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ASSEMBLY — 38TH SESSION

TECHNICAL COMMISSION

Agenda Item 32: Air Navigation — Policy

WAKE VORTEX SAFETY SYSTEM (WVSS): PROPOSAL FOR INCLUSION IN THE GANP AND ASBU BLOCK 1

(Presented by the Russian Federation)

EXECUTIVE SUMMARY

In accordance with the recommendation of the ICAO 12th Air Navigation Conference №2/4 (Optimized management of wake turbulence), point c), this paper presents proposals for developing modules B1-WAKE, B2-WAKE, B1-ASEP and B2-ASEP and creating a new module B1-WVSS required for the implementation of aircraft pair wise wake vortex separation (self-separation).

Action: The Assembly is invited to:

a) recognize the fact that acceleration of the implementation of the modified modules B1-WAKE, B2-WAKE, B1-ASEP, and B2-ASEP and introduction of the new module B1-WVSS "Wake vortex flight safety system" will significantly increase airspace throughput while providing the targeted flight safety level;

b) recommend to include the development of SARPs required for consideration of ASBU Block 1 modules, SARPs for WVSS based on technologies developed in modules B1-WAKE, B2-WAKE, B1-ASEP, B2-ASEP, and the new module B1-WVSS in the strategy in the next three years; and

c) include the Block 1 new module, B1-WVSS, in the GANP fourth edition and ASBU to develop WVSS based on technologies developed in modules B1-WAKE, B2-WAKE, B1-ASEP, and B2-ASEP.

Strategic Objectives:	This working paper relates to the Safety and the Environmental Protection and Sustainable Development of Air Transport Strategic Objectives.
Financial implications:	Funding within the budget of the ICAO regular programme for wake vortex safety issues.
References:	ICAO Aviation System Block Upgrades (ASBU) Strategy Report of the ICAO 12th Air Navigation Conference (Doc 10007), related to wake turbulence

[1] English and Russian versions provided by the Russian Federation.

(19 pages)

1. INTRODUCTION

1.1 The ICAO strategy of increasing runway throughput proposed in the aviation system block upgrades (ASBU) is based on the dynamic management of aircraft pair wise wake vortex separation minima under the real-time identification of wake vortex hazards (modules B1-WAKE and B2-WAKE).

1.2 To identify wake vortex hazards and to present this information to aircraft pilots and controllers, the appropriate airborne and/or ground wake vortex monitoring and prediction systems must be combined with the surveillance, communication and datalink systems.

1.3 The complex of airborne and/or ground software and/or hardware designed to meet the challenges of wake vortex flight safety subject to air traffic management rules and procedures, as well as to the ICAO recommended practices, developed in modules B1-WAKE and B2-WAKE, presents a wake vortex safety system (hereinafter WVSS). Therefore, the processes of WVSS creating and implementing should be reflected in the corresponding ICAO ASBU blocks and the Technology Development Roadmap "Global Air Navigation Capacity & Efficiency Plan" (Doc. 9750).

2. ICAO ASBU RELEVANT BLOCKS AND THREADS IN RESPECT OF THE WAKE VORTEX SAFETY SYSTEM DEVELOPMENT

2.1 Modern achievements in the field of wake vortices location and simulation, as well as of telecommunications means allow developing and implementing WVSS in accordance with the concept and architecture presented in Appendix A.

2.2 WVSS is a distributed (airborne and ground segments) information management system to be implemented on basic and specialized technical systems and means of the air navigation system that are developed in modules B0-ASEP, B1-ASEP, B2-ASEP, B3-ASEP, B1 -RSEQ, and B2-RSEQ, as well as on the airborne navigation equipment developed in modules B2-ASEP and B3-ASEP (Figure 1).

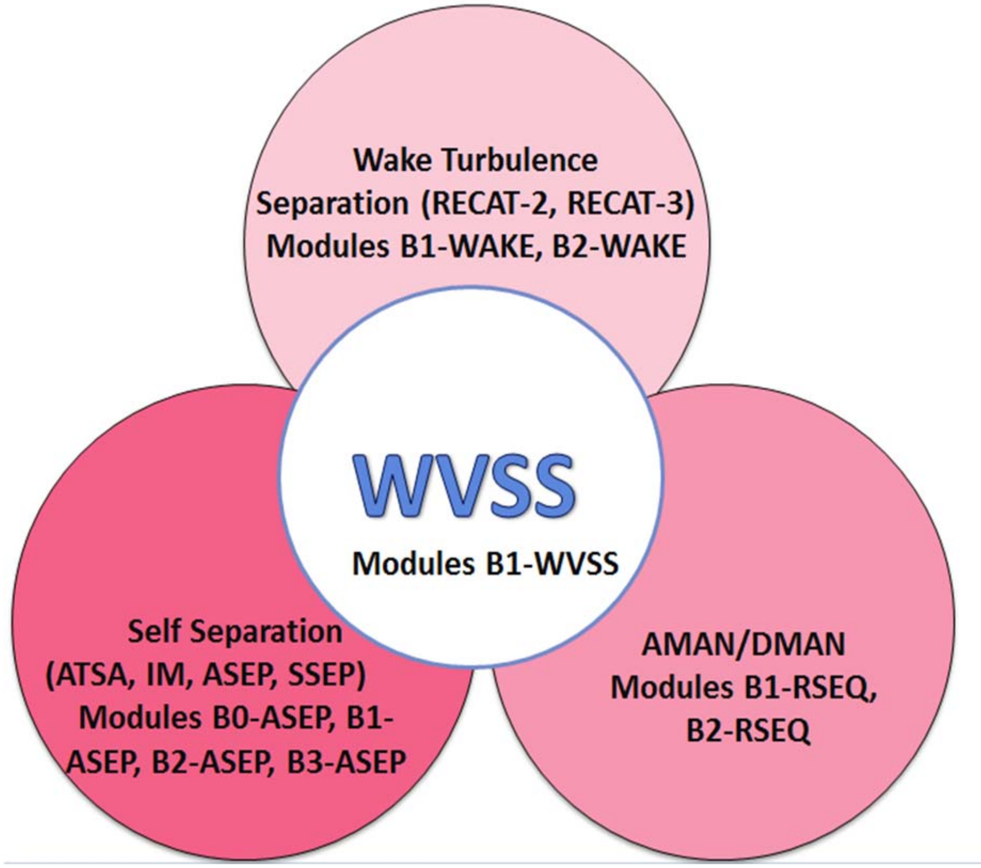

Figure 1. WVSS ICAO ASBU relevant technologies and procedures in respect to the WVSS development.

2.3 The philosophy of the WVSS building relies on the basic principle of the ICAO CNS/ATM technologies "everyone sees everyone", which is proposed to modify as "everyone sees everyone including their wake vortices". Therefore the WVSS fits well with technologies providing situational awareness of air traffic (ATSA), intervals management (IM), separation (ASEP) and self-separation (SSEP) in flight. In this regard, proposals may be submitted on further development of relevant modules B1-ASEP and B2-ASEP in terms of expanding the functionality of the developed systems and providing airspace users with additional operational benefits through implementation of aircraft pair-wise wake vortex separation.

2.4 Additionally, proposals may be formulated for further development of relevant modules B1-WAKE regarding the use of the WVSS with introduction of pair-wise wake vortex separation standards. The main drawback of the current version of module B1-WAKE description is the postulation of ensuring the wake vortex flight safety only through introduction of separation standards without introduction of requirements for development of technical means to implement them. Module B1-WAKE has no description of the required technology, airborne and ground WVSS equipment, although its components are already present implicitly, for example, the airborne wind measurement, the ADS-B Out data kinks for transmission of wind data to the ground system for monitoring and prediction of the vortex situation, the X-band radars and lidars on the airfield to detect wake vortices, the WTMD and WTMA systems in fact are already a ground WVSS segment.

2.5 WVSS is not a product that requires creation of unique technologies. It is based on the underlying solutions of the CNS/ATM concept, the further development of which is reflected in the ICAO ASBU and included in the ICAO Road map of Doc. 9750 Global Air Navigation Capacity & Efficiency Plan, Appendix 3. These include (Figure 2) technologies of automatic dependent surveillance (Surveillance), System Wide Information Management (SWIM), Aeronautical Information Management (Digital AIM), as well as of Improved Meteorological Information, Trajectory-Based Operations, and Free-Routing. But the success of the WVSS creation and its further implementation is associated with execution of the works described in blocks and threads, as well as in the relevant modules, as shown in Figure 3.

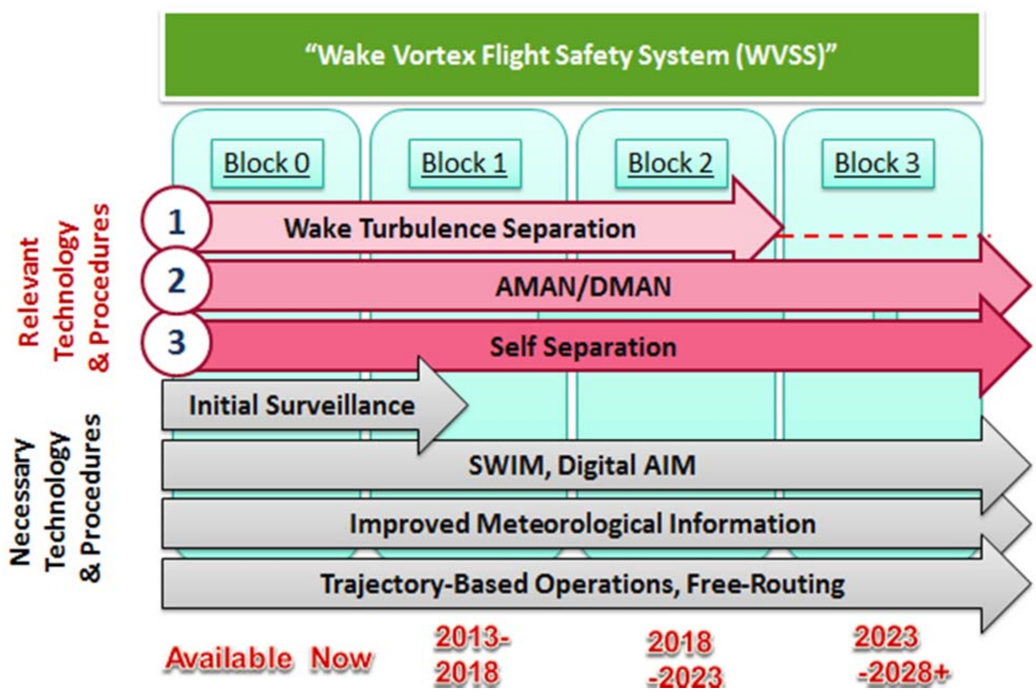

Figure 2. The ICAO ASBU relevant technologies and procedures in respect to the WVSS development.

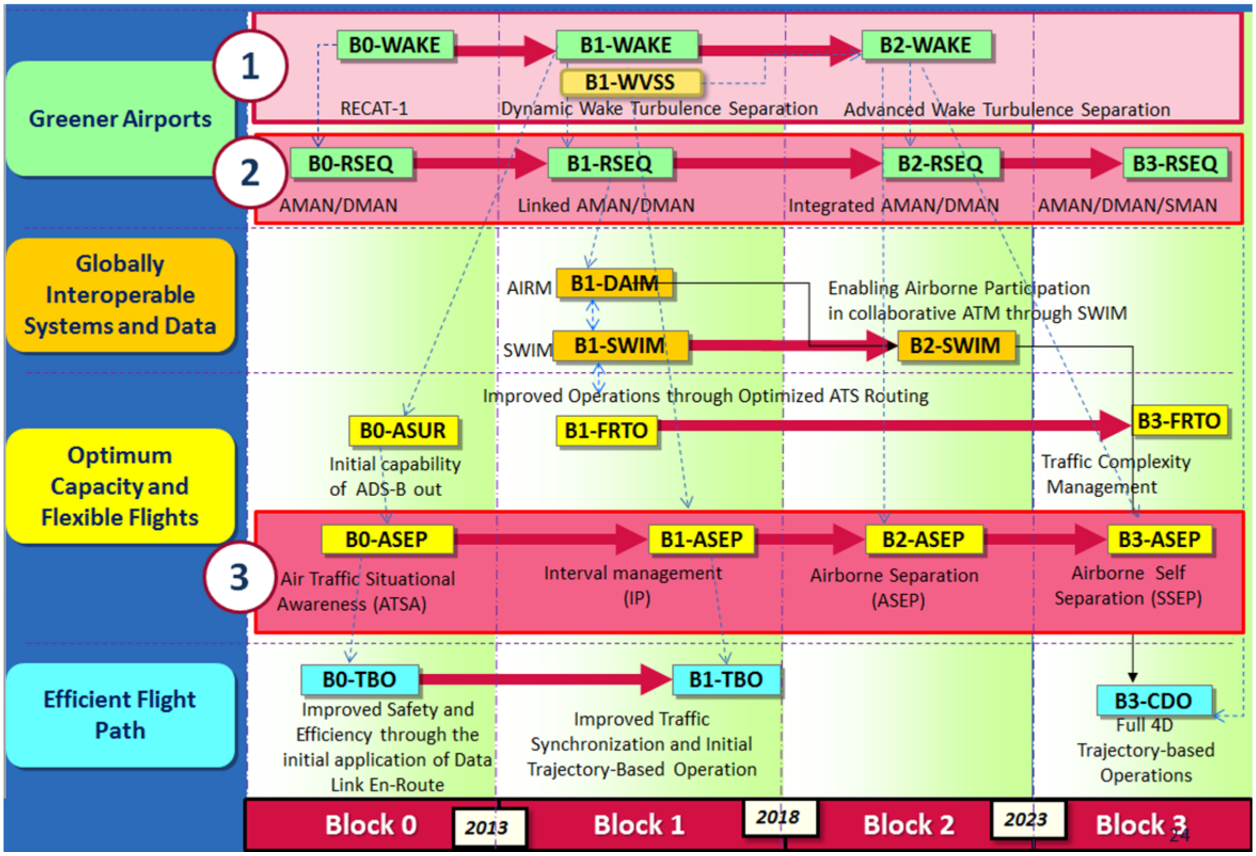

Figure 3. The ICAO ASBU relevant technologies and procedures in respect to the WVSS development.

3. ROADMAP FOR THE WVSS TECHNOLOGY DEVELOPMENT

3.1 Operational benefits which WVSS can provide, its operational flexibility and interoperability directly depend on technological development of air-navigation data transmission. “Air-to-air”, “air-to-ground”, “ground-to-air” data links (DL) “aircraft- aircraft”, “aircraft- ground” and “ground-aircraft” will provide WVSS services divided into two main categories:

a) Services directly associated with flight safety – requirements for characteristics, procedures, services and supporting technologies of these services are strictly defined and standardized; and

b) Informational services – the requirements for characteristics, procedures and supporting technologies of these services are less critical.

The WVSS services can be implemented using technologies of automatically dependent surveillance (ADS) of broadcast and contract types, and also on the basis of mobile satellite communication technologies. It is assumed that before a full-value solution for ADS-B IN/OUT (ICAO ver. 2) will be available, the WVSS services for en-route flight in continental air-space, landing approach, and operations in the terminal area can be implemented with the combination of solutions offered in module

B0-ASUR “Initial capability for ground surveillance” and in module B0-TBO “Improved Safety and Efficiency through the Initial Application of Data Link En-Route”.

3.2 Module B0-ASUR provides the capability for lower cost implementation of the WVSS initial functional capabilities supported by ADS-B OUT. Data of airborne meteorological surveillance, locations and circulations of wake vortices computed by the airborne WVSS segment are transmitted from the aircraft generating the wake vortices via the ADS-B Out channels to the WVSS ground segment . The WVSS ground segment processes the wake vortex information, evaluates the vortex situation and issues advisories for the aircraft separation.

3.3 Module B0-TBO provides the capability of obtaining data on the vortex situation and instructions on separation via a VHF data link aboard. At present it is proposed to use for this purpose the VDL mode 2 or GBAS (Ground Based Augmentation System) VDB channel.

3.4 In further development of aviation communication systems and data transmission it is expected that VHF data links will be replaced by new promising L-band digital aeronautical communication systems (LDACS). At present these systems are under development and are planned to be used in the terminal area and for en-route flights.

3.5 Further development of satellite communication systems (in particular, upgrading Iridium system up to the NEXT technology) provides the capability of implementing another data link system. In implementation of this system the WVSS system data from the aircraft generating wake vortices are transmitted via the ADS-B OUT link to the nearest satellite of the communication system, then via the satellite network, through the gates of the satellite communication system provider, to the WVSS processor (ground or airborne). The manufacturers claim that such a system can operate in near-real-time. Besides, such a system provides the capability of the WVSS adequate functioning in oceanic and remote areas.

4. CONCLUSIONS

4.1 The wake vortex safety system will allow to considerably increase airspace capacity providing the higher target flight safety level. That is why it is necessary to provide the following actions in the nearest three years:

a) consider proposals on introducing changes into the ICAO ASBU Modules B1-WAKE, B2-WAKE, B1-ASEP, and B2-ASEP;

b) consider proposals on including a new block B1-103 Wake vortex safety system (WVSS) into the ICAO ASBU; and

c) consider proposals on updating of the Global Air Navigation Capacity & Efficiency Plan (Doc. 9750) as related to development of the Wake Vortex Safety System (WVSS).

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APPENDIX A

DESCRIPTION OF THE WAKE VORTEX SAFETY SYSTEM CONCEPT AND ARCHITECTURE

1. The WVSS is a complex of software and/or hardware designed to meet the challenges of wake vortex flight safety, provide efficiency and availability of airspace in view of the applicable air traffic management rules and procedures and recommended practices.

2. The WVSS is based on the concept of determining the minimum safe wake vortex separation interval defined by current regulations or dynamically determined according to the current flight conditions, meteorological situation (including characteristics of atmospheric turbulence), specific types of aircraft being separated and their flight configuration depending on the flight phase (dynamic aircraft pair-wise wake vortex turbulence separation).

3. Depending on the airfield equipment and the need for its throughput, the WVSS provides air navigation service providers with possibility to select the standard wake vortex separation (extended wake vortex separation matrix based on the MTOW, static pair-wise wake vortex separation matrix) or dynamic pair-wise wake vortex separation of aircraft.

4. The dynamic pair-wise wake vortex separation of aircraft in the TMA is used in cases where the demand for runway operations is higher than the runway throughput defined by the standards (i.e. statically defined following intervals are a limiting factor for capacity determination), the airfield has a corresponding WVSS ground segment, and stable weather conditions at the aerodrome contribute to drift of wake vortices from the runway.

5. Dynamic pair-wise wake vortex separation of aircraft at all flight phases will enhance wake vortex flight safety, especially in specific weather conditions, where small atmospheric disturbances, weak cross wind, atmospheric temperature stratification, etc., lead to situations when safe distances may be significantly higher than the standard ones.

6. In order to ensure wake vortex flight safety and provide efficiency and availability of airspace, the WVSS assures WV separation and WV awareness for airspace users.

7. With the WV separation assurance service WVSS provides the following:

a) information for the flight crew about separation rules applicable in the area of TMA and aerodrome selected by the air navigation service provider on the basis of:
   - standard wake vortex separation matrix based on the MTOW (A-380/heavy/medium/light) of block B0-70;
   - extended standard wake vortex separation matrix of block B0-70 (European/American versions); static pair wise wake vortex separation matrix of block B1-70;
   - pair-wise dynamic wake vortex separation of aircraft depending on weather conditions (Weather depended procedure).

b) generation and transmission of instructions to the flight crew concerning pair wise separation including issuance of advisories for separation maintenance; and

c) data on the vortex situation for aircraft wake vortex turbulence self-separation.

8. With the WV awareness service WVSS provides the following:

   a) obtaining and presenting data on the current and (or) predicted vortex situation (spatial position and intensity of wake vortices) to the flight crew and (or) ground-based air traffic control services;

   b) evaluation of possible effects of wake vortex encounter;

   c) ranking of wake vortices by hazard levels in case of several aircraft generating wake vortices;

   d) detection of conflict situations with wake vortex encountering when aircraft are flying on head-on and crossing courses including flights in RVSM conditions, maneuvering aircraft, including a maneuvering aircraft generating a wake vortex;

   e) advisories to resolve potential conflicts associated with wake vortex encounter;

   f) automated identification of wake vortex encounters, generation and provision of reports on these events to persons and services concerned; and

   g) automatic avoidance of potentially hazardous wake vortices.

9. Technically the WVSS presents a distributed (airborne and ground segments) information management system based on the basic and specialized technical systems and ANS means, as well as the airborne navigation equipment, and is intended to solve at least one of the tasks described in p.2.7 and 2.8 of this document.

10. The WVSS components or the whole system can be implemented as hardware and software or software package, which is part of:

    a) automation for planning the use of airspace and air traffic flow management (ground segment);

    b) automation of air traffic control (ground segment);

    c) means of special meteorological support (airborne and ground segments);

    d) navigation equipment (ground segment);

    e) radio equipment for navigation, landing and air traffic control, equipment for air navigation data transmission (airborne and ground segments); and

    f) airborne and ground information system (information display systems and alert systems).

11. Technically, the WVSS may be based on digital transceiving lines for aeronautical data, which are a component of automatic aircraft surveillance systems. The use of the ICAO CNS/ATM technologies while creating the WVSS allows implementing the principle "everyone sees everyone including their wake vortices".

12. To implement the above principle, each aircraft equipped with an airborne WVSS segment shall provide data on the parameters of its own wake vortices or data, on which it is possible to calculate its wake vortices (data on the flight configuration, actual load, flight characteristics) via "air-to-air" and "air-to-ground" links. To predict the wake vortex dynamics, the airborne WVSS segment must also provide onboard meteorological measurements and their transmission (pressure, temperature, wind direction, wind speed, atmospheric turbulence).

13. With the development of the airborne WVSS segment, it can include on-board means of remote laser and radar wake vortex monitoring. In this case, data of on-board measurements of wake vortices from other aircraft will be integrated with data on the vortex situation coming through aeronautical data link channels.

14. Additional sources of information for the WVSS are ground means of remote laser and radar wake vortex monitoring. These means provide data on the position (location) and intensity of wake vortices necessary for wake vortex hazard evaluation and calculation of hazardous wake vortex areas in the TMA.

15. The ground WVSS segment integrates data on vortex situation surveillance coming from ground means of wake vortex monitoring, data from the airborne WVSS segment received through "ground-to-air" aeronautical data link channels. Based on the vortex situation prediction, the ground WVSS segment provides WV separation assurance and WV awareness services to airspace users through "ground-to-air" data links.

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APPENDIX B

**PERFORMANCE IMPROVEMENT AREA 3.
OPTIMAL CAPACITY AND FLEXIBLE FLIGHTS – THROUGH GLOBAL COLLABORATIVE ATM**

**THREAD. PROVISION OF WAKE VORTEX FLIGHT SAFETY
MODULE NO B1-103.THE WAKE VORTEX SAFETY SYSTEM (WVSS)**

SUMMARY	The use of the wake vortex safety system (WVSS) will allow implementing dynamic wake vortex separation of aircraft that will result in enhanced flight safety, increased runway capacity and airspace availability through air traffic disruptions avoidance when the demand is higher than available capacity. The use of the global navigation satellite system (GNSS), automatic dependent surveillance (ADS-B(C)), airborne and ground based means of prediction and surveillance of wake vortices using X-band radars and lidars, and WVSS special meteorological equipment will also contribute to these enhancements. WVSS flexibility in arrival and departure sequencing may be used to increase the runway capacity. The flight crew and ATC officers' situational awareness of the wake vortex situation at all flight phases.
MAIN PERFORMANCE IMPACT AS PER DOC. 9854	KPA-02 – Capacity, KPA-04 Efficiency, KPA-09 – Predictability, KPA-06 – Flexibility
APPLICABILITY CONSIDERATIONS	These improvements are especially required for the runway area and Terminal Maneuvering Area in large hubs. Complexity in implementation of this module depends on the aircraft equipment with ADS-B IN/OUT/CDTI capabilities, means of onboard meteorological measurements, computation and display of information about the vortex situation, such as EFBs. To obtain significant benefits, especially for those who have appropriate equipment, efficient coordination on implementation of WVSS airborne and ground segments is required. The benefits scale will grow proportionally to the number of aircraft and aerodromes equipped with WVSS airborne and ground segments.
OPERATING ENVIRONMENT/ PHASES OF FLIGHT	En-route, including oceanic and remote areas and TMA (terminal area); take-off and landing phases.

GLOBAL CONCEPT COMPONENT(S) AS PER DOC 9854	GPI-09. Situational awareness GPI-17. Data links applications DCB – Demand and capacity balancing CM – Conflict management	
GLOBAL PLAN INITIATIVES (GPI)	GPI-6: Air Traffic Flow Management GPI-9: Situational awareness GPI-12: Functional integration of ground with airborne systems GPI-14: Runway operations GPI-16: Decision support systems and alerting systems	
MAIN DEPENDENCIES	Parallel progress with B0-AMET, B0-RSEQ, B0-ASEP, B1-WAKE, B1-RSEQ, and B1-ASEP	
GLOBAL READINESS CHECKLIST		Status (ready now or estimated date)
	Standards readiness	Est. 2016
	Avionics availability	√
	Ground system availability	√
	Procedures available	Est. 2016
	Operations approvals	Est. 2018

1. NARRATIVE

1.1 General

The WVSS is intended for determination of acceptable and specified (standard) wake vortex separation intervals during current flight conditions and maintenance of the maximum one. The WVSS also may solve the following tasks:

- provide flight crew and/or ground based ATC services with information about standard and/or current acceptable aircraft separation intervals
- generation of instructions on pair wise wake vortex separation (self-separation)
- receipt and transmission of information on the current and/or predicted wake vortex situation received from an aircraft and/or ground based ATC facilities to the flight crew and/or ground based ATC services
- evaluation of potential impact of aircraft wake vortex encounters
- ranking of wake vortices according to their hazard level in case of several wake vortex generators
- detection of conflict situations with potential wake vortex encounter for aircraft flying on crossing courses or during aircraft maneuvering, as well as during maneuvering of the wake vortex generator
- provision of advisories for resolution of potentially conflict situations with wake vortex encounter
- flight crew workload reduction while flying the aircraft under wake vortex impact
- automated identification of wake vortex encounters, generation and provision of reports on these events to persons and services concerned
- automated avoidance of potentially hazardous wake vortices

1.2 Baseline

1.2.1. The baseline for this module are dynamic intervals of separation with regard to wake vortex turbulence, automation of maintaining time intervals and sequencing of aircraft arrivals and departures, automatic dependent surveillance and separation (self-separation) of aircraft, and also technologies of combined surveillance of wake vortices by X-band radars and lidars introduced by modules B0-AMET, B0-RSEQ, B0-ASEP, B1-WAKE, B1-RSEQ,and B1-ASEP.

1.3 Change brought by the Module

1.3.1. The module provides implementation of basic procedures for aircraft operations under conditions of dynamically determined intervals of wake vortex separation, including detection and prevention of hazardous wake vortex encounters.

1.3.2. WVSS is not a design that requires creation of unique technologies and procedures. It is based on technologies of automatic dependent surveillance (broadcast and contract types), system-wide information management (SWIM), aeronautical information management (Digital AIM), and Improved Meteorological Information, Trajectory-Based Operations, Free-Routing.

1.3.3 A key to obtaining maximum benefits from WVSS is aircraft equipment. Aircraft operators make decisions on aircraft equipment on their own, judging from the additional value due to the increase of take-off/landing operations number. As experience shows, aircraft operators usually prefer not to reequip existing aircraft, but to wait for updating the aircraft fleet; however, some variants of retrofitting, which provide WVSS functional capabilities (airborne equipment ADS-B, ADS-C, EFB) exist and are implemented on many business jets.

1.3.4. As was discussed above potential benefits will not be implemented if data on wake vortices are not added to ADS-B Out messages (or to alternative means of message delivery). The proposal to add wake vortex parameters to ADS-B Out messages can be realized in various ways:

- Do nothing: this option will not allow implementation of wake vortex applications and obtain benefits from deploying ADS-B data links
- Voluntary equipping: quickly address and promote intensification of researches and development of standards and operation procedures in terms of wake vortex parameters, what will allow aircraft operators to voluntarily add ADS-B Out equipment with the capability to transmit wake vortex parameters. A Follower (aircraft flying behind) equipped for ADS-B(C) In wake vortex applications will be able to perform advanced vortex operations when flying after an equipped aircraft, and “ordinary” vortex operations when flying after an aircraft non-equipped according to the up-to-date requirements
- Voluntary equipping and catch-up standard-setting: this option is similar to voluntary equipping but includes planning for consequent “catch-up” standard-setting, so as to make the latest version of the standard on data links (RTCA DO-260C/DO-282C) obligatory.

- To make the transmission of wake vortex parameters obligatory as a part of the ADS-B Out mandate;
- After development of the WVSS ground segment with the initial approach as voluntary equipping with ADS-B Out, development of WVSS applications, better understanding of benefits from dynamic wake vortex separation, with parallel standard-setting within the time-frames of block B2-WAKE, mandatory equipping with WVSS under the proper approval of the aviation community will be possible.

1.4 Other remarks

1.4.1. During the last decade USA, EC and Russia have been financing scientific researches and developments of the new approach to airborne systems alerting of wake vortex encounters (WVSS airborne segment). The new approach uses advanced achievements in the field of dynamic programming and other computing techniques for computing the dynamics of origination, development and destruction of wake vortices, prediction of aircraft behavior in the wake vortex, and for generation of warnings and advisories on safe resolution of hazardous wake vortex encounters. In this approach a large volume of actual airborne data is used for generating a high precision model of own wake vortex and a behavioral model of the aircraft in the wake vortex of other aircraft. Based on specified safety criteria and computing techniques, this approach provides an optimized table of actions determined using information on the aircraft state, observed meteorological conditions, wake vortex states and an aircraft flying ahead (Leader). This approach considerably reduces time and efforts required for development of airborne systems logics, due to the direction of the research activity.

1.4.2. The prototypes of WWSS ground segment – a subsystem of wake vortex situation monitoring and prediction , have been developed also in USA (AVOSS, WakeVAS), Europe (CREDOS, ATCWake) and Russia (VFS) during the last decade.

2. INTENDED PERFORMANCE OPERATIONAL IMPROVEMENT

2.1.. Metrics to determine the success of the module are proposed in the “*Manual on Global Performance of the Air Navigation System*” (Doc. 9883).

Access and equity	Improvement of access by preventing air traffic disruptions in periods when the demand is higher than available capacity. WVSS provides ATM controllers’ situational awareness of the wake vortex situation in the form of surveillance data. Availability of data depends on aircraft equipment with ADS-B(C) as well as on aerodrome equipment with means of wake vortex situation monitoring and prediction.
Capacity	Facilitation of restrictions concerning wake vortices implies increase of aerodrome capacity.

Safety	Anticipation of potentially hazardous or safety bearing situations affecting the flight through the access to relevant information on the wake vortex situation at all flight phases.
Efficiency	Optimization and coordination of arriving and departing aircraft in the terminal area. Positive effect in reducing ATM inefficiency or in maintaining it on the level not always justified by the system's expenses (balance between the cost of delay and the cost of unused capacity).
Environment	It is expected that adoption of reduced separation intervals will result in considerable reduction of waiting time on the ground and in the air, with corresponding reduction of noise and air pollution in the airport vicinity.
Participation by the ATM community	Common understanding of operational restrictions, capabilities and requirements.
Cost-Benefit Analysis	In Europe: preliminary calculations conducted by EUROCONTROL, with efficiency evaluation for systems like ATC-Wake, CREDOS, and Time-Based Spacing (European analog of the WVSS ground segment) in 15 busiest airports of Europe for a year of operation provided the next prediction: • increase in number of additional operations by 95 712 take-offs / landings; • reduction in delayed flights by 13 228 hours. The assumed growth of income for airports and air carriers resulted from WVSS adoption , will be $974,46 million/year. In USA: according to the research data of LMI Government Consulting (USA), the implementation of the project Wake VAS (American analog of the WVSS ground segment) in 18 airports of USA will require $64 million, and expected return for a 10 year period will be $9,649 billion, with the project profitability 15200%. The analysis of the business-case conducted by the Aviation Rulemaking Committee (ARC) for ADS-B In applications shows that a third part of incomes planned for 2025 from using ADS-B In by air carrier operators is due to improvement of interval management (IM) with wake vortex encounter risk management. According to this analysis, an application related to the wake vortex encounter risk management used in IM on the base of wake vortex information obtained from aircraft, is one of the main applications in terms of promising incomes.
Human performance	A critical element is the integration of the new information processes of displaying the vortex situation in the tasks of the pilot and ATM controller. This information can also affect the respective duties and increase workload of the aircraft crew and ATM personnel. The use of these applications during demanding flight conditions will need careful investigation, as well as development of a proper human-machine interface for WVSS that reduces workload on the aircraft crew and ATM personnel. Training will be required.

3. NECESSARY PROCEDURES (AIR AND GROUND)

Procedures are to be defined. They will define the conditions of access to information and the use of supported applications depending on the characteristics of these and of the communication channels available, in particular safety, security and latency.

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

4.1.1. The enabling technologies are at the final stage of development. The most important element is the availability of a suitable data links combination: ”air-to-ground“, “air-to-air”, “ground-to-air” to support safety and non-safety applications.

4.1.2. Airborne real-time solutions for wake vortex prediction will require certification. Considerable efforts in USA, EC and Russia during last years have been directed to development and improvement of operational algorithms for wake vortex computation working in real-time mode. It is necessary to determine “the best of the best” wake vortex model for definition of Flight Standards Wake Vortex Model, which will be used for WVSS airborne algorithms and will be available for the aviation community.

4.2 Ground systems

4.2.1 The enabling technologies, in terms of all-weather detection on the basis of radars and lidars and wake vortex predictions, are at the final stage of development. Development of standards is required for ground-based means of wake vortex situation monitoring and prediction in the terminal area.

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 Provision of wake vortex flight safety is a problem, in which the human factor plays an essential role. This implies many emergency situations related to violation of separation intervals, when generation of warnings and vortex avoidance advisories must consider the current spatial position of the wake vortex and the Follower, as well as this position dynamics. No system basing on computation of only safe separation intervals is able to effectively solve the wake vortex flight safety problem in such conditions. Therefore, in order to ensure wake vortex flight safety in such conditions, data on the wake vortex situation (location and hazard of wake vortices), as well as advisories for resolution of potential conflicts and conflict situations related to hazardous wake vortex encounters shall be displayed on the aircraft control and navigation equipment and in automated workplaces of ATM personnel.

5.1.2 A critical element is the integration of the new information processes of displaying the vortex situation in the tasks of the pilot and ATM controller. This information can also affect the respective duties and increase workload of the aircraft crew and ATM personnel.

5.1.3 The use of WVSS applications during demanding flight conditions will need careful investigation. This module is still in the research and development phase so the human factors considerations are still in the process of being identified through modeling.

5.1.4. Development of a proper human-machine interface for WVSS is needed.

5.2 Training and qualification requirements

5.2.1 Necessary training concerning operational standards and procedures will be defined in order to implement this module.. Likewise, qualification requirements will be defined and included in the regulatory aspects of the module readiness, when they become available.

6. REGULATORY/STANDARDIZATION NEEDS AND APPROVAL PLAN (Air and Ground))

Regulation/standardization: to expand operations area it is necessary to update ICAO documents: Doc 4444, *Procedures for Air Navigation Services — Air Traffic Management*, and Doc 9426, *Air Traffic Services Planning Manual*.
Development of ICAO SARPs on WVSS is required.

7. IMPLEMENTATION AND DEMONSTRATION ACTIVITIES (As known at time of writing)

7.1 Current use

WTMD, which is a prototype of the ground segment of the future WVSS, has been in use since 2011 at three airports of the United States.

7.2 Planned or ongoing activities

European Union: Within the framework of the SESAR projects works are executed on development and evaluation of the concept, procedure and tools for supporting flexible and dynamic use of wake vortex intervals of longitudinal separation, as per project 6.8.1. Flexible and Dynamic Use of Wake Vortex Separation, as well as on construction of the WVSS ground segment of (project 12.2.2. Runway Wake Vortex Detection, Prediction, and Decision Support Tools) and WVSS airborne segment (projects 9.11. Aircraft Systems for Wake Encounter Alleviation, 9.30. Weather Hazard/Wake Vortex Sensor).

Flight tests of technology demonstrator for the WVSS airborne segment based on a non-standardized data link “air-to-air” were conducted by AIRBUS in 2010 and by DLR Institute (Germany) in 2013.

United States of America:
The development of the WVSS ground segment elements is performed within the framework of NextGen and other activities: OI 102141 Wake Turbulence Mitigation for Arrivals-System (WTMA-S); OI 102140 Wake Turbulence Mitigation for Departures (WTMD); FAA R&D: Single Runway Arrival/Departure Wake Mitigation; FAA R&D: En Route Wake Vortex Avoidance Advisor (GIM-S). Flight tests of technology demonstrator for the WVSS airborne segment based on UAT data link “air-to-air” were conducted in 2003.

Russian Federation:
Development of an integrated air traffic safety system of the next generation implementing functions of TCAS, TAWS, vortex flight safety, onboard weather transceiver (AMDAR) based on ICAO CNS/ATM is envisaged by the Concept of establishment and development of the Air Navigation System of the Russian Federation (Section VI Strategic directions of development of the Air Navigation System of the Russian Federation. Technical support for avionics) and the Action Plan for the implementation of the Concept of establishment and development of the Air Navigation System of the Russian Federation (p. 4.8, 4.8.2 and 4.8.4).
Flight tests of technology demonstrator for the WVSS airborne segment based on VDL m4 data links “air-to-air”, “air-to-ground”, “ground-to-air” were conducted in 2006–2007.

Standards development:
RTCA DO-xxx AIS, and MET Services Delivery Architecture Recommendations;
RTCA DO-xxx MASPS for AIS, and Met Uplink, Crosslink, Downlink Services;
SAE AS xxx Minimum Performance Standard for WV Information Systems.
ARP xxx: Airborne Wake Vortex Information Systems;
ARP XXX 2015 Operational Requirements WVIS

8. REFERENCE DOCUMENTS

8.1 Standards

a. RTCA DO-260B APPENDIX V Provisioning For Potential Wake Vortex And Arrival Management ADS-B Applications
b. RTCA DO-339 Aircraft Derived Meteorological Data via Data Link for Wake Vortex, Air Traffic Management and Weather Applications Operational Services and Environmental Definition (OSED)
c. SAE S-10 ARP5364 Human Factors Criteria for the Design of Multifunction Displays for Transport Category Aircraft (§3.7.5)
d. ARINC 768-2-2011 Integrated Surveillance System (§1.3.3.1).

8.2 Guidance materials

D Galpin (NATS), C Pugh (NATS), D Cobo (ISDEFE), L Vinagre (ISDEFE), “European Wake Vortex Mitigation Benefits Study”, Work Package 3 Deliverable: High Level Benefits Analysis & Systemic Analysis, 2005

Wake Vortex Advisory System: Preliminary Business Case Analysis. Robert V. Hemm, Jeremy M. Eckhause, Virginia Stouffer 5/1/2003 LMI Report #: NS254T1

A Report from the ADS–B In Aviation Rulemaking Committee to the Federal Aviation Administration Recommendations to Define a Strategy for Incorporating ADS–B In Technologies into the National Airspace System. September 30, 2011

8.3 Approval documents

a. ICAO Doc. 9426, Part II, Section 5, Chapter 3, Appendix A «Wake Vortex Avoidance Systems»

b. ICAO Circular #**** «General Requirements for Wake Vortex Safety Systems» (under development).

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