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Potential Use of ADS-B 1090 Extended Squitter Message Set For Wake Turbulence Avoidance Applications

Proposal to RTCA SC 186
Work Group 3 -ADS-B 1090 MHz Extended Squitter MOPS

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1.0 Overview of Proposed Enhancement

The temporal and spatial scales of hazardous aircraft wake turbulence are critically dependent on ambient atmospheric conditions. In highly turbulent atmospheres, hazardous wake turbulence may only persist for 40-60 seconds behind the generating aircraft. In very stable atmospheric conditions, the same aircraft may generate hazardous wake turbulence that persists more than 2 minutes.

Current FAA instrument flight rules (IFR) require following distances from 4 to 8 miles behind heavy jets in the terminal area and 5 miles in trail or 1000 ft vertical separations between aircraft in the en route environment to safely avoid potential wake hazardous. With proper meteorological and aircraft data it may be possible to safely reduce these required wake avoidance separation distances. Achieving NextGen and Single European Sky ATM Research (SESAR) capacity goals will not be possible unless such reductions in separations can be safely implemented.

The FAA is pursuing a multi-faceted program strategy to develop near-, mid-, and far-term wake turbulence avoidance applications. As a mid-term application, the FAA proposes leveraging the planned Automatic Dependent Surveillance Broadcast (ADS-B) data link capabilities supplemented with one or two additional messages to down link meteorological and aircraft data for a ground based wake turbulence avoidance system. Properly equipped aircraft have the potential of measuring and reporting meteorological data at a high resolution, under all weather conditions, over any region of interest. The proposed wake turbulence data broadcasts will support future ground-based and/or airborne wake avoidance applications as these applications reach technical maturity.

A broadcast link of relevant atmospheric and aircraft data is required to accommodate the wide range of temporal and spatial scales associated with hazardous wake turbulence. In the terminal area, atmospheric profile data is needed with high vertical resolution and data transmission frequencies must accommodate short-lived wakes that may persist for less than 1 minute. To accommodate boundary layer shear effects in the lower atmosphere vertical profile data is required every few hundred feet. At cruise altitudes the required frequency of data reporting is driven by high aircraft speeds. With aircraft traveling approximately 8 miles per minute a moderately high update rate is required to produce data with length scales appropriate for wake turbulence applications. Measurements spaced too far apart would not properly capture local atmospheric phenomena that determine wake transport and wake lifetimes. A 15 second reporting frequency is recommended to provide adequate temporal and spatial data for both terminal and cruise airspace applications. Request reply and other addressed data links would not be appropriate for transmission of data to multiple aircraft and ground stations at this frequency for wake turbulence applications.

The proposed mid-term wake avoidance solution will employ ground-based systems to receive and process ADS-B down-linked meteorological and aircraft data. These data will be integrated with flight plan and National Airspace Systems (NAS) data received

through ground networks. Ground-based processors will compute wake safe 4D trajectories for individual aircraft and recommend traffic flow management options for arrival and departure operations. These data will become inputs to decision support tools (DSTs) for controllers and traffic flow management experts who will select from various alternatives to optimize NAS operations. Consistent with NextGen and SESAR concepts of operation, individual 4D wake-safe trajectories will be data linked to appropriate flight crews to provide a high level of shared situational awareness.

2.0 Background

Wake turbulence constraints have been identified as a major contributing factor for inefficient use of the Nation's airspace capacity, especially when Instrument Flight Rules (IFR) operations are in effect. Concept exploration research by NASA and FAA has indicated that greater utilization of the nation's airspace could be accomplished if the location of wake turbulence from aircraft could be known with sufficient fidelity to allow following aircraft to fly paths that are free of hazardous turbulence. Projected airspace and airport related daily operations in the NextGen year 2025 are three times the number of today's operations. Already demands on the nation's busiest airports have risen from the low of 2001 to such a level that more effective utilization of our existing runways, especially in instrument meteorological conditions (IMC), would yield significant increases in airport capacity – as much as a 40% increase at several airports during some periods of IMC.

To achieve this increased capacity, even in IMC conditions, the NextGen system will reduce separation between aircraft in four dimensions (three dimensional space, plus time). It will create new roles and responsibilities for aircrews, air traffic controllers and managers, and air traffic automation systems. Reducing separation must be accomplished safely, using technologies and procedures that account for the limitations of aircrews, air traffic controllers, air traffic automation systems, and the technologies themselves. Limitations to reducing separation include wake vortex and severe weather encounter hazards, communications, navigation, surveillance, air traffic management system performance, and human and aircraft limitations.

The FAA has undertaken a comprehensive wake turbulence program to support much needed capacity enhancements in the NAS and the NextGen capacity goals. These include a recently approved procedural rule change[1] allowing dependent staggered approaches to closely spaced parallel runways with centerlines separated by less than 2500 ft when the leading aircraft is in the large or small wake category. The FAA is in the process of acquiring and deploying the Wake Turbulence Mitigation for Departures (WTMD) system that will enable additional departures behind heavy and B-757 aircraft from adjacent closely spaced parallel runways when crosswind conditions are favorable. In partnership with EUROCONTROL, the FAA is developing a new wake vortex categorization scheme for aircraft that will facilitate more efficient use of the NAS. This re-categorization scheme is a fist step towards pair wise dynamic wake vortex separation standards.

ADS-B is an emerging technology with the potential to provide critically needed meteorological and aircraft data for safe avoidance of wake turbulence hazards and the computation of hazard free 4D trajectories in addition to its more familiar role in the surveillance and improved situational awareness arenas. Most of the meteorological and aircraft parameters needed to support wake turbulence applications are already included in the ADS-B data sets and broadcast message sets under development by the RTCA and ICAO.[23] These include aircraft-derived wind speed, wind direction, ground speed, local temperature, wake turbulence category, and intended flight path. These data can be straightforwardly supplemented with aircraft weight and type, plus a local measurement of the eddy dissipation rate (EDR) to enable, in concept, ground-based and aircraft-based wake avoidance solutions required for transition to NextGen and SESAR capabilities.

3.0 Wake-Related NextGen and SESAR Operational Improvements

Appendix A contains a listing of Operational Improvements (OI) culled from the Joint Planning and Development Office (JPDO) integrated work plan[4] with explicit linkages to wake turbulence applications and data link technologies[5]. The integrated work plan identifies required operational improvements and enabling technologies needed to achieve the mid-term NextGen operational vision. The listing in Appendix A also includes Lines of Change (LoC) from the SESAR Master Plan[6] that address specific wake turbulence avoidance concepts and technologies.

Several of the mid-term NextGen wake turbulence OIs (i.e., 400, 401,402, & 403) describe weather dependent concepts (e.g crosswind dependent) which can only be realized when favorable weather conditions exist. Determining when these weather conditions exist, or will exist, is normally a difficult task as high-resolution ground-based weather sensors covering the myriad of potential flight trajectories aircraft may be executing are not feasible. In these cases, the aircraft themselves acting as individual weather sensors can collect and report ambient meteorological conditions. This concept is fully scalable to accommodate dynamically changing airspace and/or new NextGen operational concepts since the aircraft bring with them the required measurement and reporting infrastructure.

Appendix B contains a more general listing of wake-related OIs dealing with reduced separation between aircraft and avoidance of flight hazards. While these OIs may not explicitly mention wake turbulence, the safety case for these operational improvements will, require that potential wake turbulence hazards be addressed and mitigated if necessary. In all these cases, ADS-B surveillance data, meteorological data, aircraft state data, and trajectory information could play a critical role in safely implementing NextGen and SESAR concepts.

Together Appendix A and Appendix B contain some 33 NextGen operational improvements and SESAR Lines of Change which aircraft controller, pilot, and wake

turbulence subject matter experts formally identified as having the potential to produced wake turbulence concerns.

4.0 Detailed Description of Proposed Application

The FAA Wake Turbulence Program proposes an initial ground-based wake turbulence avoidance application based on the set of ADS-B provided meteorological and aircraft data elements described below. The proposed application is a first step in the development of a series ADS-B supported wake avoidance applications enabling the transition to long-term NextGen and SESAR operational concepts. The set of data elements proposed is sufficiently robust to support envisioned ground-based and airborne wake avoidance applications.

The simplest instantiation of an ADS-B based near-term wake avoidance solution involves the use of down linked crosswind data to provide wake safe 4D trajectories for following aircraft. Ground-based processors receive mode S identification and wind speed and wind direction from ADS-B equipped aircraft. Aircraft type and flight plan data would be retrieved from ground based information networks. The ground-based system would compute wake safe 4D trajectories when the crosswind strength is sufficient to remove wakes from the flight paths of following aircraft. However, such a simplistic system would have no predictive capability and benefits would be limited to periods of favorable crosswinds.

The proposed mid-term wake solution is also a crosswind-based solution. However, it utilizes additional down linked meteorological and aircraft data to produce a more robust benefit. The proposed set of data elements below supports the development of crosswind predictive capabilities that will provide enhanced benefits. The proposed data elements are also extensible to longer term ground-based and airborne wake avoidance solutions envisioned under the NextGen and SESAR concepts.

Research conducted over a period of many years both in the U.S. and Europe has resulted in a general agreement that real-time predictions of the movement and decay of aircraft wake vortices can be developed from a list of data elements that includes:

- Wind speed
- Wind direction
- Local temperature
- Local barometric pressure
- Aircraft type
- Aircraft position
- Aircraft speed and heading
- Aircraft weight (previous results based on percentage of max landing weight)
- Local atmospheric turbulence (normally eddy dissipation rate but total kinetic energy has also been used)

Additional utility for potential future applications may be gained if the list above is supplemented with:

- Aircraft configuration data (e.g. flap setting)

The atmospheric turbulence parameter and the supplemental parameter(s) are not required for the proposed mid-term ground-based system. The turbulence parameter is used to compute the decay rate of wake vortices. The proposed mid-term solution has no reliance on wake decay mechanisms. The proposed system will retrieve the aircraft type and other flight plan related data from existing ground-based networks. However, as noted above, future wake avoidance applications and global harmonization of wake categories may require ADS-B transmission of atmospheric turbulence and aircraft type data. Individual pair wise wake turbulence separation distances are envisioned under the NextGen and SESAR concepts.

Most of the required wake application data elements are included in existing ICAO and RTCA proposed ADS-B message sets. The final draft of document of 9871 submitted to ICAO[3] reserves registers for wind speed, wind direction, static air temperature, average static pressure, and turbulence. In Table A-2-68. BDS code 4,4 – Meteorological routine air report. The turbulence register is currently a placeholder for turbulence data yet to be defined. A placeholder for a wake hazard is also currently included in Table A-2-69. BDS code 4,5 – Meteorological hazard report. Registers are reserved for aircraft type and wake turbulence category in Table A-2-8. BDS code 0,8 – Extended squitter aircraft identification and category – and Table A-2-37. BDS code 2,5 –Aircraft type.

The more familiar ADS-B registers for aircraft position are described in Tables A-2-5: BDS code 0,5 – Extended squitter airborne position report, Table A-2-81. BDS code 5,1 – Position report coarse, and Table A-2-82. BDS code 5,2 – Position report fine. Registers for velocity reporting are described in Tables A-2-9a. BDS code 0,9 – Extended squitter airborne velocity (Subtypes 1 and 2: Velocity over ground) and Table A-2-9b BDS code 0,9 – Extended squitter airborne velocity report. Additional aircraft velocity registers are described in Table A-2-83. BDS code 5,3 – Air-referenced state vector. Aircraft track and ground speed registers are described in Table A-2-11. BDS code 0,B – Air/air state information 1 (aircraft state) while vertical velocity reports are described in Table A-2-12. BDS code 0,C – Air/air state information 2 (aircraft intent).

RTCA/DO-260A, Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services (TIS-B) describes a similar partitioning of ADS-B data registers. Once again most of the data elements needed for the proposed mid-term ground-based wake solution are included in the existing message set.

The FAA Wake Turbulence Program proposes to work with the SC-186 Work Group 3 team to determine the most appropriate raw data sources for populating the planned ADS-B registers, to determine required data update rates, and to identify modifications to the planned message elements should any be required. It has been brought the attention of the FAA Wake Turbulence Program that the RTCA previously considered a low

update rate broadcast of the air reference velocity (ARV)[7] that included a derived wind velocity vector from the difference between the ground vector in the sate reports and the air vector obtained from the ARV. While not originally intended for wake avoidance purposes the derived wind velocity vector could potentially be used as a replacement for aircraft sensed winds that are known to be inaccurate when the aircraft is maneuvering.

As noted above, a broadcast link of relevant atmospheric and aircraft data is required to accommodate the wide range of temporal and spatial scales associated with hazardous wake turbulence. To provide data when wake vortices are short-lived and during ascent and descent flight operations, a data broadcast frequency on the order of 15 seconds is desirable. This represents a report once every 2 miles for wake avoidance purposes at typical cruise speeds and it provides a high likelihood of receiving broadcast data on temporal and spatial scales consistent with the current separation standards. In the terminal environment, a 15 second update frequency provides a high likelihood of receiving broadcast data every 1-2 miles traveled by the generating aircraft. It also ensures data will be received every 1000 ft during initial climb and descent operations and at higher vertical resolutions near the airport on approach when wake turbulence can be most hazardous. It is interesting to note that that the RTCA found that a default value of 20 seconds for air-ground broadcast of wind vector and temperature data would suffice for meteorological reports during aircraft ascent.[7] In 2005, Livack proposed ADS-B based meteorological and wake vortex applications to RTCA SC 206.[8] The data elements listed above would support the long-term wake vortex application he described.

While eddy dissipation rate (EDR) data is not required for the proposed ground-based system, it should be noted that potential methods to populate the ADS-B registers reserved for it may already exist. NASA developed a prototype system to detect and report atmospheric profiles of wind speed and direction, static temperature, and eddy dissipation rate from approach and departure aircraft.[9] The profile generation algorithm derived an inertial wind vector from parameters resident on the aircraft's data bus and is non-aircraft specific. A winds-based eddy dissipation rate algorithm provided a measurement of EDR based on inertial vertical wind measurements and the true airspeed. In a manner similar to the ARV derived winds this approach removed aircraft response from the estimated eddy dissipation rate. Flight data from a research aircraft was used to assess the accuracy of atmospheric profiles generated by the prototype system.

5.0 Potential RTCA and ICAO MASPS Issues

The joint FAA / EUROCONTROL program to develop a harmonized re-categorization scheme for aircraft wake turbulence purposes may impact the current ICAO and RTCA MASPS. Currently, Table A-2-8. BDS code 0,8 – Extended squitter aircraft identification and category includes a 3 bit field for aircraft/vehicle category under set A that identifies the wake category of the transmitting aircraft. The 8 possible categories are:

0 = No aircraft category information
1 = Light (< 15 500 lbs or 7 031 kg)

2 = Medium 1 (>15 500 to 75 000 lbs, or 7 031 to 34 019 kg)
3 = Medium 2 (>75 000 to 300 000 lbs, or 34 019 to 136 078 kg)
4 = High vortex aircraft
5 = Heavy (> 300 000 lbs or 136 078 kg)
6 = High performance (> 5g acceleration) and high speed (> 400 kt)
7 = Rotorcraft

This set does not include the new "super heavy" category introduced for the A-380. Similarly, the RTCA DO-260A requirements provide for a "ME" field that contains a 3 bit "ADS-B emitter category" that has the wake category embedded in set "A." This 3 bit field is based on the current U.S. aircraft wake categorization matrix and it encapsulates the 5 categories in current use. However, it also does not include provisions for the new "super heavy" category.

The joint FAA/EUROCONTROL program is likely to introduce additional aircraft wake categories. The program is striving to limit the number of aircraft wake categorizes to a set manageable by human controllers. However, research has shown, as expected, that increasing the number of wake categories and associated wake separation distances produces additional opportunities to maximize airport capacities. Future wake avoidance applications and decision support systems may, therefore, utilize significantly more aircraft wake categories

6.0 References

[1] FAA JO7110.65.308, Sept. 2008.
[2] RTCA/DO-260A, Minimum Operational Performance Standards for 1 090 MHz Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services (TIS-B), RTCA, April 2003, including Change 1 to RTCA/DO-260A, June 27, 2006, and Change 2 to RTCA/DO-260A, December 13, 2006.
[3] Document 9871, Technical Provisions for Mode S Services and Extended Squitter, First Edition, Aeronautical Surveillance Panel (ASP), April 2007.
[4] JPDO Integrated Work Plan V1.0, 2008. pp. ES-1.
[5] CSSI deliverable #5 contract DTFAWA-05-C-00044, Technical Directive Memorandum A-001-048, Dec., 2008.
[6] SESAR Master Plan D5, 2008. pp 7
[7] RTCA SC-186, WG6: "Broadcast Conditions and Operational Concept for ARV Reporting," February, 2002
[8] Livack, G: "Winds, Temperature, Turbulence and Icing Data Collection and Reporting Using ADS-B Technology: An Operational Perspective," presentation to RTCA SC 206, Oct. 11, 2005.
[9] NASA CR-2004-213236, Buck, B.K and Velotas, S.G.: "Development of an Aircraft Approach and Departure Atmosphere Profile Generation Algorithm," June, 2004.

Appendix A

		Operational Improvements With Explicit Wake Turbulence and Data Link Implications		
Initiative	**Implementation Date**	**OI Description**	**Wake Impact**	**Enablers, Predecessor OI's and Required R&D**
JPDO OI-OI-0333 and FAA OI-102141 Improved Operations to Closely Spaced Parallel Runways (CSPR)	2013	Enhanced procedures (including cockpit and ground improvements) enable parallel runway improvements, reducing impact to airport/runway throughput in lower visibility conditions. Maintaining access to closely-spaced parallel runways in limited visibility conditions by integrating new aircraft technologies will ensure safety through precision navigation, aircraft-based monitoring of the aircraft on the parallel approach, and flight guidance to avoid wake vortex generated by parallel traffic. This capability will apply aircraft-based technologies to maintain access in Instrument Meteorological Conditions (IMC), as well as support a new Instrument Flight Rules (IFR) standard for runway spacing. A number of other intermediate concepts for maintaining access to parallel runways continue	Possible wake encounters as wake separation responsibility is delegated to flight deck	FAA Predecessors: None JPDO Predecessors: •OI-0326: Airborne Merging and Spacing - Single Runway •EN-0034: Trajectory Management Decision Support - Level 1 •EN-1143: Ground Based Navigation System (GBNS) - eLORAN •PI-0120: PNT Performance Requirements
JPDO OI-0348 and FAA OI-102117 Reduce Horizontal Separation Standards - 3 Miles	2015	Metroplex airspace capacity is increased through implementing separation standards of less than 3 miles between high navigation precision arrival and departure routes. This Operational Improvement increases metroplex airspace capacity and supports super density airport operations by implementing separation standards for inter-aircraft separations of less than 3 miles. Arrival/departure routes with lower Required Navigation Performance (RNP) values (e.g., RNP<1 nm) are defined with less than 3 miles lateral separation between routes, subject to wake vortex constraints, enabling the use of more routes in a given airspace. This may require airborne lateral separation between routes. Enhanced Required Surveillance Performance (RSP) is required. This requires a Policy Decision to determine what RNP values to require based on performance benefit versus equipage requirements and operational considerations. Expected use: high density terminal and transition airspace.	Possible wake encounters with the proposed reduction in thes 3 mile separation standard. While wake vortex constraints are mentioned, the methodology to address them or resolve the impact is not captured or stated in the OI description.	FAA Predecessors: •FAA OI-102112 Current En Route Separation JPDO Enablers: •OI-0343: Reduced Separation - High Density En Route, 3-mile •OI-0363: Delegated Separation - Complex Procedures •EN-0201: Avionics - RNP •EN-0016: Separation/Trajectory Management Detail Operational Concept •EN-0152: Wake Vortex Configuration Advisory Decision Support - Level 3 Dynamic Drift/Decay •EN-0027: Metroplex Flow Management Decision Support •EN-0037: Trajectory Management Decision Support - Level 2 •EN-0038: Separation Management Decision Support - Level 2 •EN-1208: Air - Ground Data Exchange – Clearance and Instruction Services – Tower Group 3 •EN-1214: Air - Ground Data Exchange – Clearance and Instructions Services – TRACON Group 3 •EN-1101: Enhanced NextGen PNT Services •PI-0120: PNT Performance Requirements •PI-0014: Aircraft Equipage Implementation Policy •PI-0077: High Density Operations - Flight Prioritization •PI-0007: Rules of the Road •FAA OI-102112 Current En Route Separation
JPDO OI-0349 Automation Support for Mixed Environments	2014	The Air Navigation Service Provider (ANSP) automation provides the controller with tools to manage aircraft in a mixed navigation and wake performance environment. Aircraft with various operating and performance characteristics will be operating within the same volume of airspace. Controllers will use ANSP automation enhancements to provide situational awareness of aircraft with advanced capabilities (e.g., delegated self-separation maneuvers, equipped vs. non-equipped aircraft, Area Navigation [RNAV], Required Navigation Performance [RNP], and trajectory flight data management). These enhancements enable ANSP to manage the anticipated increase in complexity and volume of air traffic.	Possible wake enounters as aircraft with different technologies flying in reduced separation airspace among aircraft with more sophisticated avionics, i.e. advanced RNAV flying alongside legacy RNAV	•EN-0039: UAS Detail Operation Concept •EN-0035: Separation Management Decision Support - Level 1 •EN-0212: Parameter Driven Aircraft Separation Standards and Procedures •PI-0115: NextGen Safety Assessment/Certification - Synchronization of Aircraft and ANS Capabilities •PI-0116: NextGen Safety Assessment/Certification - Standards and Tools •PI-0110: International Commercial Space Operations
JPDO OI-0400 and FAA OI-102140 Wake Turbulence Mitigation: Departures - Wind-Based Wake Procedures	2013	Changes to wake rules are implemented based on wind measurements. Procedures allow more closely spaced departure operations to maintain airport/runway capacity. Procedures are developed at applicable locations based on the results of analysis of wake measurements and safety analysis using wake modeling and visualization. During peak demand periods, these procedures allow airports to maintain airport departure throughput during favorable wind conditions. A staged implementation of changes in procedures and standards, as well as the implementation of new technology will safely reduce the impact of wake vortices on operations. This reduction applies to specific types of aircraft and is based on wind blowing an aircraft's wake away from the parallel	Possible wake encounters as wake predictions can be inaccurate due to constantly changing weather conditions. This is very dependent on how dynamic and how spontaneously wind information is captured, the revised impact determined, and distributed to the users will determine wake vulnrability. This is not clear from the OI description.	•EN-0023: Surface Movement - Detail Operational Concept •EN-0150: Wake Vortex Configuration Advisory Decision Support - Level 1 Static Drift Only •EN-1007: Avionics - Trajectory Management - Advanced Surface Operations •EN-2470: Weather Information - Wake Vortex - Level 1

JPDO OI-0401 and FAA OI-102140 Wake Turbulence Mitigation: Arrivals - Wind-Based Wake Procedures	2015	Changes to wake rules are implemented based on wind measurements. Procedures allow more closely spaced arrival operations to maintain airport/runway capacity. Procedures are developed at applicable locations based on the results of analysis of wake measurements and safety analysis using wake modeling and visualization. During peak demand periods, these procedures allow airports to maintain airport arrival throughput during favorable wind conditions. A staged implementation of changes in procedures and standards, as well as the implementation of new technology will safely reduce the impact of wake vortices on operations. This reduction applies to specific	Possible wake encounters as wake predictions can be inaccurate due to constantly changing weather conditions	JPDO Enablers: •EN-0023: Surface Movement - Detail Operational Concept •EN-0150: Wake Vortex Configuration Advisory Decision Support - Level 1 Static Drift Only •EN-1007: Avionics - Trajectory Management - Advanced Surface Operations •EN-2470: Weather Information - Wake Vortex - Level 1 FAA Predecessors: None
JPDO OI-0402 Wake Turbulence Mitigation: Departures - Dynamic Wind Procedures	2018	Departure spacing and separation rules are dynamically adjusted to accommodate wake drift and decay. Longitudinal departure spacing is dynamically adjusted based on ground-based wind measurements, aircraft type and algorithms to predict wake drift and decay. Dynamic adjustments are made when favorable wind conditions are forecast to persist for perhaps a half hour or more. Controller automation is enhanced to provide controllers with dynamic spacing and separation information that may include a larger matrix of separation standards than the current 4x4 matrix, with more specific pair-wise spacing requirements within and between aircraft types.	Possible wake encounters as wake predictions can be inaccurate due to constantly changing weather conditions	•OI-0400: Wake Turbulence Mitigation: Departures - Wind-Based Wake Procedures •EN-0007: High-Density Arrival/Departure Detail Operational Concept •EN-0030: Wake Detection/Prediction w/Dynamic Wake Spacing - Level 2 Wake Drift/Decay •EN-0152: Wake Vortex Configuration Advisory Decision Support - Level 3 Dynamic Drift/Decay •EN-2681: Methodologies and Algorithms for Weather Assimilation into Decision-Making - Level 2 •EN-2020: NextGen 4-D Weather Cube Information - Level 2 Adaptive Control/Enhanced
JPDO OI-0403 Wake Turbulence Mitigation: Arrivals - Dynamic Wind Procedures	2020	Arrival spacing and separation rules are dynamically adjusted to accommodate wake drift and decay. Longitudinal departure spacing is dynamically adjusted based on ground-based wind measurements, aircraft type and algorithms to predict wake drift and decay. Dynamic adjustments are made when favorable wind conditions are forecast to persist for perhaps a half hour or more. Controller automation is enhanced to provide controllers with dynamic spacing and separation information that may include a larger matrix of separation standards than the current 4x4 matrix, with more specific pair-wise spacing requirements within and between aircraft types.	Possible wake encounters as wake predictions can be inaccurate due to constantly changing weather conditions	•OI-0401: Wake Turbulence Mitigation: Arrivals - Wind-Based Wake Procedures •EN-0007: High-Density Arrival/Departure Detail Operational Concept •EN-0030: Wake Detection/Prediction w/Dynamic Wake Spacing - Level 2 Wake Drift/Decay •EN-0152: Wake Vortex Configuration Advisory Decision Support - Level 3 Dynamic Drift/Decay •EN-2681: Methodologies and Algorithms for Weather Assimilation into Decision-Making - Level 2 •EN-2020: NextGen 4-D Weather Cube Information - Level 2 Adaptive Control/Enhanced Forecasts
JPDO OI-0409 Net-Centric Virtual Facility	2018	Next Generation Towers provide Air Traffic Management (ATM) services for operations into and out of designated airports without physically constructing, equipping, and/or sustaining tower facilities at these airports. Emerging technology replaces "out the window" visual observations from conventional tower cabs by acquiring, processing, communicating, and displaying equivalent information used by Air Navigation Service Providers (ANSPs) at remote locations aided with decision support tools. Deployment of Next Generation Towers allows a reduction in the total number of service delivery points. Eventually NextGen capabilities are integrated into new general service delivery point facilities. Remote NextGen tower capabilities provide ATM services for operations into and out of airports without a physical ATM presence. This accommodates managing increases in life cycle costs to sustain, expand, and improve services in response to steadily increasing demand. Instead of "out the window" visual surveillance, controllers obtain situational awareness aided by surface surveillance displayed on a tower information display system and a suite of decision support tools using ground system and aircraft-derived data. Weather, traffic and other relevant information are displayed on a traffic information display system to avoid c with the mix of heads up versus heads down operations. Weather is distributed to and from aircraft using data con data are available to aircraft and other users via a net centric information system. Clearance delivery and pushbac movement areas is accomplished by voice and/or data communications to the aircraft, aided by situational awaren surveillance sensors and conformance monitoring tools presented directly on the ANSP display. Special airport se obstructions at the airport and automatically alert controllers and pilots of the obstruction via voice and/or Data Co assurance is accomplished with the aid of ground and terminal surveillance data from sensors located at the airpo conflict alert aids available for use. Some separation responsibility is delegated to aircraft equipped with "sense an aperture type capability. Traffic management initiatives and flight plan data are available to flight operators and AN information capabilities to improve common situational awareness. Decision support tools assist ANSPs with plann	Possible wake encounters as safe separation responsibility delegated to aircraft onboard computer systems. Additionally, this OI does not indicate any of the systems being introduced into this concept accounts for need for dynamic wake information, detection, or adjustment from which the remote controller would operate.	•EN-1400: Cooperative Surveillance - ADS-B IN/TIS-B/FIS-B Level 1 •EN-2680: Methodologies and Algorithms for Weather Assimilation into Decision-Making - Level 1 •EN-1215: Air - Ground Data Exchange – FIS – Tower •EN-0031: Avionics - Airborne Merging and Spacing •EN-2010: NextGen 4-D Weather Cube Information - Level 1 Initial Operating Capability •EN-0106: Avionics - Delegated Separation Acknowledgement Information •EN-0020: Staffed Virtual Tower Capability •EN-0101: Avionics - Enhanced Obstacle Detection •PI-0120: PNT Performance Requirements •PI-0115: NextGen Safety Assessment/Certification - Synchronization of Aircraft and ANS Capabilities •PI-0116: NextGen Safety Assessment/Certification - Standards and Tools •PI-0117: NextGen Safety Assessment/Certification - Resources
SESAR LoC#10 Level 1 - Airport Throughput, Safety and Environment	2009	**Improved Low Visibility Procedure:** Introduce improved operations in low visibility conditions through enhanced ATC Procedures collaboratively developed at applicable airports involving in particular an harmonised application across airports and the use of optimised separation criteria. Deploy final approaches with vertical guidance procedures to enable Cat I like operations. **ATSA-VSA:** Introduce enhanced Visual Separation on Approach (ATSA-VSA), to assist crews to achieve the visual acquisition of the preceding aircraft and then to maintain visual separation from this aircraft. **Reduced aircraft separations:** Introduce new procedures whereby under certain crosswind conditions it may not be necessary to apply wake vortex minima. Introduce fixed reduced separations based on wake vortex prediction.. Introduce Constant time separations independent of crosswind conditions and wake vortex existence are introduced. **Parallel runway operations:** Reduce dependencies between runways by implementing more accurate surveillance techniques and controller tools as well as advanced procedures. **Foreign Object Detection:** Implement system providing the controller with information on Foreign Object Debris o movement area. **Dynamic surface navigation for aircraft:** Introduce guidance assistance to airport vehicle drivers through the pro airport moving map showing taxiways, runways, fixed obstacles, and their own mobile position.; also introduce too vehicle drivers Traffic Situational Awareness (TSA) through the provision of information regarding the surrounding and airport vehicles) during taxi and runway operations displaying it in the vehicle driver's cockpit. Introduce Guida on the Airport Surface using CDTI moving map display including dynamic traffic context information and status of r obstacles, route to runway or stand with ground signs (stop bars, centreline lights, etc.) are triggered automatically	Possible wake encounters as crosswind wake predictions can be inaccurate due to constantly changing weather conditions	Develop Guidance Material for best practices on flight deck procedures for runway crossing, while taxiing and the communication with the air traffic controller regarding aerodrome signage, markings and lighting. Validate the use of weather information to improve predictability and reliability of managing the traffic on the airport surface (e.g. meteorological information in respect of aircraft de-icing and prediction of thunderstorm). Assess the feasibility of using meteorological information to predict braking performance on surface airport. Develop and validate requirements for improved information provision to aircraft and vehicles of their position, routing and also information regarding taxiways, runways and fixed obstacles. Develop and validate procedures to improve separation through exploitation of Wake Vortex prediction for arrivals and departures. Consolidate approval of VFR procedures for IFR traffic operations.
SESAR LoC#10 Level 2 - Airport Throughput, Safety and Environment	2013	**Automated Surface Movement Planning and Routing:** Introduce Automated Assistance to Controller for Surface Movement Planning and Routing. **Airport Safety Nets (Pilot, Controllers and Vehicles):** Introduce tools to detect potential conflicts/incursions involving mobiles (and stationary traffic) on runways, taxiways and in the apron/stand/gate areas providing alarms to controllers, pilots, and vehicle drivers together with potential resolution advice. **BTV Via Datalink:** Deploy automated braking to vacate at a pre-selected runway exit coordinated with ground ATC through Datalink and based on BTV avionics that controls the deceleration of the aircraft to a fixed speed at the selected exit. **Improved LV Operations (GBAS, EVS):** Introduce GNSS / GBAS for precision approaches and EVS (Enhanced Vision System) to support final approach and surface operation Low Visibility Conditions **Enhanced Navigation for Airport Vehicles:** Introduce tools that increase the airport vehicle drivers Traffic Situational Awareness (TSA) through the provision of information regarding the dynamic traffic context including status of runways , taxiways and obstacles.	Possible wake encounters if ground sensors misread location of wake, or confuse jetwash for wake vortices	Develop and validate procedures to improve safety of operation on the airport surface through the use of alert and advisories presented to various actors (e.g. pilot, controller airport vehicle drivers). Develop and validate coordination/integration of airside operation with airport ATC operation to improve airport surface operations. Develop and validate traffic management on airport surface, including taxi routing. Develop and validate pre-selected runway exit coordination between airport ATC and aircraft, exploiting Brake To Vacate and Datalink full functionalities. Further maximize runway throughput through the development and validation of ground based wake vortex real time detection. Develop and validate precision approach and landing based on GBAS (and SBAS where appropriate for regional airfields) and/or EVS capability, maintaining operations under adverse conditions, including low visibility.

Appendix B

		Operational Improvements With Potential Wake Turbulence and Data Link Implications		
JPDO OI-0309 Use Optimized Profile Descent	2010	An Optimized Profile Descent (OPD), in its optimal form, is an arrival where aircraft is cleared to descend from cruise altitude to final approach using the most economical power setting at all times. Based on published arrival procedures at final approach, aircraft begin a continuous rate of descent using a window of predetermined height and distance. Thrust may be added to permit a safe, stabilized approach-speed and flap-configuration down a glide slope to the runway. As an initial step, conventional or Area Navigation (RNAV) Standard Terminal Automation Replacement Systems (STARs) can be defined with vertical constraints incorporated as crossing restrictions. Careful selection of constraints allows most aircraft Flight Management System (FMS) Visual Navigation (VNAV) systems to calculate a continuously descending flight path, although the flight path may require a slightly non-optimal power setting. In addition, static spacing guidance, based on weight class and winds, as well as speed commands for descending traffic, allows STAR to be used with minimal impact to airport throughput, although with a slight additional environmental penalty compared to the ideal STAR OPD. At busy airp	Possible wake encounters as flights on higher FL descend in front of flights on lower FL on same ground track	None
JPDO OI-0311 Increased Capacity and Efficiency Using RNAV and RNP	2010	Both Area Navigation (RNAV) and Required Navigational Performance (RNP) will enable more efficient aircraft trajectories. RNAV and RNP combined with airspace changes, increase airspace efficiency and capacity. RNAV and RNP will permit the flexibility of point-to-point operations and allow for the development of routes, procedures, and approaches that are more efficient and free from the constraints and inefficiencies of the ground-based Navigational Aids (NAVAIDS). This capability can also be combined with an Instrument Landing System (ILS), to improve the transition onto an ILS final approach and to provide a guided missed approach. Consequently, RNAV and RNP will enable safe and efficient procedures and airspace that address the complexities of the terminal operation through repeatable and predictable navigation. These will include the ability to implement curved path procedures that can address terrain, and noise-sensitive and/or special-use airspace. Terminal and en route	Possible wake encounters as RNAV allows for more precise flight corridors for flights in trail	•OI-0309: Use Optimized Profile Descent •EN-1020: Non-Cooperative Surveillance Legacy ASR-8 •EN-1021: Non-Cooperative Surveillance - Legacy ASR-9 •EN-1022: Air Surveillance - Legacy ASR-11 •EN-1144: Ground Based Navigation System (GBNS) - ILS Legacy •EN-0201: Avionics - RNP •PI-0120: PNT Performance Requirements •PI-0014: Aircraft Equipage Implementation Policy •PI-0008: General Aviation Benefits
JPDO OI-0316 Enhanced Visual Separation for Successive Approaches	2012	This Operational Improvement (OI) increases runway throughput in low ceiling and visibility conditions by allowing an aircraft to augment out-the-window visual separation information with onboard traffic display information on a visual approach. After establishing initial visual contact, the aircraft can continue a visual approach while traversing a light cloud layer, using the onboard traffic display briefly to augment situational awareness until visual contact is reestablished. The flight crew is responsible for safe wake separation during augmented visual approaches. This OI enables Visual Meteorological Condition (VMC) runway capacity levels to be achieved in	Possible wake encounters as flight crew is responsible for safe separation in reduced VMC that used to be IMC	•EN-1065: Ground Based Navigation System (GBNS) - Lighting Systems (Legacy) •EN-0200: Avionics - Traffic Display Level 2 •PI-0014: Aircraft Equipage Implementation Policy
JPDO OI-0325 Time-Based Metering Using RNP and RNAV Route Assignments	2014	Area Navigation (RNAV), Required Navigational Performance (RNP), and time-based metering provide efficient use of runways and airspace in high-density airport environments. RNAV and RNP provide users with more efficient and consistent arrival and departure routings and fuel-efficient operations. Metering automation will manage the flow of aircraft to meter fixes, thus permitting efficient use of runways and airspace. Building on increased capacity in terminal separation procedures, time-based metering will facilitate efficient arrival and departure flows. This will be accomplished using RNAV and RNP routings, coupled with meter fix crossing times. These will be issued to the flight crew via voice or data communications for input into the Flight Management System (FMS). Arrivals will be issued a RNAV routing to link arrival procedures to designated runways. Aircraft will navigate from en route to approach and landing phases with minimal adjustments (i.e., speed adjustments) or changes to flight trajectories by Air Navigation Service Provider (ANSP). Departures will be issued clearances that specify departure routings linked from RNAV routes into the	Possible wake encounters as spacing is based on time, not distance and controllers try to keep schedule	•OI-0309: Use Optimized Profile Descent •EN-0007: High-Density Arrival/Departure Detail Operational Concept •EN-0110: Trajectory Negotiation - Level 2 En Route Time-Based Metering •EN-1220: Air - Ground Data Exchange – Advisory Services – En Route Group 1
JPDO OI-0326 Airborne Merging and Spacing - Single Runway	2014	Arriving or departing aircraft to/from single runways are instructed to achieve and maintain a given spacing in time or distance from a designated lead aircraft as defined by an Air Navigation Service Provider (ANSP) clearance. Onboard displays and automation support the aircraft conducting the merging and spacing procedure to enable accurate adherence to the required spacing. Flight crews are responsible for maintaining safe and efficient spacing from the lead aircraft. Responsibility for separation from all other aircraft remains with the ANSP. Assigned spacing may include a gap to allow for an intervening departure between subsequent arrivals. Mixed-equipage operations are supported; a spacing-capable aircraft can perform airborne spacing behind a non-capable aircraft as long as it is transmitting cooperative surveillance information. This Operational Improvement (OI) includes multiple streams merging to a single runway and includes development of ANSP capability and	Possible wake encounters as flight crew is responsible for safe separation and takeoff/landing occurring on same runway	•OI-0316: Enhanced Visual Separation for Successive Approaches •OI-0325: Time-Based Metering Using RNP and RNAV Route Assignments •EN-1400: Cooperative Surveillance - ADS-B IN/TIS-B/FIS-B Level 1 •EN-0031: Avionics - Airborne Merging and Spacing •PI-0120: PNT Performance Requirements •PI-0004: ATM Automation Development, Performance and Interoperability Standards •PI-0077: High Density Operations - Flight Prioritization

JPDO OI-0329 Airborne Merging and Spacing with OPD	2015	Fuel consumption and noise on approaches are reduced while maintaining throughput in heavy traffic through Optimized Profile Descent (OPD) combined with airborne merging and spacing in moderate-to-heavy traffic. OPD is also known as Continuous Descent Arrival (CDA). This Operational Improvement (OI) requires airborne merging and spacing capability as well as airborne guidance to perform optimized OPD while staying within assigned lateral and vertical airspace corridor limits. This OI is complementary to OI-0325 which delivers the aircraft at top of descent with spacing to initiate a successful OPD. This OI improves individual aircraft fuel reduction through onboard energy guidance, and enables reduced spacing buffers and hence increased throughput from precision airborne spacing. Mixed equipage can be supported within a single arrival stream, with some aircraft self-spacing and other aircraft managed by Air Navigation Service Provider (ANSP). This OI requires an Implementation Decision to determine appropriate trajectory restrictions laterally, vertically, and in time, based on trade off between aircraft performance/efficiency versus optimal use of airspace, including weather	Possible wake encounters as flights on higher FL descend in front of flights on lower FL on same ground track	•OI-0326: Airborne Merging and Spacing - Single Runway •EN-2680: Methodologies and Algorithms for Weather Assimilation into Decision-Making - Level 1 •EN-2010: NextGen 4D Weather Cube Information - Level 1 Initial Operating Capability •EN-6008: Avionics to Reduce Environmental Impacts - Level 1 •PI-0077: High Density Operations - Flight Prioritization
JPDO OI-0330 Time-Based and Metered Routes with OPD	2016	Time-based and metered Required Navigational Performance (RNP) routes are flown. Where practical, arrival routes support Optimized Profile Descent (OPD) operations under moderate to heavy traffic conditions, with ground-based automation providing conflict-free, time-based metering solutions over the entire OPD trajectory to the runway. OPD is also known as Continuous Descent Arrival, or CDA. This enables aircraft with minimal equipage to perform OPDs. This Operational Improvement (OI) requires an Implementation Decision to determine the most effective method for negotiating time-based route and an Implementation Decision to determine how restricted the trajectory will be laterally, vertically, and in time, based on trade off between aircraft	Possible wake encounters as flights on higher FL descend in front of flights on lower FL on same ground track	•OI-0309: Use Optimized Profile Descent •OI-0311: Increased Capacity and Efficiency Using RNAV and RNP •OI-0325: Time-Based Metering Using RNP and RNAV Route Assignments •EN-0007: High-Density Arrival/Departure Detail Operational Concept •EN-0034: Trajectory Management Decision Support - Level 1 •EN-0110: Trajectory Negotiation - Level 2 En Route Time-Based Metering •PI-0120: PNT Performance Requirements
JPDO OI-0337 Flow Corridors - Level 1 Static	2017	High density En Route static flow corridors accommodate aircraft that are capable of self-separation traveling on similar routes, achieving high traffic throughput by minimizing complexity and crossing traffic. When there are large numbers of suitably equipped aircraft traveling in the same direction on similar routes, the Air Navigation Service Provider (ANSP) may implement flow corridors, which consist of long tubes or "bundles" of parallel lanes. Aircraft within the corridors are responsible for separation from other aircraft (that is, the corridors are self-separation airspace), and use onboard separation capabilities for entering and exiting the corridors, as well as for overtaking, all of which are accomplished with well-defined procedures to ensure safety. Flow corridors efficiently handle very high traffic densities, increasing throughput and increasing the airspace available to other traffic. Flow corridors are procedurally separated from other traffic not in the corridor. Procedures exist to allow aircraft to safely exit the corridor in the event of a declared emergency.	Possible wake encounters as crews are responsible for separation with very high traffic densities in flow corridors	•OI-0346: Improved Management of Airspace for Special Use •EN-1400: Cooperative Surveillance - ADS-B IN/TIS-B/FIS-B Level 1 •EN-2680: Methodologies and Algorithms for Weather Assimilation into Decision-Making - Level 1 •EN-0033: Airspace/Capacity/Flow Contingency Management Decision Support - Level 1 •EN-0034: Trajectory Management Decision Support - Level 1 •EN-0035: Separation Management Decision Support - Level 1 •EN-0207: Consolidated Aeronautical Information - Level 2 Integrated Status •EN-2010: NextGen 4D Weather Cube Information - Level 1 Initial Operating Capability •EN-0106: Avionics - Delegated Separation Acknowledgement Information •EN-1209: Air - Ground Data Exchange – Clearance and Instructions Services – En Route Group 1 •PI-0065: Airspace Regulatory Changes - Global Harmonization
JPDO OI-0347 Air Traffic Control Surveillance Service in Non-Radar Areas (ADS-B)	2012	The air navigation service provider (ANSP) automation uses automatic dependent surveillance broadcast in non-radar airspace to provide reduced separation and flight following. Improved surveillance enables ANSP to use radar-like separation standards and services. The Automatic Dependent Surveillance - Broadcast (ADS-B) positional reports are incorporated into the surveillance data processing systems and displayed to the controller. This allows ANSP to apply lower separation minima allowing for improved access and more efficient flight paths.	Possible wake encounters due to reduced separation in areas with no radar coverage	•EN-1023: Cooperative Surveillance - ADS-B Out Level 1 •PI-0120: PNT Performance Requirements •PI-0022: GPS Policy to Support Civil NextGen PNT Requirements
JPDO OI-0353 and FAA OI-102108 Reduced Oceanic Separation - Altitude Change Pair-Wise Maneuvers	2014	Availability of user preferred oceanic profiles for capable aircraft is increased through pair-wise altitude change maneuvers with ground-based separation responsibility. Aircraft-to-aircraft oceanic longitudinal and lateral spacing is reduced to 10 miles during altitude change maneuver. Pair-wise maneuvers (in-trail climbs and descents) are enabled through the use of improved oceanic cooperative surveillance information. This may be implemented using either 1) Automatic Dependent Surveillance-Contract (ADS-C) and satellite-based communication, or 2) Automatic Dependent Surveillance-Broadcast (ADS-B), on-board displays and algorithms, and satellite-based communications.	Possible wake encounters due to reduced separation and higher capacity	JPDO Enablers: •OI-0344: Reduced Oceanic Separation - 30 Miles for Pair-Wise Maneuvers •EN-0202: Avionics - Traffic Display Level 1 Cockpit Display of Traffic Information (CDTI) •EN-1750: Radio Data Link: Legacy Satcom •EN-0201: Avionics - RNP •EN-0035: Separation Management Decision Support - Level 1 •EN-0106: Avionics - Delegated Separation Acknowledgement Information •EN-0168: In-Trail Oceanic Separation Using ADS-C •EN-0169: In-Trail Oceanic Separation Using ADS-B •PI-0012: Surveillance - Global Harmonization •PI-0022: GPS Policy to Support Civil NextGen PNT Requirements FAA Predecessors: OI-102105 Current Oceanic Separation
JPDO OI-0355 and FAA OI-102118 Delegated Responsibility for Horizontal Separation	2015	Enhanced surveillance and new procedures enable the Air Navigation Service Provider (ANSP) to delegate aircraft-to-aircraft separation. Improved display avionics and broadcast positional data provide detailed traffic situational awareness to the flight deck. When authorized by the controller, pilots will implement delegated separation between equipped aircraft using established procedures. Broadcast surveillance sources and improved avionics capabilities provide ANSP and the flight deck with accurate position and trajectory data. Aircraft that are equipped to receive the broadcasts and have the associated displays, avionics, and crew training are authorized to perform delegated separation when recommended by the controller. Delegated separation operations include separation authority for a specific maneuver (e.g., in-trail arrival). For aircraft not delegated separation authority, ANSP automation still manages separation. Aircraft perfiorming delegated separation procedures separate themselves from one another.	Possible wake encounters as flight deck responsible for separation	JPDO Enablers: •EN-1017: Non-Cooperative Surveillance Legacy LRR •EN-0016: Separation/Trajectory Management Detail Operational Concept •EN-1023: Cooperative Surveillance - ADS-B Out Level 1 •EN-1400: Cooperative Surveillance - ADS-B IN/TIS-B/FIS-B Level 1 •EN-2680: Methodologies and Algorithms for Weather Assimilation into Decision-Making - Level 1 •EN-0031: Avionics - Airborne Merging and Spacing •EN-0035: Separation Management Decision Support - Level 1 •EN-2010: NextGen 4-D Weather Cube Information - Level 1 Initial Operating Capability •PI-0120: PNT Performance Requirements FAA Predecessors: •OI-102117 Reduce Horizontal Separation Standards -3 Miles

FAA OI-102123 ADS-B Separation	2009	The air navigation service provider (ANSP) automation uses aircraft dependent surveillance broadcast in non-radar airspace to provide reduced separation and flight following. Improved surveillance enables ANSP to use radar-like separation standards and services.	Possible wake encounters due to reduced separation in trail	•FAA OI-102301 Current Aircraft To Airspace Separation
FAA OI-102122 Use Aircraft Provided Intent Data to Improve Conflict Resolution	2012	Air navigation service provider (ANSP) automation uses aircraft position broadcast reports, velocity, and both short- and long-term intent data to provide tactical and strategic separation services and more efficient flows. Aircraft exchange of short-term intent data enables aircraft-to-aircraft delegated separation authority when operationally advantageous.	Possible wake encounters as separation duties delegated to flight deck	•FAA OI-102123 ADS-B Separation •FAA OI-102129 Current Terminal Separation
FAA OI-108203 Expand use of RNAV/RNP Procedures	2009	Provide airspace design changes to increase access, efficiency and capacity utilization by developing and publishing Area Navigation (RNA) and RNAV Required Navigation Performance (RNP) routings in the NAS. RNAV/RNP provides increased routing to allow more efficient routes of flight and merging of traffic, increased opportunities to manage flow with more defined and closely separated paths. Allows flows that are currently co-	Possible wake encounters due to more closely spaced traffic flows	•FAA OI-108201 Current Airspace Management
FAA OI-108209 Increase Capacity and Efficiency Using Area Navigation (RNAV) and Required Navigation Performance (RNP)	2010	Both RNAV and RNP will enable more efficient aircraft trajectories. RNAV and RNP combined with airspace changes, increase airspace efficiency and capacity.	Possible wake encounters due to increased capacity	•FAA OI-108201 Current Airspace Management
FAA OI-107107 Ground Based Augmentation System (GBAS) Precision	2013	Global Positioning System (GPS)/GBAS support precision approaches to Category I and eventually Category II/III minimums, for properly equipped runways and aircraft. GBAS can support approach minimums at airports with fewer restrictions to surface movement, and offers the potential for curved precision approaches. GBAS also can support high-integrity surface movement requirements.	Possible wake encounters if in trail aircraft come in contact with very wide wake due to curved approach	•FAA OI-107104 Current Precision Approach, Landing and Departure
FAA OI-105207 Full Collaborative Decision Making	2017	Timely, effective, and informed decision-making based on shared situational awareness is achieved through advanced communication and information sharing systems. Decision-makers request information when needed, publish information as appropriate, and use subscription services to automatically receive desired information through the net-centric infrastructure service. Decisions are made with an awareness of system-wide implications,	Possible wake encounters as more authority given to flight deck	•FAA OI-105205 Enhance Collaborative Decision Making •FAA OI-105208 Traffic Management Initiatives with Flight Specific Trajectories
FAA OI-104105 Expanded Conflict Resolution via Data Communication	2015	In trajectory-based airspace, decision support tools support the air navigation service provider (ANSP) by identifying conflicts/complexity/density conditions and providing alternatives to resolve the conditions. These alternatives include proposed trajectories that are exchanged with the operator via data communications. This allows multi-step solutions that are not subject to constraints imposed by voice.	Possible wake encounters as individual flights are rerouted to avoid conflicts	•FAA OI-104103 Current Conflict Probe
FAA OI-104122 Integrated Arrival/Departure Airspace Management	2012	New airspace design takes advantage of expanded use of terminal procedures and separation standards. This is particularly applicable in major metropolitan areas supporting multiple high-volume airports. This increases aircraft flow and introduces additional routes and flexibility to reduce delays. ANSP decision support tools are instrumental in scheduling and staging arrivals and departures based on airport demand, aircraft capabilities, and	Possible wake encounters as more flights arrive/depart to reduce delays	None
SESAR LoC#2 Level 1 – Moving from airspace to trajectory based operations	2007	**Uniformed application of 7 airspace classes <= FL 195:** Uniformed application of the rules associated with the 7 ICAO airspace classification at or below FL 195. **Optimum trajectories:** Implement optimum trajectories in defined airspace at particular times. Further Improvements to Route Network and airspace: Implement airspace structure (Route/sector) across airspace boundary to better align route and sectors with traffic flow and to accommodate more efficiently the various type of airspace users. **Enhanced ASM-ATFCM coordination:** Deploy collaborative activities to optimise the utilisation of the available capacity based on the continuous assessment of network impact of the expected airspace allocations. Deploy systems and procedures allowing AMC and other parties to design, allocate, open and close military airspace structures on the day of operations. **Automatic Support for dynamic sectorisation:** Deploy dynamic management of airspace/route structures based on pre-defined sector sizing and constraint management in order to pre-deconflict traffic and optimise use of controller work force. MIL flight planning and transit system (aeronautical data): Deploy filing of flight plans in a OAT/GAT and all Operational Air Traffic flights for which a filed flight plan is required and the provision of all OAT-I aeronautical information required for the ATM systems support of military aerial operations. Deploy a pan-Europea Service (OATTS), which connects national structures and arrangements to form a flexible system facilitating OAT- **Enhanced Terminal design using P-RNAV:** Deploy RNAV routes to facilitate improvements in the efficiency and Terminal Airspace through the provision of increased flexibility and reduced route separation. Includes also the dep friendly procedures like steep and curved approaches. Steep final approaches can be supported by Approach Pro Guidance (APV) with different Minima decision (from LNAV/VNAV to LPV or RNPx).	Possible wake encounters as trajectories, airspace and descent profiles are changed	Develop and validate the Airspace Allocation and Usage concepts by formalisation and modelling of Traffic Demand and Capacity Balancing (DCB) and Airspace Management (ASM) scenarios. Develop and validate the interaction of different actors for different time horizon and scenarios. Assess system support needed for optimising the interactions between actors and processes. Develop airspace design guidance material for TMA merging techniques based on P-RNAV. Identify divergences of flight planning provisions & procedures for military flights. Elaborate requirements on civil-military flight plan interoperability related to the SESAR concept of Military Mission Trajectory and its impact on military flight planning needs. Analyse convergence of the military flight planning with the ICAO Future Flight Plan. Determine Flight plan security requirements for State aircraft flights in the SESAR environment, in relation to those for scheduled, non-scheduled and private flights. Identify Military needs in terms of validated aeronautical data not covered in ICAO AIP. Assess applicability of civil standards (e.g. AIXM) for military aeronautical data mechanisms criteria and structures to enable the accommodation within EATMN of military aerial operations conducted as OAT-IFR in a way that improves ATM efficiency and cost effectiveness, reducing fragmentation and duplication of ATM infrastructure. This includes: development of new simulation systems that reflect characteristic military en-route and airspace requirements, harmonisation of military OAT flight plan and the development and validation of solutions to promote the compatibility of military aeronautical data with civil standards (including security aspects). A Par European OATTS also entails the need to identify standardised and performance-based CNS requirements interoperable with civil requirements. Develop and validate simulation tools to support Airspace Reservation dimensions and locations.
SESAR LoC#5 Level 1 – Managing business trajectory in real time	2011	**Cruise-Climb Techniques:** Deploy coordination of optimised En-Route Cruise-Climb setting between pilot and controllers so as to allow aircraft to climb as weight is decreased though fuel burn. This results in more optimised trajectories.	Possible wake encounters as aircraft climb in front of other aircraft on same ground track	Determine the modifications necessary to ground systems (and potentially airborne systems) to enable the use of cruise-climb techniques.
SESAR LoC#8 Level 1 - New separation modes	2010	**ATSAW in flight and on surface:** Deploy Airborne Traffic Situation Awareness (ATSAW) in the cockpit by displaying surrounding traffic while airborne and on the airport surface. **ATSA-ITP:** Deploy Airborne Traffic Situation Awareness In Trail Procedure (ATSA-ITP) in Oceanic Airspace. **Manual ASAS S&M:** Deploy ASAS Manually Controlled Sequencing & Merging operations in applicable TMAs, requiring the pilot to follow the speed commands manually.	Possible wake encounters as merging and spacing speeds responsibilities given to flight deck	Assess benefits of Manual S&M for different category of TMAs in the ECAC Area. Analyse its impact on runway throughput of relative Time Based Separation (ASAS) vs. Absolute Time Based Separation (RTA) Vs Absolute Time based separation (RTA) followed by relative timebased separation (ASPA S&M). Analyse and compare the use of single or multiple merging points for sequencing arrivals to the airport. Assess benefits of ASEP ITP over ASPA-ITP. Study how UAS Operations may be integrated with other managed air traffic in an ASAS Separation environment.

SESAR LoC#10 Level 1 - Airport Throughput, Safety and Environment	2009	**Improved Low Visibility Procedure:** Introduce improved operations in low visibility conditions through enhanced ATC Procedures collaboratively developed at applicable airports involving in particular an harmonised application across airports and the use of optimised separation criteria. Deploy final approaches with vertical guidance procedures to enable Cat I like operations. **ATSA-VSA:** Introduce enhanced Visual Separation on Approach (ATSA-VSA), to assist crews to achieve the visual acquisition of the preceding aircraft and then to maintain visual separation from this aircraft. **Reduced aircraft separations:** Introduce new procedures whereby under certain crosswind conditions it may not be necessary to apply wake vortex minima. Introduce fixed reduced separations based on wake vortex prediction. Introduce Constant time separations independent of crosswind conditions and wake vortex existence are introduced. **Parallel runway operations:** Reduce dependencies between runways by implementing more accurate surveillance techniques and controller tools as well as advanced procedures. **Foreign Object Detection:** Implement system providing the controller with information on Foreign Object Debris c movement area. **Dynamic surface navigation for aircraft:** Introduce guidance assistance to airport vehicle drivers through the pro moving map showing taxiways, runways, fixed obstacles, and their own mobile position.; also introduce tools that vehicle drivers Traffic Situational Awareness (TSA) through the provision of information regarding the surrounding and airport vehicles) during taxi and runway operations displaying it in the vehicle driver's cockpit. Introduce Guida on the Airport Surface using CDTI moving map display including dynamic traffic context information and status of r obstacles, route to runway or stand with ground signs (stop bars, centreline lights, etc.) are triggered automatically issued by ATC. **Improved surface markings:** Introduce improvements in lay-out of taxiway and signalling of location of runways v terminal/apron, including better placed runway crossings, use of additional perimeter taxiways, avoiding alignment entries or exits to prevent runway incursions. **Time Based separation for arrivals:** Introduce time based separation procedures for arrivals	Possible wake encounters during: visual conditions that would otherwise be IMC, reduced separation not applying wake separation minima,	Develop Guidance Material for best practices on flight deck procedures for runway crossing, while taxiing and the communication with the air traffic controller regarding aerodrome signage, markings and lighting. Validate the use of weather information to improve predictability and reliability of managing the traffic on the airport surface (e.g. meteorological information in respect of aircraft de-icing and prediction of thunderstorm). Assess the feasibility of using meteorological information to predict braking performance on surface airport. Develop and validate requirements for improved information provision to aircraft and vehicles of their position, routing and also information regarding taxiways, runways and fixed obstacles. Develop and validate procedures to improve separation through exploitation of Wake Vortex prediction for arrivals and departures. Consolidate approval of VFR procedures for IFR traffic operations.