MCNA Requirements Report
(CDRL A046)

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1 INTRODUCTION

Mobile Communication Network Architecture (MCNA) represents the aggregate of all voice, data and surveillance Air-Ground (A-G) and Air-Air (A-A) communication capabilities in support of 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) toward Network Centric Operations (NCO). The MCNA contract represents a System of Systems Engineering (SoSE) based evaluation of MCNA. The specific focus of this contract 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 Advanced CNS Architectures and System Technologies (ACAST) project and NASA's proposed initiative for Transformation of the NAS (TNAS) in support of the JPDO's vision for the next generation air transportation system.

The MCNA nomenclature was introduced within the Statement of Work (SOW) for this contract. As such, it is a common misconception that MCNA refers solely to "vision" mobile communications capabilities intended to support the most demanding SWIM-enabled applications including cockpit integration. Actually, MCNA encompasses all aeronautical communications (voice and data) to and from aircraft. While the MCNA primary focus is on safety of life services including ATS and AOC the MCNA architecture should provide mechanisms for common infrastructure to support non-safety of life communication services such AAC and APC.

VHF RT, 1090ES, 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 possibly BGAN. The primary characteristic of MCNA is that it extends voice and data communications to the aircraft during all phases of flight. The MCNA fully enables not just aircraft, but any mobile element of the NAS, to become both consumers and producers of system wide information. Figure 1 illustrates how MCNA fits in the Common Data Transport (CDT) layer of the SWIM and thus supports the Network Centric Operations (NCO) that SWIM enables.

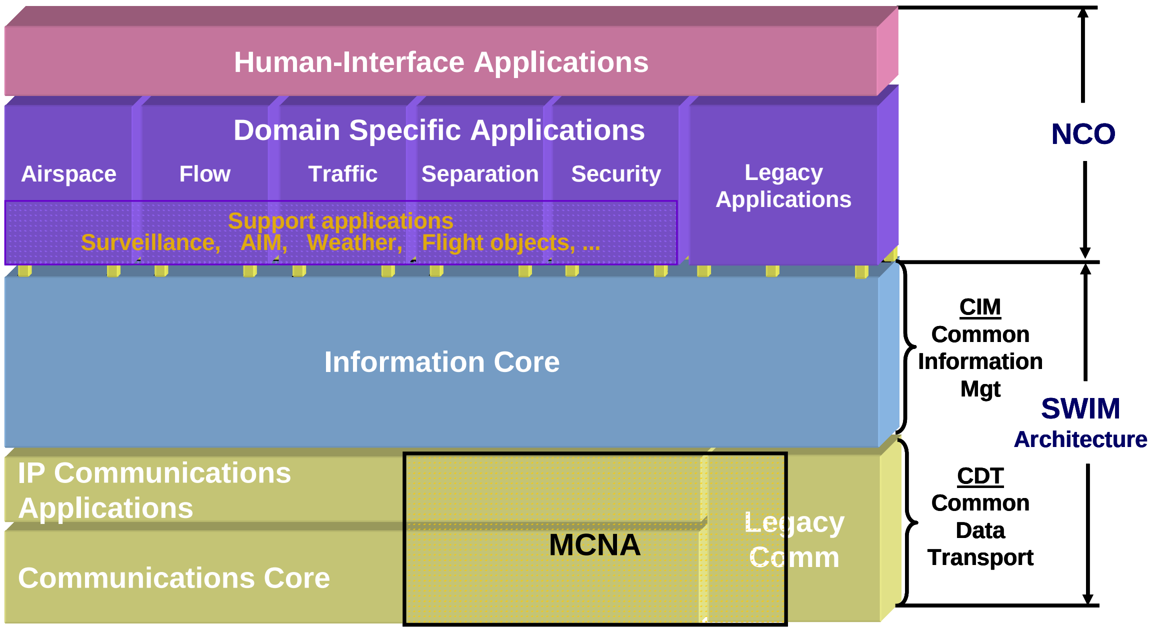

Figure 1: Relationship of MCNA to SWIM and NCO.

Initially, SWIM enabled applications (SEA) will rely upon terrestrial A-G communication gateways that configure SWIM information for exchange via existing datalink such as ACARS. In time, the prevalence and availability of structured communications protocols such as TCP/IP or ATN will provide greater flexibility and ease of information exchange with the aircraft and between aircraft. However, given the constraints on A-G bandwidth, some form of A-G gateway functionality will be retained to provide maximum functionality while preserving bandwidth. A further transition configuration may couple the terrestrial gateways with SWIM gateways on the aircraft that aggregate information from various disparate A-G links into coherent SWIM-based information services. As the availability of air-ground bandwidth expands, developers will extend select aspects of the SWIM directly to applications running on the aircraft. For clarification purposes, it is important to explicitly state what capabilities are not within the MCNA. MCNA does not include data communications that are not of ATM nature, such as passenger communications. That being said some of these services are included in discussions in of the MCNA as they must be considered for their influence and impact on MCNA architecture issues.

This document, the MCNA Requirements Report, details the results of the requirements development and analysis subtask of the MCNA contract. This includes the documentation of all the activities necessitated by a SoSE approach to requirements development. The MCNA Mission Needs and the MCNA Concept of Use, driven by use scenarios, are described with a SWIM focus. The MCNA functional analysis was performed to define the required functionality of MCNA. It should be noted that this deliverable is not meant to be a formal FAA requirements document as defined by the Acquisition Management System (AMS). Instead it is an attempt to aggregate a super set of requirements from existing industry efforts on A/G communications to that address

MCNA functionality to provides a means of determining an indicial set of baseline functional, characteristic, and performance requirements for MCNA. Some provide potential incontinences that will need to be resolved in future. Lastly, they provide a starting point for determination of potential gaps in functionality and characteristic MCNA requirements.

1.1 Document Roadmap

Section 2 describes the MCNA mission needs as an extension to the mission needs of SWIM. This section also contains a summary of the SWIM shortfalls with descriptions outlining when and how MCNA helps to address these shortcomings.

Section 3 describes the MCNA scenarios that were used to drive the requirements development processes. A large list of scenarios is described at a high-level with a select few identified for detailed description. In addition to a description of MCNA scenarios this section also contains a high level discussion of the MCNA concept of use.

Section 4 contains a detailed description of the functional analysis of MCNA.

Section 5 describes the methodology used to develop the MCNA system and performance requirements.

Section 6 contains all the current proposed MCNA requirements.

Section 7 provides conclusion that summarizes the results of the MCNA requirements development process.

Appendices provide references, list of acronyms, and a review of the SWIM surrogate Mission Needs Statement (sMNS) with annotation to identify MCNA relationships.

2 MCNA SURROGATE MISSSION NEEDS EXTENSION and SWIM Shortfalls

This section summarizes the results of activities of reviewing the SWIM surrogate Mission Needs Statement (sMNS) and the SWIM shortfalls from GCNSS II to identify areas where MCNA functionality is alluded to, specifically called out or could address a defined need. Appendix D provides a slightly modified version of the SWIM sMNS with annotation that is both bolded and colored blue to identify MCNA considerations.

In general, the results of the SWIM sMNS strongly support the hypothesis that MCNA is a key enabling technology for SWIM. More specifically, the key findings from this review include:

- **The aircraft is called out specifically as a SWIM node**
- **Capacity enhancing applications (specifically 4-D trajectory operations) infer a strong requirement/dependency upon MCNA**
- **SWIM & NCO Policy Statement call out FTI as a fundamental underlying technology but ignore any discussion of the need for MCNA (or any form of datalink)**

The review of the SWIM shortfalls identified further overlap between SWIM and MCNA (Table 1). The table below is an extension of the SWIM shortfalls table with an additional column added to provide specific discussion regarding how MCNA could help address the identified shortfalls.

Table 1: Evaluation of SWIM Shortfalls from MCNA Perspective.

Shortfall	Description	MCNA
1) The costs to develop, test, deploy and support new applications are too high.	The inherently disconnected nature of NAS systems and an historical practice of paper based management make much data invisible to potential users. Even when users know data exists, not all automation systems can make their data available. When they are available, its on the systems terms, not the users terms. Interoperability is built in through new point-to-point interfaces, when existing networks won't support new applications. There is no easy means to access real, live operations data to test new applications and support existing ones. Many data exchanges today are between systems whose interfaces are either predefined or even unanticipated.	These shortfalls are equally applicable to Airborne applications that require new interfaces. However, MCNA capabilities are a pre-requisite (much like FTI for terrestrial applications) before the benefits of SWIM can be realized.

	Application enterprise integration would enable 37 of the 53 future operational improvements cited in NAS 5 to be achieved more economically."	
2) The NAS has difficulty dynamically adapting to special events and disruptions in the short term and changing ops concepts and market demand in the long term.	One of the JPDO strategies is to "establish an agile air traffic system that accommodates future requirements and readily responds to shifts in demand from all users. The system will be responsive to market elasticity, have the flexibility to deliver capacity and efficiency improvements, and ensure that equipment and personnel are able to support a wide range and number of operations tailored to customer needs. "	A key aspect of the agile NAS is agility in A-G communications. If A-G links are geographically fixed, it becomes difficult to dynamically redefine airspace.
3) There is a lack of common situational awareness among NAS users.	One of the JPDO strategies is to "Provide each traveler and operator in the system with the specific situational awareness they need to reach decisions through the creation of a combined information network. All users of the system will have access to the air transportation data they require for their operation." Data is manually reentered as a work around to achieve common situational awareness. Data is not easily available to other agencies, organizations and users. TFR and SUA violations have jumped considerably since 9/11. One of the goals of the FAA Information Technology Strategy is the following: Improve and expand the electronic delivery of agency services and information to external customers and employees by providing high-quality, easy to find and use, one stop points of service. An FAA Information Technology Strategy objective is to "ensure that data and information that are used to conduct critical agency business or publicly disseminated are timely, accurate, accessible, understandable and secure. Kip Hawley states, "Our second priority is to get a management information framework in place that will allow the Air Traffic Organization (ATO) leadership team to use accurate, timely information.	Common situational awareness includes both the delivery of information to the aircraft and delivery of aircraft state information to the service providers and other aircraft.
4) Current metrics do not give complete performance-related information needed to assess operations.	Russ Chew adds "legacy systems may not be designed to provide the performance-related information we need and we will have to find or create new sources of data." Current metrics don't fully support FAA's goal of becoming a performance-based organization.	While probably a secondary effect, it would seem likely that aspects of this performance related information would be within the control of the aircraft and therefore require MCNA for distribution to ground monitoring systems.

3 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 2. 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.

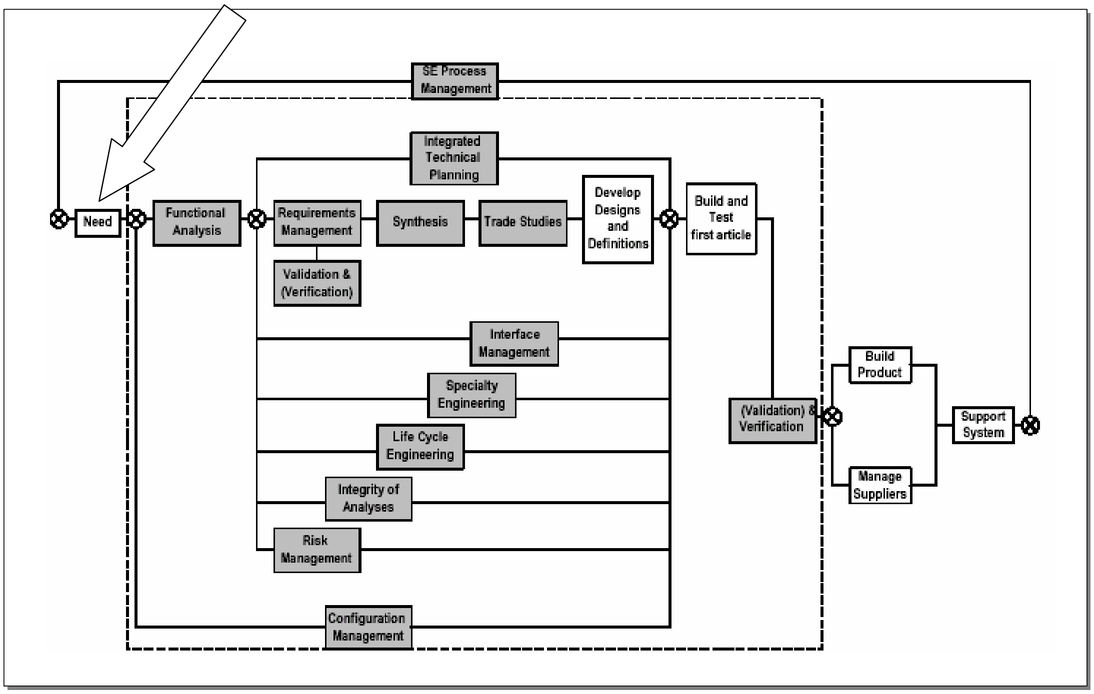

Figure 2: Scenario Analysis within the FAA Systems Engineering Process.

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 2 through Table 5.

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 this AATT research task [2]**
    - **GCNSS I**
    - **New – concept introduced as part of this analysis effort**

Table 2: 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 3: Master Scenario List (Scenarios 13-21).

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	
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 4: Master Scenario List (Scenarios 22-31).

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	
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 5: Master Scenario List (Scenarios 32-35).

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
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)

3.1 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)** - Figure 3 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)** - Figure 4 shows the ranking of the eight (8) top scenarios in BLACK and three (3) of the four (4) secondary scenarios in RED.

- **Benefits (Unweighted)** - Figure 5 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)** - Figure 6 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 - Figure 7 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.

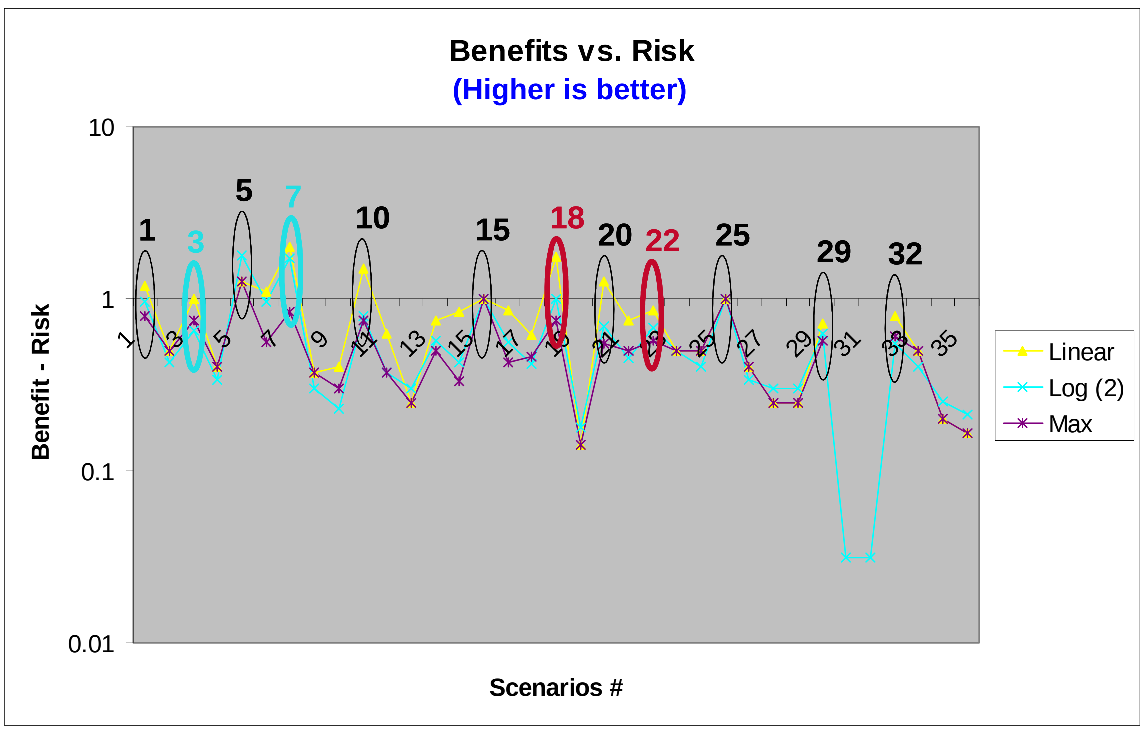

Figure 3: Benefits / Risks - Not Weighted by Flight Domain.

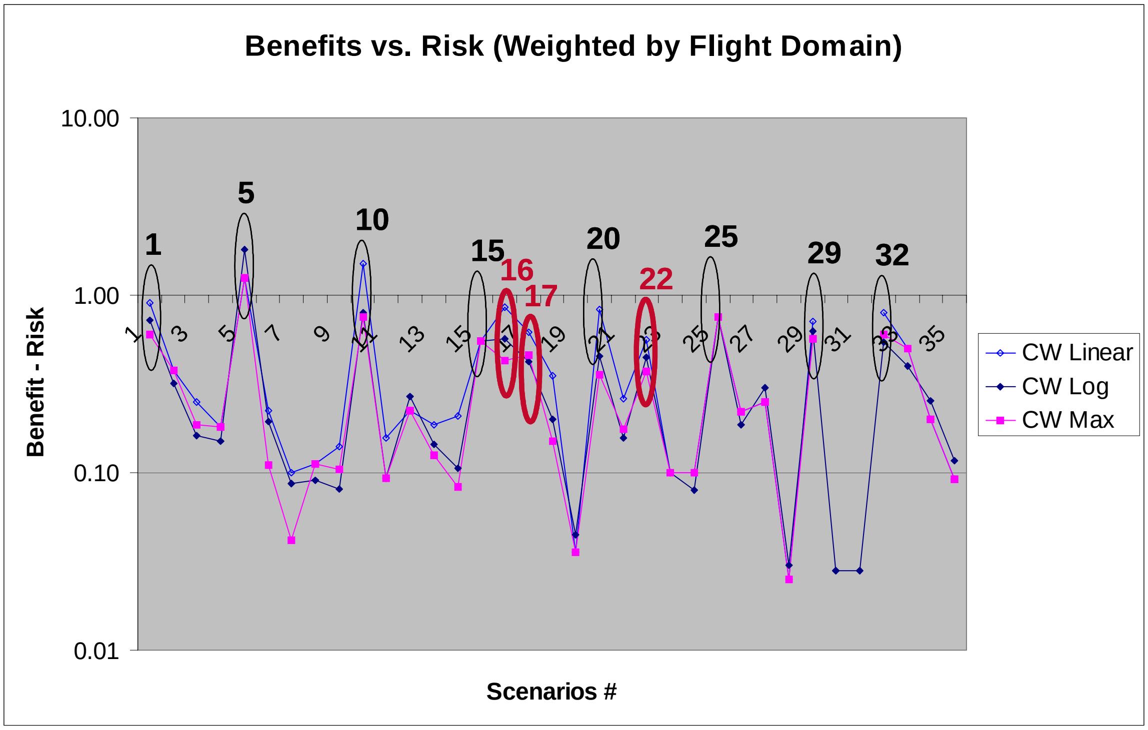

Figure 4: Benefits / Risk - Weighted by Flight Domain.

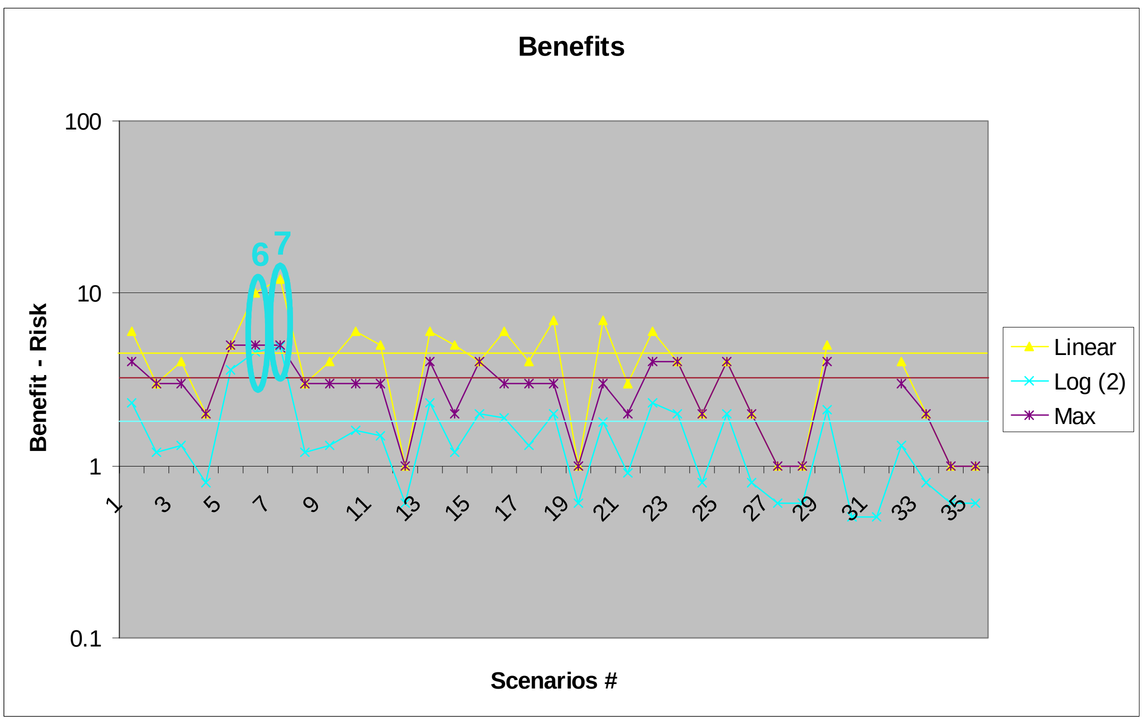

Figure 5: Benefits Only - Not Weighted by Flight Domain.

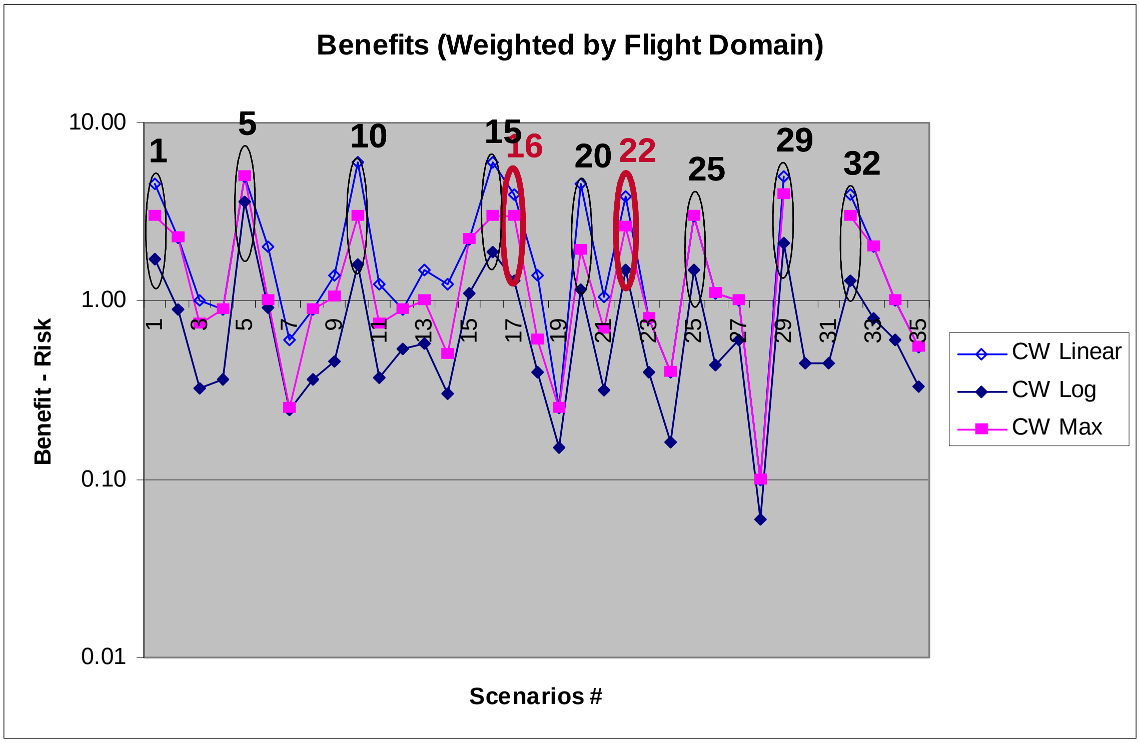

Figure 6: Benefits Only - Weighted by Flight Domain.

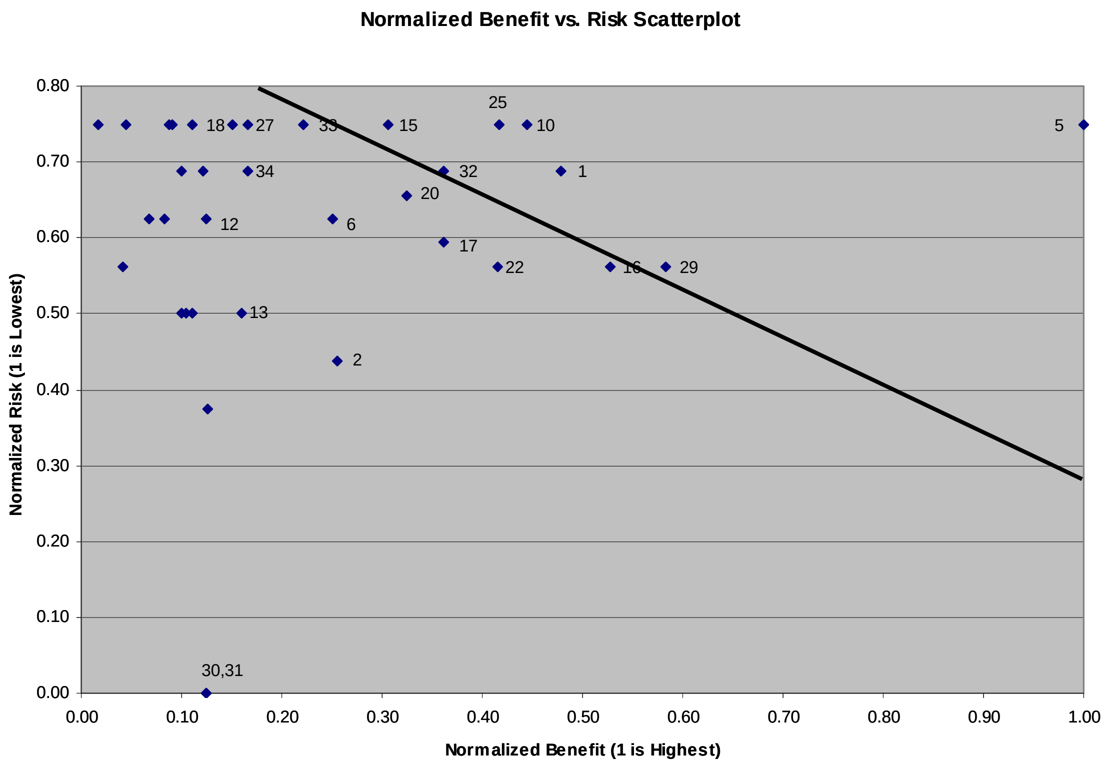

Figure 7: Scatter plot of Benefit vs. Risk.

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 6: 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 7: Secondary 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
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

3.2 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.

3.2.1 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.

3.2.2 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.

3.2.3 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 scenario provides moderate benefits in airspace capacity and efficiency and minor

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[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.

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.

3.2.4 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 information that is more precise 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 scenario is applicable to all aircraft classes and relies only upon the SWIM information class: surveillance. This scenario provides high relative safety benefits and has been determined to introduce minimal implementation risks.

3.2.5 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 en route domains to transport, cargo and business GA aircraft.

3.2.6 Controller Awareness of TCAS 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.

3.2.7 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 down-linked 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 scenario is applicable to all airspace domains since a hijacking event could occur anywhere but is only 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.

3.2.8 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 distribute rapidly and widely 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.

3.2.9 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.

3.2.10 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.

3.2.11 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.

3.2.12 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.

3.3 MCNA Concepts of Use

Since MCNA aggregates multiple disparate links, the Concept of Use (CoU) should cover scenarios that are independent of link and network technologies. Furthermore, while each of these scenarios could be discussed in far greater detail with respect to a particular technology, the level of depth of the CoU discussion will be maintained at a sufficiently high level to be independent of technology and focus instead upon interactions between technologies.

3.3.1 Communication Service Establishment

The request for the establishment of a communication service should be coupled with quality of service (QoS) requirements plus any other factors that would affect routing policy. If ground initiated, a message would be sent via an available air-ground link to the aircraft requesting service establishment. If the request is air initiated, a service initiation request is sent to the mobile router via the aircraft LAN. In both cases, the determination whether the aircraft can support the requested service is made by the aircraft. The aircraft surveys available air-ground link options and determines if the requested service level can be supported. If a positive determination is made, the aircraft responds to the initiating entity of the intent to support the requested service. Next, the mobile router initiates link establishment for each of the individual links (that are not already established) required to accommodate the service. It should be noted that depending upon the requirements of the particular service, certain links may not be established until a link failure has occurred. Upon completion of communication service establishment a final notification is sent to the requesting party that the service is available. A message sequence diagram demonstrating communication service termination is illustrated in Figure 8.

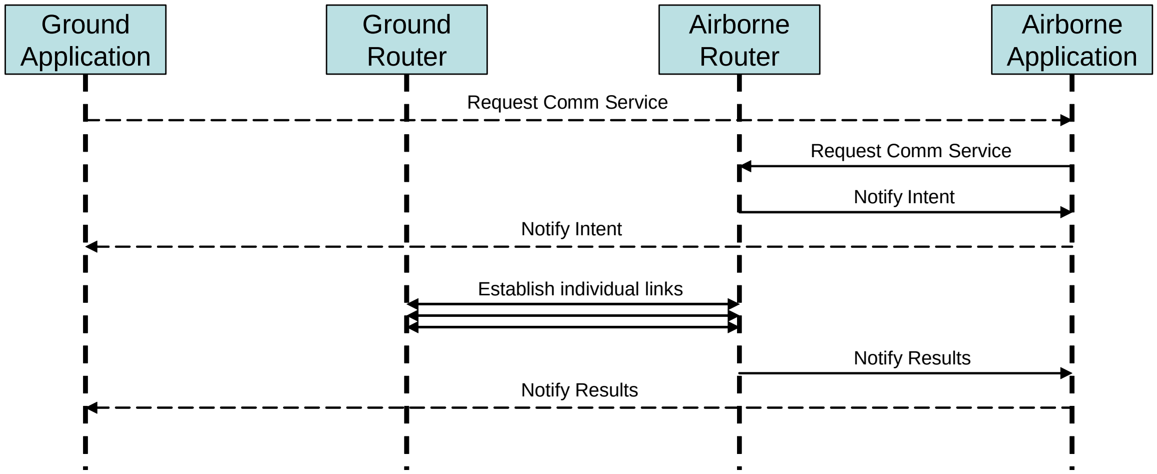

Figure 8: Communication Service Initiation.

3.3.2 Link Failure Recovery

The airborne router monitors the state of each link to determine if a failure has occurred. Upon failure notification, the router attempts to re-establish the failed link. After a predetermined duration, dependant upon the communication service classes and levels supported, the router attempts to establish one or more backup link alternatives. These actions are dependent upon the links available and performance required to support the respective communication service classes and levels.

When supporting more stringent communication services, multiple communication links may be required to be established simultaneously (multi-homing) to allow rapid conversion to a redundant path in the event of a link failure. In all cases, a policy should be established to determine what the router should do when the original link gets re-established. In some cases, such re-establishment may warrant handing the flows from the applicable communication services back to the original link while other routing policy may dictate maintaining the flows with the newly established link(s).

3.3.3 Link Handover

Link handover can occur as the result of a planned action, such as the movement between ground transceivers, or in response to a link failure. The latter case is handled under link failure recovery, therefore, this section pertains to planned link handover events. Multiple forms of link handover may exist within MCNA. Some lower level link handovers, such as Layer-2 handovers, tend to be transparent to the mobile router and are handled independently by each of the air-ground communication links.

Layer-3 handovers occur due to movement between sub-networks that are attached to different routers. Such movement is typically driven either by either standard physical mobility that results in a Layer-3 handover due to network topology changes, transition between service providers or transition between physical media such as between VHF and SatCom. Handover between similar systems is relatively straight-forward since both systems support similar communication service classes and levels. However, when handover occurs between different systems, the router must evaluate the difference in capabilities between the new and old links and determine if more links must be established or if existing communications services must be terminated.

Application layer handovers can occur in the case where a message router is used to provide services across multiple Layer-3 technologies such as IP and ATN. For example, an aircraft is heading from New York to London and moving out of VDLm3 coverage into SwiftBroadband. Assuming VLDm3 uses CLNP at Layer-3 while SwiftBroadband uses IP, a messaging service at the application layer could be introduced to abstract such disparities at Layer-3. During such a handover, the message router must evaluate the capabilities of link being lost with the capabilities of the link being gained to determine if additional connections must be established or if any communication services must be terminated.

3.3.4 Communication Service Terminate

When a communication service is terminated, notice is provided to the mobile router from the mobile application. In the case of a ground initiated communication service termination, a termination message is sent to the mobile application and the mobile application forwards this notification to the mobile router. Upon notification of termination, the mobile router acknowledges the service termination request and evaluates the new air-ground link requirements, based upon any other existing communication service requests, and terminates any unneeded air-ground links. A message sequence diagram demonstrating communication service termination is illustrated in Figure 9.

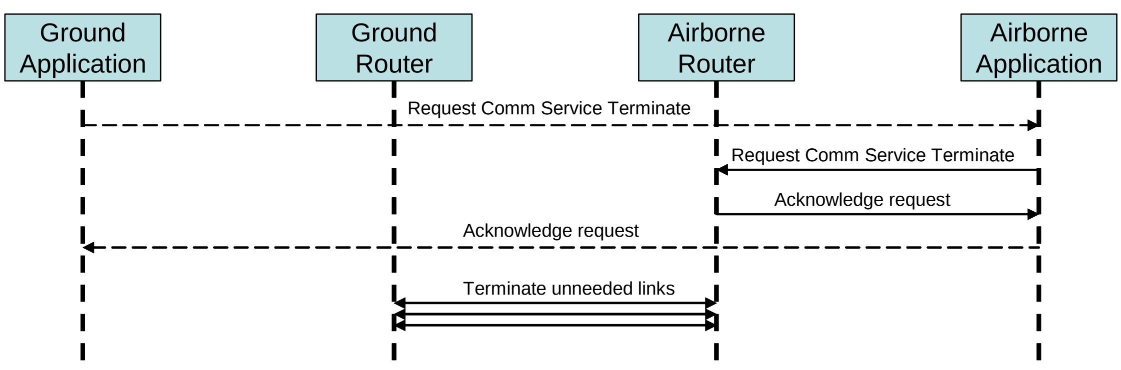

Figure 9: Communication Service Termination.

3.4 Recommended Future Work

Because MCNA is an enabling capability for a wide range of operational enhancements, the scenario analysis activity will be ongoing. Investment and benefits analysis of a capability such as MCNA is a Catch-22 from the perspective that airspace users and service providers tend not to spend much time thinking about how a technology could be applied until that technology is available or at least a very concrete concept. As the reality of MCNA draws closer, a vast array of scenarios will be defined. The developed tools and database will provide a mechanism to capture and evaluated these scenarios and determine what communication services and supporting systems will be necessary to support these new scenarios.

4 FUNCTIONAL ANALYSIS

Functional analysis provides a functional description of the MCNA that will serve as a source for functional requirements that in turn drive the architecture development task. One view of the applicability of functional analysis activities in the development process is shown in Figure 10. Here, the system development process as defined in the FAA Systems Engineering Manual (SEM) is used as a reference. The arrow indicates where functional analysis supports the development process

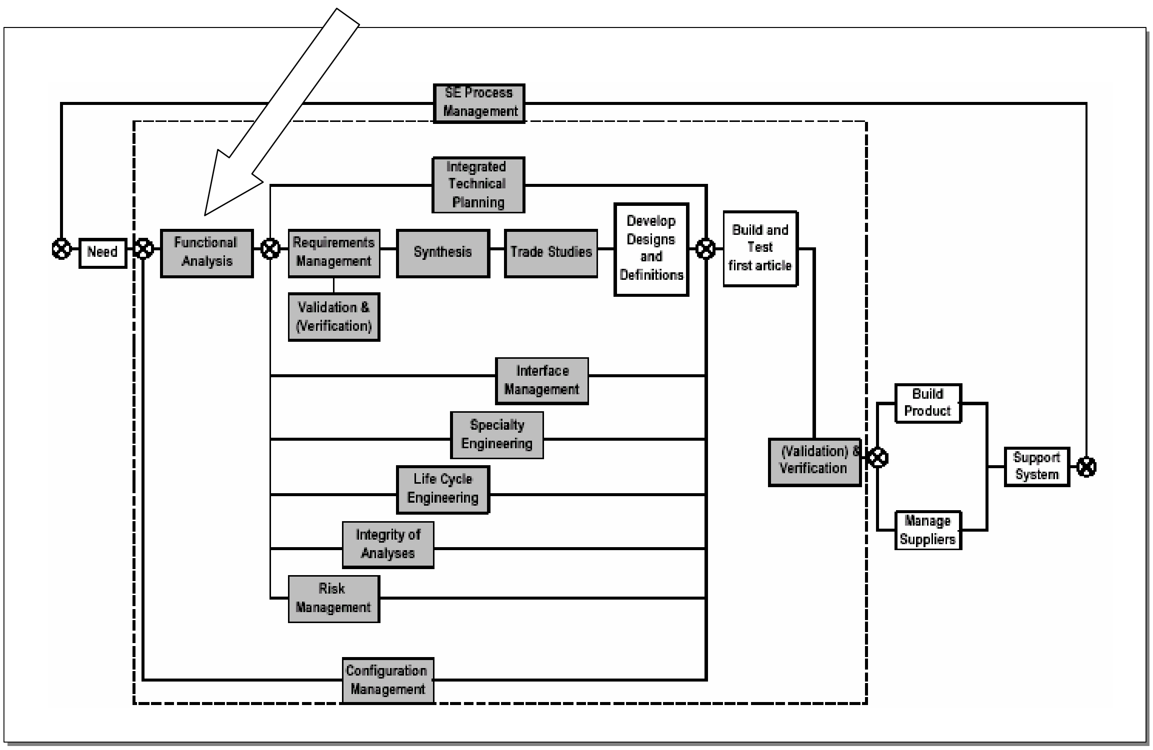

Figure 10: Functional Analysis within the FAA Systems Engineering Process.

The MCNA functional analysis leverages heavily from the SWIM functional analysis activity started during the GCNSS I extension and that continues during the GCNSS II contract. At the highest level, two primary MCNA functions were defined: Provide Data Transport and Manage Data Transport (Figure 11). Each Level-1 function is sub-divided into the five (5) Level-2 functions that are listed in the diagram below. This section describes each of the Level-1, Level-2 and Level-3 functions and includes several Functional Flow Block Diagrams (FFBD) to illustrate the relationship between the functions that reside at the same level.

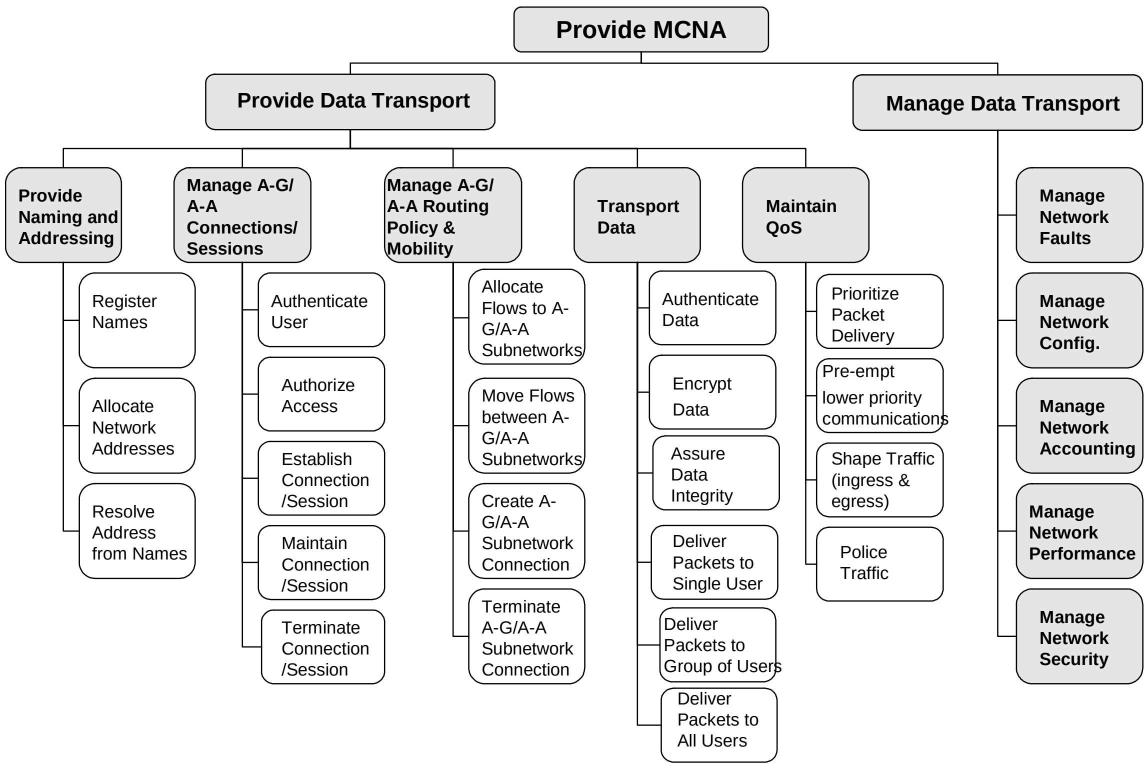

Figure 11: MCNA Functional Architecture, Levels 1, 2 & Some 3.

4.1 Provide Data Transport (Function 1.0)

Provide Data Transport is the key function that drives the air-ground and/or air-air connectivity for voice and data communication services. This Level-1 function is composed of the following five (5) level two functions as described in the table below (Table 8).

Table 8: Sub-Functions and Descriptions for Provide Data Transport.

Function Number	Function Name	Description
1.1	Provide Naming and Addressing	This function provides for unique naming and network addressing of each of the network elements as well as resolution of network addresses from names.
1.2	Manage A-G/A-A Links	This function manages each air-ground or air-air link. Links must be established (including authentication and authorization), maintained, handed over and terminated at various times within their life cycle.

Function Number	Function Name	Description
1.3	Manage A-G/A-A Flows	This function manages the aggregate of air-ground and air-air links for a mobile entity. As links are created, handed over and terminated, the various network flows must be allocated to links and moved between links as appropriate to maintain mobility and support the desired routing policies.
1.4	Transport Data	This function accounts for the actual transport of data packets between users. Packets can be delivered to either a single user (unicast), a group of users (multicast) or all users within a domain (broadcast). This function is also responsible for authentication, privacy and data integrity as applicable.
1.5	Maintain QoS	This function is responsible for assuring that traffic is delivered within the defined performance metrics of the selected service. Mechanisms included are: packet prioritization, resource pre-emption, flow shaping and flow policing.

The relationships between the Level-2 functions under "1.0 Transport Data" are shown in the functional flow block diagram (FFBD) below (Figure 12). Each mobile unit (aircraft) is capable of supporting multiple air-ground and/or air-air links. This is represented in the FFBD using a replicate with control construct, as shown by the branching from and to the circles containing "RP". For each A-G or A-A link an instance of the "Manage A-G/A-A Links" function is instantiated. A single control function, "Manage A-G/A-A Flows", is responsible for the overall management of mobile links and the allocation of traffic flows to these links. The provision of naming and addressing, transport of data and maintenance of QoS are included as ongoing functions that operate in parallel. As such, these three functions are ANDed with the primary replicate and control function to represent this parallel relationship.

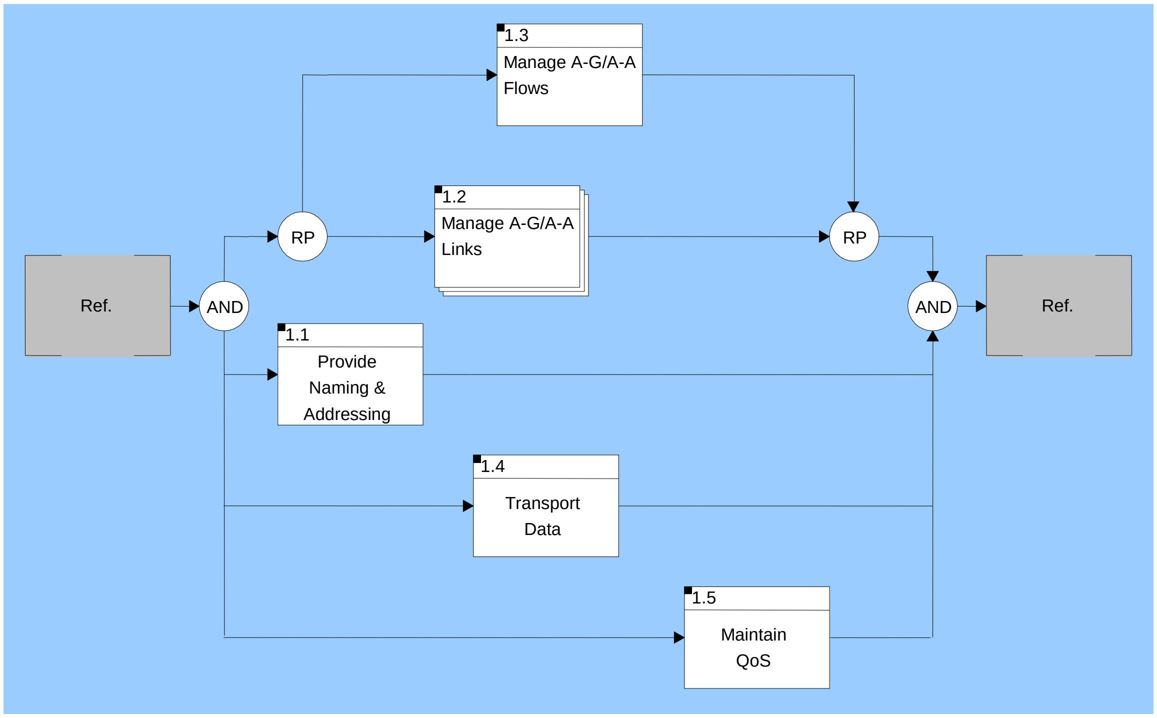

Figure 12: Provide Data Transport, Functional Flow Block Diagram.

4.1.1 Provide Naming and Addressing

This function provides mechanisms for each network element to obtain a globally unique identification (name) that can be used by other elements to initiate and sustain communications. Network addressing is used as a machine-readable unique identification for each element that may or may not be statically assigned. This function decomposes into three sub-functions as shown in Table 9. The sub-functions interrelate via nested loops as shown in the FFBD in Figure 13 and labeled as “LP”.

Table 9: Sub-Functions and Descriptions for Provide Naming and Addressing.

Function Number	Function Name	Description
1.1.1	Register Mobile Entities Names	This function allows network elements to register a static, globally unique name that can be shared with other network elements as a mechanism to initiate and sustain communications. Upon registration, the network must assure global uniqueness and respond with a negative acknowledgement if a conflict is detected.
1.1.2	Allocate Network Addresses	The aforementioned names are inefficient mechanisms for a network to use to address and route data packets. This function allocates globally unique network addresses that are both efficient and machine readable to support the transport of data packets.

Function Number	Function Name	Description
1.1.3	Resolve Addresses from Names	A network element's name is both static and globally unique. This "handle" is shared with other users and network elements for the purposes of establishing and maintaining communications. Since names are typically human readable, they are inefficient for use in addressing and routing packets. When a user or network element wants to initiate communications with another element for which they are aware of a "name" they must resolve the network address currently used by the network to communicate with that element. This function resolves the current network address of a network element given the proper name.

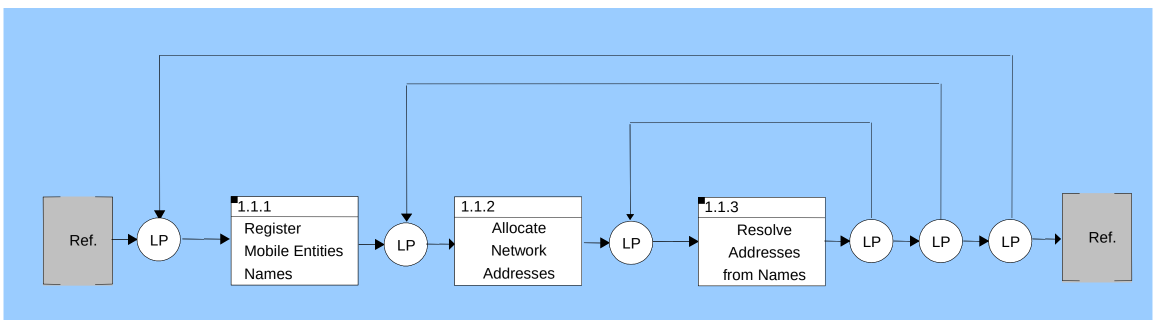

Figure 13: Provide Naming and Addressing - Functional Flow Block Diagram.

4.1.2 Manage A-G/A-A Links

This function manages each of the air-ground or air-air links from an aircraft platform. This function is composes of six (6) sub-functions that are detailed in Table 10. The functions are arranged into an iterative loop with four possible threads: establish link, maintain link, handover link or terminate link (Figure 14). During each iteration of the loop, only one of the functional threads is executed. As such, the threads are OR'ed to reflect this functional relationship. During the establishment of a link, the end points must first authenticate each other and authorize access with each other prior to link establishment.

Table 10: Sub-Functions and Descriptions for Manage A-G/A-A Links.

Function Number	Function Name	Description

Function Number	Function Name	Description
1.2.1	Authenticate Entity	This function assures that, prior to the establishment of a link, each end-point is aware of the identity of the other end point. The purpose of this function is to assure that only approved aircraft can connect to each other and the ground network and to assure that aircraft only connect to approved ground stations.
1.2.2	Authorize Access	This function verifies that each end of the connection is authorized to establish a connection with the other entity for the requested service.
1.2.3	Establish Link	This function establishes the air-ground or air-air link between two network elements. Upon link establishment, link type, service type and QoS preferences are established.
1.2.4	Maintain Link	RF communication links are highly dynamic and require constant monitoring and adjustment. The function maintains proper power levels, adjusts timing & frequency, modifies filter parameters, coding rates, link rates etc. as applicable to maintain a successful RF connection.
1.2.5	Handover Link	This function manages Layer-2 handovers in order to maintain a Layer-2 connection. Handovers could be between beams or satellites (in the case of SatCom) or ground stations (in the case of Terrestrial Com). Layer-2 handover typically includes that transfer of security credentials, QoS parameters and link settings to provide seamless continuation of the Layer-2 connection while moving the physical connection. When the handover involves routing of packets through a different subnetwork (i.e. different router) this is considered a layer-3 handover and is handles by the function "Move Flows between A-G/A-A Links".
1.2.6	Terminate Link	The function terminates an air-ground or air-air link after it is either no longer needed or no longer available for use.

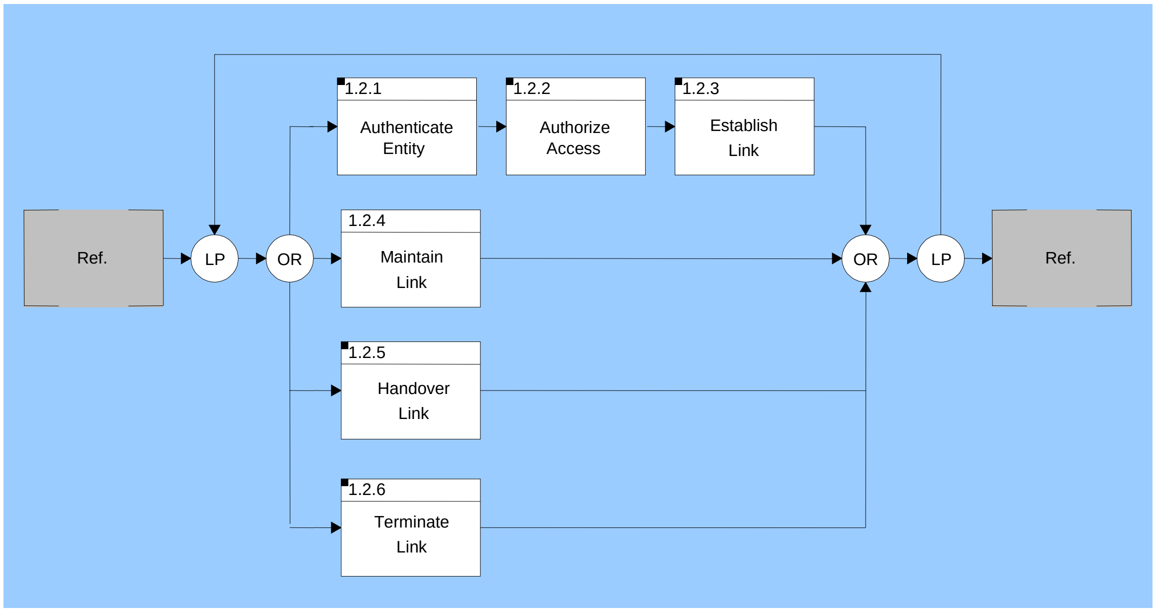

Figure 14: Manage A-G/A-A Links - Functional Flow Block Diagram.

4.1.3 Manage A-G /A-A Flows

This function is the control function that manages one or more air-ground or air-air links. When an application initiates an air-ground or air-air communication, the associated flow must be allocated to one or more of the appropriate links. As links come and go, these flows must also be moved between links as appropriate to meet service requirements and policies. This function is subdivided into two sub-functions described in Table 11. Due to the dynamic nature of the management and allocation of flows to links, the two sub-functions are OR'ed together within an iterative loop (Figure 15).

Table 11: Sub-Functions and Descriptions for Manage A-G/A-A Flows.

Function Number	Function Name	Description
1.3.1	Allocate Flows to A-G/A-A Links	This function allocates flows to the available air-ground and air-air links. Allocation may be based upon availability, cost, routing policy or other reason that would be accounted for by this function. This function supports multi-homing.
1.3.2	Move Flows between A-G/A-A Links	This function moves allocated flows between air-ground and air-air links. Movement may be based upon the availability of a new link, the pending loss of an existing link or the change in performance of one or more links. This function handles layer-3 mobility.

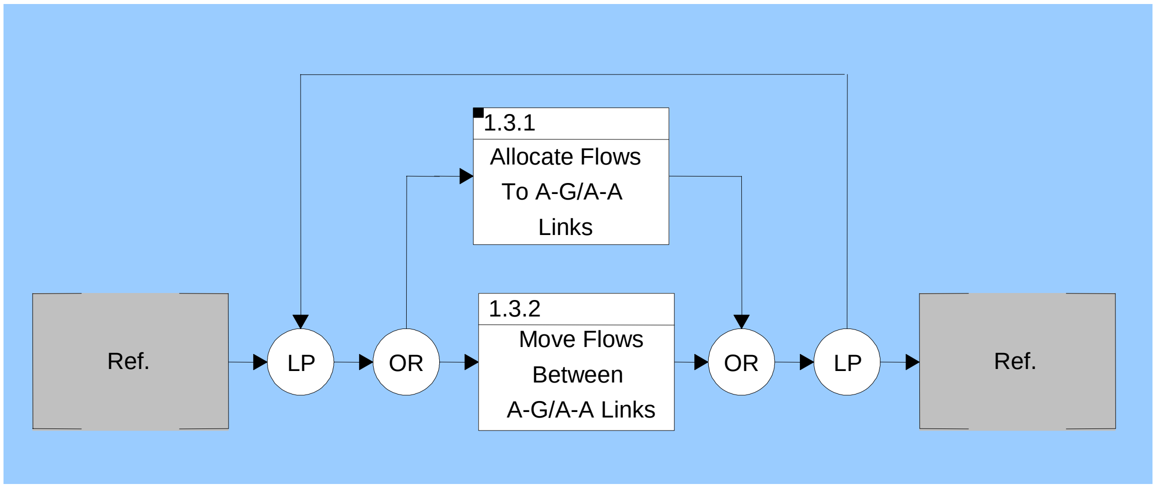

Figure 15: Manage A-G/A-A Flows - Functional Flow Block Diagram.

4.1.4 Transport Data

The transport data function is responsible for the delivery of packet via established links to individual users, groups of users or all users. The functions also handles information security aspects related to data delivery including the authentication, encryption and integrity of data during transit. The function is subdivided into six (6) sub-functions detailed in Table 12. The functions are grouped into three sets of sub-function as shown in the FFBD (Figure 16). For each packet, the data can be authenticated, made confidential, have integrity protected, none or any combination. Once the appropriate combination of security and data integrity functions have been performed, the packet is transported to a single user, a configured group of users or all users.

Table 12: Sub-Functions and Descriptions for Transport Data.

Function Number	Function Name	Description
1.4.1	Authenticate Data	This function provides the option for the receiving party to uniquely identify the sending party of a data packet.
1.4.2	Provide Data Confidentiality.	This function provides the option to prevent any entity other than the intended recipient of the packet from ascertaining the contents of the packet.
1.4.3	Assure Data Integrity	This function provides the option to assure the receiving party that contents of the packet have not been altered (intentionally or unintentionally) during transit.
1.4.4	Deliver Packets to a Single User	This function delivers a data packet to a single user.
1.4.5	Deliver Packets to a Group of Users	This function delivers a data packet to a group of users. The group of users must be previously defined (i.e. via a multicast group address).

Function Number	Function Name	Description
1.4.6	Deliver Packets to All Users	This function delivers a data packet to all users within a domain. The concept of domain is introduced because of the difference between layer-2 and layer-3 broadcast.

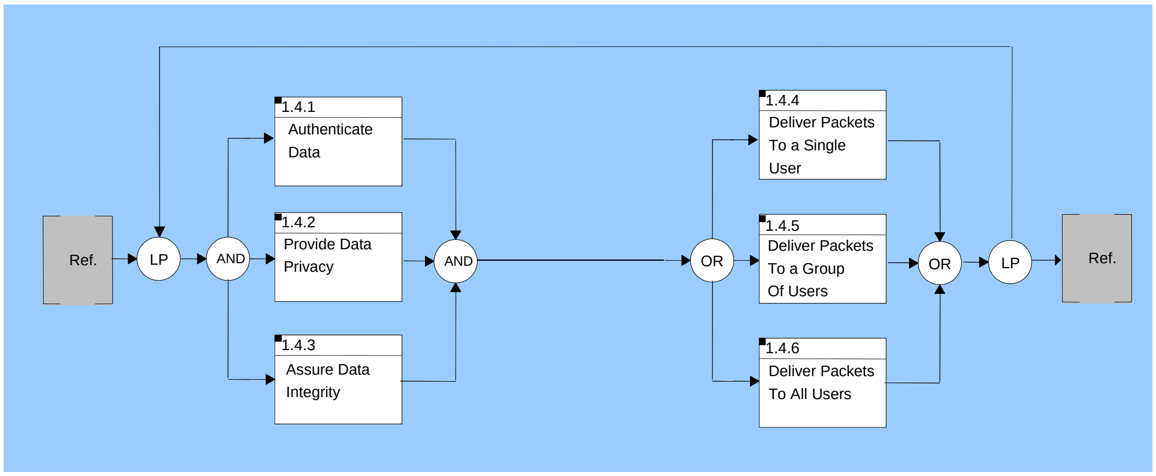

Figure 16: Transport Data - Functional Flow Block Diagram.

4.1.5 Maintain QOS

This function is responsible for providing mechanisms to differentiate between service levels and help achieve communication service performance targets. This function is sub-allocated into four sub-functions which provide the capabilities to achieve these service-level differentiations (Table 13). The functions are arranged into four parallel sub-function as shown in the FFBD (Figure 17). Any or all of these QoS functions can be applied simultaneously depending upon the specific needs of the particular communication service. As such, the functions are arranged into an iterative loop with each of the four functions AND'ed to represent the potential for concurrency. However, it should be noted these QoS mechanisms will not necessarily by applied in all cases.

Table 13: Sub-Functions and Descriptions for Maintain QoS.

Function Number	Function Name	Description
1.5.1	Prioritize Packet Delivery	This function provides mechanisms to mark packets as requiring differing levels of service and to differentiate the handling and deliver of such packets based upon those markings.
1.5.2	Pre-empt Lower Priority Communications	This function provides mechanisms to terminate lower priority resource reservation when higher priority reservations cannot otherwise be granted due to network congestion.

Function Number	Function Name	Description
1.5.3	Shape Traffic	This function provides mechanisms to buffer packets when the associated flow exceeds its negotiated profile.
1.5.4	Police Traffic	This function provides mechanisms to delete packets or lower their priority when the associated flow exceeds its negotiated profile.

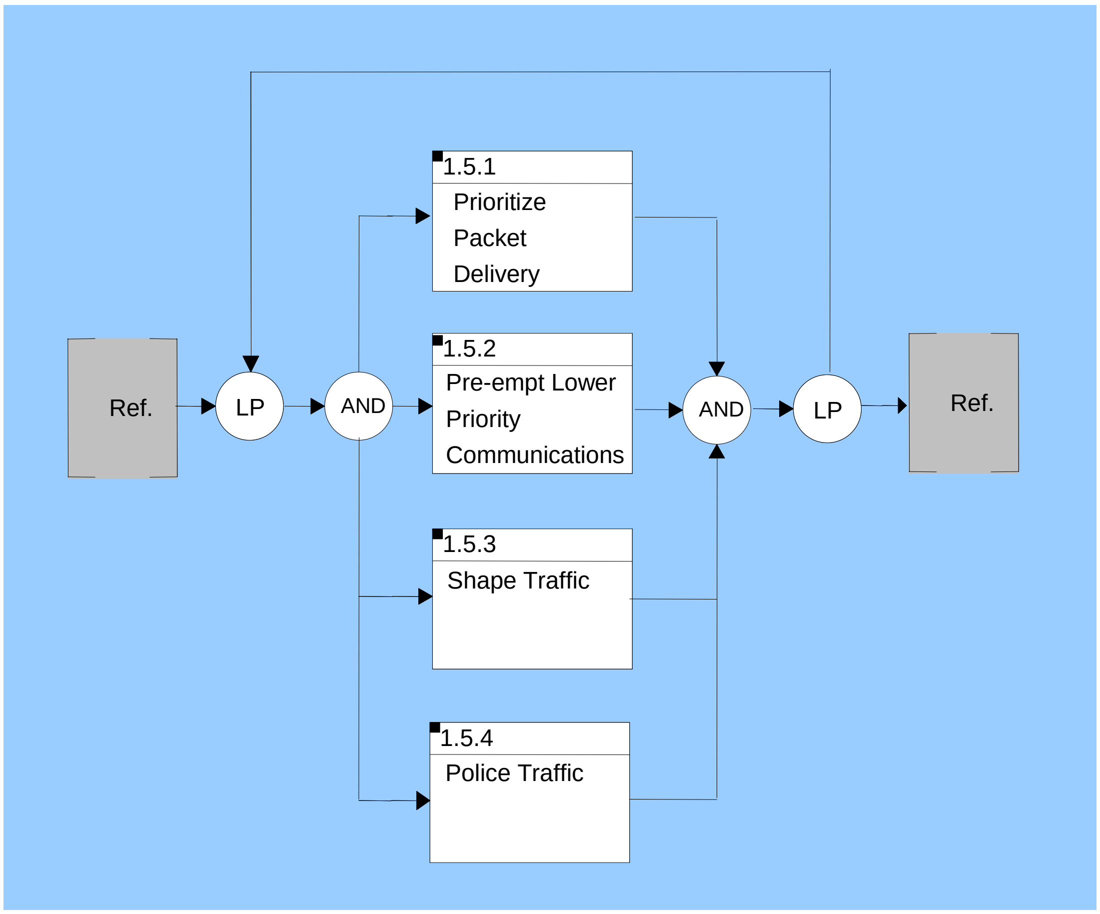

Figure 17: Maintain QoS - Functional Flow Block Diagram.

4.2 Manage Data Transport (Function 2.0)

The analysis of this function is very similar to the Manage Infrastructure function for SWIM and therefore much of the description below is slightly modified text from the SWIM functional analysis document.

The functionality associated with the management of the network (*Manage Network – 2.0*) addresses a range of network management topics including faults, configuration, accounting, performance and security (FCAPS). The roles of MCNA in providing this functionality have been defined along FCAPS topic areas as defined in Table 14. Within each area, MCNA functionality has been decomposed to identify specific tasks that are addressed within the FCAPS topic areas; each topic area is addressed separately below. It should be noted that the MCNA network management function is closely aligned with the FTI network management function and therefore common infrastructure and procedures should be used to accommodate both sets of functionality.

Table 14: Sub-Functions and Descriptions for Manage Data Transport.

Function Number	Function Name	Description
2.1	Manage Network Faults	This function is responsible for the detection, isolation, diagnosis, resolution and logging of network faults.
2.2	Manage Network Configuration	This function is responsible for monitoring the status of network elements, configuring network elements and services and providing notifications of configuration change.
2.3	Manage Network Accounting	This function monitors resource utilization and provides mechanisms to bill users for resources utilized.
2.4	Manage Network Performance	This function is responsible for monitoring and analyzing the performance of the network, maintaining service levels and adjusting resource allocations as necessary.
2.5	Manage Network Security	This function is responsible for managing all of the support functions and infrastructure necessary to provide a complete information security service within the network.

In the diagram below (Figure 18), all five network management topic areas are shown in parallel. The functions associated with the management of faults, configurations, accounting, performance and security are all active simultaneously. The loop construct is included to indicate that these processes are continuously active when the MCNA network is operational. The relationship among sub-functions associated with each of the five "FCAPS" network management functions identified above have been defined using additional functional flow diagrams and are described in the following pages.

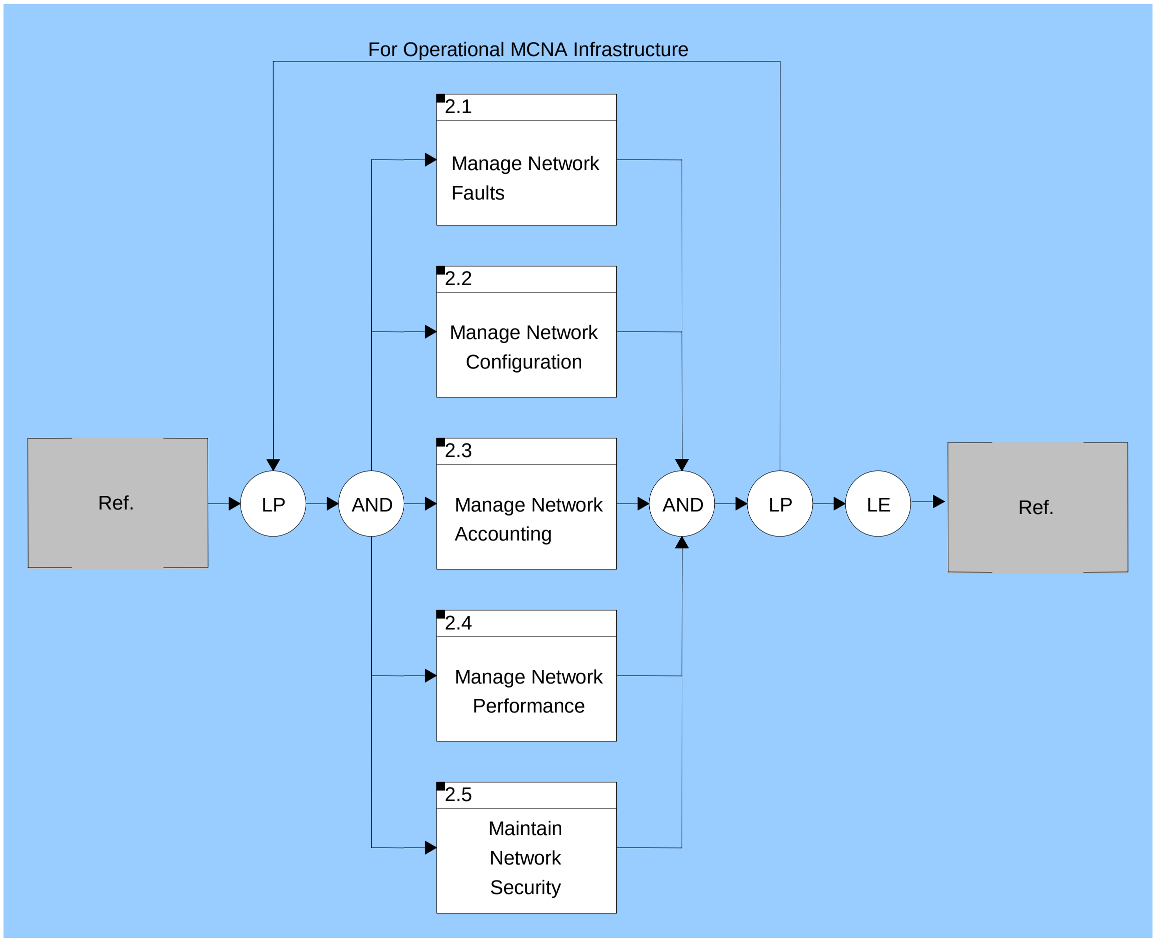

Figure 18: Manage Data Transport - Functional Flow Block Diagram.

4.2.1 Manage Network Faults

This function addresses constant monitoring of the MCNA infrastructure state; reports abnormal conditions (such as those exceeding certain threshold values during normal operations); detects faults, isolates the fault from the network, traces faults through the system and performs diagnostic tests to decide the cause of the fault; and finally removes the fault and recovers the system. Faults detected are logged and reported. The following table provides the descriptions of the third level sub-functions of Manage Network Faults (Table 15).

The relationship between the Manage Faults sub-functions is shown in Figure 19. This function runs constantly in an iterative mode attempting to identify faults. When a fault it identified, it is initially isolated then an iterative loop is kicked off to diagnose the fault and recover all of the appropriate elements. This process continues until the fault has been cleared. All faults are logged and appropriate elements are notified when the faults is detected and once again when the network has been recovered.

Table 15: Sub-Functions and Descriptions for Management of Faults.

Function Number	Function Name	Description
2.1.1	Detect Faults	This function provides mechanisms (fault threshold setting and poll) to detect fault conditions in the network nodes and links.
2.1.2	Isolate Faults	This function is responsible for identifying faults and where the faults are occurring in the network.
2.1.3	Diagnose Faults	This functionality supports the process of performing repair actions using testing and diagnostic routines. Loop back is one example of a testing routine that can be activated upon request.
2.1.4	Recover Network	This function addresses the recovery of affected network resources when a fault is corrected.
2.1.5	Log and Notify Faults	This functionality is the mechanism for logging faults occurring within a defined period of time and reporting faults to system administrators.

A FFBD depicting the interaction between these functions is shown in Figure 19.

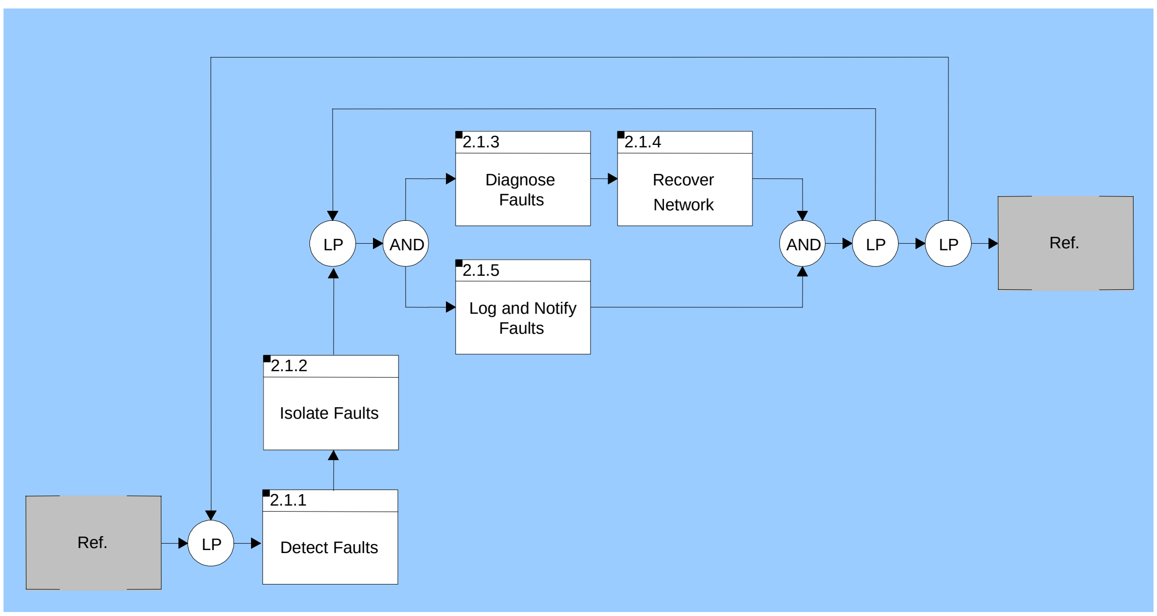

Figure 19: Manage Network Faults - Functional Flow Block Diagram.

4.2.2 Manage Network Configuration

The network configuration function describes the structure of the MCNA platform and its distributed members. It specifies how each MCNA resource is to interact with another resource. Management of the network configuration includes such functionality as configuration of MCNA services; distribution of control and status messages; monitor device configurations; protection of resource allocations; and management of security infrastructure. The following table provides the descriptions of the third level sub-functions of Manage Configurations (Table 16).

The relationship between the defined sub-functions is shown using in Figure 20. The configuration management function is iterated for each network element using configuration monitoring as the overall control function. Each network element and service is configured and appropriate status and control messages from these elements are process.

Table 16: Sub-Functions and Descriptions for Management of Configurations.

Function Number	**Function Name**	**Description**
2.2.1	Monitor Configuration	This functionality addresses the process of monitoring the configurations of devices that comprise and are connected to MCNA.
2.2.2	Configure Network and Services	This functionality addresses the capability to provide MCNA services in a distributed environment. In such an environment, some cross-component dependencies may exist (and be noted in configuration files) and are accommodated. For example, for communicating resources implementing a certain version of a protocol, the dependency relationships for the service could be specified (e.g. resource A and B or C together can provide a specific MCNA service, but B or C alone cannot). In this scenario, resource B and C cannot be taken offline for maintenance at the same time.
2.2.3	Process Network Control/Status Messages	This functionality supports the definition of actions to be taken corresponding to alert or failure conditions. When an alert or a failure is detected or generated, control commands can be generated and issued to MCNA resources. This functionality also addresses the reception and recording of member status.

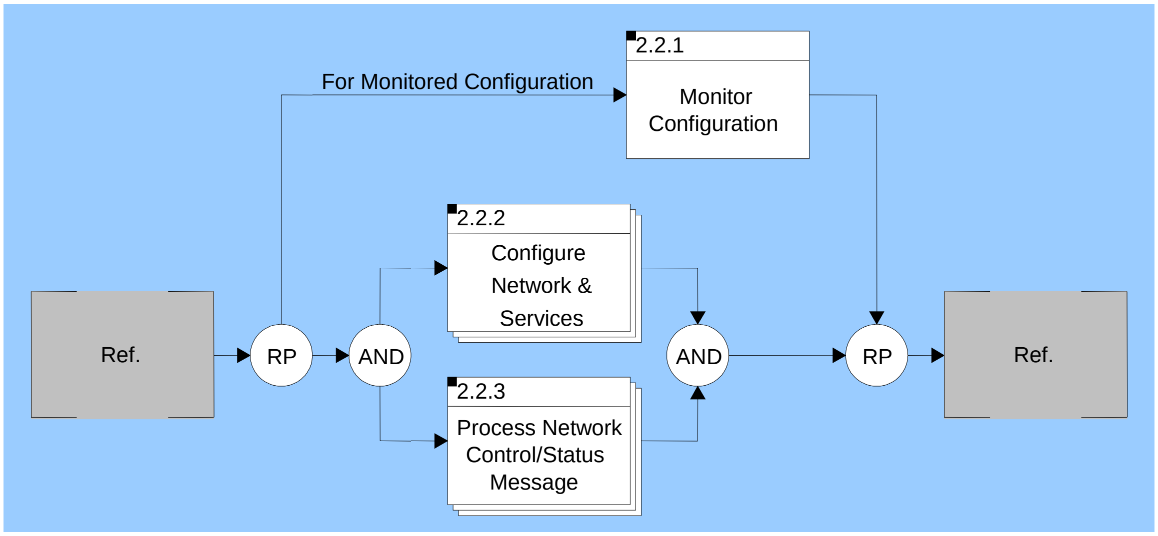

Figure 20: Manage Network Configuration - Functional Flow Block Diagram.

4.2.3 Manage Network Accounting

This function provides the capability to measure network utilization so that usage can be appropriately tracked and regulated. Such regulation minimizes resource problems (because resources can be apportioned based on resource capacities and/or other means) and maximizes the fairness of network access across all users. The following table provides the descriptions of the third level sub-functions of Manage Network Accounting (Table 17). The sub-functions of Manage Network Accounting are somewhat autonomous. This functional autonomy is represented in the FFBD via a simple AND'ing of the sub-functions (Figure 21).

Table 17: Sub-Functions and Descriptions for Management of Network Accounting.

Function Number	Function Name	Description
2.3.1	Monitor Network Resource Utilization	This functionality addresses the measurement and analysis of network utilization parameters so that individual or group members can be regulated.
2.3.2	Manage Billing	This functionality supports the ability to provide cost allocation or billing to MCNA users as well as issuing trouble tickets[3] (billing can be defined in an appropriate manner in a specific MCNA implementation).

[3] A trouble ticket is a mechanism used in an organization to track the detection, reporting, and resolution of some type of problem. Trouble ticketing systems are now mostly web-based and associated with customer relationship management (CRM) environments or with high-technology environments such as network operations centers (NOCs) (as defined at http://www.techtarget.com)

Function Number	Function Name	Description
2.3.3	Maintain Accounting Audits	This functionality addresses the monitoring of access to network resources and services and tracking of usage statistics.

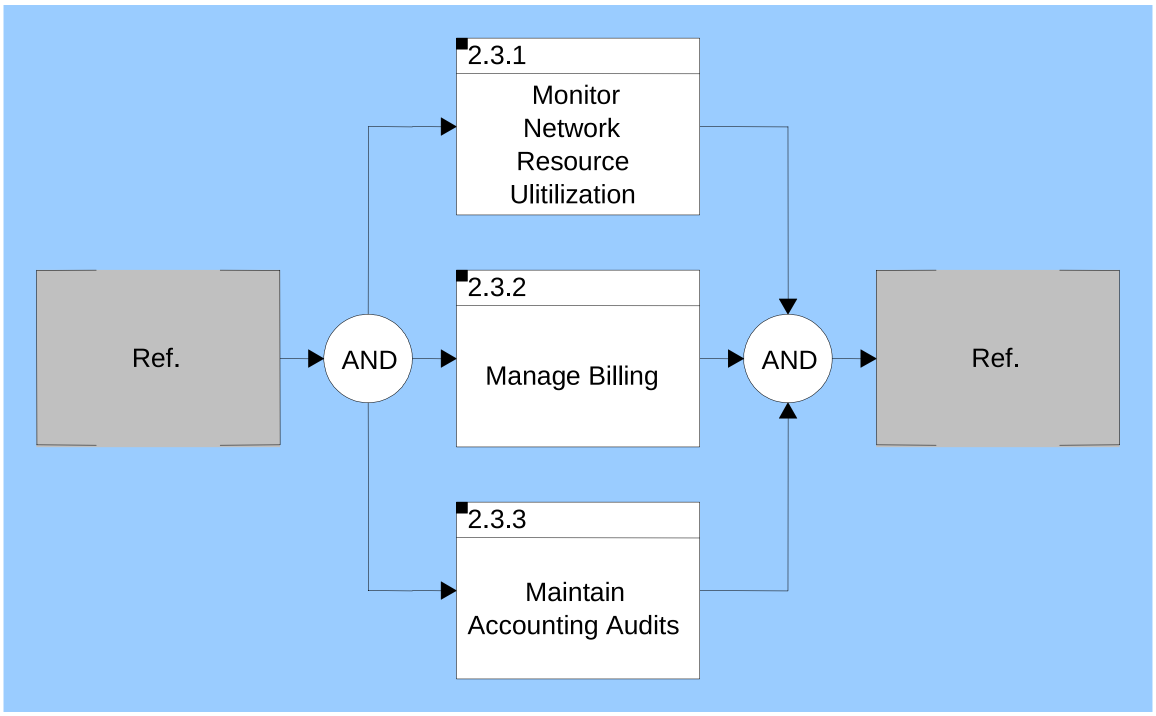

Figure 21: Manage Network Accounting - Functional Flow Block Diagram.

4.2.4 Manage Network Performance

MCNA enables SWIM information exchange services with the aircraft, and therefore must provide services that meet SWIM performance requirements. Service quality is maintained by definition and monitoring of specific events (i.e. a condition or activity of significance) addressing any aspect of MCNA. This function identifies the capability to measure and make available various aspects of network performance so that performance can be maintained at an acceptable level (i.e. performance requirements can be met). If a network resource is not available, this function evaluates its relationship to MCNA services and issues service network adjustments commands to request connection adjustments as necessary.

The following table provides the descriptions of the third level sub-functions of Manage Network Performance (Table 18). The dynamic nature of the interaction between these sub-functions is demonstrated by the iteration in the FFBD (Figure 21).

During each iteration, network performance is monitored and this performance data is analyzed to determine service quality. Resources allocations are adjusted if the services quality is determine to be unacceptable.

Table 18: Sub-Functions and Descriptions for Maintaining Network Performance.

Function Number	Function Name	Description
2.4.1	Monitor Network Performance Data	This function addresses the gathering of performance measures on variables of interest such as throughput, member response times, line utilization and etc.
2.4.2	Analyze Performance Data	This functionality addresses the analysis of collected performance data to determine network availability, network throughput, system response time, and other traffic statistics such as traffic utilization, packet lost ratio, delay, jitter and etc.
2.4.3	Manage Service Quality	This functionality supports the evaluation and comparison of performance data to normal baseline levels. If some of the performance thresholds are exceeding the normal baseline, this functionality can trigger an alert and report this behavior to network management functions.
2.4.4	Adjust Resource Allocation	This functionality addresses the monitoring of the network communication load. Associated functionality includes issuing of requests associated with actions to adjust services based on communication load levels and supporting interfaces to communication management systems.

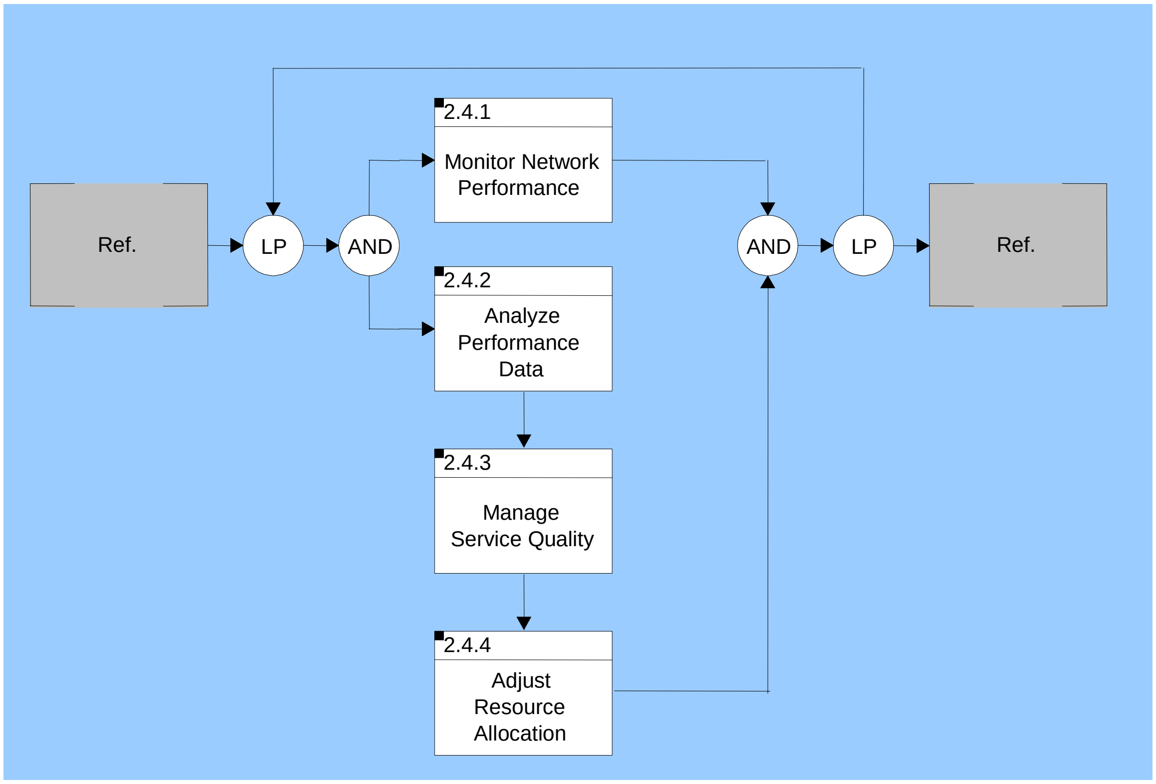

Figure 22: Manage Network Performance - Functional Flow Block Diagram.

4.2.5 Maintain Network Security

The mission-critical nature of the NAS information demands strict access control to MCNA networks. This function is responsible for maintaining network security. The following table provides the descriptions of the third level sub-functions of Maintain Network Security (Table 19). The sub-functions of Manage Network Security are also somewhat autonomous. This functional autonomy is represented in the FFBD via a simple AND'ing of the sub-functions (Figure 23).

Table 19: Sub-Functions and Descriptions for Maintaining Network Security.

Function Number	Function Name	Description

Function Number	Function Name	Description
2.5.1	Manage Security Attributes	This functionality addresses network-wide security information control. It includes maintenance of a network-wide user directory; NAS information classification directory; and access privilege directory. A local copy of each of these directories can be associated with each network user. This functionality supports updates to these directories and maintenance of integrity and consistency for these directories. This functionality supports the classification of differing data security levels and correlation of access to the validated security level with network users.
2.5.2	Manage Authentication	This functionality provides the identification, authentication, and encryption mechanisms to counter potential threats to MCNA and reduce the associated risks.
2.5.3	Maintain Security Functions and Data	This functionality addresses the management and maintenance of security functions defined based on the Common Criteria and data associated with MCNA security policies. The capability is provided to ensure that MCNA resources and other information assets are well managed, protected, and distributed within the network. Additionally, member data protection is provided during import, export, and storage.
2.5.4	Maintain Security Audits	This functionality provides the capability to maintain and log security data. This data may include: •Encrypted user passwords •Tokens and public/private keys generated for the public key infrastructure •User login event log •Others (to be determined)

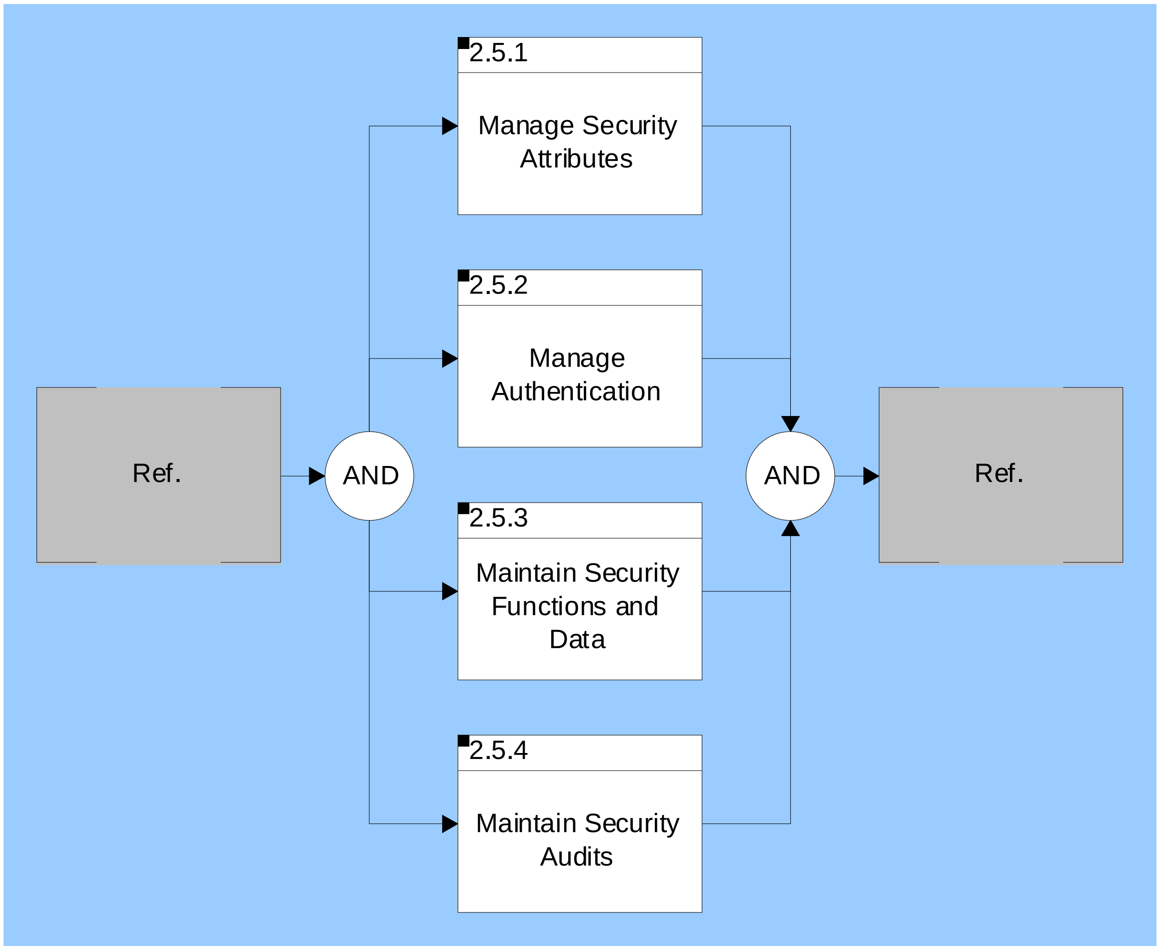

Figure 23: Manage Network Security - Functional Flow Block Diagram.

4.3 N2 Diagrams

N2 diagrams are an FAA approved SE approach to define the interfaces between functions. The following N2 diagrams depict the high-level functional interaction between each of the Level 1 functions: Provide Data Transport and Manage Data Transport and their respective Level 2 functions (Figure 24, Figure 25, & Figure 26). Each N2 diagrams also includes rows for the other Level 1 function to depict the interactions across Level 1 functional boundaries.

Column = Output

Row = Input

Provide Data Transport 1.0	Configuration state, performance, usage statistics, fault states;
Access privaleges, security credentials, configuration changes	**Manage Data Transport** 2.0

Figure 24: MCNA Level-1 N2 Diagram.

Column = Output

Row = Input

Provide Naming and Addressing 1.1	Provide source address;		Provide source address; Provide destination address;		Configuration; Fault States;
	Manage A-G/A-A Connections 1.2	Provide connection status;			Configuration; Fault States;
	Data for transport; Request connection setup; Request connection tear down;	**Manage A-G/A-A Flows** 1.3			
Request destination address lookup;		Data for transport;	**Transport Data** 1.4	Provide tranport PLR status;	Usage statistics;
	Select connection QoS level;	Request flow movement;		**Maintain QoS** 1.5	Performance;
Configuration changes;	Access Privelages; Security credentials;		Security credentials;		**Manage Data Transport** 2.0

Figure 25: Provide Data Transport Level-2 N2 Diagram.

Column = Output

Row = Input

Provide Data Transport 1.0	Fault States;	Fault States;	Usage statistics;	Performance;	
	Manage Network Faults 2.1	Reconfiguration Requests; Restoration;	Service outage information	Fault notification	
Configuration changes;		**Manage Network Configuration** 2.2			
			Manage Network Accounting 2.3		
	Performance threshold Exceptions;	Performance Exceptions; Reconfiguration Requirests	Infrastructure Resource Utilization Information;	**Manage Network Performance** 2.4	
Access Privelages; Security credentials;	Intrusion detection notification	Security Alarm; Security credentials	Security Audits/Logs;		**Manage Network Security** 2.5

Figure 26: Manage Data Transport Level-2 N2 Diagram.

5 REQUIREMENT DERIVATION METHODOLOGY

This section describes the methodology used to derive the MCNA system and performance requirements. The MCNA system requirements are the qualitative requirements that address the functional and characteristic aspects of MCNA. The performance requirements are the sets of quantitative metrics that define the different services classes and levels. One view of the relationship of requirements analysis activities in the development process is shown in Figure 27. Here, the system development process as defined in the FAA Systems Engineering Manual (SEM) is used as a reference. The arrow points out how requirements analysis supports the development process.

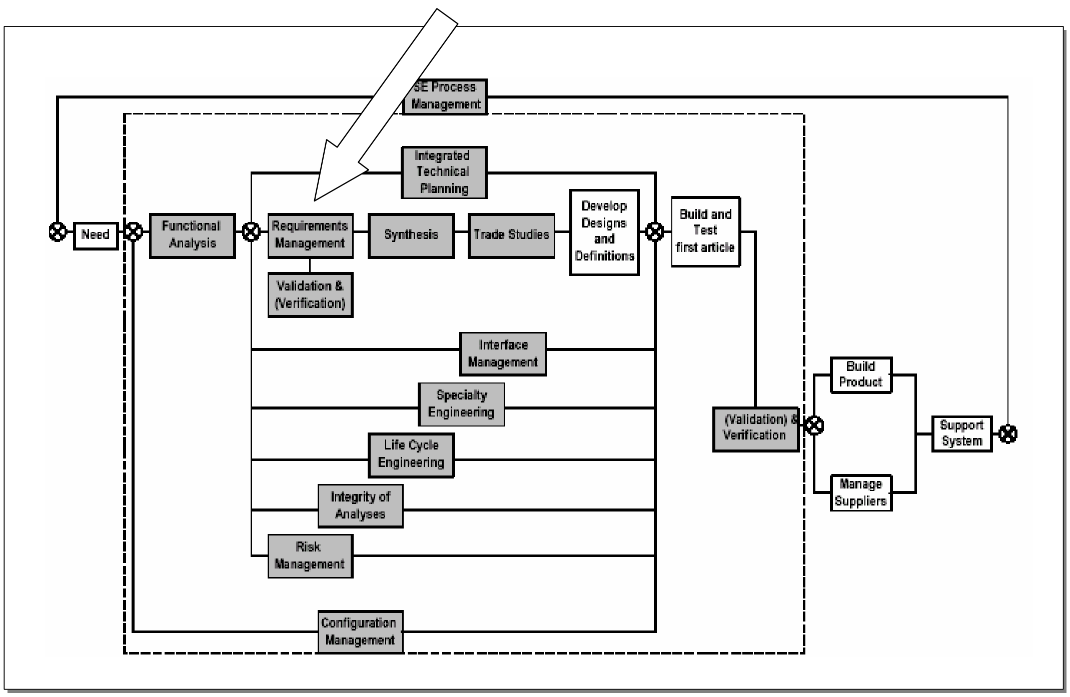

Figure 27: Requirements Analysis within the FAA Systems Engineering Process.

5.1 MCNA System Requirements Derivation

The MCNA System Requirements are qualitative requirements that are independent of individual communication services and classes. They include requirements in such categories as functional, characteristic, policy, operational, service, security, and transition. These requirements were derived utilizing two separate but correlated sources of information.

The starting point for the MCNA requirements was the list of system functional requirements compiled in the AATT RTO-24, [2]. These requirements were taken from “shall” statements found in industry-related documentation and address the current, planned, and projected A-G and A-A services. The deliverable from the AATT RTO-24 study that contains this information was completed in August of 1999. During a second iteration of the SE process, these system/program requirements were expanded to include industry-related documentation up to the time of the MCNA contract, mid-2005.

The first task performed was to disposition the system functional requirements that came from the AATT RTO-24 work. Not all the requirements that were compiled from industry documentation for the AATT RTO-24 study are applicable to MCNA given its definition as described in section 1. These requirements were taken from many different source documents each of which addressed a specific technology, service, or system approach. Thus, the requirements spanned the entire protocol stack including the layers that are outside the scope of MCNA. These include requirements that address such things as the applications themselves or of the human interface. Such requirements were given the disposition “Out of Scope” and will not be addressed in the MCNA requirement development and analysis task. Other of the system function requirements coming out of the AATT RTO work were actually scenario definitions and therefore did not qualify as requirements. These requirements were given the disposition “Scenario” and were incorporated into the scenario effort. The selection of operational scenarios for the MCNA effort is described in section 3 earlier in this report. The remaining requirements were deemed to either entirely or partially apply to the MCNA and were given the disposition “In Scope”. These requirements drive MCNA requirements and each should relate to at least one MCNA requirements. Figure 28 illustrates the breakdown of the disposition of all 233 of the original AATT RTO-24 system functional requirements.

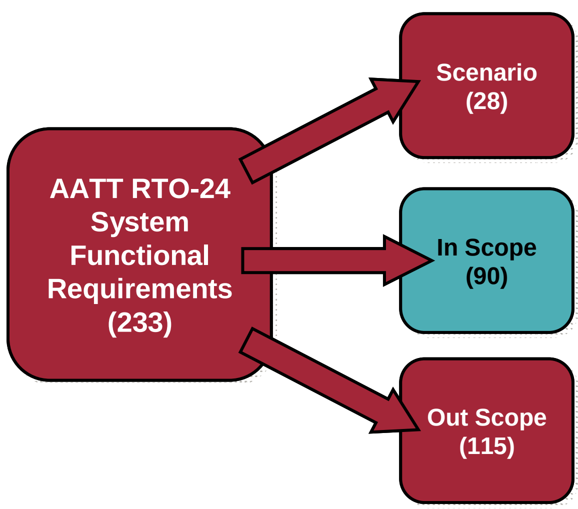

Figure 28: Disposition of the RTO-24 System Functional Requirements.

The second source of MCNA system requirements was the MCNA functional analysis described in section 4, Figure 11. This activity addressed the functionality needed to implement MCNA as envisioned with the focus on providing A/A and A/G mobile communications capabilities that extend the reach of the SWIM to the aircraft.

The list of system functional requirements from industry-related documentation and the MCNA functional analysis were then used to derive MCNA requirements. Figure 29 illustrates the relationship between the AATT RTO-24 system function requirements, the MCNA functional analysis, other sources of requirements, and the MCNA requirements. This processes produced (85) MCNA system requirements. All of the requirements, MCNA and the source requirements, and their relationship to each other were captured in a Microsoft Access database which provides traceability for every MCNA requirement back to the functional analysis or the industry system functional requirements. This relational database was developed and enhanced over the length of the contract to incorporate MCNA architecture and transition activities such as the allocation of requirements to the MCNA deployment spirals.

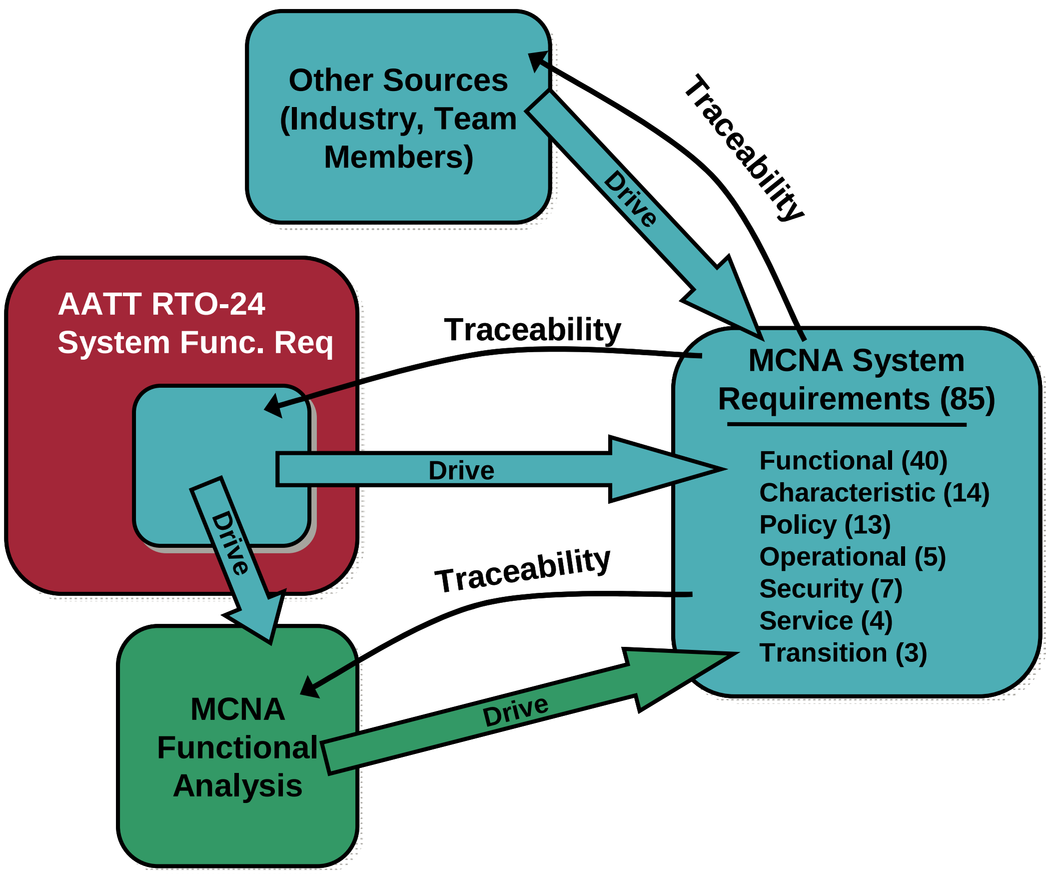

Figure 29: MCNA Requirement Derivation.

5.2 MCNA Service Classes and Levels (Performance Requirements)

A key aspect of the requirements derivation process is the concept of communication service classes and levels. Because of the wide array of uses of communications services, we anticipate the need to define a more robust set of communication services than previously envisioned. Each communication service class was further subdivided into one or more service levels to differentiate quantitative performance requirements levels required by the supported application(s).

The applications supported by a communication service class would all have similar relative performance characteristics. For example, streaming voice or video services have tight latency requirements but tend to be robust to packet losses or data errors. In contrast, file uploads or trajectory exchanges may not require as stringent of latency requirements but absolutely cannot tolerate undetected packet losses or bit errors. Since these examples represent distinct performance characteristics, they would fall into different communication service classes.

Within a service class, multiple service levels would represent different levels of performance within that service class. In the case of trajectory exchange, service levels would be mostly characterized by varying latency requirements. Notional examples of a representative set of voice and data communication service classes and associated levels are provided within the tables below (Table 20 & Table 21).

Table 20: Voice Communication Service Classes & Levels.

Service Class	Service Level	Designator	Description
Party Line Voice	1	RCP-PLV1	Emergency Party Line Service
	2	RCP-PLV2	Terminal area and surface party line voice
	3	RCP-PLV3	En-route Party line voice
	4	RCP-PLV4	Oceanic, Remote or AOC Party line voice
Selective Addressed Voice	1	RCP-VSA1	En-route ATC telephony
	2	RCP-VSA2	Oceanic, Remote, AOC or DHS telephony
	3	RCP-VSA3	Passenger telephony
Broadcast Voice	1	RCP-VB1	Emergency voice broadcast
	2	RCP-VB2	Info broadcast via voice (e.g. ATIS)

Table 21: Data Communication Service Classes & Levels.

Service Class	Service Level	Designator	Description
Data Messaging	1	RCP-DM1	Tactical CPDLC: D-ALERT, URCO, ACL, D-TAXI
	2	RCP-DM2	Strategic CPDLC: DLL, ACM, FLUP, D-RVR, PPD, ACL, DCL, D-TAXI, AMC, AUTO-CPDLC
	3	RCP-DM3	Routine CDPLC: DLL, ACM, D-ATIS, D-SIGMET, D-ORIS, DSC
	4	RCP-DM4	AOC "ACARS": OOOI, NOTAM, METAR, TAF, weather request, position report, flight status, fuel status, flight plan request, load sheet request
Trajectory Exchange	1	RCP-TE1	Tactical Trajectory Update: COTRAC, FLIPSY, FLIPINT
	2	RCP-TE2	Strategic Trajectory Update: FLIPINT, ARMAND, GRECO, DYNAV, ACL, DCL, D-TAXI
Broadcast to Aircraft	1	RCP-BTA1	TIS-B for self separation
	2	RCP-BTA2	TIS-B for situational awareness
	3	RCP-BTA3	FIS-B
Broadcast from Aircraft	1	RCP-BFA1	ADS-B for self separation (terminal & surface)
	2	RCP-BFA2	ADS-B for self separation (en-route)
	3	RCP-BFA3	ADS-B for situational awareness
Ground to Air Data	1	RCP-FU1	Tactical SWIM services
	2	RCP-FU2	Strategic SWIM services
	3	RCP-FU3	Informational SWIM services
Air to Ground Data	1	RCP-FD1	Tactical SWIM services
	2	RCP-FD2	Strategic SWIM services
	3	RCP-FD3	Informational SWIM services
Air to Air Data	1	RCP-AAD1	Collision avoidance resolution
	2	RCP-AAD2	Free flight conflict resolution
	3	RCP-AAD3	Self-separation resolution
Video Exchange	1	RCP-V1	ROA aircraft view downlink
	2	RCP-V2	DHS situation downlink
Command & Control	1	RCP-CC1	ROA CC Level 1 - Commercial airspace (maybe) and over populated areas
	2	RCP-CC2	ROA CC Level 2 - SUA over populated areas
	3	RCP-CC3	ROA CC Level 3 - Operation in SUA over unpopulated areas

A key step in the integration of the MCNA system engineering data products into the Access Database was the mapping of scenarios to communication services and levels. An example of such a mapping is illustrated in Table 22. Each MCNA enabled scenario requires the support of at least one communication service class. For each of the required communication services classes, the appropriate communication service level was defined. As this mapping gets further refined, the potential exists to define new communication services or classes. This process will help mature the baseline list of communication service classes and levels currently defined.

Table 22: Illustration of the Mapping between Scenarios and Communication Services Classes.

Scenario Number	Scenario	Description	Communication Services											
			Party-line Voice	SA Voice	Broadcast Voice	Data Messaging	Tijaecotry 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
1	Deploy FIS-B Nationally	Free access nationwide for basic weather and NAS status information to equipped aircraft						3						
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				
10	Datalink to reduce routine workload	Expanded use of datalink for routine service provide activities to reduce workload.	2			2								
15	Enhanced Emergency Alerting	Using GPS position and aircraft ID, locate distressed or downed aircraft through ADS-B							1					

5.3 Relationship with Other RCP Efforts and Recommended Future Work

The definition of the MCNA communication services and levels leveraged previous results from MACONDO[6], DO-290[3], DO-284[4], the ICAO Manual on RCP[7] and the Future Communications Study (FCS) Initial Concept of Operations and Communication Requirements (ICOCR)[8]. In general, all of these efforts attempt to address the issue of Required Communications Performance (RCP). The MCNA effort is probably most closely aligned with the previous MACONDO work with respect to the large number of individual communication services identified. However, the proposed values for the performance requirements representing each of the communication services and levels are not fully aligned. The following bullets describe the characteristics noted from the listed RCP efforts.

- MACONDO – comprehensive set of communication services classes. MCNA adopted much of the same philosophy. The MACONDO work provides many recommended performance values for these services classes. However, they tend to suggest very tight latency requirements which are not well justified by any operational analysis

- PARC CWG– This RCP effort providing valuable insights into the type of operational analysis required for a single operational scenario (30/30 Oceanic separation) but the scope of effort seems limited to separation management. In addition, the operational analysis needs to be extended to cover the justification for availability and continuity requirements and not just the latency and integrity requirements. One interesting note is that the proposed availability and continuity requirements are not particularly stringent, especially in comparison with other efforts. It should be noted that this is an active ongoing effort. Recent activity within this group is starting to address what issues arise when attempting to implement the RCP concept within an operational environment.

- DO-284 – The NexCom Safety and Performance Requirements (SPR) effectively introduced the RCP concept but later focuses upon the capabilities of a particular technology and therefore produces more stringent performance requirements than necessary because the technology of interest can support these requirements. Since RCP is supposed to be technology independent, this becomes a major shortcoming of this effort. Furthermore, this document identifies extremely high availability requirements that are not justified nor easily met by existing or future communication systems.

- DO-290 – The SPR for Air Traffic Datalink in Continental Airspace provides a very comprehensive RCP analysis for the classic datalink applications including DLIC, AMC, ACL, DCL, DSC and FIS. The RCP process followed by this document aligns very closely with the ICAO RCP Manual. While this document provides a comprehensive discussion of datalink procedure, failure modes and resultant performance requirements, the analytical process is still not clear. In general, however, the main limitation of this analysis lies in the fact that the Expiration Time (ET) is allocated to the individual contributors in the same linear fashion as the 95% transaction time TT(95).

- ICOCR – The FCS Initial Concept of Operation and Communication Requirements ICOCR extracted requirements from many of the same documents listed here. It does, however, introduce a broader set of communication applications based upon more recent R&D efforts. The ICOCR also divides the ET linearly and further makes an arbitrarily equal sub-allocation of the RCTP budget between uplink and downlink. It should be noted that this is also an ongoing effort and the characterization described above may not still be applicable in future updates of this document (as the Final Concept of Operations and Communication Requirements - FCOCR)

The MCNA RCP effort was a quick review of the existing body of work and a proposed framework from the perspective of supporting SWIM capabilities via MCNA. This is a first attempt to rationalize the strongly contrasting performance requirements.

From this effort, a few key shortcomings of the ongoing RCP processes were identified and are listed below as recommendations for process enhancement and future work.

- Allocation of Expiration Timer (values) – the linear division of 95% latency contribution is a conservative but acceptable approach. However, the expiration time represents the occurrence of rare-normal events. By allocating this additional time linearly between the contributing elements, it suggests that each element is likely to experience simultaneously a rare-normal event. In reality, it is not very likely that each element will simultaneously experience a rare-normal event and thus demanding an additional allocation of latency to accommodate. It would seem that a better approach would be to identify the RCP-level difference in latency between TT(95) and ET. This additional value should be able to be allocated in total or at least a significant fraction (e.g. 50%) to any of the contributing latency elements.

- The RCP, RCTP, ACP, ICP framework is generally based upon the notion of a single communication system providing one or more communication services. MCNA intends to provide a networked communication environment that enables communication services to be achieved via the aggregation of multiple communication systems. Provisions need to be made within the ongoing RCP development efforts to assure this methodology will be accommodated. This change in focus would shift the requirements flow from that shown in Figure 30 to the requirements flow shown in Figure 31. Unfortunately, this introduces further complexity into an already complex process. As such, future work should evaluate this proposal to identify any possibly simplifications that could be achieved while still abstracting the relationship between RCP and a particular communication system.

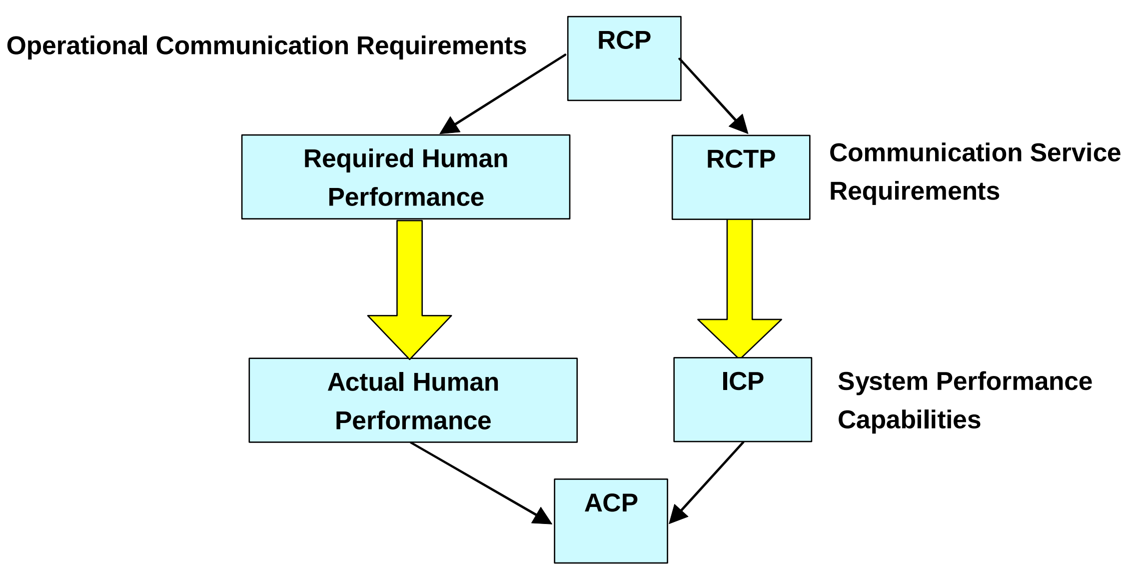

Figure 30: Current RCP Flow.

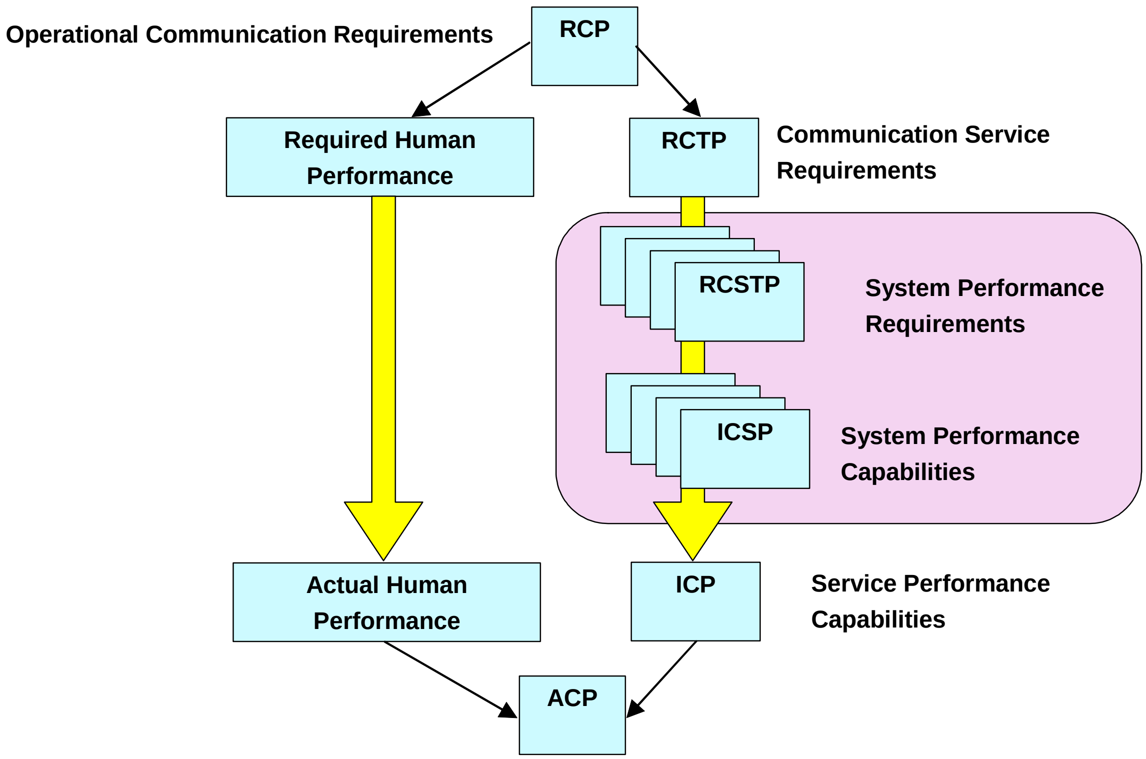

Figure 31: Proposed RCP Flow.

- The description column of Table 21 gives an indication of how the operational services defined in the ICOCR, [8], map to the MCNA services and levels. This requirements analysis needs to be performed in a more rigorous manner to assure that the MCNA services cover all of the operational services foreseen by the FCS effort.

6 REQUIREMENTS

This section contains the current set of candidate MCNA requirements. These include functional, characteristic, policy, operational, service, security, transition, and performance requirements. A high-level definition of these MCNA requirement categories is provided below:

- **Functional Requirement:** Functional requirements capture requirements related to the functions provided by MCNA.
- **Characteristic Requirement:** Characteristic requirements capture requirements related to the characteristics of MCNA.
- **Policy Requirement:** Policy requirements capture requirements that are related to FAA/ATM policy.
- **Operational Requirement:** Operational requirements capture requirements that govern the use of the MCNA.
- **Security Requirement:** Security requirements relate to the protection of data being communicated from malicious attack, being divulged to unknown/unauthorized parties.
- **Service Requirement:** Service Requirements capture the nature of the services that MCNA is required to provide.
- **Transition Requirement:** Transition requirements are imposed to assure seamlessly inter-operation during transition from exiting infrastructure to new infrastructure.
- **Performance Requirements:** A set of quantitative metrics that must be met to provide a specific service class of a specific level.

6.1 Functional Requirements

This section contains functional requirements that were derived from the MCNA functional analysis described in section 4. They describe the functions that the MCNA vision system will provide to mobile entities and other entities (fixed or mobile) that want to communicate with them. These requirements specify what MCNA capabilities are provided and not how they are provided.

6.1.1 Provide Data Transport

These functional requirements address the key functions that drive the air-ground or air-air connectivity for voice and data communication services. The functional analysis that generated these requirements can be found in section 4.1.

1. MCNA shall register all end and intermediate system names.

Note: End system refers a system that contains the OSI seven layers and contains one or more end user application processes. Intermediate system refers to a system which performs relaying and routing functions and comprises the lowest three layers of the OSI reference model

2. MCNA shall assign unique network addresses to all end and intermediate systems.
3. MCNA shall resolve network addresses from registered end and intermediate systems.
4. MCNA shall authenticate entities (end and intermediate systems) prior to link establishment.
5. MCNA shall authorize A-G/A-A link establishment upon authentication.
6. MCNA shall establish authorized A-G/A-A links.
7. MCNA shall maintain established A-G/A-A links.
8. MCNA shall handover established A-G/A-A links.
9. MCNA shall terminate established A-G/A-A links.
10. MCNA shall allocate flows to A-G/A-A links.
11. MCNA shall move flows between A-G/A-A links.
12. MCNA shall authenticate data.
13. MCNA shall provide data confidentiality.
14. MCNA shall assure data integrity.
15. MCNA shall deliver packets to a single user.
16. MCNA shall deliver packets to a group of users.
17. MCNA shall deliver packets to all users.
18. MCNA shall prioritize packet delivery.

19. MCNA shall pre-empt lower priority resource allocations.

20. MCNA shall shape traffic.

Note: Example, weighted fair queuing.

21. MCNA shall police traffic.

6.1.2 Manage Data Transport

These requirements addressed the functionality associated with the management of the network. The functional analysis that generated these requirements can be found in section 4.2.

1. MCNA shall detect faults.
2. MCNA shall diagnose faults.
3. MCNA shall isolate faults.
4. MCNA shall recover from faults.
5. MCNA shall log and notify fault detection and recovery events.
6. MCNA shall monitor the system configuration.
7. MCNA shall configure the system elements.
8. MCNA shall manage the configuration of status/control messages.
9. MCNA shall manage the system resource utilization.
10. MCNA shall manage the system billing.
11. MCNA shall maintain accounting audits of the system.
12. MCNA shall collect performance data.
13. MCNA shall analyze performance data.
14. MCNA shall manage service quality.
15. MCNA shall adjust resource allocations.
16. MCNA shall manage security attributes.
17. MCNA shall manage member credentials.
18. MCNA shall manage security functions.

19. MCNS shall maintain security audits.

6.2 Characteristic Requirements

This section contains the characteristic requirements for the MCNA.

1. MCNA shall make previsions for the efficient use of limited bandwidth subnetworks.

2. MCNA shall support voice and data communications to fixed and mobile systems.

3. MCNA shall support assured delivery data transport.

4. MCNA shall not degrade safety.

5. MCNA prioritization mechanisms shall be consistent across various services and types of messages available.

6. MCNA shall be integrated with airborne flight management, control, and information systems.

7. MCNA shall be capable of communication and fully compatible with the ground based ATS systems.

8. MCNA shall provide information to applications indicating the status and capability of subnetworks.

9. MCNA shall support the exchange of data between ground and aircraft systems in all airspace domains.

10. MCNA shall have the capability to unambiguously identify the source and destination of all transmitted messages.

11. MCNA shall provide means of managing all of the circuits and subnetworks within the system with minimum intervention required of the users or service providers.

12. MCNA shall provide a framework to develop enhanced communication services by combining the capabilities of multiple individual communication subnetworks.

13. MCNA shall use Commercial Off The Shelf (COTS) technology (i.e. core networking hardware and protocols) whenever practicable.

14. MCNA shall support commercial, military, and general aviation using a shared communication infrastructure.

6.3 Policy Requirements

Policy requirements capture requirements that are related to FAA/ATM policy

1. MCNA shall support legacy systems.
2. MCNA shall use a structured layered communication architecture such as defined by Open System Interconnection (OSI) standards.
3. MCNA shall facilitate interoperability and seamless transmission across international borders.
4. MCNA avionics installed, for transport aircraft, must be approved by FAA and be in order with FAR 25.1301, 25.1303, 25.1305, 25.1307, and 25.1309.
5. MCNA equipment shall not interfere with any essential or critical equipment.
6. MCNA shall allow controllers and pilots to manually override MCNA automation.
7. MCNA shall always provide aircrew/controller voice when air/ground data communications are used for Air Traffic Services (ATS).
8. MCNA establishment of data link for ATS purposes shall only be aircraft initiated. Once the link has been established, the initiation of a specific service or message may be either ground or air initiated.
9. MCNA systems must have FCC certification.
10. MCNA systems will adhere to all relevant NTIA rules and regulations.
11. MCNA shall allow users to manually shut down equipment when applicable.
12. MCNA shall give priority to ATM voice over data.
13. MCNA shall not violate International Traffic in Arms Regulations (ITAR).

6.4 Operational Requirements

Operational and capture the requirements that govern the use and operation of MCNA.

1. MCNA shall support the exchange of ATS and AOC messages to all suitably equipped aircraft.

2. MCNA shall not preclude the exchange of AAC and APC message to all suitably equipped aircraft.

3. MCNA shall provide users with the capability to manually select available subnetworks when required by operational circumstances (or Quality of Service).

4. MCNA shall support ATS and AOC services for aircraft operating under both IFR and VFR flight rules.

5. MCNA should facilitate the air traffic specialist's ability to communicate with each aircraft and the pilot's ability to communicate with each ATC facility in both voice and data modes and to use the available communication link that most closely matches the required QoS for that communications.

6.5 Security Requirements

Security requirements relate to the protection of data and voice communications from malicious attack and being divulged to unknown/unauthorized parties.

1. MCNA shall include a Security Management Program that will be an integral part of the design, manufacture, test, installation, operation of and maintenance of MCNA.

2. The MCNA Security Management Program shall identify the means of containing the effects of security breaches internally and externally to MCNA, identify recovery actions and also mitigation procedures to prevent re-occurrence.

3. MCNA equipment shall be secure from outside tampering.

4. A security policy shall be developed for MCNA.

5. MCNA shall support all the provisions of ICAO Annex 17.

Note: Annex 17 is the ICAO document that address Standards and Recommended Practices (SARPs) for the safeguarding of international civil aviation.

6. A protection profile shall be developed for MCNA.

7. The MCNA shall provide means to prevent service denial including from RF jamming.

Note: This is not intended to be a requirement suggesting military level resistance to RF jamming. For example, redundant links at different frequencies would address this requirement.

6.6 Service Requirements

Service Requirements capture the services that MCNA provides and their interactions.

1. MCNA shall provide simultaneous voice and data communication services to the aircraft.
2. Where MCNA ATS voice services are designated as backup to data services they shall be supported by a separate (independent) communication infrastructure.
3. MCNA establishment of party line voice services for ATS purposes shall only be aircraft initiated.
4. New MCNA Voice Services shall have voice quality equal or better than that of current analog VHF voice.

6.7 Transition Requirements

Transition requirements are imposed to assure seamless operation existing infrastructure and new infrastructure.

1. MCNA shall provide means to facilitate migrations to future versions of application entities and/or communication services and facilitate backward compatibility with previous versions.
2. MCNA shall be capable of growing incrementally to a global solution.
3. MCNA shall support multiple versions of hardware and software in its constituent components.

6.8 Performance Requirements

This section contains the performance requirements for the MCNA voice and data services. The values were compiled from numerous industry sources. In the future these requirements should be modified or verified through detailed operational analysis efforts. This process was addressed in more detail in section 5.3 in the discussion on RCP, ACP, and ICP. The performance metrics used for voice versus those for data are slightly different. Definitions of all the performance metrics are given below.

- **Mean Latency (Voice):** This is the average duration of time from when voice information enters the MCNA until it leave the MCNA.
- **95th Percentile Latency (Data):** This is the amount of time by which 95% of MCNA data packets traverse the MCNA (from entering the MCNA until exiting the MCNA).
- **Call Establish Time (Voice)**: This is the amount of time by which 95% of MCNA voice circuits are set up from an aircraft to ground system or to another aircraft.
- **Expiration Time (Data):** The maximum time to complete a transaction after which peer parties revert to an alternative communications means and/or an alternative procedure.
- **Availability:** The ability of a system to perform its required function at the initiation of the intended operation. It is quantified as the proportion of the time the system is available to the time the system is planned to be available..
- **Continuity:** The probability of a system to perform its required function without unscheduled interruptions during the intended period of operations
- **Integrity:** The probability that errors will be mis-detected. This may be when a correct message is indicated as containing one or more errors, or when a message containing one or more errors is indicated as being correct.
    - **Bit Error Rate (BER) (Voice):** This is the percentage of voice bits that are in error at the output of layer 2 at the receiving node. The higher this error rate the more likely that the VOCODER will produce misinterpreted speech.
    - **Undetected Packet Loss Rate (PLR) (Data):** This is the probability that a data packet arrives at the output of layer 2 at the receiving node with undetected errors.
- **Security:**
    - **Authentication:** The process of verifying the identity and/or authorization of a user, process or device, usually as a prerequisite for granting access to a service.
    - **Confidentiality:** The property that information is not made available of disclosed to unauthorized individuals, entities, or processes.

6.8.1 Voice Services Performance Requirements

This section contains the performance requirements of the three different voice service classes. Table 23 gives the mean latency, call establishment time, availability, integrity, and security requirements for each service level of the three different voice service classes. The service classes and service levels mirror those defined in Table 20.

The source of the values in the table are based on MACONDO except for the mean latency and call establishment values which were based upon the analysis in the FCS ICOCR. The relatively relaxed integrity requirements of 1e-3 BER, compared to other industry documents, is based upon VOCODER technology that can provide MOS scores of 3.5 and above at these BER.

Table 23: Voice Service Performance Requirements.

Service Class	Service Level	Mean Latency	Call Establishment Time	Availability	Continuity	Integrity (BER)	Security
Party Line Voice	1	350ms	150ms	0.993	0.998	1.00E-03	NA
	2	350ms	150ms	0.993	0.998	1.00E-03	Authentication
	3	350ms	150ms	0.993	0.998	1.00E-03	Authentication
	4	350ms	20s	0.993	0.995	1.00E-03	Authentication
Selective Addressed Voice	1	350ms	5s	0.993	0.998	1.00E-03	Authentication
	2	485ms	20s	0.993	0.995	1.00E-03	Authentication
	3	485ms	40s	0.993	0.95	1.00E-03	Authentication
Broadcast Voice	1	485ms	NA	0.99999	0.998	1.00E-03	NA
	2	485ms	NA	0.99	0.995	1.00E-03	NA

6.8.2 Data Services Performance Requirements

Table 24 contains the performance requirements of the MCNA service classes and levels that were described in Table 21. These are the performance requirements for the nine different digital data service classes. The main source of the values in the table, with a few exceptions, was the MACONDO study, [6]. Other sources include the Performance-based operations Aviations Rulemaking Committee (PARC) RCP effort, [9].

Table 24: Data Services Performance Requirements.

Service Class	Service Level	95% Message Latency*	Expiration Time	Availability	Continuity	Integrity (Undetected PLR)	Security
Data Messaging	1	2	20	0.9995	0.995	1.00E-05	Authentication, Confidentiality
	2	5	40	0.9995	0.995	1.00E-05	Authentication
	3	10	60	0.9995	0.995	1.00E-05	Authentication
	4	30	120	0.9995	0.995	1.00E-05	Authentication
Trajectory Exchange	1	30	120	0.9995	0.995	1.00E-08	Authentication, Confidentiality
	2	30	120	0.9995	0.995	1.00E-08	Authentication, Confidentiality
Broadcast to Aircraft	1	3	5	0.9995	0.995	1.00E-05	Authentication
	2	5	15	0.999	0.99	1.00E-05	Authentication
	3	30	60	0.999	0.99	1.00E-05	Authentication
Broadcast from Aircraft	1	3	5	0.999	0.99	1.00E-05	N/A
	2	5	15	0.999	0.99	1.00E-05	N/A
	3	10	20	0.999	0.99	1.00E-05	N/A
Ground to Air Data	1	5	40	0.999	0.99	1.00E-05	Authentication
	2	10	60	0.999	0.99	1.00E-05	Authentication
	3	30	120	0.999	0.99	1.00E-05	Authentication
Air to Ground Data	1	5	40	0.999	0.99	1.00E-05	Authentication
	2	10	60	0.999	0.99	1.00E-05	Authentication
	3	30	120	0.999	0.99	1.00E-05	Authentication
Air to Air Data	1	3	20	0.999	0.99	1.00E-05	N/A
	2	5	40	0.9995	0.995	1.00E-05	N/A
	3	30	120	0.9995	0.995	1.00E-05	N/A
Video Exchange	1	1	2	0.99999	0.999	1.00E-05	Authentication, Confidentiality
	2	5	40	0.999	0.99	1.00E-05	Authentication, Confidentiality
Command & Control	1	1	2	0.999999	1	1.00E-08	Authentication, Confidentiality
	2	1	2	0.99999	0.999	1.00E-08	Authentication, Confidentiality
	3	1	2	0.9999	0.99	1.00E-08	Authentication, Confidentiality

Note: 95% Message Latency is for 1kbit message.

6.9 Recommended Future Work

The requirements contained in this section were compiled from many different industry sources. Because of the high-level nature of MCNA, many of the system functional requirements can be characterized as vague or ambiguous. Further refinement is necessary to assure that each requirement meets highest possible quality in regards the characteristics laid out in the SEM, [1]. These include necessary, concise, implementation free, attainable, complete, consistent, traceable, unambiguous, verifiable, and allocatable.

Another task is the requirements allocation process. The requirements should be allocated to the physical architecture component categories of the MCNA, Table 25

Table 25: MCNA Physical Architecture Elements.

Airborne Architecture Elements	Terrestrial Architecture Elements
Airborne host	Terrestrial host
Airborne router	Terrestrial router
Airborne message router	Terrestrial message router
Airborne gateway	Terrestrial gateway
Airborne modem/radio	Terrestrial ground station
Airborne firewall	Network Operations Control Center (NOCC)
	Domain Name Server (DNS)

Additional attributes for the different service classes/levels need to be defined and specified. These include expected volume, priority and probability, direction and symmetry of flows, and timeliness of information.

Lastly, the number of MCNA operational scenarios should be expanded to include high risk/high benefit scenarios. These scenarios provide means of illustrating more of the transformational capabilities of MCNA to significantly improve the capacity, efficiency, safety, and security of the NAS. Thus they provide prime choices for NASA mission in Air Traffic Management to investigate high risk/high benefit transformational infrastructure and operational changes that are typically beyond those entertained by the FAA.

7 CONCLUSION

This document provides a starting point for the requirements management process as described in the FAA NAS SEM, [1]. Much like SWIM, it is unlikely that a lone program will be responsible for development and deployment of the entire infrastructure that would make up MCNA. Instead, it should evolve into an effort that produces recommendations, specifications, and guidelines that, if followed by ground networks, RF links, and airborne networks will lead to the System of Systems encompassing MCNA vision. This effort will cover the individual systems, the interface/interactions of these systems, and the system of system capabilities enabled by the aggregation of many separate communication systems into a seamless communication architecture providing ATM communication services. The MCNA performance requirements that define the MCNA services classes and service levels are not directly tied to any specific communication infrastructure. Instead, they must be derived from operational analysis of the ATM operational procedures that they are intended to support.

This concept of MCNA is needed to meet the connectivity needs of SWIM and NCO. The aircraft becomes just another node in SWIM. This will reduce the cost of deploying new applications onto aircraft that in turn will facilitate the deployment of new and improved ATM operations. This will culminate in a NAS with increased capacity, flexibility, and security.

APPENDIX A: REFERENCES

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APPENDIX B: ACRONYMS

A-A	Air to Air
AATT	Advanced Air Transportation Technologies
ACARS	Aircraft Communications Addressing and Reporting System
ACAST	Advanced CNS Architectures and System Technologies
ACL	Arrival Clearance
ACM	ATC Communications Management
ACP	Achieved Communication Performance
ADS	Automatic Dependent Surveillance
ADS-A	Automatic Dependent Surveillance - Addressed
ADS-B	Automatic Dependent Surveillance - Broadcast
ADS-C	Automatic Dependent Surveillance - Contract
A-G	Air to Ground
AIM	Aeronautical Information Management
AMC	ATC Microphone Check
AOC	Airline Operations Control
AOCDL	Airline Operations Control Data Link
ARMAND	Arrival Manager Information Delivery Service
ARTCC	Air Route Traffic Control Center
ASDE-X	Airport Surface Detection Equipment -model X
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATO-P	Air Traffic Organization operations - Planning
ATS	Air Traffic Services
BCA	Boeing Commercial Airplanes
BER	Bit Error Rate
BGAN	Broadband Global Access Network
CATS-I	Capability Architecture Tool Suite - Internet

CDT	Common Data Transport
CDTI	Cockpit Display of Traffic Information
CIM	Common Information Management
CLNP	Connectionless Network Protocol
CMU	Communication Management Unit
CNS	Communications, Navigation, and Surveillance
COTRAC	COmmon TRAjectory Co-ordination
CoU	Concept of Use
CPDLC	Controller Pilot Data Link Communications
CRM	Customer Relationship Management
CVR	Cockpit Voice Recorder
D-ALERT	Data Link Alerting
D-ATIS	Digital - Automatic Terminal Information Service
DCL	Departure Clearance
DHS	Department of Homeland Security
DHS	Department of Homeland Security
DLIC	Data Link Initiation Capability
DLL	Datalink Logon
DoD	Department of Defense
D-ORIS	Data Link - Operational En-Route Information Service
D-RVR	Datalink - Runway Visual Range
DSC	Downstream Clearance
D-Taxi	Data link - Taxi Clearance Delivery
DYNAV	Dynamic Route Availability
EFB	Electronic Flight Bag
ERAM	En Route Automation Modernization
ET	Expiration Time
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FAS	Flight Advisory Service
FCAPS	Fault, Configuration, Accounting, Performance, Security

FCS	Future Communication Systems
FDP	Flight Data Processor
FDR	Flight Data Recorder
FFBD	Functional Flow Block Diagram
FIS	Flight Information Service
FIS-B	Flight Information Service - Broadcast
FLIPINT	Flight Path Intent
FLIPSY	Flight Plan Consistency
FLUP	Flight Update
FMC	Flight Management Computer
FOMS	Flight Object Management System
FTI	Future Telecommunications Infrastructure
GA	General Aviation
GBT	Ground Based Transceiver
GCNSS	Global Communication Navigation and Surveillance System
GIS	Geographic Information System
GPS	Global Positioning System
GRC	Glenn Research Center
GRECO	Graphical Enabler for Graphical Communications
GWIS	Global Weather Information System
GWP	General Weather Processor
ICAO	International Civil Aviation Organization
ICOCR	Initial Concept of Operations and Communication Requirements
ICP	Installed Communication Performance
ICSP	Installed Communication Service Performance
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IP	Internet Protocol
ISO	International Standards Organization
ITWS	Integrated Terminal Weather Service
MCNA	Mobile Communications Network Architecture

METARS	Meteorological Actual Reports
NAIMES	NAS Aeronautical Information Management Enterprise System
NAS	National Air Space
NCO	Network Centric Operations
NOC	Network Centric Operations
NOTAM	NOtice To AirMen
OAG	Official Airline Guide
OI	Operational Improvement
OOOI	Out, Off, On, In
OSI	Open Systems Interconnection
PARC	Performance-based operations Aviations Rulemaking Committee
PIREPS	Pilot Report
PLR	Packet Loss Rate
PPD	Pilot Preferences Data
QoS	Quality of Service
RCP	Required Communication Performance
RCSTP	Required Communication Service Technical Performance
RCTP	Required Communication Technical Performance
RF	Radio Frequency
RLV	Reusable Launch Vehicles
RNP	Required Navigation Performance
ROA	Remotely Operated Aircraft
RTA	Runway Traffic Alert
RTCA	Radio Technical Commission for Aeronautics
RTO	Research Task Order
SAP	Standard Automation Platform
SatCom	Satellite Communications
SDN	Surveillance Data Network
SEA	SWIM Enabled Applications
SEM	System Engineering Manual
SIGMETS	SIGnificant METeorological information

sMNS	surrogate Mission Needs Statement
SMU	SWIM Management Unit
SoSE	System of System Engineering
SOW	Statement of Work
SPR	Safety and Performance Requirements
SUA	Special Use Airspace
SWIM	System Wide Information Management
TAF	Terminal Area Forecast
TBO	Trajectory Based Operations
TCP	Transmission Control Protocol
TFM-M	Traffic Flow Management - Modernization
TFR	Temporary Flight Restriction
TIS	Traffic Information Service
TIS-B	Traffic Information Service - Broadcast
TNAS	Transformational NAS
TOE	Target Of Evaluation
TRACON	Terminal Radar Approach Control
TT	Transaction Time
UAT	Universal Access Transceiver
UAV	Unpiloted Aerial Vehicles
UDMS	Unified Decision Management System
VDL	VHF Data Link
VFR	Visual Flight Rules
VHF	Very High Frequency
VSCS	Voice Switching and Control System
WARP	Weather and Radar Processor
WG	Working Group
XML	eXtensive Markup Language

APPENDIX C: SWIM Surrogate Mission Needs Statement (sMNS) Review

This Appendix captures the results of an analysis to review the SWIM surrogate mission needs from the MCNA perspective and identify aspects of the sMNS that specifically call out or at least suggest the need for a supporting MCNA capability. The following sections represent the SWIM sMNS with annotations in blue that identify MCNA concerns.

➢ Administrative Information

- MNS Title: System Wide Information Management (SWIM)
- MNS Number: TBD
- Originators:
- Sponsoring Line of Business: ATO-P
- Sponsor's Focal Point: TBD
- Submission Date: TBD
- Revision Number: N/A
- Revision Date: N/A

➢ Mission Area

➢ System Wide Information Management (SWIM) is unique in its ability to quickly and cost effectively share NAS information across all mission areas of the NAS. **[Access to many mission areas requires MCNA]**

❖ Safety

➢ With the aircraft as a node **[as enabled via MCNA]**, SWIM will allow a user to quickly extract all of the operational information, including Notices to Airmen (NOTAM), Special Use Airspace (SUA) schedules, other restrictions, including those arising in real time, and weather along a route of flight to improve safety.

❖ Capacity

➢ SWIM will facilitate advanced ATM concepts such as Collaborative Flow Management, Dynamic Resectorization and 4D Trajectory Management which will increase NAS system capacity. **[dynamic resectorization and 4D trajectory management both require MCNA extension]**

➢ Required to achieve Secretary Mineta's 3X capacity increase by 2015

- Security – Post 9/11 Era
  - SWIM will facilitate coordination with DoD and DHS for quick reaction to situations that appear threatening and to help confirm that a situation is not a threat, e.g., violation of a Temporary Flight Restriction (TFR). **[Access to certain surveillance information may require some form of MCNA]**
- Industry Vitality/Efficiency
  - Improved information sharing between FAA and airlines facilitates the reduction of delays and cancellations allowing for greater efficiency and lower user costs **[The MCNA can facilitate near real time information sharing among ATC, airlines, and aircraft for optimal efficiency, safety, and cost savings]**
- Business Practices/Productivity:
  - SWIM is essential for NAS transformational change and agility. A SWIM approach to information sharing and security will reduce the costs to maintain existing applications and build new ones. It will reduce redundant information procurement and storage.
- Information sharing can benefit all domains of the NAS **[if we are talking about airspace domains we are mostly concerned with operations that include the aircraft and therefore require MCNA]**

Needed Capabilities

- A secure information sharing architecture and application integration strategy based on open standards.
- SWIM is to provide efficient means of information exchange in the NAS to:
  - Lower the costs of NAS application integration, maintenance, and development
  - Improve NAS agility to unanticipated and dynamic needs
  - Improve ATM processes through improved situational awareness and collaborative decision making, e.g. flow management
  - Remove a key barrier to the deployment of operational changes needed to enhance the performance of the NAS **[availability of a general purpose MCNA capability is a secondary barrier to the deployment of operational enhancements]**

➢ Current Capability

❖ At this time, there is no current or planned and funded capability that is able to address the stated needs. However, FTI is expected to provide essential Internet Protocol transport capabilities required for SWIM.

❖ **[One could argue that ACARS / ATN provide rudimentary MCNA capabilities that will provide the building blocks to support the eventual deployment of a true MCNA solution. In the interim, gateways will be employed to effectively extend this SWIM to the aircraft.**

  ➢ **Given the free form text format of ACARS one could argue that it would be possible to exchange XML documents over ACARS**

➢ Capability Shortfall

❖ NAS operational information is contained within specific systems or facilities. Most current NAS applications were developed to meet specific ATM requirements. Many were architected without significant efforts to provide an open architecture to facilitate information sharing. As such, ATM applications tend to be monolithic and non-integrated. Therefore, when needs change, the NAS lacks the agility needed to adapt.

❖ There is information sharing today, but is primarily point-to-point, often one-offs, and does not fully support shared service provider and user collaboration.

❖ External interfaces are closely tied to internal data formats which lead to an expensive multitude of non-standard information exchanges.

❖ Each application represents a custom design to a single information sharing requirement. This adds to costs and makes maintenance and administration unduly difficult.

❖ Information security is fragmented without a systematic approach for ensuring system-wide information security and integrity to all users.

❖ Legacy databases are often isolated and not constructed well for shared, secure access.

  ➢ **[Information exchange involving the aircraft typically involve a very tight coupling between the application and the datalink technology, this requires updates to the datalink technology each time a new application is to be supported]**

❖ Real time information transfer is inadequate for shared situational awareness during in-flight security situations or emergencies.

❖ **[Full access to information (other than just aircraft surveillance) will require MCNA capability]**

❖ NAS information protection and security has not been "planned in."

- Information is procured more than once increasing costs.
- Information is unnecessarily duplicated.
- Each application must provide its own services which may be better accomplished in a more centralized fashion.
- **[This often extends down to the A-G datalink level (although this is slowly improving)]**
- The aircraft is not part of the information network.
- **[This is directly applicable to MCNA]**

Impact of Not Approving Mission Need

- As the number of systems grows, the costs of developing, deploying, maintaining, and integrating NAS applications can be anticipated to rise more rapidly at the same time performance of the NAS will suffer.

- The costs to maintain applications will continue to rise and the cost to build new applications requiring data from existing applications will continue to grow, making it both cost- and time-prohibitive to develop new applications aimed at increasing system capacity. As a result, NAS performance will suffer and the ability to achieve global leadership will be put at risk.

- ***[New ATM enhancements that requires unique MCNA capabilities in order to be deployed will be deferred or canceled because the cost of equipage (unique to that particular enhancement) cannot be justified by the benefits of just that single enhancement]***

Benefits

- The benefits described in this surrogate MNS address high level analyses of what benefits could be reasonably expected to accrue if the capability described were in place today. The cost of developing SWIM and migrating applications to SWIM will be estimated during GCNSS II.

- SWIM is the needed cross-connecting NAS element that:

  - Maximizes NAS operational flexibility

  - Enables the FAA to meet future operational needs within fiscal constraints

  - Ensures the flexibility to dynamically deliver the required system assets in order to ensure sufficient capacity in response to dynamic business factors

    - Ensures NAS agility by enabling infrastructure de-coupling

- **[MCNA is an extension of CDT(FTI) that expands the number of application and enhancements that can be achieved through SWIM]**

➢ Timeframe

- Planning for implementation should proceed now so that SWIM is “built in” rather than “added-on” planned infrastructure upgrades
- Implementation of SWIM should be designed to take advantage of the major windows of opportunity and synergy arising from important upgrade programs such as ERAM and TFM-M. SWIM capability used in these systems would provide a jumpstart to reach a critical mass in which SWIM could pay for itself and quickly enable, at low cost, numerous other NAS applications with data generated from TFM-M and ERAM processing.
- The SWIM Transition Working Group (WG) is developing a detailed list of applications representing early windows of opportunity. These will be added here as they are vetted by the WG.
- **[Retrofit of avionics is expensive and time consuming, understanding the future needs sooner and developing flexible avionics architectures that can support both current and future configuration would provide minimal cost and transition “pain”]**