization of Ground and on-board mitigation techniques of GNSS loss of service; and

b) direct ICAO to:
   1) compile and publish more detailed guidance for States to use in the assessment and mitigations of global navigation satellite system vulnerabilities; and
   2) support the regional activities to define alternative position, navigation and timing system where needed.

Strategic Objectives:	This working paper relates to the Safety and Air Navigation Capacity and Efficiency Strategic Objectives.
Financial implications:	No additional resources required.

References:	Annex 10 — *Aeronautical Telecommunications,* Volume I — *Radio Navigation Aids* Doc 10075, *Assembly Resolutions in Force (as of 6 October 2016)* Doc 9849, *ICAO Global Navigation Satellite System (GNSS) Manual.* Doc 9750, *Global Air Navigation Plan (GANP).* GNSS Strategy endorsed by MIDANPIRG 15.

1. INTRODUCTION

1.1 The sixth edition of the *Global Air Navigation Plan* (GANP) (A40- WP/24-TE/4 refers) is the result of feedback provided by States and international organizations on the fifth edition of the GANP during the 39th Session of the ICAO Assembly, discussions and recommendations on the technical content from the Thirteenth Air Navigation Conference (AN-Conf/13), and feedback gathered from experts during workshops and through the ICAO Regional Offices.

1.2 The global technical level (Level 2 in the new GANP structure), it includes an updated draft of the ASBU framework, its associated performance framework and an initial version of the Basic Building Blocks (BBB) framework.

1.3 The ASBU modules/elements covering information management, operational performance, communications, navigation, and surveillance (CNS) technology and services (https://www4.icao.int/ganpportal/ASBU/Thread refers) are heavily relying on Global Navigation Satellite System (GNSS) either for positioning, navigation or timing (ANT) and can be impacted directly or indirectly from any loss or interference caused on GNSS signals.

2. IMPACT OF GNSS DISTURBANCE

2.1 The very low strength of GNSS signals received from satellites at user receivers make GNSS vulnerable to interference and other effects that have the potential to affect multiple aircraft over a wide area. The sources of GNSS vulnerabilities include unintentional interference, intentional interference, effects of the ionosphere and solar activity (space weather) and others technical outages.

2.2 As GNSS enables performance-based navigation (PBN) and provides navigation guidance for all phases of flight, from en-route through to precision approach, any GNSS interference, disturbance or degradation affects the navigation performance and capabilities.

2.3 By providing position information, GNSS enables also automatic dependent surveillance — broadcast (ADS-B), automatic dependent surveillance — contract (ADS-C), moving map displays, terrain awareness and warning systems (TAWS) and synthetic vision systems. All these applications are impacted by any GNSS loss of service.

2.4 The GNSS is also providing position data for emergency locator transmitters (ELTs) and supports a wide variety of precision timing applications that are used in many aviation systems to synchronize local clocks to Co-ordinated Universal Time (UTC). Synchronized clocks may then be used to assign a globally valid and comparable time stamp to events. Consequently, GNSS disturbance impacts all positioning and timing applications that may lead to degradation or unavailability of critical functions.

2.5 The AN-Conf/13 held in October 2018 recognized that the evolution of the GNSS towards the introduction of dual-frequency, multi-constellation (DFMC) services could provide operational benefits by improving performance and robustness for all CNS applications based on GNSS.

2.6 The new constellations and frequencies for GNSS will significantly reduce the probability of loss of service caused by unintentional interference, by virtue of the diversity of frequencies and increased number of satellites in view. The availability of dual GNSS frequencies will also help compensate for the ionosphere delay effect.

2.7 The ICAO *Global Navigation Satellite System (*GNSS) *Manual* (Doc 9849) describes a radio frequency interference (RFI) mitigation strategy and measures. The primary means to reduce the likelihood of both intentional and unintentional interference is effective spectrum management. This involves the creation of a strong regulatory framework controlling the allocation and use of spectrum in such a way as to secure protection of GNSS frequencies. At the national level, this is the responsibility of the radio regulatory authorities in each State. At the international level, the International Telecommunication Union (ITU) provides such a framework through its Radio Regulations.

2.8 2.5 Although the likelihood of GNSS signal disruption can be significantly reduced as described in ICAO Doc 9849, disruption cannot be completely ruled out, and therefore the aircraft operators and air navigation services providers (ANSPs) should be prepared to deal with potential loss of GNSS signals. This requires the completion of a risk assessment that will determine the residual likelihood of service outages and the impact of an outage in specific airspace, and the application of realistic and effective mitigation strategies to ensure the safety and regularity of air services.

3. GNSS DISTURBANCE MITIGATION STRATEGIES

3.1 The ICAO Doc 9849 describes three principal methods to mitigate GNSS loss of service which can be applied in combination:

a) taking advantage of on-board equipment, such as inertial reference system (IRS) provides a short-term area navigation capability after the loss of GNSS updating;

b) taking advantage of conventional navigation aids and radar; and

c) employing procedural (aircrew and/or ATC) methods.

3.2 The ICAO guidance indicates also several States have identified the need for an alternative position, navigation and timing system (APNT) strategy with the goal of maintaining services to the maximum extent possible in the event of a GNSS signal outage. The APNT strategy must have global application and must be implemented in a short time.

3.3 The conventional aids can provide alternative sources of guidance. distance measuring equipment (DME) is the most appropriate conventional aid available in the near- to mid-term for supporting PBN operations, since it currently provides input to multi-sensor navigation systems that allow area navigation in both en-route and terminal airspace.

3.4 The procedural (aircrew or ATC) methods can provide effective mitigation taking due consideration of:

a) the airspace classification and the availability of surveillance data;

b) the avionics in aircraft using the airspace (e.g. most aircraft in high-level airspace will have IRS and/or DME/DME updating of navigation systems);

c) aircrew and air traffic controller workload implications and the availability of controller decision support tools;

d) the impact that the loss of GNSS will have on other functions, such as surveillance in an ADS-B or ADS-C environment;

e) the potential for providing the necessary increase in aircraft route spacing and/or separation in the airspace under consideration; and

f) use of pre-defined ATS routes network based on ground-based navigation aids.

3.5 As the loss of GNSS service may impact small or wide area, there is a need to adopt mitigations that can be deployed at national and regional levels where an adequate terrestrial navigation and air traffic management infrastructure remains available. The infrastructure will support navigation continuity both for en-route, in terminal and approach phases.

3.6 The Assembly Resolution A-32-19 defines the rights and obligations of States relating to GNSS services. This resolution states that each State providing GNSS services shall ensure the continuity, availability, integrity, accuracy and reliability of such services, including effective arrangements to minimize the operational impact of system malfunctions or failure, and to achieve expeditious service recovery. The GNSS Services and performance are subject of detailed SARPs in Annex 10, Volume I.

4. CONCLUSION

4.1 As the GNSS loss of service is impacting a large number of ASBU modules/elements and all applications providing positioning, navigation and timing, there is a need to strength the current obligations on GNSS services and its continuity and identify mitigation methods that can be applied at national, regional and global levels.

4.2 The collaborative engagement between States, ICAO and the industry will ensure the continuity of GNSS services and reduce the likelihood of unexpected loss of GNSS signals that may impact critical functions and applications associated with ABSUs.

4.3 The protection of GNSS signals starts with an effective spectrum management and protection of GNSS frequencies to reduce the likelihood of unintentional interference or degradation of GNSS performance. This can be achieved through:

a) the development and enforcement of a strong regulatory framework governing the use of global navigation satellite system repeaters, pseudofiles, spoofers and jammers; and

b) cooperation between States, ICAO and the industry for design and development of effective and efficient ground and on-board mitigation techniques of GNSS service loss.

— END —