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MCNA Investment Analysis

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1 Investment Analysis Overview

1.1 Background

The Mobile Communication Network Architecture (MCNA) encompasses the aggregate of all voice and data communication capabilities in support of communications, navigation and surveillance (CNS) services for Air Traffic Management (ATM) operations. Like System Wide Information Management (SWIM), MCNA is a key enabling technology for transformation of the National Airspace System (NAS) towards Network Centric Operations (NCO). The MCNA effort represents a System of Systems Engineering (SoSE) based evaluation of MCNA. The specific focus of this effort is the evaluation of the requirements, architecture and associated transition plan necessary to assure that the air-ground and air-air communications capabilities will support of the needs of SWIM-enabled applications (SEA) to provide NCO. The goal of this effort is to develop an integrated SoSE approach and technology development roadmap that will provide guidance for ongoing and planned NASA Glenn Research Center (GRC) and FAA research activities including NASA GRC's Advanced CNS Architectures and System Technologies (ACAST) Project and NASA Airspace Systems Program's proposed initiative for the Transformation of the NAS (TNAS).

The MCNA nomenclature was introduced within the SOW of this GCNSS II contract task. As such, it is a common misconception that MCNA refers solely to the "vision" of mobile communications capabilities intended to support the most demanding SWIM-enabled applications including cockpit integration. In fact, all communications to mobile networks in the NAS, such as1090ES, ACARS and FANS are all existing components of the MCNA. In time, these components will likely be augmented by ATN over VDLm2 and VDLm3, UAT and broadband SatCom. Eventually, the NAS will be supported by the suite of enhanced datalink services recommended by the Future Communication System (FCS). The key aspect of MCNA is that it extends voice and data communications to the aircraft during all phases of flight. **Figure 1** illustrates how MCNA fits in the Common Data Transport (CDT) portion of the SWIM and thereby supports Network Centric Operations (NCO).

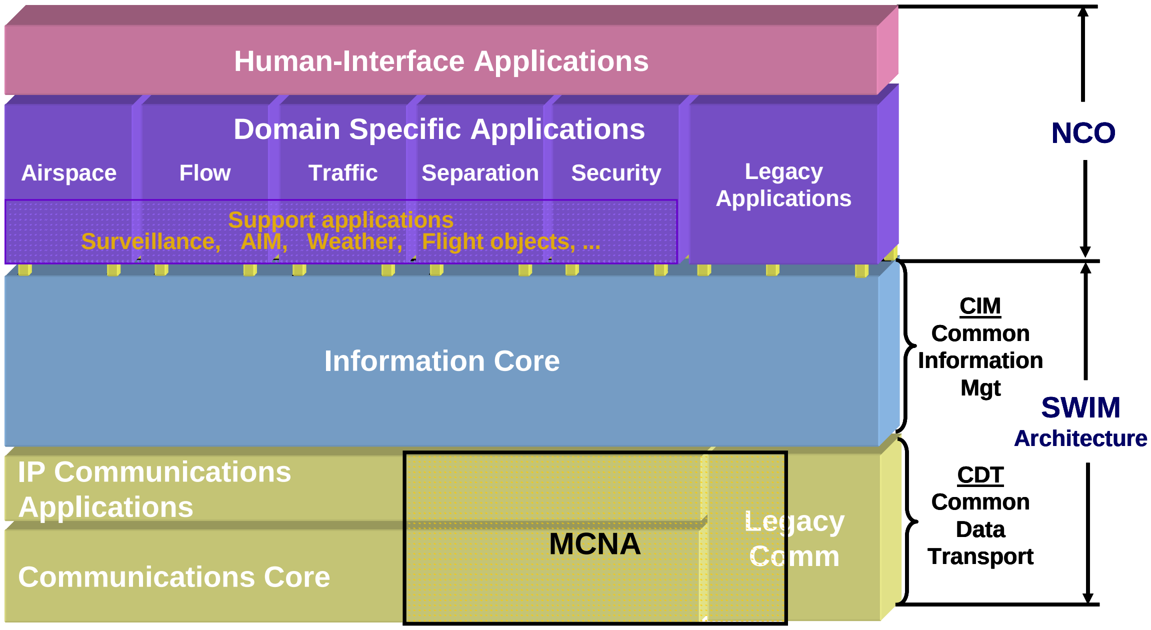

Figure 1: Relationship of MCNA to SWIM and NCO.

While the goal of MCNA is to extend the reach of SWIM information nodes to the aircraft this does not mean even in the MCNA visions that all communications to and from the aircraft will use SWIM as means of information exchanges. Basically, SWIM will enable the ubiquitous sharing of information between applications. The sharing of information is a result of integrating applications via common mechanisms. SWIM will support multiple integration frameworks (i.e., .NET, J2EE, CORBA, Web Services) and platforms (i.e., Windows, Linux, etc.) for flexibility and evolutionary reasons. The SWIM environment will enable both anticipated and non-anticipated users of information, with anticipated users defined primarily at build-time and unanticipated users defined primarily at run-time. But the fact that the SWIM environment will support and even promote ubiquitous information sharing doesn't mean that all applications should exchange all information with all other applications. Only authenticated and authorized users of information will be allowed to access it, as determined by the "owner" of the information source.

In early SWIM development and deployment spirals, existing information exchange mechanisms will continue to coexist alongside the new SWIM mechanisms. This will be done for both reliability/availability and backwards compatibility reasons. In some cases, it may make sense to retain information exchange mechanisms outside of SWIM beyond the initial spirals. The desirability of these out-of-band information exchange mechanisms will, in general, be greater for application groups that are tightly coupled, synchronous, unlikely to change and unlikely to be expanded. But this decision will be decided on a case-by-case basis and will require a thorough analysis. In most instances the information exchange mechanisms offered by SWIM will be sufficient.

1.2 MCNA Cost/Benefit Analysis SIR Requirements

The MCNA Screening Information Request specifies the following statement of work from the MCNA cost benefit analysis:

2.6.1. Conduct a high-level cost/benefit analysis for each total communications performance level in selected NAS environment(s) or operational scenario(s) to establish the rationale for future investments.

Our response: Communication services were assessed against their ability to deliver 17 scenarios assessed as high value scenarios. See section 5.

2.6.1.1. For scenarios not selected for cost/benefit analysis, provide a qualitative assessment of the relative costs and benefits (compared to the selected scenarios) that lead to their de-selection.

Our response: 35 scenarios were evaluated against a set of 5 benefits criteria and 4 risk criteria. (The risk criteria are intended to be a proxy for cost). A qualitative evaluation of the 35 scenarios against risk and benefit led to the selection of 8 primary scenarios and 4 secondary scenarios. A further analysis of the scenarios added 5 more high payoff/high risk scenarios to the set of scenarios that would be evaluated against the communication classes. See Section 4.

2.6.2. Conduct high-level cost/benefit analyses to determine those enabling technologies and certification methodologies with most return on investment for development through technology readiness level (TRL) 6.

Our response: A set of enabling technologies and certification technologies were identified and evaluated for their cost-benefit risk in terms of development through technology readiness level (TRL) 6.

- Common IP Stack
- SWIM Messaging
- System certification process
- RCP process independent of an individual candidate link

2.6.3. Estimate the value contributed by the communications and/or network technologies to the overall benefit of each operational enhancement (by individual technology, when possible, or by clusters of complementary technologies), and also the benefits assessments of operational enhancements from the GCNSS and NASA VAMS contracts and from other sources as may be available.

Our response: NAS-VAMS and GCNSS documentation were excerpted for their value information relative to MCNA. See section 7.

In addition, an evaluation of the current 2005 MCNA implementation, and a projected 2015 and 2025 implementation of MCNA was evaluated against its ability to deliver the 17 high value scenarios. As a point of comparison, the FAA Target System Description was also evaluated in terms of its ability to deliver the 17 high value scenarios. See section 7.

1.3 Document Organization

Section 1 provides the background and purpose of the MCNA Investment Analysis task in relation to the other MCNA tasks and the GCNSS II program overall.

Section 2 describes the primary value propositions for SWIM and MCNA.

Section 3 describes the overall investment analysis methodology for MCNA.

Section 4 describes the scenarios considered, the evaluation and down-select of the scenarios, and an in-depth description of the 8 primary and 4 secondary scenarios selected.

Section 5 describes the evaluation of the communication services.

Section 6 defines an approach for specifying an MCNA strategy and identifies and evaluates MCNA strategies for 2005, 2015, and 2025. For comparison purposes, an MCNA strategy based on the Target System Description is also identified and evaluated. A sensitivity analysis is presented for the 2015 MCNA strategy.

Section 7 provides a survey of the potential economic benefits identified in other studies of applying MCNA technology to a variety of shortfalls in the NAS.

Section 8 provides a high level cost-benefit analysis for key enabling technologies to enable the MCNA vision.

2 The Value Propositions for SWIM and MCNA

2.1 The Value of SWIM

In the GCNSS investment analysis, a set of shortfalls were associated with FAA's current approach to information management. After identifying these shortfalls and considering the scope of SWIM, it was determined that the primary benefit of SWIM is to develop, deploy and maintain applications at a much lower cost than today and increase NAS agility. SWIM will also reduce manual data sharing, increase common situational awareness, and improve metrics, but these benefits will be indirect to the initial implementation of SWIM, which is focused on implementing a set of core services and a set of information migrations that will publish data to the SWIM environment.

SWIM will accomplish its primary objective by implementing a platform approach to information management. A platform approach seeks commonality across a product line. For instance, in the automobile industry, Toyota used a platform approach to leverage its Camry and used it as the basis for designing and manufacturing the Lexus. In the FAA's case, the product line is the applications and systems the FAA uses to operate the NAS. The commonality it seeks is how it manages information for those applications.

For the FAA, instead of each application designing and implementing its own information management approach, SWIM will take a system-wide approach. It will primarily achieve this in two ways:

1. Instead of using custom interfaces to interface two applications, an application will publish its data to the SWIM environment to make its data available to any authorized subscriber.

2. Instead of each application building its own private network to share data, SWIM implements a layer on top of FTI similar to the world-wide web on the internet. This provides a virtual network to share data across the NAS.

Over the course of the SWIM program, it was determined that virtually any new application can be built without SWIM by building custom interfaces between applications and by building a purpose-built private network to share information. Over the long term this approach results in a tight coupling of applications. It is not scalable and results in higher costs than necessary.

2.2 The Value of MCNA

MCNA is different than SWIM in terms of its value proposition. The value that MCNA delivers is determined by the capability of the links and the applications that are implemented that take advantage of those links. In a system of systems sense, the MCNA looks to meet the air-ground communications requirements a specific application with the most appropriate link or links available at the time. While any one individual link can provide only a specific combination of latency, bandwidth and reliability, a network of communications links can provide a variety of latencies, bandwidths, availability, and quality of service more closely matched to the requirements and preferences of each specific application. In turn, these applications then deliver five primary benefits:

- Increased Airspace Capacity: Increase the number of airplanes that can travel in a given sector at any moment in time. (Note that increasing airspace capacity by definition increases controller productivity.)
- Increased Airport Capacity: Increase the number of operations that an airport can handle in a given amount of time. (Note that increasing airport capacity by definition increases controller productivity.)
- Increased Flight Path Efficiency: Increase the efficiency of the aircraft's flight route to save fuel and flying time.
- Increased Safety: Reduce the number of accidents, injuries and incidents.
- Increased Security: Increase the barriers to intrusions to the air traffic system by both intentional and unintentional acts.

As MCNA evolves, these factors, which drive the value of the scenarios, must be balanced against the cost and risk of fielding the links and implementing the associated operational scenarios.

Ideally, MCNA strategies would be assessed based on benefits more directly delivered by the communications benefits of MCNA. For instance, MCNA provides datalink capability to reduce dependence on voice and improve accuracy and speed of information exchange; multiple links to enable varying levels of quality of service and connectivity to support a wide variety of applications; interoperability across links with different networking protocols; security, priority and preemption to support ATS, AOC, and AAC on the same system to help transform cultural, regulatory and certification perspectives; and an increased ability to leverage commercially provided services and technologies to lower life cycle cost. These capabilities then help to provide increases in airspace and airport capacity, flight path efficiency, safety and security. In order to address the problem in this way, the MCNA problem would need to be re-framed in terms of how the alternatives are described and the evaluation criteria used to evaluate the alternatives. A change in evaluation approach of MCNA strategies should be considered for follow-on work.

One of the challenges with the benefits listed is that it is quite challenging to come up with a tradeoff function between these factors. Multi-objective utility theory would suggest the solution is to determine a scale for measuring the utility in each of the categories and then assess how any two factors should be traded off. That would be straightforward in a situation where there is one decision-maker. The challenge in the MCNA domain is that the decision-makers, those who will invest in MCNA, are a very diverse group and each of these sets of decision-makers trade off values differently.

The FAA, Airlines, and General Aviation are the primary stakeholders who will pay for the changes and reap the benefits and therefore the ultimate decision-makers. However, controllers, airline manufacturers, equipment manufacturers, are secondary stakeholders who will also participate in the process of developing and implementing the solution.

3 MCNA Investment Analysis Methodology

To meet the SIR objective for a "high-level cost/benefit analysis for each total communications performance level in selected NAS environment(s) or operational scenario(s) to establish the rationale for future investments," described in Section 1.2, an analysis of the overall MCNA strategy was conducted. The analysis included three primary phases:

- Scenario Assessment
- Communications Services Assessment
- MCNA Strategy Roadmap

The methodology is described in Figure 2 and the text below.

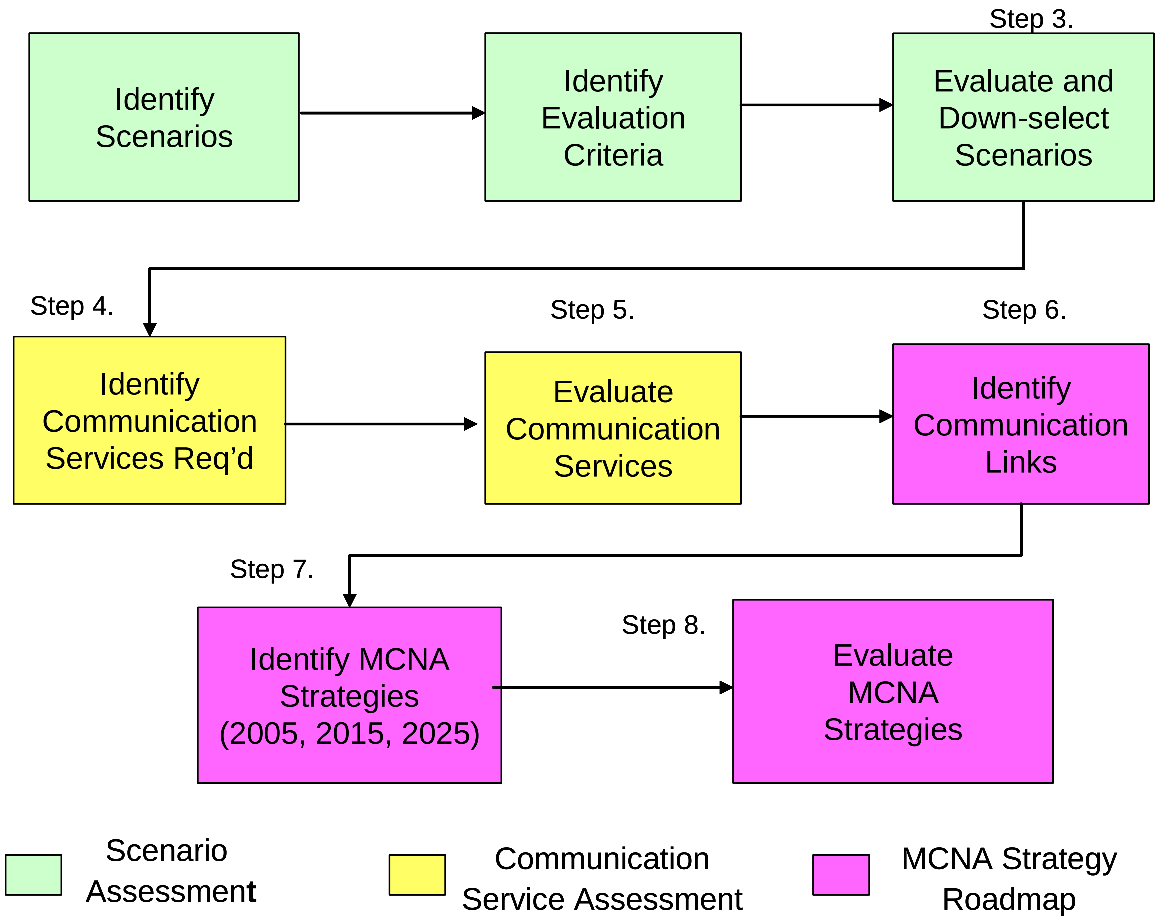

Figure 2: MCNA Investment Analysis Strategy.

1. **Identify Scenarios:** A set of 35 synthesized scenarios were identified. These scenarios identify potential improvements to the NAS that are enhanced or enabled by MCNA. They were synthesized from NAS 5.0 Operational Improvements (OI), AATT RTO-24, MACONDO, FAA SWIM Investment Analysis (Information Migrations & SWIM enabled applications). Each scenario delivers operational value in terms of improved flight path efficiency, increased safety, increased security, increased airspace capacity or increased airport capacity. (Examples: Deploy FIS-B Nationally; Datalink to reduce routine workload.) (See Table 1, Table 2, Table 3 and Table 4).

2. **Identify Evaluation Criteria:** A set of benefit and risk criteria were identified to evaluate the scenarios against. The benefit criteria are Airspace Capacity, Airport Capacity, Flight Path Efficiency, Safety and Security. The risk criteria are Non Technical, Technical, Ground Implementation, and Airline Implementation. The criteria are explained in more detail in Section 4.

3. **Evaluate and Down-select Scenarios.** The 35 scenarios were down-selected to a set of 12 scenarios, based on qualitative assessments of benefits and risk. The

intention was to narrow down the list of scenarios to those that added the most benefit with the least cost/risk. (Proposed follow-on work will explore several high payoff/high risk scenarios or SWIM-enabled applications scenarios that are most promising to fully realize the potential of the MCNA in its 2025 visionary state. These additional scenarios may be appropriate for NASA's research investment.) The 12 scenarios were categorized into primary and secondary value based on their relative benefit/risk ratio. (See Table 5 and Table 6.)

4. **Identify Communication Services Required.** The 35 synthesized scenarios were mapped to a set of 13 possible communications classes to determine the set of communication classes required to enable each scenario. In some cases multiple communication classes are necessary to meet a scenario, in others, alternative communication scenarios can be used to achieve the same operational scenario.

5. **Evaluate Communications Services.** The communications classes were then ranked in terms of the degree they enabled the 12 priority scenarios, taking into account dependencies between communications classes in terms of enabling a scenario.

6. **Identify Communications Links.** The potential universe of communication links were identified to enable the communication services identified. The communication links were mapped to the communication services.

7. **Identify MCNA Strategies.** Strategy tables were created to describe the current state of MCNA, the 2015 preferred strategy, the 2025 strategy and the Target System Description strategy. The strategies suggest the modes of communication for the following domains in their designated timeframes. (The Target System Description is assessed as a comparison against the suggested 2015 strategy.)

   - Air to Ground Voice
   - Air-to Ground Data
   - Satellite Communications supporting Polar, Remote and Oceanic Communications
   - Air-to-Air Communications
   - Airport Communications
   - Networking Protocols.

The strategies also provide a roadmap for evolving MCNA and assessing MCNA capability at any point in time. (See Section 6.)

8. **Evaluate MCNA Strategies.** The strategies were then evaluated against how they achieved the 8 primary scenarios, the 4 secondary scenarios. 5 additional scenarios were added to the evaluation to capture potentially high-value scenarios that did not make it through the first screening process but were deemed important enough to include in the analysis. A sensitivity analysis was conducted on the 2015 strategy to determine how additional scenarios could be enabled at a minimum cost

4 MCNA Scenarios

The philosophy of the MCNA scenarios activity has been to conduct a broad survey of potential ATM scenarios that would be enhanced or enabled via MCNA. While the primary focus of this effort is the MCNA enhancement of SWIM, many scenarios were included (usually taken from other sources) that do not necessarily incorporate the SWIM concept. One view of the applicability of scenario analysis activities in the development process is shown in Figure 3. Here, the system development process as defined in the FAA Systems Engineering Manual (SEM) is used as a reference. The arrow points out where scenario analysis supports the development processes that are identified on the figure. As can be seen, the FAA SEM does not specifically call out scenario analysis within their process. However, the process of defining a systems needs includes this activity.

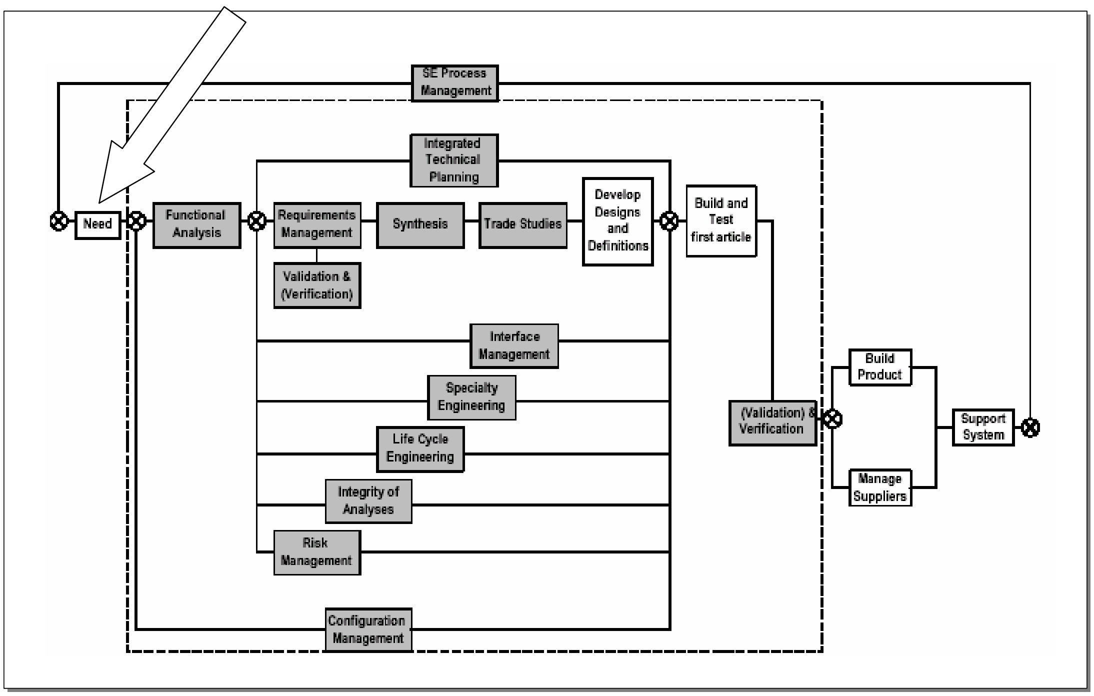

Figure 3: Scenario Analysis within the FAA Systems Engineering Process.

Scenarios were extracted from NAS 5.0 Operational Improvements (OI), AATT RTO-24, MACONDO, SWIM Investment Analysis (Information Migrations & SWIM enabled applications) and MCNA team brainstorming. The scenarios were initially compiled using an Excel spreadsheet to allow easy migration to the Access database once the team agreed that a reasonable baseline set of scenarios has been defined via a comprehensive set of parameters. The scenario compilation process generated over 70 scenarios. Careful review of these scenarios identified a significant amount of duplication of scenarios. The original list of scenarios was synthesized to eliminate redundant scenarios, non-scenarios and scenarios that would be better defined as supporting communication applications. The resultant scenario list included 35 scenarios. When duplicate scenarios were identified, precedence was given to NAS 5.0 OI scenarios. As a result, the majority of the scenarios are referenced from this source. The master list of evaluated scenarios is shown in tables Table 1 through Table 4.

The compilation of scenarios included the following parameters:

- **Name**: Title given to each of the scenarios
- **Description**: A short description of the scenario
- **Communication Services**: A series of columns representing each of the identified communication service classes. For each scenario, the minimum communication service level required to support that scenario is identified by the integer in the appropriate cell. Lower numbers represent more stringent QoS requirements.
- **Airspace Domain**: a series of columns representing the identified airspace domains. Each scenario is marked with a Y or N in each field to define whether the scenario is applicable within that airspace domain.
- **Aircraft Class**: a series of columns representing the identified aircraft classes. Each scenario is marked with a Y or N in each field to define whether the scenario is applicable to that particular aircraft class.
- **Information Class**: a series of four columns representing the four (4) SWIM information classes: surveillance, weather, aeronautical information and flight objects. Each scenario is marked with a Y or N in each field to define whether the information class is applicable to the specific scenario.
- **Benefits**: a series of columns representing the five (5) benefit areas. Each scenario is ranked 1 through 5 (5 being the greatest benefit) in each field.
    - **Airspace Capacity**
    - **Airport Capacity**
    - **Efficiency**
    - **Safety**
    - **Security**
- **Risk**: a series of columns representing the four (4) identified risk areas. These risks do not include technology risks since they are accounted for elsewhere in the MCNA study. Scenarios are ranked 1 through 5 (1 being the lowest risk) in each field.
    - **Non Technical:** Political and operational acceptance

- **Technical:** Workload or technology risk of automation
- **Ground Implementation:** Cost of ground implementation, typically automation, since SWIM and air-ground communication infrastructure costs are not included.
- **Airline Implementation:** Includes non-datalink related cost, including the cost for non-datalink related equipage.
- **Source**: identifies the source of the scenario. In the case of the NAS 5.0 operational improvements, a specific identifier is also included. The coloring of the rows highlights the source of the scenario making it easy to identify which scenarios come from the same source. Sources include:
  - **NAS 5.0 Operational Improvements**
  - **Swim Enabled Applications (SEA) from GCNSS II**
  - **RTO-24 – previously identified during AATT research task**
  - **GCNSS I**
  - **New – concept introduced as part of this analysis effort**

Table 1: Master Scenario List (Scenarios 1-12).

			Communication Services												Airspace Domain							Aircraft Class						Information Classes				Benefits					Risk (1-Lowest)				
Scenario Number	Scenario	Description	Party-line Voice	SA Voice	Broadcast Voice	Data Messaging	Trjaecotry exchange	Broadcast to Aircraft	Broadcast From Aircraft	Ground to Air Data	Air to Ground Data	Air to Air Data	Video Exchange	Vehicle Command and Control	Gate	Surface	Terminal	En-route	Remote	Oceanic	Polar	Transport	Cargo	Military	UAV	GA - Business	GA - Personal	Surveillance	Weather	AIM	Flight Objects	Airspace Capacity (5 is highest)	Airport Capacity (5 is highest)	Efficiency (5 is highest)	Safety (5 is highest)	Security (5 is highest)	Non-Technical	Technical	Ground Implementation	Airline Implementation	Source
1	Deploy FIS-B Nationally	Free access nationwide for basic weather and NAS status information to equipped aircraft						3							Y	Y	Y	Y	N	N	N	Y	Y	Y	N	Y	Y	N	Y	Y	N			4	2		1	1	1	2	OI - 103104
2	Enhanced MDCRS	Receive additional atmospheric parameters from a larger set of aircraft to improve icing and turbulence forecast									2				N	N	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	N	Y	N	N				3		2	1	1	2	OI - 103116
3	Improved Oceanic Weather Products	Distribution of weather products such as convection, volcanic ash, in-air icing and turbulence						3							N	N	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	N	Y	N	N			1	3		1	1	1	1	OI - 103115
4	Improved Terminal Weather Products	Distribution of weather products such as ASOS, ITWS, WSDDM.						2							Y	Y	Y	N	N	N	N	Y	Y	Y	N	Y	Y	N	Y	N	N				2		1	1	1	2	OI - 103113
5	Autonomous Hazard Weather Alert Notification	Enhanced situations awareness via immediate simultaneous dissemination of hazardous weather to service providers, aircraft and airlines. **These products shall include microburst, turbulence and windshear warning in terminal airspace and shall be provided both automatically or upon pilot request.**			2	2		2		2					Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N				5		1	1	1	1	OI - 103117
6	Evolve Oceanic Procedures to En-route Domestic Separation	Apply advanced CNS capabilities to change oceanic separation procedures and standards closer to those currently in use within domestic airspace.	3			1					2				N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	Y	5		3	2		3	3	2	1	OI - 102136
7	Extend the Use of RADAR Separation to Non-Radar Airspace	Integrating surveillance sources to provide expanded separation service throughout the NAS.							1						N	N	N	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	5	2	3	2		2	1	2	1	OI - 102123
8	Reduce Horizontal Separation Standards	Integrate ADS, en-route and terminal surveillance data to provide 3-nmi horizontal spacing within en-route airspace							1						N	N	N	Y	N	N	N	Y	Y	Y	Y	Y	N	Y	N	N	N	3					3	2	2	1	OI - 102117
9	Shared Responsibility for Horizontal Separation	Delegate separation responsibility to pilots when it is operationally beneficial to do so.	2						1			1			N	N	N	Y	Y	N	N	Y	Y	Y	Y	Y	N	Y	N	N	N	3		1			3	3	1	3	OI - 102118
10	Datalink to reduce routine workload	Expanded use of datalink for routine service provide activities to reduce workload.	2			2									Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	N	N	Y	3		2	1		1	1	1	1	OI - 102114
11	Oceanic Pairwise Maneuvers to Increase Tactical Capacity	Improved Oceanic Surveillance and Communications allow reduction in separation and multiple entry points into oceanic tracks	3			2					2				N	N	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N	N	Y	2		3			2	2	1	3	OI - 102108
12	Shared Responsibility for Terrain Separation	Armed with more complete terrain information, aircraft position and automation tools to provide warnings of pending conflicts, the service provider can allocate terrain separation responsibility to the aircrew.					2	2							N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y				1		1	1	1	1	OI - 102203

Table 2: Master Scenario List (Scenarios 13-21).

Scenario Number	Scenario	Description	Communication Services: Party-line Voice	SA Voice	Broadcast Voice	Data Messaging	Trjaecotry exchange	Broadcast to Aircraft	Broadcast From Aircraft	Ground to Air Data	Air to Ground Data	Air to Air Data	Video Exchange	Vehicle Command and Control	Airspace Domain: Gate	Surface	Terminal	En-route	Remote	Oceanic	Polar	Aircraft Class: Transport	Cargo	Military	UAV	GA - Business	GA - Personal	Information Classes: Surveillance	Weather	AIM	Flight Objects	Benefits: Airspace Capacity (5 is highest)	Airport Capacity (5 is highest)	Efficiency (5 is highest)	Safety (5 is highest)	Security (5 is highest)	Risk (1-Lowest): Non-Technical	Technical	Ground Implementation	Airline Implementation	Source
13	Improved Surface Separation Assurance	Pilots are provided high definition surface target information such as position, identification, velocity and infrastructure location (runways, taxiways etc.). On board automation systems display and advise the flight crew on surface movements and potential conflicts.	2			1			1	2					Y	Y	N	N	N	N	N	Y	Y	N	Y	Y	N	Y	N	Y	Y		2		4		2	2	1	3	OI - 102408
14	Provide Enhanced Surface Target Displays to Service Providers	Service providers are provided with high definition surface target information such as position, ID and velocity. Ground automation displays these targets relative to surface GIS map to assist with ground movement.							1						Y	Y	N	N	N	N	N	Y	Y	N	Y	Y	N	Y	N	N	N		2	1	2		1	2	2	1	OI - 102405
15	Enhanced Emergency Alerting	Using GPS position and aircraft ID, locate distressed or downed aircraft through ADS-B							1						N	N	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N				4		1	1	1	1	OI - 106202
16	Enhance Flight Data Management	FDP incorporates flight data info from flight deck into trajectory and conformance modeling. All plans treated as trajectories with protected volumes. Flight profiles can be negotiated and changes with strategic planners.					2								Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	Y	3				3	1	2	2	2	OI - 101202
17	Interactive Flight Planning From Anywhere	Interactive feedback of proposed flight plans based upon all current constraints. Provide near real time flight plan negotiation and changes.					2								Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	1		3			2	2	2	1	OI - 101103
18	Oceanic Separation to RNP-4	Oceanic separation is reduce to 30nmi lateral and 30nmi longitudinal based upon GPS based navigation, ADS surveillance and satellite communications (ADS & CPDLC)	3				2				2				N	N	N	N	Y	Y	N	Y	Y	Y	Y	Y	N	Y	N	N	Y	3		3	1		1	1	1	1	OI - 107102
19	Low Visibility Operations	Aircraft and ground vehicle movement on airport in low visibility conditions is guided by accurate location information and moving map displays.						1	1						Y	Y	N	N	N	N	N	Y	Y	N	Y	Y	N	Y	N	Y	N				1		2	1	3	1	OI - 107202
20	Optimize Runway Assignments	Improve sequencing and spacing of arriving aircraft with tools for better management of runway assignment. Tool provide and deliver pilot instructions and wake vortex warnings. Also provides hooks for a path from runway to en-route to improve flow.					2			2					N	Y	Y	Y	N	N	N	Y	Y	N	N	Y	N	N	N	Y	Y	2	3	2			2	1	2	1	OI - 104114
21	Provide Conflict Probe / Multi-Objective Data Linked Resolution	Enhanced ability to accommodate pilot requests for flight plan changes by providing conflict detection and trial planning in en-route operations.					2								N	N	N	Y	Y	N	N	Y	Y	Y	Y	Y	N	N	N	N	Y	1		2			1	1	1	1	OI - 104105

Table 3: Master Scenario List (Scenarios 22-31).

Scenario Number	Scenario	Description	Communication Services: Party-line Voice	SA Voice	Broadcast Voice	Data Messaging	Trjaecotry exchange	Broadcast to Aircraft	Broadcast From Aircraft	Ground to Air Data	Air to Ground Data	Air to Air Data	Video Exchange	Vehicle Command and Control	Airspace Domain: Gate	Surface	Terminal	En-route	Remote	Oceanic	Polar	Aircraft Class: Transport	Cargo	Military	UAV	GA - Business	GA - Personal	Information Classes: Surveillance	Weather	AIM	Flight Objects	Benefits: Airspace Capacity (5 is highest)	Airport Capacity (5 is highest)	Efficiency (5 is highest)	Safety (5 is highest)	Security (5 is highest)	Risk (1-Lowest): Non-Technical	Technical	Ground Implementation	Airline Implementation	Source
22	Flow Planning with distributed Schedule Recovery and Post Departure Rerouting	Distributed airline schedule recovery automation for utilizing combinations of ground delay, flight cancellation, and pre and post-departure re-routing to replan schedules in the face of convective weather disruptions. Take advantage of SWIM-enabled weather information distribution, improved forecasting, flight object, standardized route databases, and centralized allocation of forecast airport and airspace capacities					2								N	Y	Y	Y	N	N	N	Y	Y	N	N	Y	N	N	N	N	Y	2		4			2	2	2	1	SEA
23	CDA	Accommodate CDA mixed with conventional profiles in high-traffic conditions while maintaining maximum runway throughput. Show how this is feasible with multiple streams of CDA aircraft to a single arrival runway through the use of air/ground datalink, advanced navigation with Center and TRACON planning automation.					2								N	N	Y	N	N	N	N	Y	Y	N	N	Y	N	N	N	N	Y			4			3	2	2	1	SEA
24	Tailored Arrivals	Provision of pre-defined alternative arrival paths to enable FMS RNAV approaches					2								N	N	Y	N	N	N	N	Y	Y	N	N	Y	N	N	N	N	Y			2			1	1	1	1	SEA
25	Controller awareness of ACAS resolutions	The system shall support the delivery and display to controllers of any resolution advisories generated by aircraft ACAS systems.				1									N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N				4		1	1	1	1	RTO-24
26	ADS-based VFR support (Air Traffic Situational Awareness - ATSAW)	The system solution shall support the VFR flight advisory service by enabling the transmission of aircraft position reports, transfer of communications, traffic advisories and airspace alerts.						2	2						N	N	Y	Y	Y	N	N	N	N	N	N	N	Y	Y	N	N	N				2		1	1	1	2	RTO-24
27	Hazard alerts	Alerts of impending hazards shall be automatically uplinked to the pilot.				2									Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	N	Y	Y	Y				1		1	1	1	1	RTO-24
28	Pre-Departure Clearance (PDC) at gate	The flight crew shall have the capability to receive PDC at the gate.				2									Y	N	N	N	N	N	N	Y	Y	N	N	Y	N	N	N	N	Y		1				1	1	1	1	RTO-24
29	Aircraft push of security video and aircraft performance during emergency	For the purposes of security, it may be valuable to have mechanisms to trigger the downlink of streaming video and audio of the cockpit and cabin environments and send down critical aircraft performance data.							2		2		2		Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	N	N	Y				1	4	3	1	1	3	NA (similar to GCNSS Demo Segment A)
30	ROA Control	Ground control of an unpiloted aircraft												1	N	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	N	Y	Y	N	N						4	4	4	4	NA (new)
31	UAV Control	Autonomous control of an unpiloted aircraft with ground management					1	2	1	2	2				N	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	N	Y	Y	Y	Y						4	4	4	4	

Table 4: Master Scenario List (Scenarios 32-35).

Scenario Number	Scenario	Description	Communication Services												Airspace Domain							Aircraft Class						Information Classes				Benefits					Risk (1-Lowest)				Source
			Party-line Voice	SA Voice	Broadcast Voice	Data Messaging	Trjaecotry exchange	Broadcast to Aircraft	Broadcast From Aircraft	Ground to Air Data	Air to Ground Data	Air to Air Data	Video Exchange	Vehicle Command and Control	Gate	Surface	Terminal	En-route	Remote	Oceanic	Polar	Transport	Cargo	Military	UAV	GA - Business	GA - Personal	Surveillance	Weather	AIM	Flight Objects	Airspace Capacity (5 is highest)	Airport Capacity (5 is highest)	Efficiency (5 is highest)	Safety (5 is highest)	Security (5 is highest)	Non-Technical	Technical	Ground Implementation	Airline Implementation	
32	Push of Security advisories to aircraft	When an airspace emergency occurs, it would be desirable to quickly distribute notification to affected aircraft, AOC/FOC, ARTCC and other government agencies				2									Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N				1	3	2	1	1	1	NA (new)
33	CDM - National Playbook	Distribution of the National Playbook selection to the cockpit for enhanced situational awareness. If pilots know ASAP what changes are happening and why it should improve the overall process. Ideally, the plays would be available on the aircraft and just a message would need to be sent identifying which play is active.								2					Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	N	Y	Y	N			2			1	1	1	1	NA (New)
34	Separate DHS Voice and Video network	Provision a separate (maybe just logically) voice, video and data network for communication between DHS and the FAMS	3	2		2				2	2		2		Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N					1	1	1	1	2	NA (New)
35	Commercial space & suborbital flight (and other dynamic TFR scenarios)	Space launch and re-entry is typically based upon time windows. For aviation purposes, a TFR would have to be submitted for the entire possible duration of the launch. MCNA equipped aircraft could receive TFR termination updates that are sent following a launch or launch abort that opens up this airspace. This same concept would also apply to many other dynamic TFR scenarios.					2			3					N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	1					2	1	2	1	NA (New)

4.1 Scenario Down-selection

The master list of scenarios was further evaluated to roughly rank scenarios. First the risk and benefit of each of the 35 scenarios was evaluated using a small team of operational analysis experts. These individual evaluations were then combined mathematically to rank the scenarios. In order to prevent the down-selection of scenarios to be driven by a single equation the individual rankings for the risks and benefits combined several different methodologies. The selection of scenarios was extracted based upon either consistent performance across the all techniques or exemplary performance in one or more methods. The following three considerations were used in the evaluation of the different cost/benefit equations:

- Techniques used for evaluating total benefit:
  - Sum of the benefits
  - Sum of 2^each benefit (represents a log-2 ranking of the benefits)
  - Maximum of the benefits (assumes that the maximum benefit in any one class is the driving factor
- Techniques used for evaluating total risk:
  - Average risk
  - 2^(average risk)
- Airspace applicability weighting
  - Provides weighting based upon the domain of applicability of the scenario
  - Gate 10 %
  - Surface 15%
  - Terminal 20 %
  - En-route 30%
  - Remote 5%
  - Oceanic 15%
  - Polar 5%

From all of the considerations above a number of scenario comparisons were developed as described below:

- **Benefits / Risk (unweighted) - Error! Reference source not found.** shows the ranking of the eight (8) top scenarios (in BLACK), two (2) of the four (4) secondary scenarios (in RED) and remaining two secondary scenarios (in CYAN). The last two do not stand out consistently because they apply to only oceanic or remote airspace.

- **Benefits / Risk (Weighted by flight domain) - Error! Reference source not found.** shows the ranking of the eight (8) top scenarios in BLACK and three (3) of the four (4) secondary scenarios in RED.
- **Benefits (Unweighted) - Error! Reference source not found.** is not very insightful. However, two scenarios do stand out (6 and 7) that were not down-selected. These stand out in this graph because 7 is applicable only to Oceanic airspace and 6 is very high risk relative to the benefits.
- **Benefits (Weighted by flight domain) - Error! Reference source not found.** shows the ranking of the eight (8) top scenarios in BLACK and two (2) of the four (4) secondary scenarios in RED.
- **Risks only** – A plot was created to compare only the risks, but the results were sufficiently interesting to include in the report.
- Scatter plot of normalized Benefit vs. normalized Risk - **Error! Reference source not found.** shows a scatter plot of the normalized risks versus normalized benefit. In both cases, the normalization was set such that larger numbers are more desirable. The black link demonstrates the cut-off between the eight (8) selected primary scenarios and the remained of the scenario set.

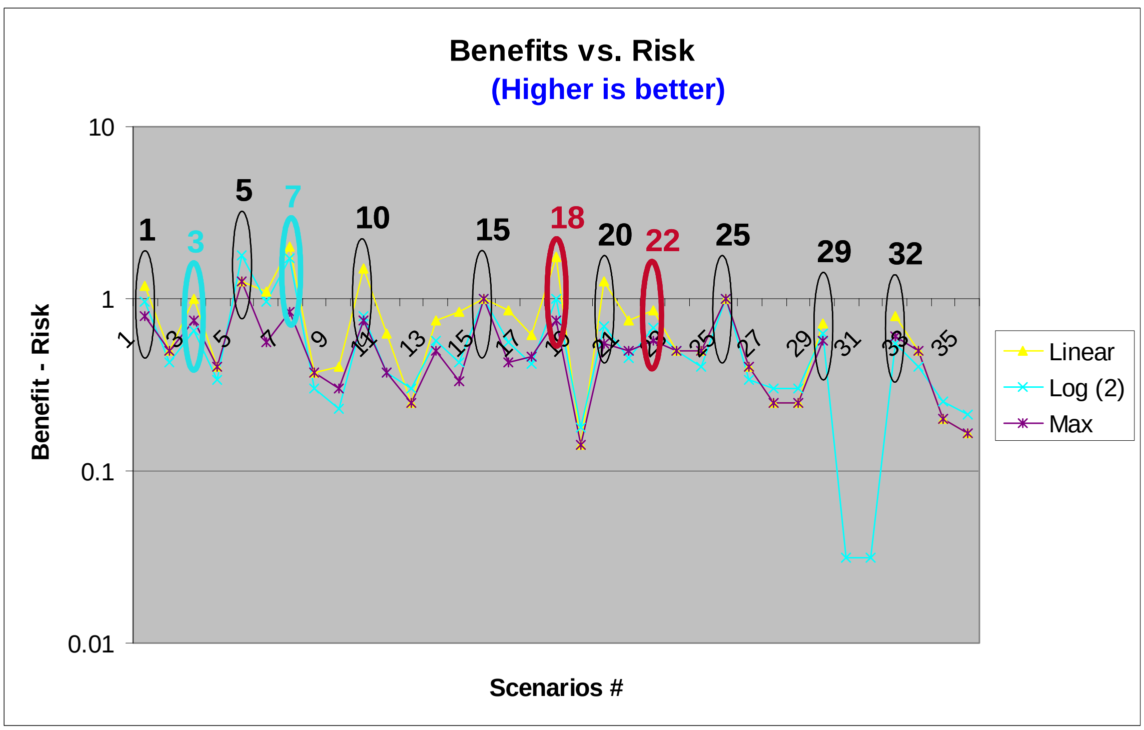

Figure 4: Benefits / Risks - Not Weighted by Flight Domain.

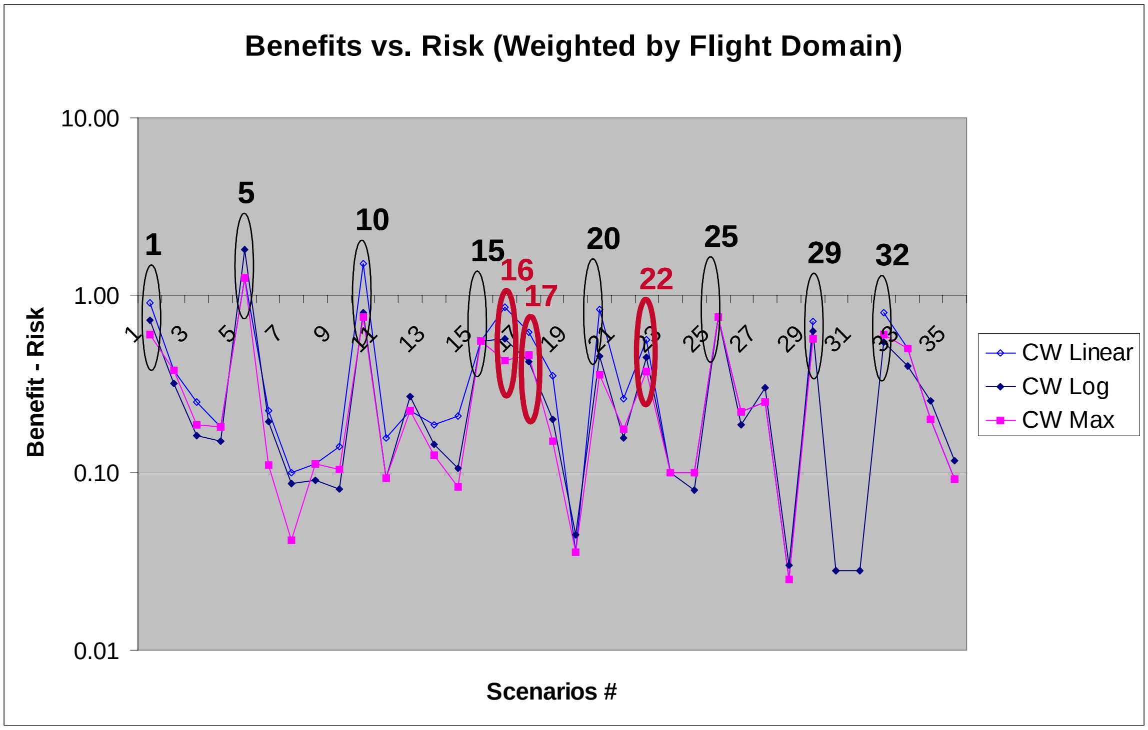

Figure 5: Benefits / Risk - Weighted by Flight Domain.

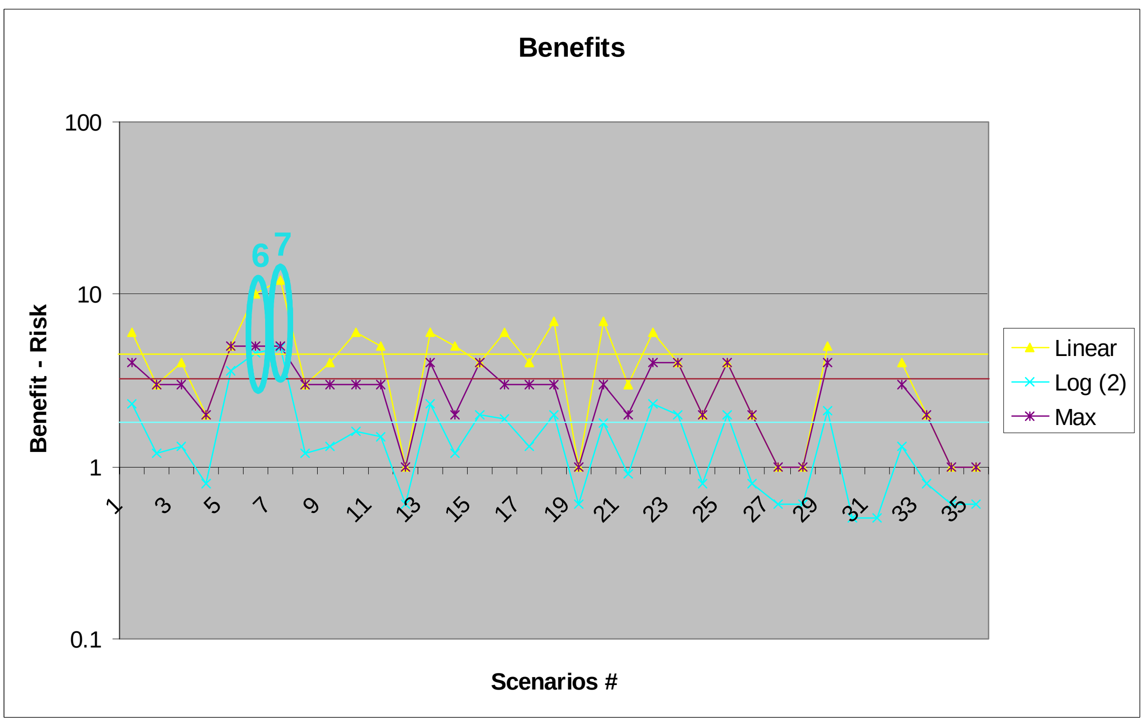

Figure 6: Benefits Only - Not Weighted by Flight Domain.

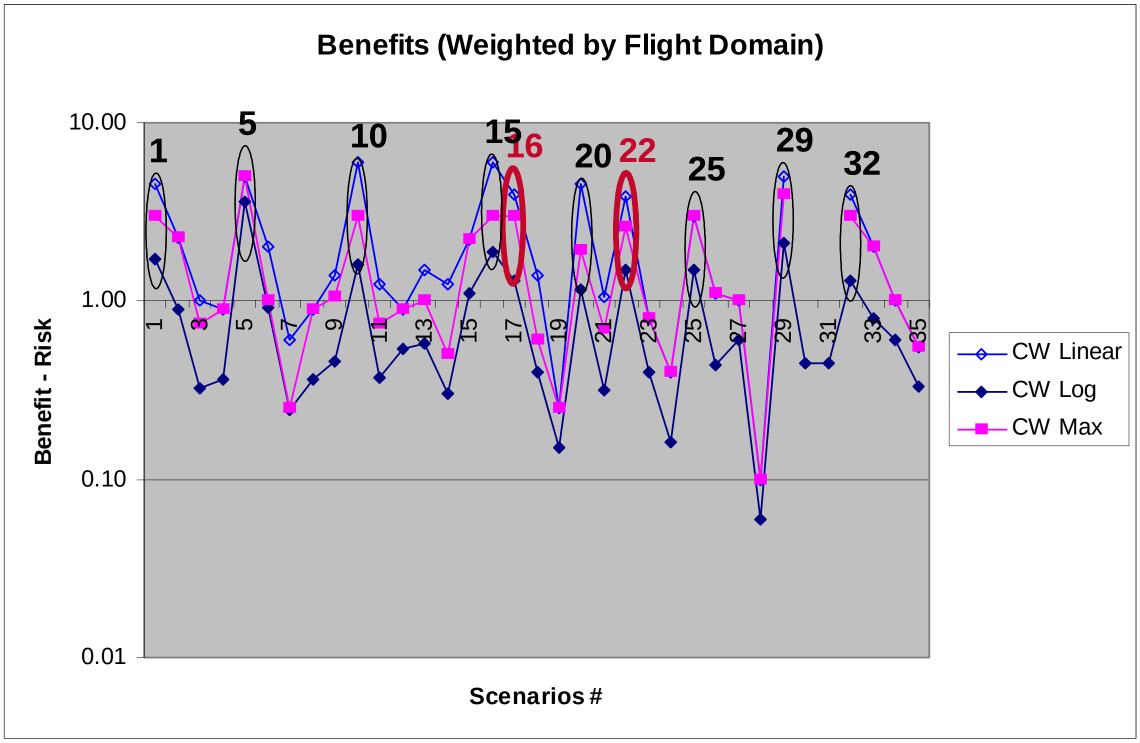

Figure 7: Benefits Only - Weighted by Flight Domain.

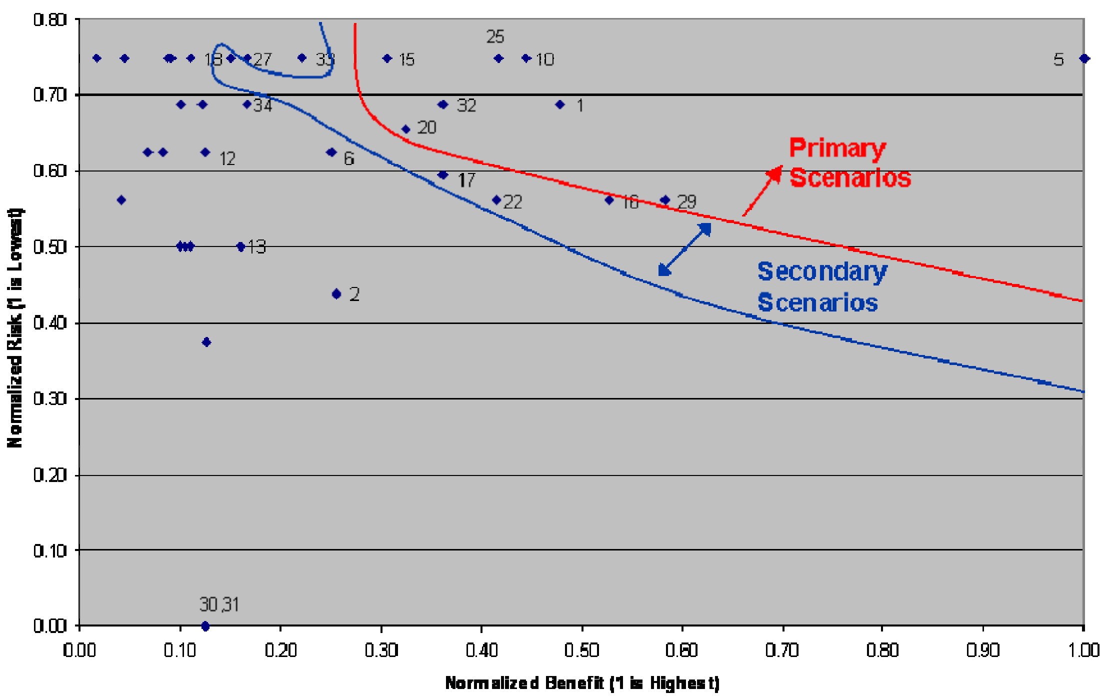

Figure 8: Scatter plot of Benefit vs. Risk.

In summary, the eight (8) primary scenarios selected were scenarios # 1, 5, 10, 15, 20, 25, 29 and 32. In addition, four (4) secondary scenarios (scenarios # 16, 17, 18 and 22) were also selected for further consideration. These scenarios are list below in the following tables:

Table 5: Primary Scenario Down-Selection.

			Communication Services												Airspace Domain							Aircraft Class						Information Classes				Benefits					Risk (1-Lowest)				
Scenario Number	Scenario	Description	Party-line Voice	SA Voice	Broadcast Voice	Data Messaging	Trjaecotry exchange	Broadcast to Aircraft	Broadcast From Aircraft	Ground to Air Data	Air to Ground Data	Air to Air Data	Video Exchange	Vehicle Command and Control	Gate	Surface	Terminal	En-route	Remote	Oceanic	Polar	Transport	Cargo	Military	UAV	GA - Business	GA - Personal	Surveillance	Weather	AIM	Flight Objects	Airspace Capacity (5 is highest)	Airport Capacity (5 is highest)	Efficiency (5 is highest)	Safety (5 is highest)	Security (5 is highest)	Non-Technical	Technical	Ground Implementation	Airline Implementation	Source
1	Deploy FIS-B Nationally	Free access nationwide for basic weather and NAS status information to equipped aircraft						3							Y	Y	Y	Y	N	N	N	Y	Y	Y	N	Y	Y	N	Y	Y	N			4	2		1	1	1	2	OI - 103104
5	Autonomous Hazard Weather Alert Notification	Enhanced situations awareness via immediate simultaneous dissemination of hazardous weather to service providers, aircraft and airlines. **These products shall include microburst, turbulence and windshear warning in terminal airspace and shall be provided both automatically or upon pilot request.**			2	2		2		2					Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N				5		1	1	1	1	OI - 103117
10	Datalink to reduce routine workload	Expanded use of datalink for routine service provide activities to reduce workload.	2			2									Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	N	N	Y	3		2	1		1	1	1	1	OI - 102114
15	Enhanced Emergency Alerting	Using GPS position and aircraft ID, locate distressed or downed aircraft through ADS-B							1						N	N	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N				4		1	1	1	1	OI - 106202
20	Optimize Runway Assignments	Improve sequencing and spacing of arriving aircraft with tools for better management of runway assignment. Tool provide and deliver pilot instructions and wake vortex warnings. Also provides hooks for a path from runway to en-route to improve flow.					2			2					N	Y	Y	Y	N	N	N	Y	Y	N	N	Y	N	N	N	Y	Y	2	3	2			2	1	2	1	OI - 104114
25	Controller awareness of ACAS resolutions	The system shall support the delivery and display to controllers of any resolution advisories generated by aircraft ACAS systems.				1									N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N				4		1	1	1	1	RTO-24
29	Aircraft push of security video and aircraft performance during emergency	For the purposes of security, it may be valuable to have mechanisms to trigger the downlink of streaming video and audio of the cockpit and cabin environments and send down critical aircraft performance data.							2		2		2		Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	N	N	Y				1	4	3	1	1	3	NA (similar to GCNSS Demo Segment A)
32	Push of Security advisories to aircraft	When an airspace emergency occurs, it would be desirable to quickly distribute notification to affected aircraft, AOC/FOC, ARTCC and other government agencies				2									Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N				1	3	2	1	1	1	NA (new)

Table 6: Secondary Scenario Down-Selection.

Scenario Number	Scenario	Description	Communication Services: Party-line Voice	SA Voice	Broadcast Voice	Data Messaging	Trjaecotry exchange	Broadcast to Aircraft	Broadcast From Aircraft	Ground to Air Data	Air to Ground Data	Air to Air Data	Video Exchange	Vehicle Command and Control	Airspace Domain: Gate	Surface	Terminal	En-route	Remote	Oceanic	Polar	Aircraft Class: Transport	Cargo	Military	UAV	GA - Business	GA - Personal	Information Classes: Surveillance	Weather	AIM	Flight Objects	Benefits: Airspace Capacity (5 is highest)	Airport Capacity (5 is highest)	Efficiency (5 is highest)	Safety (5 is highest)	Security (5 is highest)	Risk (1-Lowest): Non-Technical	Technical	Ground Implementation	Airline Implementation	Source
16	Enhance Flight Data Management	FDP incorporates flight data info from flight deck into trajectory and conformance modeling. All plans treated as trajectories with protected volumes. Flight profiles can be negotiated and changes with strategic planners.					2								Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	Y	3				3	1	2	2	2	OI - 101202
17	Interactive Flight Planning From Anywhere	Interactive feedback of proposed flight plans based upon all current constraints. Provide near real time flight plan negotiation and changes.					2								Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	1		3			2	2	2	1	OI - 101103
18	Oceanic Separation to RNP-4	Oceanic separation is reduce to 30nmi lateral and 30nmi longitudinal based upon GPS based navigation, ADS surveillance and satellite communications (ADS & CPDLC)	3				2				2				N	N	N	N	Y	Y	N	Y	Y	Y	Y	Y	N	Y	N	N	Y	3		3	1		1	1	1	1	OI - 107102
22	Flow Planning with distributed Schedule Recovery and Post Departure Rerouting	Distributed airline schedule recovery automation for utilizing combinations of ground delay, flight cancellation, and pre and post-departure re-routing to replan schedules in the face of convective weather disruptions. Take advantage of SWIM-enabled weather information distribution, improved forecasting, flight object, standardized route databases, and centralized allocation of forecast airport and airspace capacities					2								N	Y	Y	Y	N	N	N	Y	Y	N	N	Y	N	N	N	N	Y	2		4			2	2	2	1	SEA

Table 8: High Value/High Risk Scenarios.

	Scenario	Description	Party-line Voice	SA Voice	Broadcast Voice	Data Messaging	Trjaecotry exchange	Broadcast to Aircraft	Broadcast From Aircraft	Ground to Air Data	Air to Ground Data	Air to Air Data	Video Exchange	Control	Gate	Surface	Terminal	En-route	Remote	Oceanic	Polar	Transport	Cargo	Military	UAV	GA - Business	GA - Personal
30	ROA Control	Ground control of an unpiloted aircraft	2						1		1			1	N	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	N
31	UAV Control	Autonomous control of an unpiloted aircraft with ground management					1	2	1	2	2				N	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	N
36	Dynamic Resectorization	Provides tools to allow for more defintion of aispace configuration changes with automated functions to evaluate and develop asset assignments. Supports system to system coordination (SYSCO) of the reassignments across facility boundaries.	2			1	2	1	1						N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
13	Improved Surface Separation Assurance	Pilots are provided high definition surface target information such as position, identification, velocity and infrastructure location (runways, taxiways etc.). On board automation systems display and advise the flight crew on surface movements and potential conflicts.	2			1			1	2					Y	Y	N	N	N	N	N	Y	Y	N	Y	Y	N
9	Shared Responsibility for Horizontal Separation	Delegate separation responsibility to pilots when it is operationally beneficial to do so.	3						1			1			N	N	N	Y	Y	N	N	Y	Y	Y	Y	Y	N

4.2 MCNA Enabled Scenarios

The following sections provide detailed descriptions for the eight primary scenarios down-selected based upon relative benefit and risk performance. Furthermore, additional scenarios from the secondary down-selection group are also provided with further elaboration.

4.2.1 Deploy FIS-B Nationally (Scenario #1)

This Operational Improvement (103104) builds upon the current FIS-B commercial service, extending the capabilities by distributing advanced graphical and textual weather products to FIS-B vendors via SWIM for nationwide free distribution to aircraft. Aircraft display these enhanced weather products using the cockpit display of traffic information (CDTI) and moving map displays.

Weather information products include outputs from the integrated terminal weather service (ITWS), weather and radar processor (WARP), global weather information system (GWIS) and general weather processor (GWP) are made available to approved FIS-B vendors via SWIM. FIS-B vendors subscribe to the aggregate of weather services, developing increasingly customized weather products for pilot consumption including:

- Precipitation
- Lightning
- In-flight icing
- Low-ceiling/visibility maps
- Surface hazards
- Wind shear & turbulence
- Site specific weather reports
- PIREPS
- SIGMETS
- Winds aloft
- Surface braking conditions

The FIS-B service delivers weather and AIM SWIM information classes, the AIM information will likely be extracted from the FAA NAIMES system that is currently under development. This service is applicable to all airspace classes except: Remote, Oceanic and Polar since these domains are not readily serviced by ground based transceivers (GBT). However, this service could easily be extended to these airspace domains via satellite communications if a business justification were provided. This service is applicable to all classes of aircraft except UAV.

The benefits of this FIS-B deployment are increased efficiency due to a reduction in controller weather reports via voice and enhanced safety since pilots have better situational awareness of potentially hazardous weather conditions. Aside from the MCNA requirements, the risks of FIS-B deployment are generally low. However, the avionics for CDTI are somewhat expensive and may prove a considerable hurdle for airline and GA adoption.

4.2.2 Hazardous Weather Alert Notification (Scenario #5)

This scenario is based upon Operational Improvement (103117) and is closely related to the last scenario, focusing on providing immediate alert of hazardous weather reports to pilots within the immediate vicinity of the reported weather hazard. Reported weather hazards would be published to the SWIM and immediately distributed to all affected aircraft, controllers and AOC via available means[1]. Communication mechanisms to distribute these weather alerts include voice broadcast, data broadcast and various forms of datalink. The scenario is concerned only with weather information distribution including the following data products:

- Windshear
- Microburst
- Turbulence

This scenario requires an aircraft to provide at least one form of connectivity to SWIM to assure message delivery. The scenario is applicable to all airspace domains and all aircraft classes. A single area of benefit, safety, is provided by this scenario and the implementation risks are all low.

4.2.3 Datalink to Reduce Routine Workload (Scenario #10)

This scenario is based upon Operational Improvement (102114) and is the NAS-wide deployment of the initial CPDLC capabilities to increase controller efficiency by moving routine communication exchanges from voice to datalink. The scenario is well defined by the LINK2000+ work ongoing in Europe.

Initial deployment of routine datalink is not dependant upon SWIM but can certainly benefit from some of the SWIM shared services such as messaging, message translation and message archival. Future implementations of datalink will include the exchange of flight objects for actions such as trajectory negotiation. The scenario is applicable in all airspace domains and is applicable to all classes of aircraft except UAV[2] and GA. This

[1] Eventually this distribution to the aircraft could be through SWIM but initially it could be through another means.

[2] There are some UAV/ROA programs such as Access 5 that are planning on relaying information from the aircraft to remotely located pilot via satellite links.

scenario provides moderate benefits in airspace capacity and efficiency and minor benefits in safety due to the increased integrity of exchanged messages. The risks for datalink are all considered low, in part because the required modifications to the CMU are considered part of the MCNA cost.

4.2.4 Enhanced Emergency Alerting (Scenario #15)

This scenario is based upon Operational Improvement (106202). With GPS navigation and position reporting via ADS, the ability of the controller to support search and rescue (SAR) operations can be greatly enhanced. This scenario relies upon ADS-B broadcasts of aircraft position to provide more precise information to controllers about aircraft position.

In the case of a downed aircraft, this more accurate position provides a smaller search region for SAR operations. The only communication service required for this scenario is ADS-B for terminal, en-route and some remote airspace. The service could be readily extended to all remote airspace and oceanic airspace via ADS-A or ADS-C services via SatCom. This scenarios is applicable to all aircraft classes and relies only upon the SWIM information class: surveillance. This scenarios provides high relative safety benefits and has been determined to introduce minimal implementation risks.

4.2.5 Optimize Runway Assignments (Scenario #20)

This scenario is based upon Operational Improvement (104114). This scenario is composed of three specific runway assignment enhancements as defined below.

- Expedite Departure Path – decision support tools that assist controllers in load management of departing traffic, sequencing, spacing and merging into the en-route stream. The NAS 5.0 OI does not specifically state the use of datalink to communicate instructions to aircraft, but this effort identified such a datalink extension as a valuable extension to this OI.

- Approach Spacing – Automation tool to assist controllers with runway assignments in mixed traffic environments. In particular the tool helps determine optimum runway assignments to maximize arrival throughput considering complex limitations such as wake vortex restrictions between different aircraft classes. MCNA enhances this process by delivering runway assignments in real time to aircraft, thus freeing up controller workload.

- Parallel Approaches – ADS-B and CDTI will enhance the ability to perform closely spaced parallel runway approaches in Instrument Meteorological Conditions (IMC) at airports that cannot otherwise conduct such operations. These parallel approaches will further be enhanced by sending arrival trajectories via datalink that minimize wake vortex effects. These airports account for 16 of the top 35 delayed airports.

This scenario depends upon ADS-B, datalink trajectory exchange and the uplink of SWIM AIM information to aircraft. This scenario provides moderate benefits in airport capacity increases and lower relative benefits in airspace capacity and efficiency. The implementation risks of this scenario are generally low, but the non-technical risk and the ground infrastructure risks are more significant due to the ground automation aspects involved. This scenario is applicable in surface, terminal and enroute domains to transport, cargo and business GA aircraft.

4.2.6 Controller Awareness of ACAS Resolutions (Scenario #25)

This scenario was defined during this contract in response to the midair collision in Germany on July 1, 2002 that was caused, in part, by a conflict of directions given by the controller and TCAS. In order to prevent such incidences in the future, the scenario is proposed to downlink messages to the controller providing notification of TCAS resolutions. This scenario would only require a simple messaging communication service. However, the latency of the service must be rather small in order to provide the information to the controller in a sufficiently timely manner to be useful.

This scenario would be applicable in all airspace except gate and surface and to all aircraft except GA since they are not likely to equip with TCAS. This scenario would provide significant safety benefit and has been assessed to introduce very low risks in all categories.

4.2.7 Aircraft Push of Security Video and Aircraft Performance Data During Emergencies (Scenario #29)

This scenarios was defined during GCNSS I in response to the events that transpired within the NAS on September 11, 2001. Several communication system concepts were evaluated following those tragic events, including the ability to downlink live cabin and cockpit video during an aircraft emergency. This concept was later extrapolated to include the downlink of aircraft state. The real time broadcast of cockpit voice recorded (CVR) and flight data recorder (FDR, also know as black box) was defined as “white box”.

In this scenario, cameras would be installed in the cockpit and cabin or commercial transport aircraft and instrumentation would be installed, possibly in the DFDAU, to allow the transmission of CVR and FDR information. During an emergency, the desired data would be down-linked to a ground facility to assist with conflict resolution. In the case of a hijacking event, the data may be downlinked to the TSA or the Department of Homeland Defense while during a flight emergency the data may be downlinked to the FAA (ARTCC, TRACON and/or the closest airport) and the aircrafts AOC.

The scenario can be particularly demanding in terms of communication services. Video downlink is very bandwidth intensive while “white box” services are only moderately bandwidth intensive. However, both services require significantly more bandwidth per aircraft than has been demanded by previously defined scenarios. This scenarios is applicable to all airspace domains since a hijacking event could occur anywhere but is only really applicable to transport aircraft. This scenario provides significant security benefits and minor safety benefits. The risks, however, are more significant for this scenario given the terrestrial bandwidth required, the political issues of placing video cameras within aircraft and the cost to purchase and install all of this additional avionics.

4.2.8 Push of Security Advisories to Aircraft (Scenario #32)

Another scenario that was inspired by the events of September 11, 2001 is the concept of being able to push security advisories to aircraft. This scenario is similar in many respects to the hazardous weather advisories. The SWIM is used to distribute critical security advisories to large groups of aircraft in response to a major security event such as a hijacking. Rapid distribution of such advisories may help prevent large coordinated attacks.

This scenario is applicable to all airspace domains and all classes of aircraft. The security advisory message is not really classified as a SWIM information source, but the SWIM would be used to rapidly and widely distribute the advisory to all aircraft, FAA facilities, AOC and interested government agencies. This scenario offers moderate security benefits and minor safety benefits but the risks and implementation complexities are generally very low. One potential political risk would be the coordination of multiple government agencies.

4.2.9 Enhanced Flight Data Management (Scenario #16)

This scenario is based upon Operational Improvement (101202). Flight planning up to 180 days in advance of the flight through to the day of the flight and shortly before flight termination is all handled by a common Flight Object Management System (FOMS) which employs the SWIM for management and distribution of flight objects. This scenario eliminates the reliance upon the Official Airline Guide (OAG) and provides the underlying framework to support long term flow planning activities. Flights are treated as trajectories with protected volumes, thus providing more dynamic support of military operations (without the need for SUA) as well as the operations of Remotely Operated Aircraft (ROA) and Reusable Launch Vehicles (RLV). Datalink is employed to exchange trajectories with aircraft during all phases of flight for purposes of flight replanning and trajectory negotiation to resolve conflicts are reroute due to weather or turbulence.

This scenario supports all airspace domains and all classes of aircraft except GA. SWIM is employed for the distribution of surveillance data objects and the distribution and management of flight objects. Benefits are provided in the areas of airspace capacity and security (due to the conformance monitoring ability). The risks associated with deploying this scenario are more significant due to the required changes in the flight data processors (FDP) and the flight management computers (FMC) to properly manage and utilize these trajectory-based flight objects.

4.2.10 Interactive Flight Planning From Anywhere (Scenario #17)

This scenario is based upon Operational Improvement (101103). This scenario is very similar to Scenario #16 with the key exception being that the purpose is specific to flight planning versus separation management and conformance monitoring. As such, the same communication services are required and the scenario is still applicable to all airspace domains but in this case the scenario applies to all classes of aircraft, including GA. When applied to flight planning, this scenario provides moderate relative increases in efficiency and minor increases in airspace capacity. The risks for deploying this scenario are moderate, as with the last scenario, due to the integration with new ground automation systems.

4.2.11 Oceanic Separation to RNP-4 (Scenario #18)

This scenario is based upon Operational Improvement (101202). Extended current oceanic separation via FANS to RNP-4 and increasing the ADS-A reporting rate can result in the reduction in oceanic spacing down to 30nmi lateral by 30nmi longitudinal. This scenario is dependant upon the deployment of the ATOP automation system at key oceanic centers including New York, Oakland and Anchorage.

The communication services required to support this scenario is data messaging and trajectory exchange to support ADS-A and CDPLC services. This scenario is only applicable to oceanic and remote airspace but could apply to all classes of aircraft except GA. This scenario provides moderate benefits in efficiency and airspace capacity due to the reduced spacing that provides greater access to optimal routes. A small safety benefit is also provided due to the enhanced communication and surveillance services. The risks of deploying this scenario are considered low in all cases.

4.2.12 Flow Planning with distributed Schedule Recovery and Post Departure Rerouting (Scenario #22)

This scenario was extracted from the GCNSS II SWIM Enabled Applications identified as part of the operational analysis activity. The scenario allows for distributed airline schedule recovery automation utilizing combinations of ground delay, flight cancellation, and pre-departure re-routing and post-departure re-routing to replan schedules in the face of convective weather disruptions. It takes advantage of SWIM-enabled weather information distribution, improved forecasting, flight object, standardized route databases, and centralized allocation of forecast airport and airspace capacities.

A centralized flow management function predicts airport and sector demand and system capacity, and allocates available capacity to each airline. In a distributed concept, each airline AOC receives allocated capacity and replans its own schedule to adhere to constraints while maximizing its own recovered schedule value. MCNA enhances this scenario by providing datalink capability from the flow planning automation to the aircraft to enable the post-departure re-routing capability.

The MCNA extension to this scenario requires trajectory exchange datalink. The scenario is considered applicable in surface, terminal and en-route domains and only applicable to transport, cargo and business jets. The scenario provides large benefits in efficiency and moderate benefits in airport capacity while incurring elevated but moderate risks.

5 MCNA Communication Services

This section describes the process and results for and evaluating the voice and data communication services.

Thirteen communication services were identified:

- **Party-line Voice:** A half-duplex push-to-talk (PTT) voice service that allows all users to monitor the communications from all other users sharing the same channel.

- **SA Voice:** Selective Addressed (SA) voice is a private voice circuit that is established between two addressed end-points. This service is typical of most fixed and land mobile telephony services.

- **Broadcast Voice:** A broadcast channel that continually provides voice information. An example in the NAS would be ATIS.

- **Data Messaging:** The exchange of data messages between two addressed end-points. CDPLC is an example of a data messaging application.

- **Trajectory exchange:** Trajectory exchange is a specific example of a data messaging service. In this case, the data message is exchanged between an aircraft FMC and a ground automation systems and the message provides specific aircraft routing directions.

- **Broadcast to Aircraft:** Broadcast of data information to the aircraft. Examples of such a service include: FIS-B or TIS-B

- **Broadcast From Aircraft:** The broadcast of information from the aircraft. This service is specifically focused upon the ADS-B service in which aircraft broadcast their current position and intent to surrounding aircraft and any listening ground transceivers.

- **Ground to Air Data:** This service is specific to the delivery of SWIM information to the aircraft. Examples might be the request for and delivery of weather information along an aircrafts anticipated flight path.

- **Air to Ground Data:** This service is specific to the delivery of aircraft data into the SWIM. An example might be the delivery of information about turbulent weather into a SWIM database for distribution to other affected aircraft.

- **Air to Air Data:** This service represents the exchange of generic messages between aircraft. An example of the application of such a service would be the datalink exchange and conflict resolution of aircraft position and intent data to resolve a TCAS-like collision avoidance maneuver.

- **Video Exchange:** This service reflects the downlink of video information from an aircraft to a ground facility. The purposes for this service include: monitoring of cockpit and cabin activity by the Department of Homeland Defense or the monitoring of an out the window (OTW) view from a ground pilot in command of a remote operated vehicle (ROA).

- **Vehicle Command and Control:** The service represents a high availability low latency datalink communication service capable of supporting the delivery of aircraft control commands and the receipt of aircraft telemetry necessary to remotely operate an unmanned aerial vehicle (UAV).

Each of these communication services classes has multiple levels of service. They start with service level of one that is the must stringent in terms of performance requirements (latency, availability, etc) and move on to higher numbers to indicate less stringent requirements. This optimizes the cost of the system by preventing operations with the must stringent requirements driving the cost of the entire communication system.

These communication services were then mapped to the 12 high value scenarios, plus five additional scenarios that didn't make it through the initial screening process but were deemed as potentially high value. See Table 7 below.

Table 7: Communication Services Mapped to Scenarios.

	Scenario	Party-lin Voice	SA Voice	Broadcast Voice	Data Messaging	Trajectory exchange	Broadcast to Aircraft	Broadcast From Aircraft	Ground to Air Data	Air to Ground Data	Air to Air Data	Video Exchange	Vehicle Command and Control
		Communication Services											
1	Deploy FIS-B Nationally						3						
5	Autonomous Hazard Weather Alert Notification			2	2		2		2				
10	Datalink to reduce routine workload	3			2								
15	Enhanced Emergency Alerting							1					
20	Optimize Runway Assignments					2		1	2				
25	Controller awareness of ACAS resolutions				1								
29	Aircraft push of security video and aircraft performance during emergency							2		2		1	
32	Push of Security advisories to aircraft				2								
16	Enhance Flight Data Management					2							
17	Interactive Flight Planning From Anywhere					2							
18	Oceanic Separation to RNP-4	4			2	2							
22	Flow Planning with distributed Schedule Recovery and Post Departure Rerouting					2							
30	ROA Control	2			2					1	1		1
31	UAV Control					1	2	1	2	2			
38	Dynamic Resectorization	2			1	2	1	1					
13	Improved Surface Separation Assurance	3			1			1	2				
9	Shared Responsibility for Horizontal Separation	3						1			1		
	Total number of Hits *	6	0	1	8	7	4	7	4	3	2	1	1

Communication Service Level	Description
1	Most stringent performance level.
2	More stringent performance level.
3	Less stringent performance level.
4	Least stringent performance level.

*Note: The entries in the rows (except for the bottom row) are the service level requirements. A higher number service level indicates less stringent requirements and therefore lower infrastructure costs. The bottom row is a sum of all the times the particular service is called out. Based on the number of times that a communication service is called out, the services are ranked in terms of the number of "hits" in Figure:

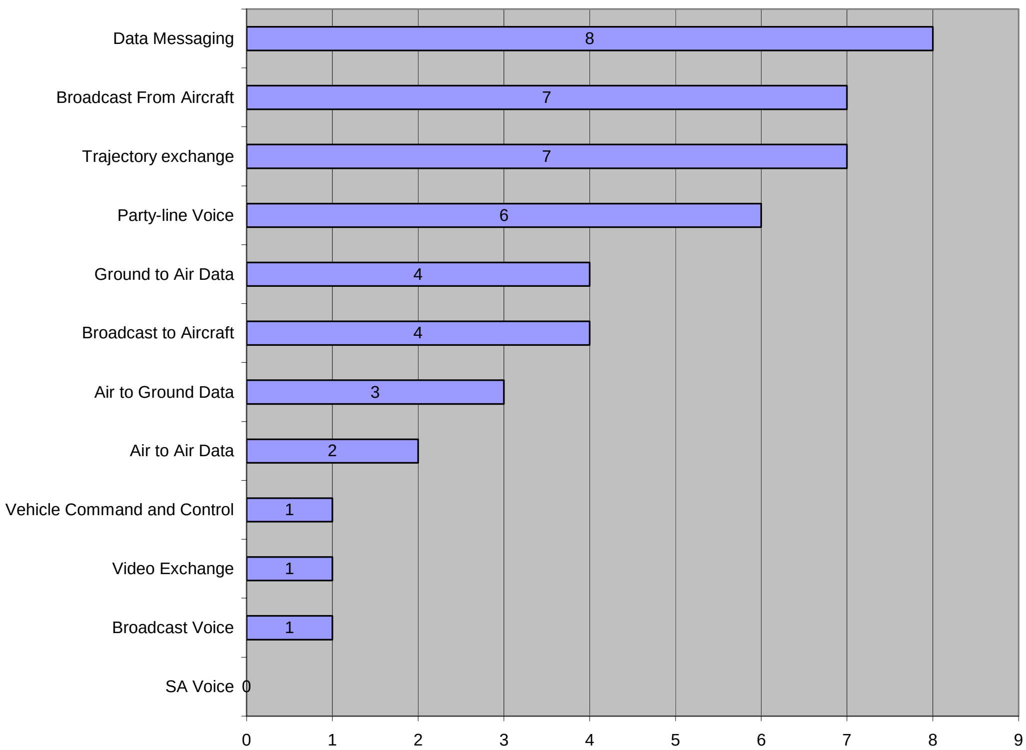

Figure 9: Number of "hits" per Communication Service.

Based on this analysis, Data Messaging, Broadcast from Aircraft, Trajectory Exchange and Party-line Voice are the most valuable services in terms of meeting the 17 identified scenarios. These services account for 64% of the hits. Vehicle Command and Control, Video Exchange, Broadcast Voice and SA Voice are the least valuable services accounting for only 7% of the hits.

In another analysis, the 13 communication services were evaluated based on the number of the top 12 scenarios they enabled. If a scenario was enabled by a single communication service it was given a 1. If a scenario requires several communication services, each communication service required is denoted "OR." If a scenario is enabled by one of several communication services (e.g. Autonomous Weather Alert Notification) it was labeled an "AND." Then each service was credited for each scenario it enabled and the scenarios were sequenced in order to maximize the number of scenarios enabled with the fewest communication services. When several communication services were required to enable a scenario, only the communication service that fully enabled the scenario was given credit.

Table 8: Incremental Value Ranking of Communication Services.

	Deploy FIS-'B Nationally	Autonomous Hazard Wx Alert Notification	Datalink to reduce routine workload	Enhanced Emergency Awareness	Optiumize Runway Assignments	Controller awareness of ACAS resolutions	Aircraft push of security	Push of security advisories	Enhance Flight Data Management	Interactive Flight Planning From Anywhere	Oceanic Separation to RNP-4	Flow Planning with distributed schedule reco	Scenarios Enabled	Rank
Data Messaging		OR	&			1		1			&		3	1
Trajectory Exchange					&				1	1		1	3	1
Party-line Voice			&								&		2	2
Broadcast from Aircraft				1	&		&						1	3
Broadcast to Aircraft	1	OR											1	3
Ground to Air Data		OR			&								1	4
Air to Ground Data							&						0	4
Video Exchange							&						1	4
Broadcast Voice		OR											0	5
SA Voice													0	6
Air to Air Data													0	6
Vehicle Command and Control													0	6

This analysis confirmed that Data Messaging and Trajectory Exchange are the most valuable scenarios. Party Line Voice and Broadcast from Aircraft remained in the top 4. Broadcast Voice, SA Voice, Air to Air Data and Vehicle Command and Control are the bottom value scenarios according to this analysis.

In terms of investing resources wisely, one of the implications of this analysis is that it may be better to concentrate on just a few communication services, such as Data Messaging and Trajectory Exchange, and exploiting these to their fullest rather than trying to implement all of the service classes and all of the associated scenarios.

6 MCNA Strategies

In the MCNA arena, communication links deliver communications services; communication services enable scenarios; and scenarios deliver value. An MCNA strategy identifies the communication links and protocols that will be prevalent during a specific time period. With this approach, each strategy can be evaluated against how well it delivers the 17 scenarios identified as high value. The strategy can then be evaluated for gaps (i.e. scenarios not delivered) and adjusted to enable more scenarios.

Six decision areas were identified as required to identify a complete MCNA strategy:

- Air to Ground Voice (CONUS)
- Air to Ground Data (CONUS)
- Polar, Remote and Oceanic Communications
- Air to Air Communications
- Airport Communications
- Networking Protocols

A standard strategy table was constructed to identify all of the options available for each of the decision areas. The base strategy table is shown below:

Table 9: MCNA Baseline Strategy Table.

	Air-to-Ground Voice (CONUS)	Air-to-Ground Data (CONUS)	Polar, Remote, Oceanic Communications	Air-to-Air Communications	Airport Comm	Networking Protocols
	VHF Analog Voice 8.33 kHz Analog Voice VDLM3	POA VDL2 VDL3 3G Satellite	HFDL HF Voice Aero-H SWIFT-64 SWIFT Broadband SDARS SDLS Iridium Connexion	1090-ES UAT VDL4 B-VHF P-25 P-34	IEEE 802.11 IEEE 802.16 IEEE 802.20 TETRA I/II Future Airport Airport Data Link	ACARS CLNP IP Layer 2 Multiple Protocols

To define a strategy, one or more selections are made in each column. These selections across the strategy table define a strategy.

Strategies were defined for 2005, 2015, and 2025 based on expected technology availability and providing the highest overall value.

6.1 2005 MCNA Strategy

Table 10: 2005 MCNA Strategy.

	Air-to-Ground Voice (CONUS)	Air-to-Ground Data (CONUS)	Polar, Remote, Oceanic Communications	Air-to-Air Communications	Airport Comm	Networking Protocols
	VHF Analog Voice	**POA**	**HFDL**	**1090-ES**	IEEE 802.11	**ACARS**
	8.33 kHz Analog Voice		**HF Voice**	**UAT**	IEEE 802.16	CLNP
		VDLm2	**Aero-H**	VDLm4	IEEE 802.20	IP
			SWIFT-64	B-VHF	TETRA I/II	Layer 2
	VDLm3	VDLm3	SWIFT Broadband	P-25		Multiple Protocols
				P-34	Future Airport	
		3G	SDARS			
		Satellite	SDLS		Airport Data Link	
			Iridium			
			Connexion			

The 2005 strategy is designated in bold, blue font.

In 2005, VHF Analog Voice is used for Air-to-Ground Voice in the CONUS. Air-to-Ground Data in the CONUS is provided by Plain Old ACARS (POA) and VDLm2. Polar, Remote and Oceanic communications are provided by High Frequency Data Link, High Frequency Voice and Aero-H. For Air-to-Air Communications 1090 Extended Squitter (ES) is used. There are some deployments of airline specific wireless communications of Gatelink, specifically those operated by Southwest and Fedex, but these are limited. The primary networking protocol is ACARS.

6.2 2015 MCNA Strategy

Table 11: 2015 MCNA Strategy.

	Air-to-Ground Voice (CONUS)	Air-to-Ground Data (CONUS)	Satellite Comm (Polar, Remote, Oceanic)	Air-to-Air Communications	Airport Comm	Networking Protocols
2015	VHF Analog Voice **8.33 kHz Analog Voice** VDLm3	POA **VDLm2** VDLm3 3G Satellite	**HFDL** HF Voice **Aero-H** **SWIFT-64** **SWIFT Broadband** **SDARS** SDLS Iridium Connexion	**1090-ES** **UAT** VDLm4 B-VHF P-25 P-34	**IEEE 802.11** **IEEE 802.16** IEEE 802.20 TETRA I/II Future Airport Airport Data Link	ACARS CLNP IP Layer 2 **Multiple Protocols**

In 2015, the growing congestion in the VHF band has required the migration of analog voice from 25kHz to 8.33 kHz. Datalink is provided in CONUS via VDLm2 over both ACARS and ATN. The BGAN satellite network provides nearly global datalink coverage, including as either primary or backup for certain applications in the NAS. This satellite network also provides backwards compatibility for Aero-H and Swift-64 equipped aircraft. Remote, Oceanic and Polar regions are further augmented by HFDL for availability and SDARS for more efficient data broadcast.

ADS-B services are widely adopted using 1090-ES for transport aircraft and UAT for GA. The airport provide short and medium range datalink communications via the family of 802.x protocols, specifically a much wider deployment of 802.11 and an initial deployment of 802.16 a select airports. From a network protocol perspective, a significant amount of IP-based links have been deployed by this timeframe. However, since these links are newly deployed the distribution of networking protocols is fairly diverse with a majority of users splits between IP and ATN and a smaller percentage still hanging onto ACARS (this is assuming that FANS has been upgraded to FANS-2, thus providing a mechanism for FANS equipped aircraft to migrate to ATN at a reasonable cost).

6.3 TSD Strategy

Table 12: TSD MCNA Strategy.

	Air-to-Ground Voice (CONUS)	Air-to-Ground Data (CONUS)	Satellite Comm (Polar, Remote, Oceanic)	Air-to-Air Communications	Airport Comm	Networking Protocols
TSD Strategy	VHF Analog Voice 8.33 kHz Analog Voice **VDLm3** 3G P-25 BVHF	POA VDLm2 **VDLm3** P-34 B-VHF 3G Satellite	**HFDL** **HF Voice** **Aero-H** SWIFT-64 SWIFT Broadband SDARS SDLS Iridium Connexion	**1090-ES** **UAT** VDLm4 B-VHF P-25 P-34	IEEE 802.11 IEEE 802.16 IEEE 802.20 TETRA I/II Future Airport Airport Data Link	ACARS **CLNP** IP Layer 2 Multiple Protocols

In the FAA Target System Description, the primary difference from the 2015 strategy is that VDLm3 is used for voice and data instead of 8.33 kHz Analog Voice and VDLm2. This represent a significant risk given that the NexCom program has been cancelled and was originally targeting only voice services in this timeframe. Also, the TSD represents a much less aggressive use of satellite technology than the 2015 strategy, relying instead upon the existing Aero-H SatCom capabilities and augmenting this with HFDL. The TSD is focused on migrating networking protocols to ATN (CLNP and TP4). This contrast with the 2015 MCNA strategy that acknowledges a brief introduction of ATN as a necessary step to maintain progress on datalink towards a vision state of IP-based networking.

6.4 2025 MCNA Strategy

Table 13: 2025 MCNA Strategy.

	Air-to-Ground Voice (CONUS)	Air-to-Ground Data (CONUS)	Satellite Comm (Polar, Remote, Oceanic)	Air-to-Air Communications	Airport Comm	Networking Protocols
2025	VHF Analog Voice **8.33 kHz Analog Voice** VDLm3 3G **P-25** BVHF	POA VDLm2 VDLm3 **P-34** B-VHF 3G **Satellite**	HFDL HF Voice Aero-H SWIFT-64 **SWIFT Broadband** **SDARS** SDLS Iridium Connexion	**1090-ES** **UAT** VDLm4 B-VHF P-25 P-34	IEEE 802.11 **IEEE 802.16** IEEE 802.20 TETRA I/II Future Airport Airport Data Link	ACARS CLNP **IP** Layer 2 Multiple Protocols

In 2025, unless the FAA/Eurocontrol Future Communications Study leads to a decision to revive VDLm3 for A/G data and voice, by 2025, derivatives of P25 and P34 are introduced and provide voice and data services over IP throughout the NAS. Legacy voice services remain for GA aircraft, but these have been transitioned to 8.33kHz to maximize spectral efficiency. Inmarsat satellite services have migrated completely (or at least mostly) to Swift-Broadband to maximize spectral efficiency but SDARS still provides specific broadcast data services.

Air-to-air communications have migrated to P25 and P34 but 1090-ES and UAT still exist for legacy system support. In the surface and terminal domain, 802.16 has supplanted 802.11 because it provides a wider range of coverage and airlines do not want to equip for redundant avionics that are not necessary. By 2025 IP has become the dominant network protocol, used by P25, P34, Swift-Broadband, SDARS and 802.16. However, some legacy ATN usage remains.

6.5 Summary of Strategies

The table below summarizes the progression from the current 2005 strategy to the 2025 strategy.

Table 14: Summary of MCNA Strategies.

	Air-to-Ground Voice (CONUS)	Air-to-Ground Data (CONUS)	Satellite Comm (Polar, Remote, Oceanic)	Air-to-Air Communications	Airport Comm	Networking Protocols
2005	VHF Analog Voice	POA VDLm2	HF Voice HFDL Aero-H	1090- ES UAT	Limited	ACARS
2015	8.33 kHz Analog Voice P25	VDLm2 Satellite	HF Voice Aero-H Swift-64 SWIFT Broadband SDARS	1090-ES UAT	IEEE 802.11 IEEE 802.16	Multiple Protocols
2025	8.33 kHz Analog Voice P25	P34 Satellite	SWIFT Broadband SDARS	1090-ES UAT	IEEE 802.16	IP

6.6 Evaluation of Strategies

The analysis shows, Table 15, that MCNA will deliver all of the high value scenarios in 2025 and all but two (ROA Control and Shared Responsibility for Horizontal Separation) by 2015. Moreover, the analysis shows that MCNA delivers more capability than the strategy described in the FAA Target System Description, primarily by embracing satellite technology.

The key areas of risk for the MCNA 2015 strategy are providing the Level-1 Air-Air data exchange and providing Level-1 Command and Control Datalink. The risks to providing these services subsequently result in risk to providing the ROA Control and Shared Responsibility for Horizontal Separation scenarios. The 1090-ES candidate link should provide the ability to support Level-1 Air-Air data communications. However, it is not clear that much effort is currently underway to focus on CLNP-based data exchanges via 1090-ES. The recommended approach to reduce risk in this area would be to introduce less stringent operational scenarios in the near term that leverage the use of CLNP over 1090-ES. A good candidate might be the Controller Awareness of ACAS resolution. If these messages were delivered via CLNP over 1090-ES, a migration strategy could be initiated that would transition to the datalink being utilized to assist with ACAS resolutions and eventually relying upon the 1090-ES for full conflict resolution based upon intent exchange and trajectory negotiation.

The other high risk communication service for the 2015 strategy is Level-1 Vehicle Command and Control. This communication service demands low latency and very high availability and continuity. No individual candidate link is expected to provide sufficient performance in the terminal and en-route airspaces. Consequently, a combination of multiple candidate links is required. Swift-Broadband would make a good contributor to such an aggregate service but VDLm2 is not expected to provide sufficient bandwidth. The chances of supporting this scenario in the 2015 timeframe would be greatly increased by expediting the P25/P34 deployment cycle.

Table 15: Evaluation of MCNA Strategies.

	Scenario	Communication Services: Party-line Voice	SA Voice	Broadcast Voice	Data Messaging	Trjaecotry exchange	Broadcast to Aircraft	Broadcast From Aircraft	Ground to Air Data	Air to Ground Data	Air to Air Data	Video Exchange	Vehicle Command and Control	2005	TSD 2015	MCNA 2015	MCNA 2025
1	Deploy FIS-B Nationally						3							Yes	Yes	Yes	Yes
5	Autonomous Hazard Weather Alert Notification			2	2		2		2					Maybe	Yes	Yes	Yes
10	Datalink to reduce routine workload	3			2									Maybe	Yes	Yes	Yes
15	Enhanced Emergency Alerting							1						No	Maybe	Yes	Yes
20	Optimize Runway Assignments					2		1	2					No	Maybe	Yes	Yes
25	Controller awareness of ACAS resolutions				1									No	Maybe	Yes	Yes
29	Aircraft push of security video and aircraft performance during emergency							2		2		1		No	No	Yes	Yes
32	Push of Security advisories to aircraft				2									No	Yes	Yes	Yes
16	Enhance Flight Data Management					2								No	Maybe	Yes	Yes
17	Interactive Flight Planning From Anywhere					2								No	Maybe	Yes	Yes
18	Oceanic Separatoin to RNP-4	4			2	2								Maybe	Maybe	Yes	Yes
22	Flow Planning with distributed Schedule Recovery and Post Departure Rerouting					2								Maybe	Maybe	Yes	Yes
30	ROA Control	2			2					1	1		1	No	No	Maybe	Yes
31	UAV Control					1	2	1	2	2				No	No	Yes	Yes
38	Dynamic Resectorization	2			1	2	1	1						No	Maybe	Yes	Yes
13	Improved Surface Separation Assurance	3			1			1	2					No	Maybe	Yes	Yes
9	Shared Responsibility for Horizontal Separation	3						1			1			No	Maybe	Maybe	Yes

Legend

Yes Maybe No

6.7 Sensitivity Analysis

The key areas of risk for the MCNA 2015 strategy are providing the Level-1 Air-Air data exchange and providing Level-1 Command and Control Datalink. The risks to providing these services subsequently result in risk to providing the ROA Control and Shared Responsibility for Horizontal Separation scenarios. The 1090-ES candidate link should provide the ability to support Level-1 Air-Air data communications. However, it is not clear that much effort is currently underway to focus on CLNP related data exchanges via 1090-ES. The recommended approach to reduce risk in this area would be to introduce less stringent operational scenarios in the near term that leverage the use of CLNP over 1090-ES. A good candidate might be the Controller Awareness of ACAS resolution. If these messages were delivered via CLNP over 1090-ES, a migration strategy could be initiated that would transition to the datalink being utilized to assist with ACAS resolutions and eventually relying upon the 1090-ES for full conflict resolution based upon intent exchange and trajectory negotiation.

The other high risk communication service for the 2015 strategy is Level-1 Vehicle Command and Control. This communication service demands low latency and very high availability and continuity. No individual candidate link is expected to provide sufficient performance in the terminal and en-route airspaces. Consequently, a combination of multiple candidate links is required. Swift-Broadband would make a good contributor to such a service but VDLm2 is not expected to provide sufficient bandwidth. The chances of supporting this scenario in the 2015 timeframe would be greatly increased by expediting the P25/P34-derivative datalink deployment cycle.

7 Economic Value of MCNA

One of the SIR requests was to "estimate the value contributed by the communications and/or network technologies to the overall benefit of each operational enhancement (by individual technology, when possible, or by clusters of complementary technologies), and also the benefits assessments of operational enhancements from the GCNSS and NASA VAMS contracts and from other sources as may be available."

To meet this request, a survey of several documents was done to identify the economic benefits of the scenarios enabled and how MCNA enabled those scenarios.

7.1 Arrival Management

In the GCNSS I contract, one of the concepts the Boeing team analyzed was the benefits of arrival management and extended terminal management.

In the scenario analysis, Arrival Management was called Continuous Descent Arrivals (CDA), scenario #23. (See Table 3) It had a high rating on flight path efficiency but high risk and didn't make the cut to the final round of scenarios evaluated. Given the potential benefits cited below, it should be added back into the set of scenarios driving MCNA for any future analysis. However, the MCNA strategy roadmap as proposed still stands: CDA is requires Trajectory Exchange at performance level 2, a performance level met by the proposed 2015 strategy.

7.1.1 Concept Description

Arrival management uses trajectory-based datalink, integrated with the airplane's Flight Management System (FMS) to provide a more optimal flight path between the top of descent and the runway. Extended terminal management extends that capability to airspace-constrained airports such as the New York area airports.

SWIM and MCNA are the key enablers to this operational capability. They provide operators with preferences and priorities for their aircraft, current terminal status and constraints, wind and weather information to the sequencing and trajectory algorithms, and the latest in aircraft performance characteristics for use in the trajectory algorithm. SWIM and MCNA enables the sharing of this data so that all those involved with a flight – service providers, dispatchers, and other users – have the same information when they need it.

In the arrival management concept, non-equipped aircraft continue to fly the traditional step-downs, while equipped airplanes are given a more efficient trajectory at top of descent that is loaded into the aircraft's FMS. An additional benefit from arrival management is a slight increase in capacity in Instrument Meteorological Conditions (IMC) through advanced runway management of aircraft sequencing and runway assignment to minimize any capacity lost due to the addition of separation buffers beyond the wake vortex separation requirements. The benefits of this capability have not been quantified.[3]

7.1.2 Economic Benefits

The identified economic benefit was 3.8 minutes per flight time savings, due to the more efficient flight path associated with continuous descent relative to step downs. The savings is accrued entirely to the equipped air carrier. The annual savings accrued to a typical air carrier, assuming 1600 flights per year and $37 per minute in operating costs amounts to about $225,000 per year. Assuming 5000 air carrier implementing the option the annual savings would be $1.1B per year. The calculated net present value for the proposed concept, assuming a 20-year business case, gradual equipage, and a 7% discount rate is $1.1B.[4]

7.2 Space-Based CNS

In the GCNSS I contract, the second concept the Boeing team analyzed was the benefits of utilizing space-based CNS to reduce separation in the Gulf of Mexico (GOM).

7.2.1 Concept Description

Today, aircraft spacing in the GOM and oceanic regions is greater than in the domestic NAS due to a lack of surveillance and direct controller to pilot communications. In order to reduce spacing within this airspace-specific domain, improved surveillance and communication services are required. The global space-based CNS enhancement equips airplanes with the next generation of Satcom and FANS.

FANS, with GPS, provides contract-based automatic dependent surveillance (ADS-C) with sufficient accuracy but unacceptable position update rates to replace radar. FANS offers a direct controller to pilot voice communication capability based upon circuit-switched telephony, which has not yet been adopted for human factors reasons. The proposed next generation Satcom and FANS systems offer improved ADS update rates and a party-line voice service intended to emulate the current VHF voice capability. Although Satcom party-line voice introduces higher latency, it may be acceptable for en-route operations.

[3] Global Communication Navigation & Surveillance System (GCNSS) Concept Exploration,Volume II ─ Cost Benefit Analysis; CDRL A003; D794-100127-1, Rev A; May 21, 2004 , pp. 12 -13

[4] ibid, p. 24.

With these improvements in the GOM, spacing can be reduced from the baseline provided by the OEP and RVSM of 60 NM longitudinal, 60 NM lateral, and 1000' vertical (60/60/1000) to 20/20/1000 or 10/10/1000, for equipped aircraft depending upon service-provider capabilities. In the GOM, there are two sub-business cases to consider – the North-South (N-S) routes and the East-West (E-W) routes. Through reduced spacing provided by the proposed enhancement, aircraft would be able to fly at optimal altitudes without incurring any delay.

The E-W case provides new airspace capacity, for those equipped aircraft that are flying to and from Florida (Miami, Tampa and Orlando) and western cities south of San Francisco, including Denver, Houston, Las Vegas and Dallas Fort-Worth.[5]

7.2.2 Economic Benefits

The net present value was negative in both business cases. The economic benefits for the both the North-South business case and the East-West case did not close the case for equipage, even if equipage were $150K. The annual savings per aircraft was estimated to be only $25K per year.[6] One of the challenges for the GOM business case is that an aircraft typically flies in the Gulf on only a fraction of their flights and airlines are reluctant to isolate a "sub-fleet" for Gulf operations. Their was insufficient data to analyze other regions but based on the Gulf of Mexico business case it's not clear whether the business case for those regions would close either. One of the suggestions made to close the business case was to share the communication services equipment with other needs such as passenger communications.[7]

7.3 Controller-Pilot Data Link Communications

In September 2004, MITRE released a cost benefit analysis on Controller-Pilot Data Link Communications (CPDLC).[8]

7.3.1 Concept Description

In their analysis, MITRE analyzed the costs and benefits of implementing CPDLC in the en route domain. Two benefit mechanisms were identified and quantified: 1) Controller workload reduction and 2) reduced delays as a result of increased en route capacities.[9]

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[5] Ibid, p. 42-43.

[6] Ibid, p. 49.

[7] Ibid, p. 54.

[8] Giles, Stephen, Lowry, Niamh, Steinbach, Michele, and Shingledecker, Clark; "Controller-Pilot Data Link Communications Benefit-Cost Analysis Methodology; MTR 04W0000081; September 2004.

7.3.2 Economic Results

The concept evaluated had an expected Net Present Value of $558M. [10] The cost-benefit analysis covered 20 years and assumed a 2004 implementation.

7.4 Boeing 2020 Gate-to-Gate Concept

In December 2003, under the NASA-VAMs contract, Boeing analyzed their "Gate-to-Gate Capacity Increasing Concept."[11]

7.4.1 Concept Description

The NASA-VAMs concept is a far-reaching concept that impacts every aspect of air traffic management and strives to meet the capacity, efficiency and safety requirements for the forecasted traffic in 2020. The three pillars of the concept are Precision Procedural Control, 4D Trajectory Operations, and Required Total System Performance. The concept description does not describe in much detail the MCNA requirements, but clearly 4D trajectory operations would require trajectory exchange. Required Total System Performance includes Required Communications Performance. RCP issues and challenges for NCNA are discussed in the Certification report. Also refer to Section 8.4 below.

Table 16: Operational Elements Summary Table.

Operational Concept Element	Concept Features	Operating Element Features	Capacity Increase Target	Basis of Estimate
Runway Management	Trajectory Based Planning Precision Procedural Control High Performance Trajectory DL Medium Term Conflict Mgmt Planning Integration	Precision Approach Gate Sequencing Variable Glide Path Displacement Precision Runway Operations Planner Autopilot Auto-brakes & Auto-spoilers Precision Rollout Guidance Wake Class GPIP Assignment	Runway Occupancy Time Reduction by 20% of Current Value VMC Capacity	Statistical Analysis and NAS Delay Model

[9] Ibid, p. 5-11.

[10] Ibid. p. 6-6

[11] Sipe, Al, et. Al; "Boeing ATM Concept Assessment Document for NASA VAMS," D780-11023-1, Rev A; December 12, 2005.

Operational Concept Element	Concept Features	Operating Element Features	Capacity Increase Target	Basis of Estimate
Runway Management	Trajectory Based Planning Precision Procedural Control High Performance Trajectory DL Medium Term Conflict Mgmt Planning Integration	Precision Approach Gate Sequencing Variable Glide Path Displacement Precision Runway Operations Planner Autopilot Auto-brakes & Auto-spoilers Precision Rollout Guidance Wake Class GPIP Assignment	Runway Occupancy Time Reduction by 20% of Current Value VMC Capacity	Statistical Analysis and NAS Delay Model
Closely Spaced Parallel Runway Operations Staggered Approach	Trajectory Based Planning Precision Procedural Control High Performance Trajectory DL Separation Management Monitoring And Back Up Modes Coordinate with ACAS	Lateral Containment Variable Glide Path Displacement Wake Vortex Atmospheric Monitoring Arrival Weight Class Planning & Sequencing	2X Single Runway Capacity Down to 1200 ft	Airport Analysis and NAS Delay Model
Advanced Flow Management	Required Total System Performance High Performance Trajectory DL Coordinated Flight Re-planning Equity Based Allocation Schedule Connectivity Complexity Management Dynamic Airspace Configuration	Collaborative Re-routing Planner Advanced Convective Weather Forecasting System Integrated NAS Delay System	Convective Weather Capacity @ 95% Of Good Weather Capacity	Initial Modeling and Extrapolation
Sector Productivity	Trajectory Based Planning Multi Sector Traffic Planning Enlarged Sector Span of Control Planning Integration Complexity Management Medium Term Conflict Probe Traffic Management Coordination Traffic Flight Plan Controls Required Total System Performance Equity Based Allocation Schedule Connectivity		3X to 4X Current MAP Values	Sector Loading Analysis and Extrapolation
Enhanced	Trajectory Based Planning	Surface Traffic	Surface	Initial Surface

Operational Concept Element	Concept Features	Operating Element Features	Capacity Increase Target	Basis of Estimate
Runway Management	Trajectory Based Planning Precision Procedural Control High Performance Trajectory DL Medium Term Conflict Mgmt Planning Integration	Precision Approach Gate Sequencing Variable Glide Path Displacement Precision Runway Operations Planner Autopilot Auto-brakes & Auto-spoilers Precision Rollout Guidance Wake Class GPIP Assignment	Runway Occupancy Time Reduction by 20% of Current Value VMC Capacity	Statistical Analysis and NAS Delay Model
Surface	Planning Integration High Performance Trajectory DL Precision Procedural Control	Management Precision Taxiway Guidance	Capacity 1.5 Time Runway Capacity	Analysis and Extrapolation
Extended TMA Routing, Sequencing And Assignment	Trajectory Based Planning Planning Integration High Performance Trajectory DL Precision Procedural Control		Transition Airspace Capacity 4X Current Values	Industry Studies and Engineering Judgment
IMC and MVMC Final Approach Spacing (Not Included)	Trajectory Based Planning Enhanced ETA and RTA Control		10% Increase in VMC and in MVMC airport capacities	Industry Studies and Engineering Judgment

7.4.2 Economic Benefits

Based on a very high level assessment of the benefits of delay reduction only, the entire concept saves a projected $11.8B per year in 2020. This estimate is relative to a do-nothing scenario where traffic grows according to forecasted rates but nothing is done in addition to already planned and funded runway projects.

8 Enabling Technology Analysis

One of the requested analyses for MCNA was to "conduct high-level cost/benefit analyses to determine those enabling technologies and certification methodologies with most return on investment for development through technology readiness level (TRL) 6."

Four research areas have been identified as potentially high value research for MCNA. The highest value research area identified is "RCP process independent of an individual candidate link." However, it also has the highest risk. From a risk-return perspective, the proposed projects are fairly close and there is no obvious priority.

8.1 Methodology

The methodology used for the enabling technology analysis is based on R&D decision analysis methodology. In R&D decision analysis, the following basic steps are taken.[12]

1. Identify the objective of the research and define what technical success for that project means.
2. Identify the costs of the research.
3. Identify the probability of technical success.
4. Identify the benefits if technical success is achieved.

Ideally costs and benefits are quantified in dollar terms and the net present value for the project is computed. Proposed projects are then plotted on a graphic similar to Figure 8.1 and evaluated in terms of their expected benefit-cost ratio, taking into account the probability of success.

The graphic below puts a label on projects depending on their risk-reward ratio. High risk, low value projects are deemed "white elephants" and should not be funded. Ideally all projects are "pearls" low risk, high value. However, pearls usually emerge from oysters, projects with high risks where the technical hurdles are eventually overcome. "Bread-and-butter" projects are projects of low risk but relatively low value. The objective of this approach is to funnel R&D funds to a mix of projects with highest risk-reward ratio, balancing higher risk, higher value projects with lower risk but lower value projects.

[12] The Smart Organization; Matheson, James and Matheson, David; Harvard Business School Press; 1998 p. 199 – 220.

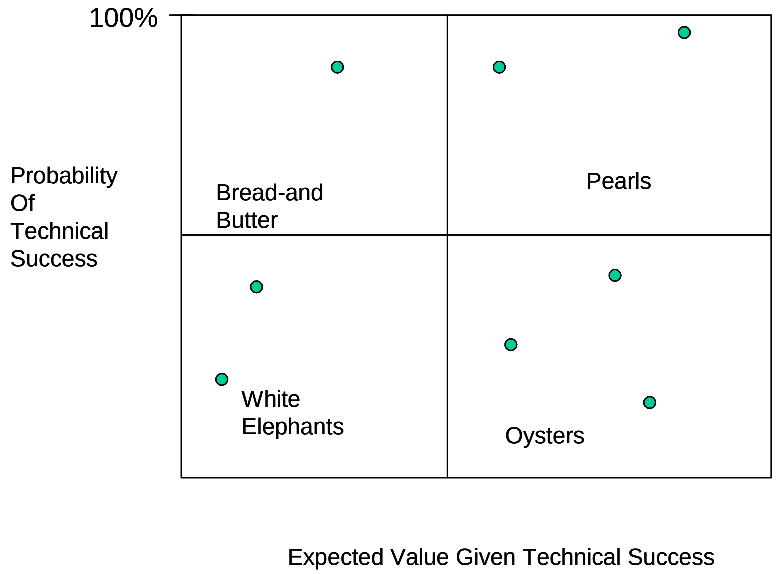

Figure 10: R&D Portfolio Grid.

Due to resource and time constraints, a qualitative assessment of the benefits was assessed on the scale described below by the Boeing MCNA team The scale measures MCNA technical, schedule and cost risk (the three risks typically modeled in a program) in terms of meeting the MCNA vision as defined by the strategy roadmaps in Section 6.5. The higher the risk the higher the benefit of successful research.

Table 17: Qualitative Rating Methodology Description.

Risk Type	**Qualitative Rating**				
	1	2	3	4	5
Technical	Minimal or No impact	Moderate Impact same approach retained	Moderate impact, but workarounds available	Major impact, but workarounds available	Unacceptable, No Alternatives Exist
Schedule	Minimal or No impact	Additional activities required, roadmap slips 1 year	Additional activities required, roadmap slips 3 years	Additional activities required, roadmap slips 6 years	Cant' achieve key MCNA milestones
Cost	Minimal or No impact	Cost to industry increases 10%	Cost to industry increases 25%	Cost to industry increases 50%	Cost to industry increases 100%

8.2 Enabling Technology Analysis

8.2.1 Common IP Stack

Objective of the Research: NASA or FAA funding to develop a TCP/IP stack that is DO-178B certified to Level C or higher and made generally available to spur the development of lower cost IP- compliant avionics. Such a product would eliminate the need for each avionics manufacturer to develop a separate certified IP stack and recoup those development costs over a small set of avionics. The effort should concentrate on a concise set of TCP/IP requirements based on avionics-specific tailoring of accepted standard, such as IPV6, a widely supportable, well-documented and traceable design, well-documented and traceable code in a widely supported language, such as C++, and a standard test suite. The effort would not encompass final instantiation-specific certification issues, which would be left to the equipment manufacturer.

Estimated Cost of Research: 10 labor years over 2 – 3 year period. (TBR)

Exit Criteria: Release of common certifiable TCP/IP stack.

Technical Showstoppers: Modification of TCP/IP protocols to accommodate aeronautical requirements would indeed not make a great deal of sense as such a strategy would quickly lose any advantage that may come from the re-use of COTS systems. However, there may be the opportunity to influence the evolution of the TCP-IP protocols to accommodate the needed aeronautical-specific mobility requirements; in which case the mobility requirements for A/G safety critical communications could be met with COTS systems, but only when the standards evolve to that point.

Non-technical Showstoppers: Industry agreement on need and adoption of protocol stack.

Probability of success: 75%. To be resolved (TBR).

Description of impact if we fail: Cost of IP-based avionics will increase resulting in delayed IP convergence. This would delay SWIM services to the aircraft.

Technical Risk Impact:	1
Schedule Risk Impact:	2
Cost Risk Impact:	3
Overall Impact:	2

8.2.2 SWIM Messaging

Objective of the Research: Develop and demonstrate the use of SWIM messaging as a means to introduce IP networking in the near term for ATS applications. An IP-based Message Transport Service (MTS) is a commercial technology that is rapidly growing in use and popularity and it has been selected as a key information transport service in the initial spiral SWIM design. Applying this SWIM MTS would address the short term IP mobility issues and provide a means to handle AAC, AOC and ATS message exchanges that are currently handled via ACARS. A further benefit is that SWIM MTS provides a means of interoperability between the various internetworking protocols in the NAS. Analysis, simulation and laboratory experimentation leading to flight trial of such an MTS used for CPDLC, ADS and the extension of SWIM services to the aircraft would result in a demonstration of transformational technology.

Estimated Cost of Research: 20 labor years over 3 to 5 year period. (TBR)

Exit Criteria: Flight demonstration using SWIM messaging over commercial IP links.

Technical Showstoppers: The latency performance of SWIM messaging may only support a small subset of ATC services.

Non-technical Showstoppers: None identified.

Probability of success: 90%

Description of impact if we fail: Delayed deployment of IP networking resulting in a longer period of diverse networking protocols in the aeronautical industry.

Technical Risk Impact:	2
Schedule Risk Impact:	4
Cost Risk Impact:	1
Overall Impact:	2.3

8.2.3 System Certification Process

Objective of the Research: A cooperative effort between FAA and interested parties should be undertaken to develop and approve an agreed-upon process for the submission and review of relevant data and the approval of commercial services and related avionics for AOC and ATS applications. One possible means for the service certification might be the development of *System/Service* Type Certification or *System/Service* Supplemental Type Certification. For avionics certification DO-262 should be used as a baseline for this effort.

Estimated Cost of Research: 15 labor years over a 5-year period. (TBR)

Exit Criteria: Release of SARPS with certification process that has reasonable cost.

Technical Showstoppers: None identified.

Non-technical Showstoppers: Agreement of a common definition and process for application of Requirements Communications Performance (RCP) to decouple communications systems from the services they support. Sufficient interest from government and industry to participate.

Probability of success: 60%.

Description of impact if we fail: Reduced availability of commercial communication services, resulting in increased service costs and delayed service deployment.

Technical Risk Impact:	1
Schedule Risk Impact:	4
Cost Risk Impact:	3
Overall Impact:	2.7

8.2.4 RCP process independent of an individual candidate link

Objective of the Research: The RCP framework must be defined such that a communication service can be addressed using one or more candidate links. Furthermore, the performance allocations for the various RCP levels must be derived through operational analysis. Basic operational analysis has been conducted for separation analysis by relating communication and controller intervention time into distance using aircraft closing velocity. Through this analysis, safe spacing distances can be related to navigation accuracy, surveillance accuracy and timeliness and communication and controller intervention latency.

Estimated Cost of Research:15 over a 5-year period.

Exit Criteria: RCP roadmap and guidance material (e.g. RTCA documents for datalink materials). The resulting RCP certification process must be simpler than the current certification process without RCP.

Technical Showstoppers: None identified.

Non-technical Showstoppers: Sufficient industry participation and agreement.

Probability of success: 50%.

Description of impact if we fail: Reduced availability of commercial communication services, resulting in costly government-owned custom communication systems.

Technical Risk Impact:	4
Schedule Risk Impact:	4
Cost Risk Impact:	4
Overall Impact:	4

8.3 Summary of Results

The results are summarized in the chart below. Each bubble contains the expected number of labor years required for the research.

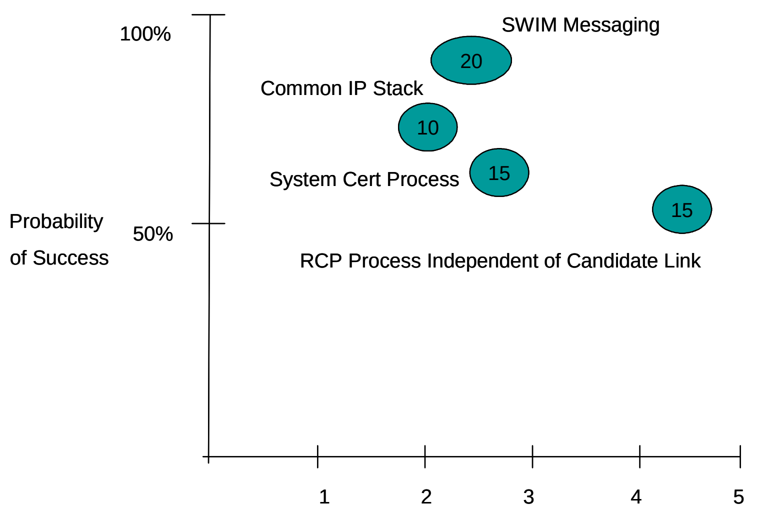

Figure 11: Enabling Technology Results.

In terms of benefit, "RCP Process Independent of Candidate Link" provides the largest benefit but has the lowest overall probability of success, 50%. The overall cost of research is estimated at 60 labor years.

Ideally this analysis would have yielded some clear priorities. However, based on a cost-risk-benefit tradeoff none of the projects are clearly dominated. For instance, Common IP Stack, while it has lower benefit and lower probability of success than SWIM Messaging, it also requires only 10 labor years instead of 20. With that exception, a project's value goes up as the probability of success goes down.

Appendix A. Acronyms

Term	Definition
ADS-A, B, C	Automatic Dependent Surveillance-addressable, broadcast, contract
AIM	Aeronautical Information Management
ASDE-X	Airport Surface Detection Equipment Model X
ASSA	Airport Surface Situational Awareness
ATC	Common Air Surveillance Picture
CASP	Continuing Analysis and Surveillance Program
CDRL	Contract Data Requirements List
CDT	Common Data Transport
CGW	Communication Gateway
CIWS	Corridor Integrated Weather System
CORBA	Common Object Request Broker Architecture
COTS	Commercial-Off-The-Shelf
DDG	Data Distribution Gateway
ECG	En Route Communications Gateway
ERAM	En Route Automation Program
ETMS	Enhanced Traffic Management System
FAA	Federal Aviation Administration
FAROA	Final Approach and Runway Occupancy Awareness
FIS	Flight Information Service
FO	Flight Object
GBT	Ground Based Transceiver
GCNSS	Global Communication Navigation and Surveillance System
ISO	International Standards Organization
ITWS	Integrated Terminal Weather System
J2EE	Java 2 Platform Enterprise Edition
JPDO	Joint Program and Development Office
MIAWS	Medium Intensity Airport Weather System

Term	Definition
NAS	National Airspace System
NASR	NAS Resources Repository
NGATS	Next Generation Air Traffic System
NOTAM	Notice to Airmen
SDN	Surveillance Data Network
SDS	Surveillance Data Server
SEA	Swim-Enabled Application
SIU	System Interface Unit
STARS	Standard Terminal Automation Replacement System
SWIM	SWIM
SWWE	System-Wide Weather Enterprise
TFM-M	Traffic Flow Management Modernization
TIS-B	Terminal Information Service--Broadcast
UDDL	Universal Description, Discovery, and Integration
USNS	US NOTAMS System
WARP	Weather And Radar Process
WSDL	Web Services Description Language
Wx	Weather
XML	Extensible Markup Language