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Mobile Communication Network Architecture (MCNA) Simulation, Emulation and Demonstration (SED) Plan

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1 Introduction

1.1 Background

The vision for the Mobile Communication Network Architecture (MCNA) is a communication capability encompassing mobile digital voice and data supporting communications, navigation and surveillance (CNS) services for Air Traffic Management (ATM) operations. MCNA is a key enabling technology for transformation of the National Airspace System (NAS) towards Network Enabled Operations (NEO). The MCNA extends voice and data information services defined in the NAS System Wide Information Management (SWIM) concept to the aircraft during all phases of flight and supports the highly automated "interstate skyway system"[1], depicted in Figure 1-1.

Figure 1-1: MCNA Enables the Future ATM Vision

A systems engineering approach is being used to develop and evolve the System of Systems (SoS) that address the digital communications needs of the NAS[2]. The specific approach for MCNA development is shown in Figure 1-2. This approach accommodates

[1] The "interstate skyway system" vision was introduced in the final report of the Commission on the Future of the United States Aerospace Industry, November 2002; the referenced figure is extracted from this report.

[2] The integrated system engineering approach to development and evolution of a SoS is sometimes referred to as the Systems-of-Systems Engineering (SOSE) approach.

the large-scale integration of many independent, self-contained systems in order to satisfy the NEO needs of the NAS.

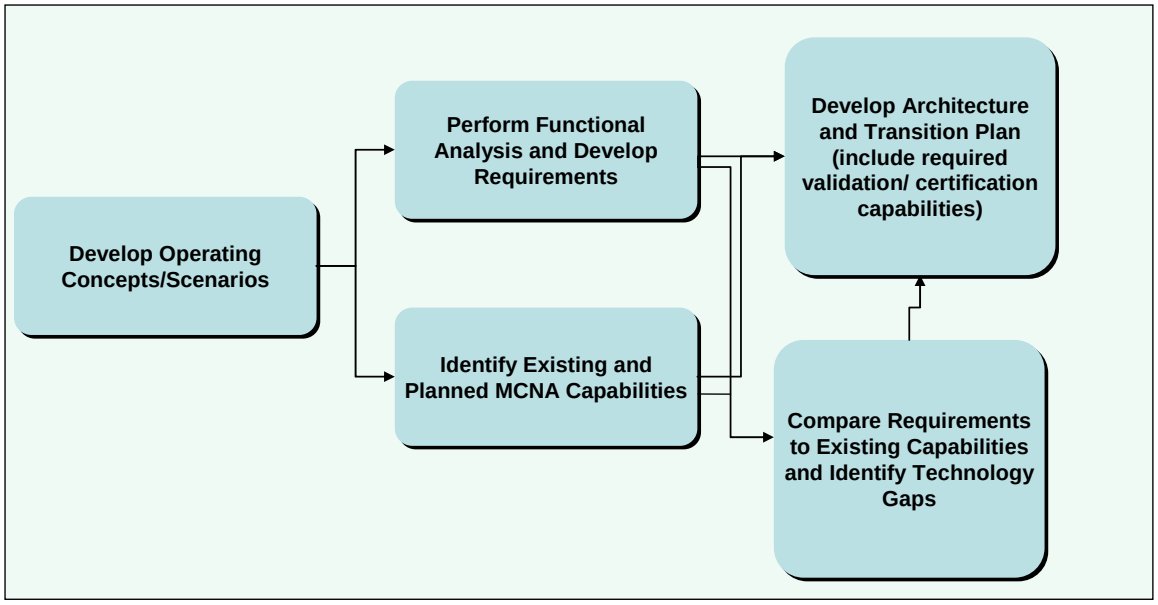

Figure 1-2: Initial MCNA Development Approach

After identifying operating scenarios and concept of operations, the MCNA development process includes the definition of requirements and subsequent evaluation of requirements against existing and planned MCNA capabilities. This is to identify gaps and/or inconsistencies that must be addressed either through the enhancement of current systems and capabilities or the development of new MCNA systems. The primary focus of the initial development effort, performed under the Global CNS System Phase II (GCNSS II) contract[3], is the definition and evaluation of MCNA requirements, architecture development, and an associated transition plan. These activities will be conducted from the perspective of assuring that the air-ground (A/G) and air-air (A/A) communications capabilities will be compatible with and supportive of the needs of SWIM as necessary to enable NEO.

[3] The MCNA Task under the GCNSS II contract is co-funded by NASA Glenn Research Center (GRC) and the FAA. The primary contractor for this contract is the Boeing Corporation (Air Traffic Management Division).

1.2 Purpose and Scope

As part of the MCNA development process, early identification of needed modeling and simulation capability for validation of MCNA technologies and concepts is being performed. Modeling and simulation, as well as definition and planning of capability demonstrations, can be resource and schedule intensive. Early identification of MCNA modeling and simulation, emulation and demonstration needs and comparison to existing capabilities enables proper planning for conducting validation activities. This report identifies simulation, emulation, and demonstration (SED) needs of the MCNA, reports on a survey of existing SED capabilities, compares the needs to existing capabilities and defines a plan that includes:

- Required development and/or enhancement of existing or to-be-developed models/tools for validating MCNA performance and operational scenarios
- Concepts for demonstration of capabilities enabled by MCNA
- Coordination of multiple simulation/emulation/demonstration activities supporting MCNA validation

1.3 Document Organization

Section 1 states the purpose and scope of this specification, and its relationship to other MCNA activities. This section also identifies applicable reference documents cited in this specification

Section 2 identifies needed simulation, emulation and demonstration capabilities to be used to validate MCNA concepts, technologies and architectures

Section 3 provides a result of a survey of SED models, tools and capabilities applicable to digital voice and data communication capabilities supporting communications, navigation and surveillance (CNS) services for future ATM operations. These tools and capabilities are candidates for supporting MCNA validation activities.

Section 4 documents the association of SED capabilities with the identified MCNA SED needs.

Section 5 defines a plan for use of, development and/or enhancement of simulation and emulation capabilities supporting the validation of MCNA concepts, technologies and architectures. This section also defines validation demonstration concepts.

Several appendices are included to provide additional detailed support material, including the Request for Information (RFI) submitted as part of the survey of SED capability and excerpts from the RFI responses.

1.4 Applicable Documents

[1] Concept of Operations for the National Airspace System in 2005, FAA Traffic Services, 9/30/1997

[2] Concept of Operations for the National Airspace System in 2005, Addendum 1: Operational Tasks & Scenarios, FAA Office of Commercial Space Transportation, 9/15/1998.

[3] Requirements and Desirable Features of a Future VHF Air Ground Communications System, Federal Aviation Administration.

[4] Initial Communications Operating Concept and Requirements for the Future Radio System, EUROCONTORL/FAA Future Communications Study Operational Concepts and Requirement Team, 18 January 2005.

[5] "Communication System Architecture Development for Air Traffic Management & Aviation Weather Dissemination, Subtask 4.6 (Develop AATT 2015 Architecture)," submitted to NASA Glen Research Center under Contract NAS2-98002, May 2000, http://www.asc.nasa.gov/aatt/rto/RTOFinal24_5.pdf.

[6] Operational Concepts of Mobile Aviation Communication Infrastructure Supporting ATM beyond 2015 (MACANDO), EUROCONTROL, 2002

2 Identification of MCNA SED Needs

For this task, simulation, emulation, and demonstration are defined as follows:

- **Simulation:** A model of system functionality
- **Emulation:** A model of system functionality, where parts of the model functionality are carried out by a real or near-real system. It can accommodate system-in-the-loop and human-in-the-loop testing.
- **Demonstration:** A model and/or implementation of system functionality that can exhibit and/or validate a stated function, performance characteristic or user need.

These capabilities can be used to support various activities during the development of a system. One view of the applicability of simulation, emulation and demonstration activities in the development process is shown in Figure 2-1. Here, the system development process as defined in the FAA Systems Engineering Manual (SEM) is used as a reference. Various places where SED activities support the development process are identified on the figure by the arrows.

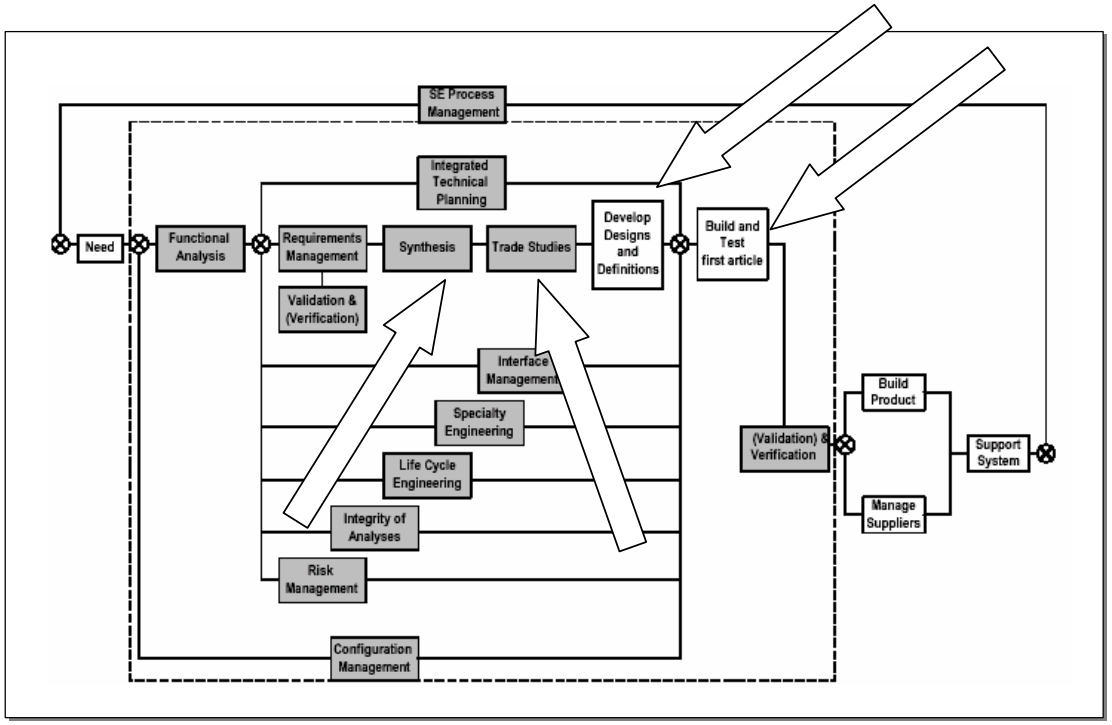

Figure 2-1: Opportunities for Simulation, Emulation, and Demonstration to Support Systems Development Activities

The following sections address the identification of needed simulation, emulation, and demonstration activities specific to MCNA development and validation. First, insight into the general role of SED supporting the systems development process is defined. Next, an overview of the MCNA development process and key outputs are provided. Finally, the SED needs specific to the MCNA are identified.

2.1 Roles of SED in Systems Development

Based on the definitions of simulation, emulation and demonstration provided above, the general roles of these activities to support system design, development, and validation can be identified. In each of these roles, the relative strengths and weaknesses of the SED activities can be identified. A summary of the roles of SED supporting design, development and validation and associated strengths/weaknesses is provided in Table 2-1.

Table 2-1: Roles of SED to Support Design, Development, and Validation

	Roles in Development Support	Strengths	Weaknesses
Simulation	**Design**: alternative function/component mapping evaluation; technology evaluation; trade-studies; concept refinement **Development**: technology evaluation, trade-studies; **Validation**: functional/performance requirement validation	Rapid virtual prototyping; rapid refinement of design or concept (accommodating requirement changes or technology advancements); examination of alternative technologies, strategies, cost, risks/mitigation factors	Outputs are only as good as model fidelity; validation of modeled behavior, interfaces and interactions, can be difficult

Emulation	**Design**: explore interfacing alternatives; real-time model of alternative design performance **Development**: Interface/interaction validation; human-in-the-loop testing; technology gap assessment **Validation**: Feasibility verification; design function/performance verification	Can accommodate actual interfaces (system-in-the-loop) or human-in-the-loop interactions; Provides a more real-time, real-function capability;	Development of specific capabilities is generally more time consuming and complex; Refinement of capability is not as dynamic as with simulation; typically requires more time/cost for emulation as compared to simulation
Demonstration	**Design**: Share simulation/emulation analysis results **Development**: design feasibility; progress sharing; cost/risk assessment **Validation**: early design validation; functional/performance requirement validation; function/component mapping validation	Supports sharing of results and capabilities with stakeholders/developers; provides validation of functionality and performance;	May involve considerable time/cost for development; limited to a specific implementation or small sets of implementations that are static

The information summarized above indicates the significant role simulation can provide during design and development activities, and an important but perhaps less significant role during validation. On the other end of the spectrum, demonstration activities are less efficient and effective during design, but contribute a greater role during later development and validation activities. Emulation activities fall somewhere in the middle, with the most significance during system development activities.

2.2 MCNA Development Process and Key Outputs

To tailor needed SED capabilities to the MCNA development process, an understanding of the MCNA concept and architecture is useful. This section provides an introduction to the development process and key outputs.

Figure 1-2 provides a high-level view of the various activities that are contributing to the MCNA development process. This includes identification of MCNA operating concepts and scenarios; performing a functional analysis of MCNA to identify required functionality; developing avionic and ground architecture concepts; and exploring different transition strategies.

The vision for the MCNA is a communication capability encompassing mobile digital voice and data supporting communication, navigation[4] and surveillance services for future air traffic management operations. It provides the role of extending the NAS SWIM concept to mobile elements of the NAS and enabling NEO.

To provide this functionality, a set of MCNA functions has been defined. These functions are grouped into two functional categories, namely *Provide Data Transport* and *Manage Data Transport*. The sub-functions associated with *Provide Data Transport* address various naming and addressing, mobility/connection management, transport and QoS aspects of MCNA. The sub-functions associated with *Manage Data Transport* address standard network management (associated with Faults, Configuration, Accounting, Performance and Security (FCAPS)) functionality. A high-level view of the MCNA functional hierarchy is provided in Figure 2-2.

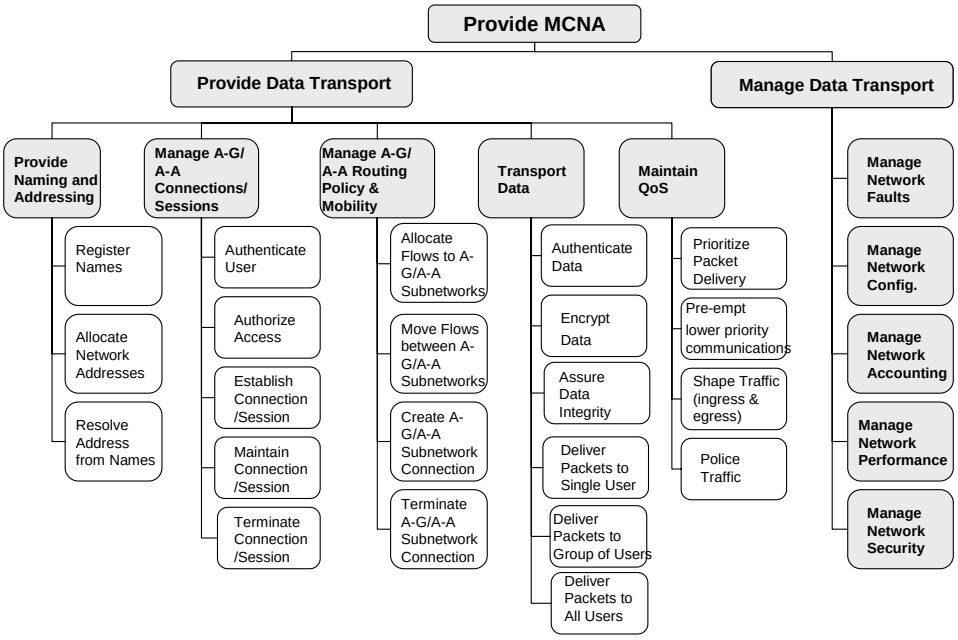

Figure 2-2: MCNA Functional Hierarchy

[4] It is not entirely clear whether or not MCNA includes Navigation services. This needs to be resolved.

Ongoing architecture development work for MCNA is identifying components to accommodate the defined MCNA functionality. In general, three physical architecture component categories are considered. These include:

- Ground Network
- Radio Frequency Links
- Avionics Network

Specific elements within each of these component categories are being defined. As details are refined, the definition of SED requirements will be updated so that the identification of needed SED capability aligns with specific aspects of the MCNA architecture. An important concept for the MCNA is that it can be described as a complex system-of-systems with seamless interoperability. Thus, the *individual systems* category identified below is one aspect of the systems-of-systems concept. Other aspects of the MCNA systems-of-systems concept include *system interfaces and interactions* and *systems-of-systems capabilities*. A summary of the three aspects of the MCNA system-of-systems concept with specific examples of elements associated with each aspect is provided below in Table 2-2.

Table 2-2: MCNA System-of-Systems Elements

	Sample Elements
Individual Systems	Ground Network; RF Links; Avionic Network
System Interfaces/Interactions	A/G to G/G protocol interaction; ATM application to MCNA interface/gateway;
System-of-Systems Capabilities	Multiple communication systems combined to provide enhanced voice and data communication services (potentially with improved availability and continuity over existing services). These may include: *Voice Communication Services* (Party-line Voice, Selected Addressed Voice, Broadcast Voice*); Data Communication Services* (Data Messaging, Trajectory Exchange, Broadcast to Aircraft, Broadcast from Aircraft, Ground-to-Air Data, Air-to-Ground Data, Air-to-Air Data, Video Exchange, Command and Control)

2.3 SED Needs for MCNA Development

The process for identifying SED Needs for MCNA is depicted in Figure 2-3.

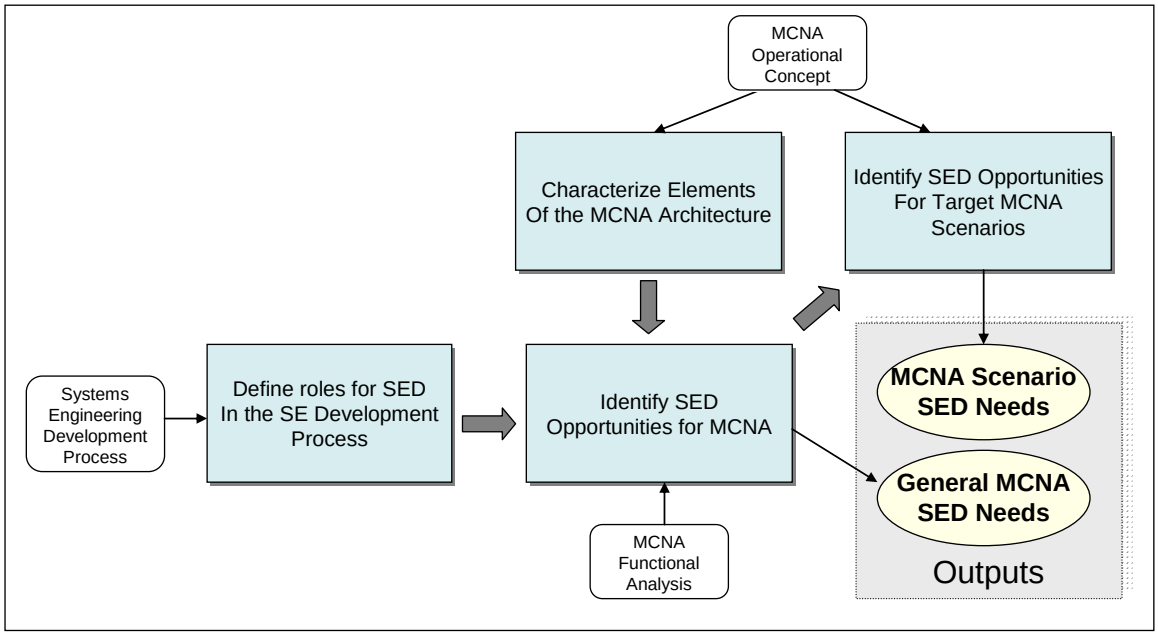

Figure 2-3: Process for Identifying SED Needs

The figure above illustrates that two classifications of MCNA Needs were sought, namely identification of general SED Needs and SED Needs specific to target MCNA operating scenarios (as described later in Table 2-4).

First, to identify general MCNA SED needs, the roles of SED in the system development process (as described in Table 2-1) were considered in the context of the MCNA system-of-systems elements defined in Table 2-2. This information is documented in Table 2-3.

Table 2-3: SED Applicability to MCNA System-of-System Elements

System-of-System Elements	Simulation Applicability			Emulation Applicability			Demonstration Applicability		
	Design	**Development**	**Validation**	**Design**	**Development**	**Validation**	**Design**	**Development**	**Validation**
Individual Systems	Alternative design evaluation; technology gap analysis	Alternative build evaluation; technology tradeoff evaluation;	Requirements compliance; Needs compliance	Proof of technology/ concept	Interface development; interaction evaluation	Requirements compliance; Performance confidence; HMI evaluation	Concept exploration/ evaluation/ education; Cost/benefit analysis;	Design/development confidence; cost evaluation; risk evaluation;	Performance validation; Requirements validation;
System Interface/ Interaction	Interface alternative evaluation	Interaction/interface feasibility/ performance evaluation	Interoperability validation	Interface option exploration; Interoperability evaluation	Interface evaluation; Interoperability evaluation	Interoperability validation	Interface/ interaction concept exploration/ evaluation/ education; Cost/benefit analysis;	Design/development confidence; integration evaluation; cost/risk evaluation;	Integration confidence; investment analysis support; interoperability validation
System-of-Systems Operations	Evaluation of alternative Function/system mapping	Functional allocation evaluation; Performance evaluation for alternative implementation strategies	Needs compliance; requirements compliance	Human-in-the-loop evaluation of alternative function/system mapping and architectures	System-in-the-loop testing;	System-in-the-loop validation; requirements compliance validation	Architecture technology proof-of-concept	Functional/performance verification	Needs compliance; requirements compliance; system/human-in-the-loop testing; interoperability validation

Next, the SED activities captured in the table above were tailored to more specific MCNA system components, interfaces, and operations. The captured needs have been considered in two ways. First, SED needs associated with specific MCNA system components, interfaces and operations across all MCNA operating scenarios (as defined within the MCNA operational concept) are presented. Next, MCNA SED needs organized by "target" MCNA scenario (as defined in Section 2.3.1) are presented. The following subsections, described below, address the definition of MCNA SED needs:

- Section 2.3.1: Introduction to Target MCNA Scenarios
- Section 2.3.2: Organization of MCNA Component Elements
- Section 2.3.3: Identification of MCNA SED Needs

2.3.1 Introduction to Target MCNA Scenarios

As part of the effort to define an operating concept for MCNA and specify high-level MCNA requirements, a range of operating scenarios to be accommodated by the MCNA was identified. Several of these scenarios were then identified as target applications based on a benefit-to-risk ranking. An introduction to these eight scenarios is provided in the table below.

Table 2-4: Target MCNA Scenarios

Scenario Number	Scenario Name	Description
Scenario #1	Deploy FIS-B Nationally	*"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."*
Scenario #2	Autonomous Hazard Weather Alert Notification	*"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. Communications 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, and Turbulence."*

Scenario Number	Scenario Name	Description
Scenario #3	Datalink to Reduce Routine Workload	*"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".*
Scenario #4	Enhanced Emergency Alerting	*"This scenario is based upon Operational Improvement (106202). With GPS navigation and position reporting via ADS, the ability of the controller to support search and rescue (SAR) operations can be greatly enhanced. This scenario relies upon ADS-B broadcasts of aircraft position to provide more precise information to controllers about aircraft position."*
Scenario #5	Optimize Runway Assignments	*"This scenario is based upon Operational Improvement (104114). This scenario is composed of three specific runway assignment enhancements as defined below: Expedite Departure Path, Approach Spacing, and Parallel Approaches. This scenario depends on ADS-B, datalink trajectory exchange and the uplink of SWIM AIM information to aircraft."*
Scenario #6	Controller Awareness of ACAS Resolutions	*"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."*
Scenario #7	Aircraft Push of Security Video and Aircraft Performance during Emergency	*"This scenario 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 the cockpit voice recorder (CVR) and flight data recorder (FDR, also known as the little black box) was defined as "white box"."*
Scenario #8	Push of Security Advisories to Aircraft	*"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."*

2.3.2 Organization of MCNA Component Elements

To organize identified SED needs, categories of component elements that apply to the MCNA system-of-system concept have been defined. These include:

- System Components
    - *RF Link Components*: A/G Communication Links, A/A Communication Links
    - *Ground Network Components*: Includes naming and addressing systems, session/flow management elements
    - *Avionic Network Components*
- System Interfaces/Interactions
    - *Protocol interactions* (A/G to G/G; alternate G/G to G/G; A/A to A/G); Application interfaces (avionic applications to avionic MCNA components, ATM applications to ground session/flow management elements, etc)
    - *Ground element interactions* (ground session/flow management elements to ground transport network and A/G link portals)
    - *SWIM/MCNA interaction*
- System-of-System Operations
    - *Voice Services* (e.g. party-line/selected address voice connectivity for ATM; broadcast voice services)
    - *Data Services* (e.g. messaging data services; trajectory exchange data services; A/A data services; command and control data services; etc.)

General MCNA SED needs as well as SED needs specific to the MCNA target scenarios have been captured within this categorization (see Section 2.3.3).

2.3.3 Identification of MCNA SED Needs

To identify MCNA SED Needs, the general functionality associated with the MCNA concept as defined in the MCNA functional analysis was reviewed. Additionally, this functionality was considered in the context of implementing the target MCNA scenarios

(as described in Table 2-4). A listing of a wide variety of MCNA SED needs is provided in Table 2-5. Key MCNA SED needs extracted from this table include:

- Need simulation models for existing and future (e.g. FCS) A/G communication links
- Need simulation models for existing ATM ground networks (e.g. ACARS, ATN)
- Need algorithms and simulation models for architectures that accommodate dynamic routing across multiple communication links
- Need simulation tools that can accommodate modeling of mobility protocols (e.g. mobile IP)
- Need capability to emulate ATC operations associated with target MCNA scenarios
- Need capability to simulate and emulate avionics architectures to accommodate target MCNA scenarios
- Need capability to demonstrate use of mobility protocols and dynamic routing
- Need capability to demonstrate target MCNA scenarios

Table 2-5: Identification of MCNA Simulation, Emulation, and Demonstration Needs

System-of-System Elements	Specific Items within each Element Category		Simulation	Emulation	Demonstration
Individual Systems	RF Link Components (A/G Comm and A/A Comm)	A/G Communications	Evaluate/compare FCS technology alternatives; Evaluate physical layer performance in a high speed mobility multipath environment; Antenna/link budget evaluation; spectrum analysis; evaluation of capacity; Evaluate use of existing or future (e.g. FCS) links to support traffic associated with target MCNA scenarios. Determine traffic load associated with MCNA scenarios (e.g. FIS-B uplink, aircraft security video downlink) and suitability of candidate A/G links to accommodate this new traffic	Develop testbed for leading FCS technology alternatives to evaluate performance;	Prototype FCS technology(ies) and validate performance to accommodate defined service classes (e.g. RCP classes);
		A/A Communications	Evaluate physical layer performance in a high speed mobility multipath environment; Antenna/ link budget evaluation; spectrum analysis; Evaluate suitability of candidate FCS technologies to	Evaluate performance of FCS technologies to accommodate A/A links	Prototype FCS technology(ies) and validate performance to accommodate A/A links

System-of-System Elements	Specific Items within each Element Category		Simulation	Emulation	Demonstration
			support A/A communications		
	Ground Network Components (G/G Comm)	General	Evaluate performance of emerging network technologies and standards (e.g. mobile IP); Evaluate loading implications on existing and planned ATM networks resulting from the implementation of MCNA scenarios (e.g. aircraft security video) Support evaluation of ground network architecture concepts required to support MCNA scenarios (e.g. routing of ADS-B data to SAR applications)	Validate performance of existing ground networks (e.g. ACARS, ATN to accommodate new traffic associated with MCNA target scenarios); Evaluate interaction existing ground networks (e.g. ATN, ACARS) and SWIM service components	Demonstrate/validate existing ground networks (e.g. ATN, ACARS) can accommodate traffic associated with MCNA scenarios. Evaluate performance and suitability of ATN, ACARS and new network architectures to accommodate MCNA target scenarios
		Registry/Directory Systems	Support evaluation of registry/directory information associated with management of a mobile user network; Model interface MCNA-specific registry/directory components with SWIM registry/directory components	Analyze MCNA user interface with SWIM via emulation through SWIM testbed	Demonstrate interface of SWIM with MCNA users
		Session/Flow Management Elements/Systems	Evaluate use of pub/sub or other messaging techniques to accommodate MCNA target scenarios	Validate mobility management/dynamic routing algorithm performance through development of testbed	Demonstrate ability to provide mobility management and dynamic routing to existing and FCS

System-of-System Elements	Specific Items within each Element Category		Simulation	Emulation	Demonstration
			Evaluate pub/sub stream reconstruction standards, alternatives and performance for a mobile user environment and implications on ACARS/ATN; Evaluate QoS for mobility management strategies	products to implement emerging or to be defined mobility protocols; Validate performance of mobility management strategies	communication links; Validate performance of products (COTS or development items) providing session/flow management functionality in the context of MCNA scenarios;
	Avionic System Components		Evaluate avionic architecture alternatives supporting interface to the MCNA (components, topology, protocol); Evaluate interaction of various MCNA avionic components (e.g. A/A and A/G link, avionic ATM applications, etc)	Evaluate proposed MCNA architectures/protocols with actual avionic systems/applications (CMU, FMC, VHF comm., SatCom, HF comm.)	Demonstrate/validate functionality and performance of proposed avionic MCNA architectures
System Interface/ Interaction	Protocol Interactions	A/G transport to G/G transport	Evaluate FCS/ATM protocol performance (CLNP, CPDLC, MIPv6, NeMo, SCTP,); Evaluate candidate A/G and G/G interfaces (e.g. TIS-B interface to SWIM or MCNA network); Evaluate utilization/optimization strategies for interoperable A/G and G/G protocols	Evaluate interaction of proposed FCS with actual ATM network systems;	Validate interface of existing A/G links with MCNA architecture components; Validate interaction of FCS with existing ATM G/G network and/or MCNA architecture components
		Alternative G/G	Evaluate gateway/interface architecture alternative	Evaluate protocol interface utilizing	Demonstrate/validate protocol

System-of-System Elements	Specific Items within each Element Category		Simulation	Emulation	Demonstration
		protocols	performance (e.g. interaction of CLNP, IP, MIPv6)	system-in-the loop testing (actual network implementations of specific protocols)	conversion/interface architectures
		A/A transport to A/G transport	Evaluate interaction of proposed A/A protocols (e.g TCAS) with existing and planned (i.e. FCS) A/G protocols as needed; Evaluate impact of A/A services on existing A/G frequencies and support A/A service specification development; Support requirements development of A/A communications; Evaluate multipath performance of proposed A/A links; Measure interference potential and mitigation strategies for propose A/A links	--	Validate A/A service technology and requirements;
	Application Interface	Avionic applications to avionic MCNA components	Analyze interface functionality alternatives for existing/planned avionic applications with MCNA components (e.g. existing/planned A/G links, SWIM interface elements)	--	Demonstrate/validate avionics architectures to accommodate SWIM/MCNA scenario data;
		ATM applications to ground session/flow	Analyze interface design alternatives for existing/plan	Verify interaction of existing ground	Demonstrate/validate interface/performance

System-of-System Elements	Specific Items within each Element Category		Simulation	Emulation	Demonstration
		management functions	NAS systems and proposed MCNA ground architecture components; Support development of architectures and requirements for interfacing existing ground networks (e.g. ACARS, ATN) to new MCNA ground network components	networks (e.g. ACARS, ATN) with new ground network components associated with MCNA (e.g. mobility management elements and/or dynamic routing algorithms)	of existing ground networks (ACARS, ATN) or new ground networks with new ground networks components associated with MCNA (e.g. mobility management elements)
		ATM applications to ground transport (G/G network) functions	Support development of architectures for interfacing ATM applications to MCNA ground networks (e.g. ATN, ACARS) specific to the MCNA scenarios (e.g. DLP to MCNA, SAR applications to MCNA, AIM databases to MCNA, aircraft video monitors to MCNA, security advisory applications to MCNA)	--	Demonstrate/validate interface of ATM applications to MCNA networks
	Ground element interactions	Ground session/flow management functions with Ground transport network(s)	Evaluate architecture alternatives for integrating MCNA session/flow management elements (e.g. mobility management elements) with ground transport elements (e.g. ACARS, ATN)	Expand evaluation of session/flow management interface with ground network(s) by incorporating system-in-the-loop testing (to include management and/or transport systems)	Demonstrate/validate interface of ground session/flow management functions with ground transport networks(e.g. ATN, FTI)

System-of-System Elements	Specific Items within each Element Category		Simulation	Emulation	Demonstration
		G/G transport/management functions with A/G links	Support development of FCS ground architecture concepts and interfaces to ATN/ACARS	--	Demonstrate/validate interface of FCS ground transport network elements ATN, ACARS, etc
	SWIM/MCNA interaction	Management interactions	Evaluate performance of alternative SWIM/MCNA management interfaces (including registry interfaces, subscription/query request sharing, etc)	Add MCNA interfaces to SWIM testbed	Demonstrate/validate management interface strategies between SWIM and MCNA
		Flow interactions	Evaluate performance of data flows that space both SWIM and MCNA; gather performance statistics and support requirements/architecture development	--	Demonstrate/validate flow of data from SWIM (or SWIM testbed) to mobile network implementation (testbed?)
System-of-Systems Operations	General		Evaluate communication link combinations that can meet RCP definitions and support specific MCNA scenarios		
	Voice Service	Party Line Voice	Analyze performance of FCS links to accommodate transfer of ATC clearances; weather forecasts; NOTAMs; hazardous weather alerts; aeronautical charts; TFR,; and SUA status in different NAS domains ;	Analyze and validate ability of new A/G links to meet voice service requirements; Test A/A links to support voice services;	Demonstrate/validate use of new A/G and/or A/A RF links to provide party line voice services for ATC; Validate interoperability of new

System-of-System Elements	Specific Items within each Element Category		Simulation	Emulation	Demonstration
			Evaluate A/A link support for party line voice service	Evaluate combination s of A/A and A/G links to provide party line voice services; Support evaluation of interoperability studies of new RF links with existing voice services. Evaluate efficiency changes associated with use of datalink for routine services	A/G links with existing links; Validate operations where pilots are delegated responsibility for separation; Validate sufficient communication capability to support oceanic separation reduction to 30/30
		Selected Addressed Voice	Evaluate performance of alternate A/G links to accommodate selective addressing; Evaluate alternative distribution architecture options for dissemination of selected addressed voice (e.g. routing passenger telephony to PSTN); Support development of performance requirements for SA services such as DHS voice/video network	Evaluate routing architecture options using real systems; test interface of new voice routing architectures with existing ATM applications that require/provider talker-ID information	Demonstrate/validate MCNA to support selected address voice applications and interface with ATM applications that utilize this service.
		Broadcast Voice	Evaluate performance of emerging services such as hazardous weather distribution	Evaluate use of MCNA A/G links to support TWIP, ATIS and	Validate/demonstrate support of TWIP, ATIS and other broadcast

System-of-System Elements	Specific Items within each Element Category		Simulation	Emulation	Demonstration
			utilizing MCNA A/G links	emerging services (validate interface support and performance);	voice applications (e.g. hazardous weather distribution) over MCNA A/G links
	Data Service	Messaging	Evaluate architecture concepts for integrating ATN, ACARS and new IP network architectures to provide an integrated and interoperable messaging service (e.g. evaluate number, location, performance of routers, gateways, MCNA SWIM shared services components, etc); evaluate architectures for MCNA to support/interface to hazardous weather messaging systems; evaluate performance of FCS providing MCNA data message links to support routine ATC service messages and to support provision of high definition surface target information to pilots	Test suitability of ATM applications (e.g. ATOP, URET) to interface to the MCNA; evaluate protocol interactions between MCNA/SWIM shared service components that provide mobility/security/multi-homing management and ATN/ACARS and IP data networks via actual interface with these networks; Validate performance of MCNA gateways and gateway interactions with SWIM shared services;	Demonstrate and validate the use of MCNA G/G and A/G links to provide ATN messaging; demonstrate provision/management of mobility/multi-homing capability in the MCNA supporting data messaging to mobile users
		Trajectory Exchange	Evaluate architecture concepts for end-to-end trajectory exchange between NAS ATM applications and aircraft applications, supporting System-to-System Coordination (SYSCO);	Test interface of MCNA A/G and G/G network protocols with ATM and aircraft networks; validate performance of trajectory exchange	Demonstrate use of MCNA G/G and A/G networks to support trajectory exchange messages; Demonstrate SYSCO operating concepts including

System-of-System Elements	Specific Items within each Element Category		Simulation	Emulation	Demonstration
			support development of SYSCO operation performance requirements	concepts using real end-system interfaces	automate negotiation of flight profiles; automated provision of instructions/wave vortex warnings for runway approach procedures; and negotiated entry into oceanic tracks.
		Broadcast to/from Aircraft	Evaluate performance of broadcast services over MCNA links; evaluate alternative ground architectures supporting provision of broadcast weather and NAS status information (where/how application end-systems interact with MCNA); verify protocol interactions (end-to-end) to meet service requirements;	Evaluate use of MCNA A/G links to support TIS-B, FIS-B and TWIP (validate interface support and performance)	Validate/demonstrate support of TIS-B and FIS-B applications over MCNA A/G links; Validate emerging broadcast services can be supported over MCNA
		G/A and A/G	Support development of performance requirements for emerging G/A and A/G exchanges including atmospheric parameters fro aircraft; pilot instruction for approach; transfer of ACS messages; cockpit audio/video streaming and other new services	Validate end-to-end performance and interoperability of G/A and A/G data services (e.g. exchange of atmospheric parameters) using existing and proposed data links	Demonstrate use of A/G links to provide emerging services such as oceanic ADS; atmospheric parameters from aircraft; pilot instructions for approach; transfer of ACAS messages; cockpit audio/video

System-of-System Elements	Specific Items within each Element Category		Simulation	Emulation	Demonstration
					streaming; etc
		A/A	Evaluate use of A/A links to support evolving A/A service scenarios such as delegated responsibility to pilots for separation assurance; support develop of A/A service requirements	Validate performance of A/A links to support applications such as messages supporting separation assurance by pilots	Demonstrate use of A/A links to provide emerging services (such as pilot separation assurance
		Command and Control	Support development of C2 services and performance requirement; Evaluate use of MCNA A/G and G/G links to support C2	Evaluate routing of modeled C2 data over actual MCNA links	Demonstrate performance of C2 links; Possible demonstration of MCNA A/G and G/G links to support C2 messages
	SWIM and MCNA		Evaluate interface of MCNA mobility management, session/connection management and security elements (specific to MCNA) with corresponding SWIM functions; support development of ground architectures to support mobility management; multi-homing and mobile exchange security; support development of MNCA/SWIM performance requirements specific to MCNA; support evaluation of technologies to	Test real technology implementation of mobility management, session/connection management and multi-homing to support MCNA applications; validate interface of MCNA gateways to SWIM	Validate/demonstrate technologies and implementation to provide MCNA mobility management and multi-homing; validate ability to meet MCNA requirements on interface of MCNA to SWIM

System-of-System Elements	Specific Items within each Element Category		Simulation	Emulation	Demonstration
			provide mobility management, multi-homing; security functions as required by MCNA		

The table above includes a range of the general needs of the overall MCNA concept. It was considered informative to also document key SED needs specific to each target scenario. Table 2-6 provides this perspective of MCNA SED needs.

Table 2-6: SED Needs for MCNA Target Scenarios

Scenario Number	Scenario Name	SED Needs
Scenario #1	Deploy FIS-B Nationally	➢ Evaluate loading effects of FIS-B traffic over existing and future (e.g. FCS) communication links (simulation) ➢ Emulation/demonstration of CDTI/moving map applications integrating into future avionic network architectures (emulation/demonstration) ➢ Evaluate the use of multiple A/G communication links (with associated mobility management) to accommodate FIS-B service (simulation) ➢ Validate functionality/performance needs associated with a MCNA interface to SWIM weather services to support FIS-B (emulation/demonstration)
Scenario #2	Autonomous Hazard Weather Alert Notification	➢ Evaluate suitability for existing and future FCS A/G communication links to support this application in a timely fashion (simulation) ➢ Determine possible reduction in controller workload associated with pro-active forwarding of hazardous weather to the cockpit (emulation) ➢ Evaluate avionics application to accommodating this scenario with existing and planned avionic network architectures (emulation/demonstration)
Scenario #3	Datalink to Reduce Routine Workload	➢ Evaluate loading effects of CPDLC traffic over existing and future (e.g. FCS) communication links (simulation) ➢ Evaluate the use of multiple A/G communication links (with associated mobility management) to accommodate CPDLC service (simulation) ➢ Validate reduction in controller workload associated expanded use of CPDLC (emulation)
Scenario #4	Enhanced Emergency Alerting	➢ Evaluate alternative ground architectures (e.g. interfaces of ADS ground stations or other systems to SAR applications) to accommodate this scenario (simulation)

Scenario Number	Scenario Name	SED Needs
		➢ Evaluate performance of SWIM service to publish ADS information associated with this scenario (simulation, emulation)
Scenario #5	Optimize Runway Assignments	➢ Evaluate loading effects of runway assignment traffic over existing and future (e.g. FCS) communication links (simulation) ➢ Evaluate the use of multiple A/G communication links (with associated mobility management) to accommodate runway assignment service (simulation) ➢ Validate reduction in controller workload associated with use of data links for runway assignment (emulation) ➢ Investigate MCNA interface options to AIM information (possible SWIM services) (simulation, emulation, demonstration) ➢ Evaluate implementation of AIM subscription services within the existing and future avionics architectures (emulation)
Scenario #6	Controller Awareness of ACAS Resolutions	➢ Evaluate performance of existing and planned A/G communications to support this service in a timely and accurate manner (simulation) ➢ Validate performance of NAS application to process ACAS resolutions interfacing with MCNA (simulation, emulation) ➢ Evaluate ability of the NAS/controllers to process ACAS resolution information and improve conflict resolution (emulation, demonstration)
Scenario #7	Aircraft Push of Security Video and Aircraft Performance during Emergency	➢ Evaluate loading effects of aircraft video traffic over existing and future (e.g. FCS) communication links (simulation) ➢ Evaluate the use of multiple A/G communication links (with associated mobility management) to accommodate aircraft service (simulation) ➢ Validate effective use of video to address security events and/or other emergencies (emulation) ➢ Evaluate loading effects of aircraft video traffic over existing and future ground communication architectures (simulation)
Scenario #8	Push of Security Advisories to Aircraft	➢ Evaluate suitability of existing and future FCS A/G communication links to provide advisories to the aircraft in a timely and accurate fashion (simulation) ➢ Determine possible operational benefits associated with the

Scenario Number	Scenario Name	SED Needs
		provision of this information to pilots (emulation) ➢ Evaluate alternative architectures (ground, A/G, avionics) for providing and processing security advisories (simulation) Evaluate avionics applications to accommodate this scenario with existing and planned avionic network architectures (emulation/demonstration)

3 Survey of SED Capability for Air Traffic Management Technologies and Applications

3.1 Survey Approach

One of the requirements of MCNA SED activity, as specified in the GCNSS Phase II Statement of Work is to: “consider the unique facilities and capabilities that exist or are planned within the U.S. at NASA Centers, FAA Facilities, federally-funded organizations and companies, and to the extend practical, internationally”. There are several ways to identify these facilities and capabilities; the general approach used for this task included: 1) an Internet search, 2) feedback to the results of the Internet search by MCNA/GCNSS Phase II team members, and 3) a NASA released Request for Information (RFI).

3.2 Survey Results

Two primary results are provided. The first is a table listing the results of the Internet survey of simulation/emulation tools and capabilities, and includes feedback comments, updates, and revisions to the results by the GNCSS-II partners. The second is a table associated with responses to the RFI.

3.2.1 General Survey of Simulation/Emulation Tools Output

Table 3-1 provides a listing of SED tools identified through an Internet search and refined based on feedback from MCNA/GCNSS II team members and NASA GRC personnel.

Table 3-1: General SED Tool Survey Results

Tool Name	Tool Owner/Developer	Category	Type	Description/Capability
Future Flight Central	NASA	Human-in-the-loop, NAS Operations Analysis	Simulation, Emulation, Demonstration	"facility consists of a full-scale control tower, which depicts a 360-degree view of the airport under various weather conditions and times of day. Actual air traffic controllers operation the tower and communicate with pilots, ramp controllers and vehicle operators"; "Recent integration of the tower with full-mission flight simulation allows assessment of airport changes from both the controller and pilot perspectives" The Tower Cab includes emulation of ASDE-3 for surface radar display, and ASR-9 for radar imagery for 10-30 miles from the mock airport; ASR-9 data can be presented on consoles or hanging monitors (which replicate BRITE displays); The tower cab includes the touch screen communication panel, with multiple frequencies, multiple pages, intercom and interphone connectivity to outlying facilities; comm system emulates VHF radio and is used to communication with pseudo-pilots and psuedo-range controllers; Research capabilities include custom traffic scenarios, and a wide array of data collection, ability to integrate external software or simulators. Simulation facility has been linked to the Crew Vehicle Systems Research Facility (CVSRF) Boeing 747-400 Flight simulation and one of the cabs at the Vertical Motion Simulator (VMS) Complex
Initial Academy Training System (IATS)	FAA	Human-in-the-loop, NAS Operations Analysis	Simulation, Emulation, Demonstration	"a high fidelity en route training system that consists of Display System consoles, HOST emulation, ghost pilot personal computers, En Route simulation and VSCS emulation"; Planned deployment is 2004/2005 timeframe
MaxSim	Adacel	Human-in-the-loop	Simulation, Emulation, Demonstration	"MaxSim Tower is the market; control tower simulation systems. Visual scene can be scaled from a single channel desktop display to 360-degree projected scene in a full-scale cabin environment…Typical tower equipment including surface movement radar, lightning panel, crash phone, tower radar and light gun can be included"; MaxSim Radar is fully scalable from a single seat approach control to a multiple seat en-route facility and is able to seamlessly integrate with MaxSim Tower...With pseudo pilot control or .. voice recognition and speech synthesis system, MaxSim's simulation aircraft behave in a consistent and realistic manner...includes configurable interfaces ranging from FAA ARTS IIIA systems to ODID HMI

Tool Name	Tool Owner/Developer	Category	Type	Description/Capability
ATC Lab	NASA Ames	Human-in-the-loop	Simulation	Generic simulation capable of operating in 3 modes: single cab (with either Advanced Concepts Flight Simulator (ACFS) or B747-400 participating), dual-cab (with both cabs participating) or stand-alone. Can also participate in simulations run from the ATC Tower part of Future Flight Central to allow for gate-to-gate flight simulation involving all facets of the NAS. "ATC Lab uses a NASA-developed target generator, which allows it to function either as a control facility or simply as a traffic generator. ..target generator provides high-fidelity, site-specific radar video mapping as well as accurate flight dynamics and piloting systems..[to] recreate flight operations"
Virtual Airspace Simulation Technology-Real-Time (VAST-RT)	NASA Ames	Airspace/Traffic Analysis	Simulation	
Airport and Airspace Simulation Model (SIMMOD)	NASA Ames	Airspace/Traffic Analysis, NAS Operations Analysis	Simulation	
Total Airspace and Airport Modeler (TAAM)	NASA Ames	Airspace/Traffic Analysis	Simulation	
Enhanced Tower Simulator (ETOS)	US Army	Human-in-the-loop	Simulation, Emulation	"Newest and most advanced Army air traffic control simulator…210 degree horizontal and 47 degree vertical field of view, the Enhanced Tower Simulator…gives ATC students a realistic representation of what it is like to be in an ATC tower
ATCsimulator	Aerosoft Corporation	Human-in-the-loop	Emulation	Commercial product that allows a user to assume the role of an Approach or Departure controller at a choice of 120 TRACON facilities..standalone tool.
FIRSTplus	Raytheon	Human-in-the-loop	Simulation, Emulation, Demonstration	Visual tower simulation… image-generation and projection display capability to meet customer training objectives; "tower simulator is based on a network of FIRSTplus simulators connected to the tower visual display system…each ..node interfaces with an information display subsystem to provide weather reports, direction finder, and other airfield related data...

Tool Name	Tool Owner/Developer	Category	Type	Description/Capability
Virtual Airspace Modeling and Simulation (VAMS)	NASA	Human-in-the-loop, NAS Operations Analysis	Simulation, Emulation, Demonstration	R&D effort to explore advanced operational air traffic management (ATM) concepts and associated technology roadmaps that will result in a significant enhancement in airspace system capacity, while maintaining safety and affordability"; Consists of 3 elements: System Level Integration Concepts (SLIC); Virtual Airspace Simulation Technologies (VAST) and System Evaluation and Assessment (SEA); "VAST .. is developing both a non-real-time modeling environment for system-wide assessments (Airspace Concept Evaluation System simulation environment) and a real-time modeling environment (software models and human interfaces) for specific human-in-the-loop assessments" "SEA element is responsible for the identification, development and oversight of the common scenarios sets, methods and metrics used within VAMS"
ACES	NASA	Human-in-the-loop, NAS Operations Analysis	Simulation, Emulation, Demonstration	Non-real time implementation of VAMS
Free-Flight Simulation (FFSIM)	Seagull Technology/Raytheon Team	NAS Operations Analysis	Simulation, Emulation, Demonstration	High fidelity distributed hardware and software simulation system enabling investigation and evaluation of critical air traffic system technologies and operations; examples of infrastructure components include CTAS, CTAS-Host interface, CPDLC, ADS-B, FIS-B, SSR, Mode S, VDL-2/3/4 A/G data links, WAAS and LAAS.
FastWin	NASA		Simulation	
TMX (Target-Aircraft Generator)	National Aerospace Laboratory (NLR) The Netherlands	Operations Analysis	Simulation	
AIRSIM	National Aerospace Laboratory (NLR) The Netherlands	Operations Analysis	Simulation, Demonstration	Distributed simulation (designed to investigate free flight)
NARSIM	National Aerospace Laboratory (NLR) The Netherlands	Operations Analysis		

Tool Name	Tool Owner/Developer	Category	Type	Description/Capability
ESCAPE (European Simulation Capability and Platform for Experimentation)	Eurocontrol	Operations Analysis	Simulation	Distributed ATC Simulation (using OASIS (an Open Architecture for Simulation Systems) and FREER); OASIS is a soft real-time framework aimed at simulation activities; offers object-oriented distribution based on CORBA implementations (Orbix & ORBexpress)
ATSP	Lockheed Martin			
VDL-3 OPNET Model	MITRE	Airspace/Traffic Analysis	Simulation, Demonstration	OPNET model that implements the VDL3 protocol
VDL-2 OPNET Model	MITRE	Airspace/Traffic Analysis	Simulation, Demonstration	OPNET model that implements the VDL2 protocol (Brian Hung)
MPDS OPNET Model	Boeing ATM	Airspace/Traffic Analysis	Simulation, Demonstration	OPNET model that implements the Inmarsat IAI-1 packet data protocol
IAI-2 OPNET Model	Inmarsat	Airspace/Traffic Analysis	Simulation, Demonstration	OPNET model that implements the Inmarsat IAI-2 packet data protocol (need to verify with Inmarsat the maturity of this model
DAMA OPNET Model	Boeing ATM	Airspace/Traffic Analysis	Simulation, Demonstration	OPNET model that implements a suite of DAMA based SatCom air interface protocols (could be used as a basis for modification)
OPNET Traffic Model	ITT	Airspace/Traffic Analysis	Simulation, Demonstration	OPNET ATC traffic models ???
National Flow Model (NFM)	Boeing ATM	Operations Analysis	Simulation, Demonstration	Simulates Traffic Flow at the national levels to evaluate Flow Management techniques
Regional Traffic Model (RTM)	Boeing ATM	Operations Analysis	Simulation, Demonstration	Simulates Traffic Flow at the regional level to evaluate Traffic Management techniques
SWIM Testbed	Boeing ATM	Airspace/Traffic Analysis	Simulation, Emulation and Demonstration	Aggregate of networking and information management technologies to test and evaluate network and application performance of SWIM concepts. This testbed could readily be extended to account for A-G and/or A-A links.

Tool Name	Tool Owner/Developer	Category	Type	Description/Capability
Global Assessor	MITRE	Airspace/Traffic Analysis	Simulation	I recall this tool being used for several VHF capacity analyses, I would expect this tool (with modifications) may be necessary to evaluate the actual capacity for various combinations of waveforms in the VHF band and help with defining a reasonable transition plan in the VHF band. In particular a modification of this tool would probably be required to evaluate B-VHF.
Satellite Capacity Density Analysis Tool	Boeing ATM	Airspace/Traffic Analysis	Simulation	This is a loosely couple suite of tools developed to generate aircraft distribution for future growth scenarios and map these aircraft distributions over time to configurable satellite beam sizes.
Air Traffic Control (ATC) simulator	MITRE CAASD		Simulation, Demonstration	
ATCC Pro	Xavius ATC Systems	Human-in-the-loop	Simulation, Emulation, Demonstration	Several products offered including Air Traffic Control Center (ATCC) a "realistic simulation of the actual radar sectors at both approach and area control centers" Features include: simulates… using the same radar displays used in the U.S…includes DSR, STARS, ARTS...print strips or display in electronic bays on the same or separate monitors; simulation of U.S. VSCS touch-screen interphone system -- communicate with adjacent computer controllers with point-outs, handoffs and appreqs.; easy to use keyboard interface for issuing radio commands or use speech recognition; use the included sectors or create your own."; Another product is ATCC Pro, a "training lab and simulation platform" where "scenarios can be run randomly with "traffic flow" parameters and "problem concentration areas" for point-and-click scenario generation"; Another product is ATCC Analyst which "combines ...core professional simulation with advanced monte-carlo simulation techniques to analyze existing or proposed procedures, sectorization and facility ops."
OPNET		Architecture/ Technology Performance Analysis	Simulation, Demonstration	Environment for network modeling and simulation … supports design and study of communication networks, devices, protocols and applications….utilizes object-oriented modeling approach and graphical editor; can analyze impact of failures, performance for different network configurations; availability and response times seen by end-users; etc
QUALNET		Architecture/ Technology Performance Analysis	Simulation, Demonstration	

Tool Name	Tool Owner/Developer	Category	Type	Description/Capability
Si3		Architecture/ Technology Performanc e Analysis		
Psuedo Aircraft Systems	Logicon		Simulation	Target generator (used in the Free Flight Simulation (FFSIM))

3.2.2 RFI Response Outputs

In January 2005, on behalf of the project team, NASA Glenn Research Center distributed a RFI to industry requesting input on available or planned simulation, emulation, and demonstration capabilities specific to air traffic management. The complete RFI is provided in Appendix A. Ten organizations/groups responded to this RFI. They included:

- BoozAllenHamilton
- Calian – SED Systems
- NASA Glenn Research Center & Computer Networks and Software, Inc
- FASTE-CNS: Mulkerin Associates Inc and Computer Networks & Software, Inc.
- Lucent Technologies Inc.
- NASA Ames
- Ohio University
- Seagull Technology, Inc.
- Sensis Corporation

A summary of the responses is provided in Table 3-2.

Table 3-2 Summary of RFI Responses

RFI Responding Organization	Summary of Response	Applicability to MCNA
Booz Allen Hamilton	• Description of general SED capabilities and facilities • Specific listing of particular modeling and simulation tools for their Center for Network Analytics and Solutions (CNAS) • Modeling and Simulation Experience Matrix • Emulation Experience Matrix • Demonstration Experience matrix • Discussion of past performance and use of relevant SED tools/capabilities	Extensive capabilities across most areas identified in the RFI
Calian – SED Systems	• Overview description of experience in systems engineering development and design of mainly satellite systems • Descriptions of: o Satellite Network Spectrum Planning Experience and related tool(s) o Satellite Resource Management Systems Experience and related tool(s) o Satellite Network Gateways provided by SED Systems o Satellite Monitor and Control System Experience o Carrier/Spectrum Monitoring and In-Orbit Test System Experience o RF and Antenna Systems Experience o Mission Control Systems	Though most of the response does not fit the RFI, SED Systems Frequency Planning System (FPS) tool might have some MCNA applicability be of some use

RFI Responding Organization	Summary of Response	Applicability to MCNA
NASA Glenn Research Center & Computer Networks and Software, Inc	Advanced CNS Architectures and System Technologies (ACAST) Project report (130 pages): "Survey of Communications, Navigation, and Surveillance (CNS) Models, Tools and Testbeds Report," including detailed descriptions of the capabilities of the following facilities: • FAA William J. Hughes Technical Center (WJHTC) • Department of Defense Technical Labs • Embry-Riddle Aeronautical University • Joint University Program (Massachusetts Institute of Technology – Lincoln Laboratory, Ohio University, and Princeton University) • Mike Monroney Center (MMAC) • MIT Lincoln Laboratory • MITRE Center for Advanced Aviation Systems Development (CAASD) • NASA Ames Research Center • NASA Glenn Research Center • NASA Langley Research Center • Northwestern University • The John A. Volpe National Transportation Systems Center (Volpe Center)	Extensive applicability to MCNA; needs further detailed review

RFI Responding Organization	Summary of Response	Applicability to MCNA
Mulkerin Associates Inc. And Computer Networks & Software, Inc.	Description of the Future Aeronautical Subnetwork Traffic Emulator for Communications, Navigation, and Surveillance (FASTE-CNS), a "Virtual Airspace Modeling and Simulation (VAMS) research tool that provides the capability to dynamically model the characteristics and performance of current and future aeronautical data communications traffic". Has the ability to: • Estimate communications requirements for a given geographical area. • Validate communications concepts. • Determine communications loading plus the frequency and load requirements needed to evaluate the feasibility of proposed scenarios and operational concepts. • Evaluate o The communications aspects of operational concepts. o The impact of current and future plans on the National Airspace System. o The impact of traffic loading on frequency requirements. o The impact of altitude on frequency requirements RFI response also includes detailed description of the tools/capabilities	Useful tool(s) for MCNA; needs further review
Lucent Technologies Inc.	• Description of Lucent Sandia program support providing assistance on analysis of telecommunications infrastructures and analysis of the interdependencies between telecommunications infrastructures and other infrastructures • Description of OCELOT® Network Optimization Tool • Description of N-SMART (Network Simulation Modeling and Analysis Research Tools) • Description of UNISIM (Unified Simulation) Model	Though model descriptions cover traditional ground based telecom/network applications, response indicates that "Models can be used beyond traditional telecom." Further analysis of models is necessary to validate this assertion

RFI Responding Organization	Summary of Response	Applicability to MCNA
NASA Ames	• Two page summary: "Testbeds and Simulations for Mobile Communications in the National Air Space" • Describes the NAS Division's NASA Research and Engineering Network (NREN) Project. States that NREN provides several facilities and capabilities to enable the demonstration of emergent technologies relevant to the MCNA. These include a high-speed, nationwide backbone network, wireless and satellite connectivity, and experience with protocol deployment, including Mobile IP and IP multicast, end-to-end data encryption, and IPv6 • Briefly describes Project Columbia, through which the NAS Division supports large scale, scientific and engineering modeling and simulation requirements of the entire Agency	Likely to be highly applicable to MCNA, though not enough specific information is provided to verify this.

RFI Responding Organization	Summary of Response	Applicability to MCNA
Ohio University	• Description of physical and data link layers models, including: o Modeling physical layer waveform transmission across a channel, and reception at the receiver. o Modeling to enable evaluation of: ▪ Data link protocol performance ▪ Physical layer performance over multiple channel models, which include dispersion (multipath), interference, filter bandlimiting, antenna effects, etc. ▪ Communication system capacity ▪ Spectral occupancy and efficiency ▪ Link budget parameters (transmit powers, antenna gains and beamwidths, etc.) o Modeling of various current aeronautical and other waveforms, e.g., VDL; UAT; B-VHF; IEEE 802.11; 2G, 2.5G, and 3G cellular; military aeronautical waveforms, etc. • For network analysis and simulation: o Analysis of protocol behavior at OSI layers 2 through 7 based on data collected in either operational networks or network emulation testbeds. o Creation, Operation, and Instrumentation of network emulation testbeds. o Software simulations of new protocols or protocol combinations. • Description of the Avionics Engineering Center	Useful capabilities for MCNA; needs further information and review

RFI Responding Organization	Summary of Response	Applicability to MCNA
Seagull Technology, Inc. (recently acquired by Sensis Corp.)	• Seagull provides software tools to support NASA's Virtual Airspace Modeling and Simulation (VAMS) Project Airspace Concepts Evaluation System (ACES), which is useful for "evaluation of strategies to leverage MCNA voice and data information services to support Network Enabled Operations (NEO) and the NAS System Wide Information Management (SWIM)." Tools include: o Future NAS Flight Demand Generation Tool: *AvDemand* o NAS Performance Analysis Tool: *AvAnalyst* • Describes software development support to NASA Langley Research Center for the Airspace & Traffic Operations Simulation (ATOS), a real-time simulation that models a generic future flight deck architecture that contains air/air and air/ground data links • Describes other relevant Simulation, Modeling and System Development Experience	Useful capabilities for MCNA; needs further review
Sensis Corp.	• Describes its ATM products • Describes its potential tools for aeronautical MCNA: Mode S and UAT data link transceivers and test and evaluation tools for those links; the Ground Interface Tester (GIT) and Air Interface Test Transceiver (AITT); and Mode S generator • Also describes its network and data protocol devices and ASDE-X Siting Tool	Potentially useful test tools/equipment for MCNA demonstrations/emulation

4 Associating SED Capabilities to MCNA SED Needs

4.1 Organization of SED Capabilities and Needs

The survey of SED capabilities resulted in numerous tools and facilities, as described in Section 3. Upon review of the survey results, many of the 150+ SED capabilities were identified as either duplicate capabilities, non-pertinent capabilities, or capabilities that were too generalized (e.g., 'OPNET' by itself is not a relevant capability, but 'VDLM3 OPNET Model' is a capability immediately applicable to MCNA). Such capabilities were eliminated from further consideration in a first pass of the results. This culling process reduced the total number of SED capabilities to a manageable subset of SED capabilities relevant to MCNA.

The SED capabilities were then organized into major categories, where applicable, to simplify the process of mapping SED capabilities to MCNA needs. Two such categories are 'RF SED & Planning Tools' and 'Tower Simulation/Target Generation/ATC Tools'. Tools in these categories only apply to a specific subset of MCNA needs. Some of the tools are part of a larger toolset in which the tools function best together so it made sense to group these tools together. The table below displays the culled list of tools and tool categories.

Table 4-1: SED Tools & Tool Categories

Tools Category (if applicable)	Tool
	A fleet of specially instrumented aircraft
	Air/Ground Communications Segment of CISL
	Airborne Internet
	AIRSIM
	ATOS (Airspace & Traffic Operations Simulation)
	Avionics Engineering Center (AEC) Aircraft
	Boeing GCNSS Future Concept Demonstrations
	Broadcast Services Lab
	Communications and Information Security Laboratory (CISL)
	Controller Pilot Data Link Communication Build 1 (CPDLC/1)
	Infrastructure Damage Assessment/Connectivity Analysis Model (IDA/CAM)
	NREN (NASA Research and Engineering Network)
	N-Smart (Network-Simulation and Modeling and Analysis Research Tools) / UNISIM
	OCELOT Network Optimization Tool
	Reduced Complexity Partitioned Multi-user Detection

Tools Category (if applicable)	Tool
	Research and Development Human Factors Laboratory
	Small Aircraft Tranportation System (SATS)/System Integration
	SWIM Testbed
	Total Airspace and Airport Modeler (TAAM)
	Traffic Analysis by Method of Iteration (TAMI)/Network Performance Model (NetPM)
	Virtual Aircraft and Control (VAC) System and Testbed
RF SED & Planning Tools	1030/1090 MHz Simulations
	Adaptive Multi-carrier DS-SS for Fading Channels
	Aeronautical Communications Model - OU
	Air Interface Test Transceiver
	Airspace Analysis Model (AAM) - OU
	ASDE-X Siting Tool
	Automated Frequency Manager (AFM)
	Benefeild Anechoic Facility (BAF)
	CADRE C-band model
	CADRE L-band model
	Cell Tool
	Direct Sequence Spread Spectrum
	EDX Signal Pro
	Frequency Planning System (FPS)
	Global Assessor
	Ground Interface Tester (GIT)
	HTZ-Warfare ATDI Tool
	Integrated Defensive Avionics Laboratory (IDAL) Facility
	Joint Communications Simulator (JCS)
	Mode S Generator
	Multi-carrier Waveform Evaluation
	RACOMS
	RF Propagation and Performance Model
	RFI Measuring System (RFIMS)
	Satellite Capacity Density Analysis Tool
	SatView
	Spectrum Prospector
	Statistical Parallel Interference Canceling (STPIC)
	System Interface Unit
	UAT Spectral tool
	Wireless Coverage Tool (WCT)
OPNET Models	OPNET - Cleveland State University (CSU) Models
	OPNET - DAMA Model
	OPNET - IAI-2 Model
	OPNET - MPDS Model
	OPNET - VDL-2 Model
	OPNET - VDL-3 Model

Tools Category (if applicable)	Tool
Tower Simulation/ Target Generation/ ATC	AERALIB (C++ object library)
	AWSIM
	ATC Lab
	ATCsimulator
	Cockpit Simulation Facilities
	FIRSTplus
	Flight Deck Simulation Facility
	Free-Flight Simulation (FFSIM)
	Future Flight Central
	MaxSim
	NARSIM
	NASPAC
	SATORI
	SDAT
	Surface Simulation
	Target Generator Facilities
	Terminal Area Simulation Facility ARTS Simulation
	TMX (Target-Aircraft Generator)
Virtual Airspace Modeling and Simulation (VAMS)	ACES (Airspace Concepts Evaluation System)
	AvAnalyst (Output tool for ACES)
	AvDemand (Input tool for ACES)
	FASTE-CNS
	SIMMOD (Airport and Airspace Delay Simulation Model)
	VAST-RT (Virtual Airspace Simulation Technology-Real-Time)

4.2 Associating SED Capabilities to MCNA SED Needs

In order to map SED capabilities to MCNA Needs, several Tools-to-Needs Mapping Matrices were created. First, a general (i.e. applicable to all MCNA scenarios) MCNA matching matrix was created. In this matrix, the tools are listed by row and the general MCNA Need categories (as defined in Table 2-5 of Section 2.3) distributed into columns. The Needs categories are organized by three major aspects of the MCNA system-of-system concept. These include individual systems themselves (e.g. specific RF communication links), system interfaces (e.g. A/A communication link interface with A/G communication link), and voice/data capabilities or services (e.g. data trajectory exchange).

If a particular tool was capable of simulating, emulating, or demonstrating a need, an S, E, or D (respectively) was entered in the matrix at the intersection of the row (tool) and column (need). The Tools-Needs Mapping Matrix spans many pages altogether. To

simplify analysis and for display purposes, the matrix was divided into the three smaller matrices, each pertaining to one of the major areas according to the MCNA system-of-systems concept defined in Section 2: Individual Systems, System Interfaces/Interactions, and System-of-Systems Operations. Table 4-2 shows the mapping of the SED tools to MCNA Needs for Individual Systems.

Table 4-2: Mapping of SED Tools to MCNA Needs for Individual Systems

Tools		Individual Systems						
Tool Category (if applicable)	Tool Name	RF Link Components				Ground Network Components		Avionics System Components
		A/G & A/A Communications				Protocols/ Topology	Session/Flow Managemen	
		Type 1 (FCS-VHF)	Type 2 (FCS-Sat)	Type 3 (FCS-Cell)	Type 4 (Existing)			
	A fleet of specially instrumented aircraft							
	Air/Ground Communications Segment of CISL	S, E						
	Airborne Internet	D				D	D	D
	AIRSIM	S, E	S, E		S, E	S, E	S, E	S, E
	ATOS (Airspace & Traffic Operations Simulation)				S	S	S	
	Avionics Engineering Center (AEC) Aircraft							
	Boeing GCNSS Future Concept Demonstrations		S, E, D		S, E, D			
	Broadcast Services Lab				S, E, D			
	Communications and Information Security Laboratory (CISL)	S, E				S, E	S, E	S, E
	Controller Pilot Data Link Communication Build 1 (CPDLC/1)							
	Infrastructure Damage Assessment/Connectivity Analysis Model (IDA/CAM)							
	NREN (NASA Research and Engineering Network)	S	S	S	S	S	S	S
	N-Smart (Network-Simulation and Modeling and Analysis Research Tools) / UNISIM			S, E, D				
	OCELOT Network Optimization Tool			S, E, D		S	S	
	Reduced Complexity Partitioned Multi-user Detection			S				
	Research and Development Human Factors Laboratory							
	Small Aircraft Tranportation System (SATS)/System Integration				D			
	SWIM Testbed	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D
	Total Airspace and Airport Modeler (TAAM)							
	Traffic Analysis by Method of Iteration (TAMI)/Network Performance Model (NetPM)					S	S	
	Virtual Aircraft and Control (VAC) System and Testbed				S, E			
RF SED & Planning Tools	1030/1090 MHz Simulations	S	S	S	S			
	Adaptive Multi-carrier DS-SS for Fading Channels			S				
	Aeronautical Communications Model - OU	S		S				
	Air Interface Test Transceiver				E, D			
	Airspace Analysis Model (AAM) - OU	S	S	S	S			
	ASDE-X Siting Tool				S			
	Automated Frequency Manager (AFM)	S	S	S	S			
	Benefeild Anechoic Facility (BAF)	S	S	S	S			
	CADRE C-band model		S	S	S			
	CADRE L-band model		S	S	S			
	Cell Tool			S				
	Direct Sequence Spread Spectrum			S				
	EDX Signal Pro	S	S	S	S			
	Frequency Planning System (FPS)		S					
	Global Assessor	S			S			
	Ground Interface Tester (GIT)				E, D			
	HTZ-Warfare ATDI Tool	S						
	Integrated Defensive Avionics Laboratory (IDAL) Facility	E, D	E, D	E, D	E, D			
	Joint Communications Simulator (JCS)	S	S	S	S			
	Mode S Generator				E, D			
	Multi-carrier Waveform Evaluation			S				
	RACOMS	S, E	S, E	S, E	S, E		S, E	
	RF Propagation and Performance Model	S	S	S	S			
	RFI Measuring System (RFIMS)	S	S	S	S			
	Satellite Capacity Density Analysis Tool		S					
	SatView	S	S	S	S			
	Spectrum Prospector	S	S	S	S			
	Statistical Parallel Interference Canceling (STPIC)			S				
	System Interface Unit				E, D			
	UAT Spectral tool				S			
	Wireless Coverage Tool (WCT)	S	S	S	S			
OPNET Models	OPNET - Cleveland State University (CSU) Models	S				S	S	S
	OPNET - DAMA Model		S			S	S	S
	OPNET - IAI-2 Model		S			S	S	S
	OPNET - MPDS Model		S			S	S	S
	OPNET - VDL-2 Model				S	S	S	S
	OPNET - VDL-3 Model	S				S	S	S
Tower Simulation/ Target Generation/ ATC	AERALIB (C++ object library)							
	AWSIM							
	ATC Lab							
	ATCsimulator							
	Cockpit Simulation Facilities							
	FIRSTplus							
	Flight Deck Simulation Facility							
	Free-Flight Simulation (FFSIM)							
	Future Flight Central							
	MaxSim							
	NARSIM							
	NASPAC							
	SATORI							
	SDAT							
	Surface Simulation							
	Target Generator Facilities							
	Terminal Area Simulation Facility ARTS Simulation							
	TMX (Target-Aircraft Generator)							
Virtual Airspace Modeling and Simulation (VAMS)	ACES (Airspace Concepts Evaluation System)	S	S	S				
	AvAnalyst (Output tool for ACES)							
	AvDemand (Input tool for ACES)							
	FASTE-CNS				S			
	SIMMOD (Airport and Airspace Delay Simulation Model)							
	VAST-RT (Virtual Airspace Simulation Technology-Real-Time)							

Table 4-3 shows the mapping of the SED tools to MCNA Needs for System Interfaces/Interactions.

Table 4-3: Mapping of SED Tools to MCNA Needs for System Interfaces/Interactions

Tools		System Interface/Interaction									
		Protocol Interactions			Application Interface			Ground Element Interactions		SWIM/MCNA interaction	
Tool Category (if applicable)	Tool Name	A/G transport to G/G transport	Alternative G/G protocols	A/A transport to A/G transport	Avionic applications to avionic MCNA components	ATM applications to ground session/ flow management functions	ATM applications to ground transport (G/G network) functions	Ground session/flow management functions with Ground transport network(s)	G/G transport/ management functions with A/G links	Management interactions	Flow interactions
	A fleet of specially instrumented aircraft										
	Air/Ground Communications Segment of CISL	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D
	Airborne Internet	D	D	D	D	D	D	D	D	D	D
	AIRSIM	S, E	S, E	S, E	S, E	S, E	S, E	S, E	S, E	S, E	S, E
	ATOS (Airspace & Traffic Operations Simulation)	S	S	S	S	S	S	S	S	S	S
	Avionics Engineering Center (AEC) Aircraft										
	Boeing GCNSS Future Concept Demonstrations	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D		
	Broadcast Services Lab										
	Communications and Information Security Laboratory (CISL)	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D
	Controller Pilot Data Link Communication Build 1 (CPDLC/1)										
	Infrastructure Damage Assessment/Connectivity Analysis Model (IDA/CAM)							S	S		
	NREN (NASA Research and Engineering Network)	S	S	S	S	S	S	S	S	S	S
	N-Smart (Network-Simulation and Modeling and Analysis Research Tools) / UNISIM										
	OCELOT Network Optimization Tool							S	S		
	Reduced Complexity Partitioned Multi-user Detection										
	Research and Development Human Factors Laboratory										
	Small Aircraft Tranportation System (SATS)/System Integration										
	SWIM Testbed	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D
	Total Airspace and Airport Modeler (TAAM)										
	Traffic Analysis by Method of Iteration (TAMI)/Network Performance Model (NetPM)							S	S	S	S
	Virtual Aircraft and Control (VAC) System and Testbed										
RF SED & Planning Tools	1030/1090 MHz Simulations										
	Adaptive Multi-carrier DS-SS for Fading Channels										
	Aeronautical Communications Model - OU										
	Air Interface Test Transceiver										
	Airspace Analysis Model (AAM) - OU										
	ASDE-X Siting Tool										
	Automated Frequency Manager (AFM)										
	Benefeild Anechoic Facility (BAF)										
	CADRE C-band model										
	CADRE L-band model										
	Cell Tool										
	Direct Sequence Spread Spectrum										
	EDX Signal Pro										
	Frequency Planning System (FPS)										
	Global Assessor										
	Ground Interface Tester (GIT)										
	HTZ-Warfare ATDI Tool										
	Integrated Defensive Avionics Laboratory (IDAL) Facility										
	Joint Communications Simulator (JCS)										
	Mode S Generator										
	Multi-carrier Waveform Evaluation										
	RACOMS										
	RF Propagation and Performance Model										
	RFI Measuring System (RFIMS)										
	Satellite Capacity Density Analysis Tool										
	SatView										
	Spectrum Prospector										
	Statistical Parallel Interference Canceling (STPIC)										
	System Interface Unit										
	UAT Spectral tool										
	Wireless Coverage Tool (WCT)										
OPNET Models	OPNET - Cleveland State University (CSU) Models	S	S	S	S	S	S	S	S	S	S
	OPNET - DAMA Model	S	S	S	S	S	S	S	S	S	S
	OPNET - IAI-2 Model	S	S	S	S	S	S	S	S	S	S
	OPNET - MPDS Model	S	S	S	S	S	S	S	S	S	S
	OPNET - VDL-2 Model	S	S	S	S	S	S	S	S	S	S
	OPNET - VDL-3 Model	S	S	S	S	S	S	S	S	S	S
Tower Simulation/ Target Generation/ ATC	AERALIB (C++ object library)										
	AWSIM										
	ATC Lab										
	ATCsimulator										
	Cockpit Simulation Facilities										
	FIRSTplus										
	Flight Deck Simulation Facility										
	Free-Flight Simulation (FFSIM)										
	Future Flight Central										
	MaxSim										
	NARSIM										
	NASPAC										
	SATORI										
	SDAT										
	Surface Simulation										
	Target Generator Facilities										
	Terminal Area Simulation Facility ARTS Simulation										
	TMX (Target-Aircraft Generator)										
Virtual Airspace Modeling and Simulation (VAMS)	ACES (Airspace Concepts Evaluation System)										
	AvAnalyst (Output tool for ACES)										
	AvDemand (Input tool for ACES)										
	FASTE-CNS										
	SIMMOD (Airport and Airspace Delay Simulation Model)										
	VAST-RT (Virtual Airspace Simulation Technology-Real-Time)										

Table 4-4 shows the mapping of the SED tools to MCNA Needs for System-of-Systems Operations.

Table 4-4: Mapping of SED Tools to MCNA Needs for System-of-Systems Operations

Tools		System-of-Systems Operations									
		Voice Service			Data Service						SWIM and MCNA
Tool Category (if applicable)	Tool Name	Party Line Voice	Select Addressed Voice	Broadcast Voice	Messaging	Trajectory Exchange	Broadcast to/from Aircraft	G/A and A/G	A/A	Command and Control	
	A fleet of specially instrumented aircraft	D	D	D	D	D	D	D	D	D	D
	Air/Ground Communications Segment of CISL										SED
	Airborne Internet							D			D
	AIRSIM				S, E	S, E	S, E	S, E	S, E	S, E	S, E
	ATOS (Airspace & Traffic Operations Simulation)	S, E	S, E	S, E	S, E	S, E	S, E	S, E	S, E	S, E	
	Avionics Engineering Center (AEC) Aircraft	D	D	D	D	D	D	D	D	D	D
	Boeing GCNSS Future Concept Demonstrations										
	Broadcast Services Lab										
	Communications and Information Security Laboratory (CISL)										S
	Controller Pilot Data Link Communication Build 1 (CPDLC/1)				S, E, D						
	Infrastructure Damage Assessment/Connectivity Analysis Model (IDA/CAM)										S
	NREN (NASA Research and Engineering Network)										S
	N-Smart (Network-Simulation and Modeling and Analysis Research Tools) / UNISIM										
	OCELOT Network Optimization Tool										S
	Reduced Complexity Partitioned Multi-user Detection										
	Research and Development Human Factors Laboratory	E, D	E, D	E, D	E, D	E, D	E, D	E, D	E, D	E, D	
	Small Aircraft Tranportation System (SATS)/System Integration										
	SWIM Testbed										S, E, D
	Total Airspace and Airport Modeler (TAAM)	S	S	S	S	S	S	S	S	S	
	Traffic Analysis by Method of Iteration (TAMI)/Network Performance Model (NetPM)										S
	Virtual Aircraft and Control (VAC) System and Testbed	S, E	S, E	S, E	S, E	S, E	S, E	S, E	S, E	S, E	
RF SED & Planning Tools	1030/1090 MHz Simulations										
	Adaptive Multi-carrier DS-SS for Fading Channels										
	Aeronautical Communications Model - OU										
	Air Interface Test Transceiver										
	Airspace Analysis Model (AAM) - OU										
	ASDE-X Siting Tool										
	Automated Frequency Manager (AFM)										
	Benefeild Anechoic Facility (BAF)										
	CADRE C-band model										
	CADRE L-band model										
	Cell Tool										
	Direct Sequence Spread Spectrum										
	EDX Signal Pro										
	Frequency Planning System (FPS)										
	Global Assessor										
	Ground Interface Tester (GIT)										
	HTZ-Warfare ATDI Tool										
	Integrated Defensive Avionics Laboratory (IDAL) Facility										
	Joint Communications Simulator (JCS)										
	Mode S Generator										
	Multi-carrier Waveform Evaluation										
	RACOMS										
	RF Propagation and Performance Model										
	RFI Measuring System (RFIMS)										
	Satellite Capacity Density Analysis Tool										
	SatView										
	Spectrum Prospector										
	Statistical Parallel Interference Canceling (STPIC)										
	System Interface Unit										
	UAT Spectral tool										
	Wireless Coverage Tool (WCT)										
OPNET Models	OPNET - Cleveland State University (CSU) Models										S
	OPNET - DAMA Model										S
	OPNET - IAI-2 Model										S
	OPNET - MPDS Model										S
	OPNET - VDL-2 Model										S
	OPNET - VDL-3 Model										S
Tower Simulation/ Target Generation/ ATC	AERALIB (C++ object library)	S	S	S	S	S	S	S	S	S	
	AWSIM	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	
	ATC Lab	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	
	ATCsimulator	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	
	Cockpit Simulation Facilities	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	
	FIRSTplus	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	
	Flight Deck Simulation Facility	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	
	Free-Flight Simulation (FFSIM)	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	
	Future Flight Central	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	
	MaxSim	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	
	NARSIM	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	
	NASPAC	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	
	SATORI	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	
	SDAT	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	
	Surface Simulation	S	S	S	S	S	S	S	S	S	
	Target Generator Facilities	S	S	S	S	S	S	S	S	S	
	Terminal Area Simulation Facility ARTS Simulation	S, E, D						S, E, D			
	TMX (Target-Aircraft Generator)	S	S	S	S	S	S	S	S	S	
Virtual Airspace Modeling and Simulation (VAMS)	ACES (Airspace Concepts Evaluation System)	S	S	S	S	S	S	S	S	S	S
	AvAnalyst (Output tool for ACES)										
	AvDemand (Input tool for ACES)										
	FASTE-CNS	S	S	S	S	S	S	S	S	S	
	SIMMOD (Airport and Airspace Delay Simulation Model)										
	VAST-RT (Virtual Airspace Simulation Technology-Real-Time)	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	S, E, D	

To further focus the mapping of tools to MCNA SED needs, a mapping of tools that may contribute to the satisfaction of the key general SED needs (defined in a bulleted list in Section 2.3.3 above) was generated. This mapping is provided in Table 4-5. Note that a question mark was used to indicate possible accommodation of a need by the indicated tool; more detailed investigation of the tool capabilities is required in these cases.

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Table 4-5: Candidate Tools for Addressing Key MCNA SED Needs

Tools		Key MCNA SED Needs							
Tool Category (if applicable)	Tool Name	Simulation Models for existing and future (e.g. FCS) A/G communication links	Simulation models for existing ATM ground newtorks (e.g. ACARS, ATN)	Algorithms and simulation models for architectures that accommodate dynamic routing across multiple communication links	Simulation Tools that can accommodate modeling of mobility protocols	Capability to emulate ATC operations associated with target MCNA scenarios	Capability to simulate and emulate avionics architectures	Capability to demonstrate use of mobility protocols and dynamic routing	Capability to demonstrate target MCNA scenarios
	A fleet of specially instrumented aircraft								
	Air/Ground Communications Segment of CISL								
	Airborne Internet								
	AIRSIM								
	ATOS (Airspace & Traffic Operations Simulation)								
	Avionics Engineering Center (AEC) Aircraft								
	Boeing GCNSS Future Concept Demonstrations								
	Broadcast Services Lab								
	Communications and Information Security Laboratory (CISL)								
	Controller Pilot Data Link Communication Build 1 (CPDLC/1)								
	Infrastructure Damage Assessment/Connectivity Analysis Model (IDA/CAM)								
	NREN (NASA Research and Engineering Network)			?	?				
	N-Smart (Network-Simulation and Modeling and Analysis Research Tools) / UNISIM			?	?				
	OCELOT Network Optimization Tool			?	?				
	Reduced Complexity Partitioned Multi-user Detection								
	Research and Development Human Factors Laboratory								
	Small Aircraft Tranportation System (SATS)/System Integration								
	SWIM Testbed								
	En Route Simulation								
	Total Airspace and Airport Modeler (TAAM)								
	Traffic Analysis by Method of Iteration (TAMI)/Network Performance Model (NetPM)			?	?				
	Virtual Aircraft and Control (VAC) System and Testbed		?				?		
RF SED & Planning Tools	1030/1090 MHz Simulations								
	Adaptive Multi-carrier DS-SS for Fading Channels								
	Aeronautical Communications Model - OU								
	Air Interface Test Transceiver								
	Airspace Analysis Model (AAM) - OU								
	ASDE-X Siting Tool								
	Automated Frequency Manager (AFM)								
	Benefeild Anechoic Facility (BAF)								
	CADRE C-band model								
	CADRE L-band model								
	Cell Tool								
	Direct Sequence Spread Spectrum								
	EDX Signal Pro								
	Frequency Planning System (FPS)								
	Global Assessor								
	Ground Interface Tester (GIT)								
	HTZ-Warfare ATDI Tool								
	Integrated Defensive Avionics Laboratory (IDAL) Facility								
	Joint Communications Simulator (JCS)								
	Mode S Generator								
	Multi-carrier Waveform Evaluation								
	RACOMS								
	RF Propagation and Performance Model								
	RFI Measuring System (RFIMS)								
	Satellite Capacity Density Analysis Tool								
	SatView								
	Spectrum Prospector								
	Statistical Parallel Interference Canceling (STPIC)								
	System Interface Unit								
	UAT Spectral tool								
	Wireless Coverage Tool (WCT)								
OPNET Models	OPNET - Cleveland State University (CSU) Models								
	OPNET - DAMA Model								
	OPNET - IAI-2 Model								
	OPNET - MPDS Model								
	OPNET - VDL-2 Model								
	OPNET - VDL-3 Model								
Tower Simulation/ Target Generation/ ATC	AERALIB (C++ object library)								
	AWSIM								
	ATC Lab								
	ATCsimulator								
	Cockpit Simulation Facilities						?		
	FIRSTplus								
	Flight Deck Simulation Facility						?		
	Free-Flight Simulation (FFSIM)								
	Future Flight Central								
	MaxSim								
	NARSIM								
	NASPAC								
	SATORI								
	SDAT								
	Surface Simulation								
	Target Generator Facilities								
	Terminal Area Simulation Facility ARTS Simulation								
	TMX (Target-Aircraft Generator)								
Virtual Airspace Modeling and Simulation (VAMS)	ACES (Airspace Concepts Evaluation System)								
	AvAnalyst (Output tool for ACES)								
	AvDemand (Input tool for ACES)								
	FASTE-CNS								
	SIMMOD (Airport and Airspace Delay Simulation Model)								
	VAST-RT (Virtual Airspace Simulation Technology-Real-Time)								

As noted in Section 2.3, specific target operating scenarios have been defined for MCNA (see Table 2-4 for a description of each scenario). These MCNA scenarios will require development support and proof of concept (i.e. validation) via SED before implementation in the NAS. To further refine the MCNA tools to needs mapping and to provide more insight and detail about the identified MCNA needs, a mapping of tools to needs specific to the eight target operational scenarios (as defined in Table 2-6) has been performed. This is provided in Table 4-6 below. Section 4.3 to follow will address shortfalls of SED capabilities to support development and validation activities for these scenarios as applicable.

Table 4-6: Tools Mapped to Specific MCNA Scenario SED Needs

Tools		First-Tier Scenarios																											
		Deploy FIS-B Nationally (1)				Autonomous Hazard Weather Alert Notification (5)			Datalink to reduce routine workload (10)			Enhanced Emergency Alerting (15)		Optimize Runway Assignments (20)					Controller awareness of ACAS resolutions (25)			Aircraft push of security video and aircraft performance during emergency (29)				Push of Security advisories to aircraft (32)			
Tool Category (if applicable)	Tool Name	Evaluate loading effects of FIS-B traffic over existing and new comm links	Evaluate integration of CDTI/moving map applications into future avionic networks	Evaluate use of multiple A/G comm links to accommodate FIS-B	Validate performance associated with MCNA interface to SWIM wx services for FIS-B service	Evaluate suitability of existing and future A/G comm links to provide timely/accurate notifications	Evaluate reduction in controller workload and increase pilot safety	Evaluate avionic applications for this application within existing and planned avionic architectures	Evaluate loading effects of CPDLC traffic over existing and new comm links	Evaluate use of multiple A/G comm links to accommodate CPDLC	Validate reduction in controller workload associated with expanded use of CPDLC	Evaluate alternative ground architectures for provision of ADS info to SAR applications	Evaluate performance of SWIM services to publish this ADS information	Evaluate loading effects of runway assignment traffic over existing and new comm links	Evaluate use of multiple A/G comm links to accommodate runway assignment information	Validate reduction in controller workload associated with use of datalink for runway assignment	Investigate MCNA interface options to AIM information (or SWIM AIM services)	Evaluate implementation of AIM subscription services within existing/future avionics architectures	Evaluate suitability of existing and future A/G comm links to provide timely/accurate transmission of ACAS resolutions	Validate performance of NAS applications to process ACAS resolutions interfacing with MCNA	Evaluate ability of the NAS/Controllers to process ACAS resolution info and improve conflict resolution	Evaluate loading effects of aircraft video traffic over existing and new comm links	Evaluate use of multiple A/G comm links to accommodate aircraft video/performance information	Validate effective use of video to address security events and/or other emergencies	Evaluate loading effects of aircraft video traffic over existing and future ground communication architectures	Evaluate suitability of existing and future A/G comm links to provide timely/accurate transmission of security advisories	Determine/validate operational benefits associated with the provision of this information to pilots	Evaluate alternative architectures (ground, A/G, avionics) for providing and processing security advisories	Evaluate avionics applications to accommodate this scenario with existing/planned avionic network architectures
	A fleet of specially instrumented aircraft				?																								
	Air/Ground Communications Segment of CISL				?																								
	Airborne Internet																												
	AIRSIM																												
	ATOS (Airspace & Traffic Operations Simulation)																												
	Avionics Engineering Center (AEC) Aircraft																												
	Boeing GCNSS Future Concept Demonstrations																												
	Broadcast Services Lab																												
	Communications and Information Security Laboratory (CISL)																												
	Controller Pilot Data Link Communication Build 1 (CPDLC/1)																												
	Infrastructure Damage Assessment/Connectivity Analysis Model (IDA/CAM)																												
	NREN (NASA Research and Engineering Network)			?						?					?								?					?	
	N-Smart (Network-Simulation and Modeling and Analysis Research Tools) / UNISIM			?						?					?								?		?			?	
	OCELOT Network Optimization Tool			?						?					?								?		?			?	
	Reduced Complexity Partitioned Multi-user Detection																												
	Research and Development Human Factors Laboratory																												
	Small Aircraft Tranportation System (SATS)/System Integration																												
	SWIM Testbed																												
	Total Airspace and Airport Modeler (TAAM)																												
	En Route Simulation																												
	Traffic Analysis by Method of Iteration (TAMI)/Network Performance Model (NetPM)			?						?					?								?						
	Virtual Aircraft and Control (VAC) System and Testbed																												
RF SED & Planning Tools	1030/1090 MHz Simulations																												
	Adaptive Multi-carrier DS-SS for Fading Channels																												
	Aeronautical Communications Model - OU																												
	Air Interface Test Transceiver																												
	Airspace Analysis Model (AAM) - OU																												
	ASDE-X Siting Tool																												
	Automated Frequency Manager (AFM)																												
	Benefeild Anechoic Facility (BAF)																												
	CADRE C-band model																												
	CADRE L-band model																												
	Cell Tool																												
	Direct Sequence Spread Spectrum																												
	EDX Signal Pro																												
	Frequency Planning System (FPS)																												
	Global Assessor																												
	Ground Interface Tester (GIT)																												
	HTZ-Warfare ATDI Tool																												
	Integrated Defensive Avionics Laboratory (IDAL) Facility																												
	Joint Communications Simulator (JCS)																												
	Mode S Generator																												
	Multi-carrier Waveform Evaluation																												
	RACOMS																												
	RF Propagation and Performance Model																												
	RFI Measuring System (RFIMS)																												
	Satellite Capacity Density Analysis Tool																												
	SatView																												
	Spectrum Prospector																												
	Statistical Parallel Interference Canceling (STPIC)																												
	System Interface Unit																												
	UAT Spectral tool																												
	Wireless Coverage Tool (WCT)																												
OPNET Models	OPNET - Cleveland State University (CSU) Models																												
	OPNET - DAMA Model																												
	OPNET - IAI-2 Model																												
	OPNET - MPDS Model																												
	OPNET - VDL-2 Model																												
	OPNET - VDL-3 Model																												
Tower Simulation/ Target Generation/ ATC	AERALIB (C++ object library)																												
	AWSIM																												
	ATC Lab																												
	ATCsimulator																												
	Cockpit Simulation Facilities																												
	FIRSTplus																												
	Flight Deck Simulation Facility																												
	Free-Flight Simulation (FFSIM)																												
	Future Flight Central																												
	MaxSim																												
	NARSIM																												
	NASPAC																												
	SATORI																												
	SDAT																												
	Surface Simulation																		?		?								
	Target Generator Facilities																												
	Terminal Area Simulation Facility ARTS Simulation																												
	TMX (Target-Aircraft Generator)																												
Virtual Airspace Modeling and Simulation (VAMS)	ACES (Airspace Concepts Evaluation System)																												
	AvAnalyst (Output tool for ACES)																												
	AvDemand (Input tool for ACES)																												
	FASTE-CNS																												
	SIMMOD (Airport and Airspace Delay Simulation Model)																												
	VAST-RT (Virtual Airspace Simulation Technology-Real-Time)																												

4.3 Identification of Key SED Shortfalls

Review of the SED tools to MCNA Need mapping documented in Section 4.2 led to two general conclusions. These include:

- The MCNA concept requires the development of a tool kit to address the various SED needs associated with individual systems as well as elements that support the system-of-systems concept

- There are tools that exist to cover the general kinds of SED needs that have been identified for MCNA; however, tools will need to be tailored and integrated to address SED needs

Although Table 4-5 and Table 4-6 above indicate that there are some candidate tools that are candidates for support general MCNA SED activities as well as SED activities specific to the target MCNA scenario, several significant SED gaps were identified[5]. These include:

1) Insufficient tools to simulate dynamic routing of MCNA data over multiple weighted communication links (e.g. implementation of mobility management, policy-based routing, etc. in an aeronautical environment) [investigate possible expansion of NREN, N-Smart, NetPM, and ACES tool capabilities]

2) Insufficient models/tools for analyzing existing ATM ground networks (e.g. ACARS, ATN) [investigate possible expansion of CISL, VAC, En Route Simulation and ACES tool capabilities]

3) Insufficient models/tools to analyze full complement of existing and future NAS RF links (only a subset of models were identified)

4) Insufficient models/tools for evaluation of SWIM interfaces to MCNA and implementation of SWIM core services within the MCNA architecture

5) Insufficient integration of simulation modes for RF and ground network with operation modeling/emulation tools [investigate integration of simulation capabilities with ACES, etc]

[5] This may have been due to the inability to uncover specific tools during the course of this task; because the specific needed tools do not exist; because identified applicable tools are not currently integrated; etc.

6) Insufficient integration of various RF simulation models/tools needed to support exploration of the MCNA system-of-systems concept

7) Insufficient model/emulation environments for avionics architectures

8) Insufficient capabilities/tailored applications within emulation environments to evaluate target MCNA scenarios

5 MCNA SED Plan

5.1 Plan Inputs

The implementation of operational improvements to the NAS requires adherence to a certification process (at least for avionics) that includes proof-of-concept demonstrations. Figure 5-1 illustrates the process defined to facilitate the development of the MCNA SED Plan, which will bring the eight target or 'first-tier' MCNA operational scenarios from a set of performance requirements to a flight test demonstration.

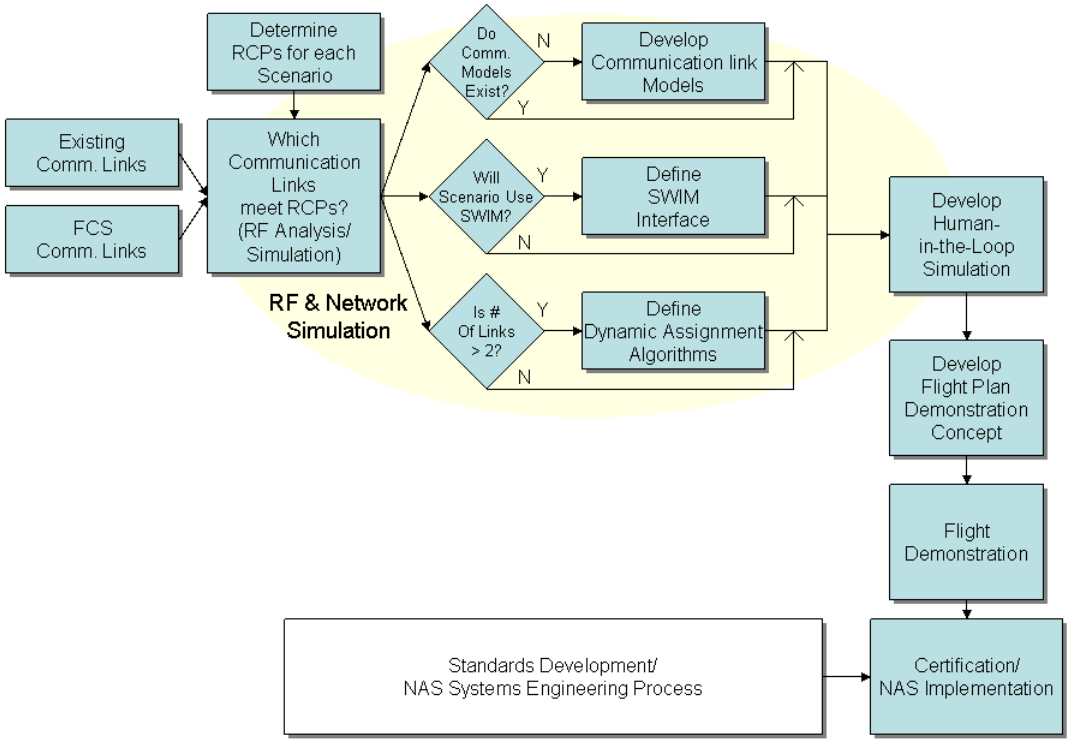

Figure 5-1: Process for Generating MCNA SED Plan by Scenario

The key inputs considered during the development of the MCNA SED Plan are the inputs to the process shown above. These are the eight target operational scenarios, the required communications performance (RCP) parameters associated with for these scenarios, as well as all existing and potential communications links for the FAA. The scenarios, RCP parameters, and existing communications links are presented in other MCNA

documentation. The potential communications links for the FAA are an output of the FCS.

5.2 MCNA Simulation, Emulation, Development Plan

The MCNA SED Plan was developed by applying the process shown in Figure 5-1 to each of the operational scenarios. The first step of the process incorporates all of the key inputs identified in Section 5.1. The MCNA Requirements Report includes a mapping of scenarios to relevant service classes for which there are defined RCP parameters. An analysis of each communications link is conducted to verify which links can meet the performance parameters associated with each scenario.

The result of this first step is a subset of communications links that either meet or exceed these performance parameters. These links will then be modeled and incorporated into a scenario-based simulation. If communications models are not available, they must be developed. If the scenario envisions the use of SWIM, an appropriate SWIM interface must be developed. If multiple links are to be considered, appropriate routing algorithms, and dynamic assignment of messages to available links must be defined. All of these issues must be resolved to produce high fidelity models and simulations. These simulations may include human-in-the-loop type test facilities such as Tower or Cockpit Simulations to emulate any controller or pilot involvement.

Simulation results will assist the development of flight-test demonstration concepts including test cases for each scenario. These proof-of-concept flight-tests will integrate many of the MCNA concepts into one exhaustive demonstration. Figure 5-2 illustrates the MCNA SED Plan.

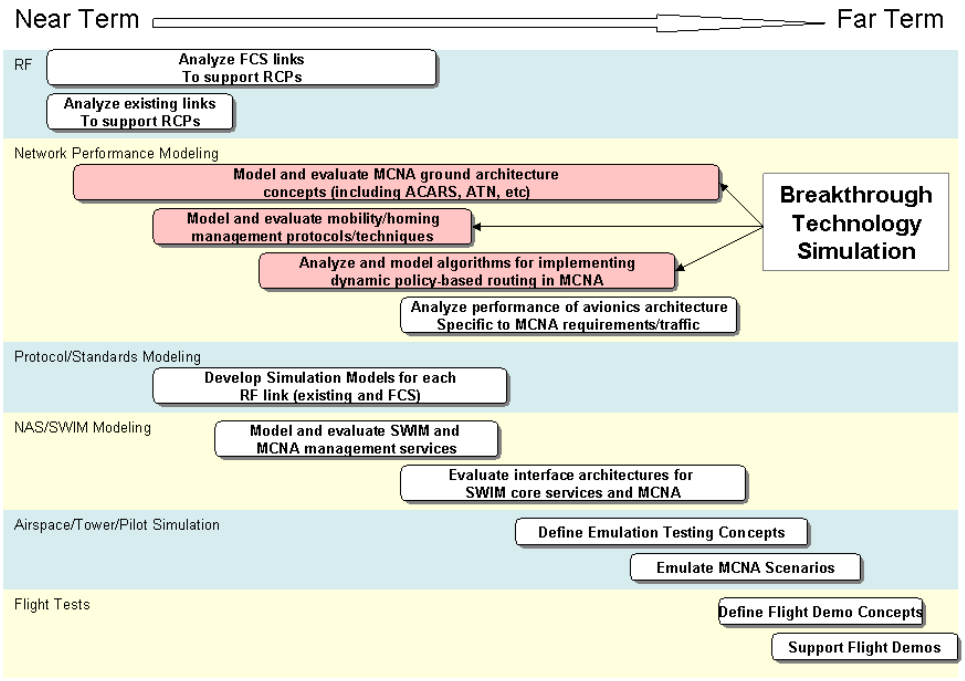

Figure 5-2: MCNA SED Plan

The MCNA SED Plan has been categorized into six areas of work, each comprised of its own tasks. Although work in these six areas will overlap, the most near-term work is located in the upper-left of Figure 5-2 and the more far-term work is located in the bottom right. These work areas and tasks are described below.

RF – This area is comprised of two tasks:

- Analyze FCS links to support RCPs – This task requires an analysis of all of the potential communications links being considered in the FCS. Performance metrics must be gathered for each communication technology to verify which links are capable of meeting the performance requirements for each scenario (i.e. – latency, availability, bandwidth, etc.). For FCS links, this may require RF simulations, as many of the FCS technologies anticipate implementation in frequency bands that they were not originally intended for.

- Analyze existing links to support RCPs – This task requires an analysis of all of the existing communications links currently in use by the FAA. Performance metrics must be gathered for each communication technology to verify which links are capable of meeting the performance requirements for each scenario (i.e.

– latency, availability, bandwidth, etc.). Many of these metrics are already known for these communication links since they are already a part of the NAS.

Network Performance Modeling – This area is comprised of four tasks:

- Model and evaluate MCNA ground architecture concepts (including ACARS, ATN, etc.) – This task includes the evaluation of alternate architectures for integrating existing and future MCNA ground network components into a "system-of-systems". This includes the implementation of components to support mobility management and dynamic assignment of traffic to communication links, as applicable.

- Model and evaluate mobility management/multi-homing protocols and techniques – This task requires evaluation of methodologies and architectures for maintaining and managing mobile user location information. There are several protocols that have mechanisms for mobility management such as Mobile IP, but special mechanisms may be needed to accommodate a unique environment such as the ATN.

- Analyze and model algorithms for implementing dynamic policy-based routing in MCNA – This task requires development and evaluation of policy-based routing schemes for MCNA messages. Two or more links may exist on the aircraft that are capable of transmitting messages for a particular scenario or service. If one or more of these links is unavailable, a real-time re-routing methodology must be made to prevent service interruption. The schemes should be tailored to accommodate MCNA traffic associated with the target MCNA scenarios.

- Analyze performance of avionics architecture specific to MCNA requirements/traffic – This task evaluates alternative implementation of new avionics components to support FCS communications, applications to accommodate new traffic associated with the MCNA target applications, utilization of multiple communication links (e.g. dynamic traffic routing over multiple links) and implementation of SWIM services on the aircraft.

Protocols/Standards Modeling – This area is comprised of one task:

- Develop simulation models for each RF link (existing and new) – This task requires the development of simulation models for protocols and air interface standards for use in evaluating their role and performance in the NAS. For example, OPNET models already exist for VDLM2 & VDLM3, but not necessarily for air interfaces such as B-VHF or 802.11. If these communications links are being evaluated for their use with any particular scenario, these simulation models will need to be developed.

- This task may require the integration of multiple simulation RF simulation models and/or the integration of one or more models with ground network models. Additionally, this task may include the integration of simulation models with tools to evaluate operational impacts of specific MCNA scenarios.

NAS/SWIM Modeling – This area is comprised of two tasks:

- Model and evaluate SWIM and MCNA management services – This task addresses the interface of MCNA elements that support mobility management with SWIM registry and directory services to support the implementation of SWIM services within the MCNA.

- Evaluate interface architectures for SWIM core services and MCNA – This task requires the development and analysis of any MCNA-SWIM interfaces for the operational scenarios. Most of the scenarios envision utilization of SWIM for implementation. These interfaces will need to be defined and simulated as they will be implemented in the NAS.

Airspace/Tower/Pilot Simulation – This area is comprised of two tasks:

- Define emulation testing concepts – This task requires the development of human-in-the-loop simulation/emulation environment. This may include an airspace simulation, a control tower simulation, or even pilot/cockpit simulation environment. Several of the SED tools already emulate the environment, but modifications would need to be made to existing simulation to incorporate the MCNA operational scenarios.

    - This task may include the integration of MCNA ground network, A/G communication link and/or SWIM models with the emulation environment to support the end-to-end evaluation of "system-of-systems" MCNA concepts.

- Emulate MCNA scenarios – This task consists of conducting simulations in the airspace, tower, or cockpit simulation environment to verify performance of the MCNA operational scenarios. For example, for Scenario #1: Deploy FIS-B Nationally, verification of reception and display of FIS-B messages in a cockpit simulation environment would be typical of the type of simulation.

Flight Tests – This area is comprised of two tasks:

- Define Flight Demonstration Concepts – This task requires the development of test cases for in-flight test demonstrations validating MCNA target scenarios. One or more demonstration test plans would need to be developed specific to one or more MCNA operating concepts. At least one flight demonstration should

target the validation of the MCNA integrated "system-of-systems" concept where two or more communication links are provided to an aircraft; mobility management and dynamic routing of data across all available links to the aircraft based on an established policy is employed; and operations specific to an MCNA target scenario are supported. At least one additional flight demonstration should address the implementation of SWIM services on the aircraft.

- Support Flight Demonstrations –This task includes everything from equipment acquisition to equipment installation to conducting the in-flight demonstrations to documenting results.

5.3 Key Breakthrough MCNA SED Opportunity

Upon review of MCNA SED needs, tool capabilities and shortfalls, one breakthrough SED opportunity for MCNA has been identified. This relates to the implementation of simulation and demonstration capabilities to validate the feasibility, flexibility, and applicability of a highly flexible and integrated MCNA "system-of-systems" concept. In this concept, an integrated set of A/G communication capabilities and aeronautical ground networks interact to provide a seamless set of A/G communication services to support MCNA operating scenarios. This concept includes the incorporation of mobility management and dynamic routing features within multiple aeronautical ground networks with interfaces to multiple A/G links to the aircraft.

The implementation of the MCNA opportunity described above requires the following:

- Identification of one or more MCNA target scenarios to be used to illustrate the MCNA system-of-systems concept
- Identification of communication classes specific to the selected MCNA target scenario
- Association of communication classes with two or more A/G communication links to be included in the simulation/demonstration
- Modeling or emulation of avionics elements to accommodate target scenario traffic and support dynamic routing
- Modeling or emulation of selected A/G communication links
- ***Key Task:*** Definition of algorithms and development of modeling/emulation capabilities for ground network elements supporting mobility management and dynamic routing in the aeronautical environment. The ground models/emulations should accommodate routing of data associated with selected target scenarios among at least two integrated aeronautical ground networks.

- Modeling or emulation of air traffic control operations accommodating the selected target MCNA scenarios.

As technologies, standards, modeling tools and actual products supporting mobile communication networks mature, the simulation/demonstration concept described in this section provides the opportunity to assess and validate the implementation of these emerging concepts in the aeronautical environment. This effort could provide a key role in validating concepts for transforming the current aeronautical communication capability to a highly capable, highly flexible “system-of-systems” MCNA.

Appendix A. MCNA Request for Information

Contracting Office Address:

NASA/Glenn Research Center, 21000 Brookpark Road, Cleveland, OH 44135

Description:

THIS IS NOT A NOTICE OF SOLICIATION. IT IS A REQUEST FOR INFORMATION (RFI) ONLY.

In responding to this notice, please refer to "**Aeronautical Mobile Communication Network Architecture (MCNA) Simulation, Emulation and Demonstration Capabilities."** Send information/literature/qualification statement no later than **February 17, 2005** to the e-mail or postal address as provided herein. NASA does not intend to award a contract based on this information. This RFI is for planning purposes only and to allow industry the opportunity to provide information relative to the goals set forth below.

NASA Glenn Research Center (GRC) is seeking information about existing and near-future, high fidelity simulation, emulation and demonstration capabilities to support the validation of proposed concepts and enabling technologies for an aeronautical Mobile Communication Network Architecture (MCNA). The MCNA encompasses the mobile digital voice and data communication capabilities required to support communications, navigation and surveillance (CNS) services for future Air Traffic Management (ATM) operations. A clearly defined MCNA is a key element for transformation of the National Airspace System (NAS) towards Network Enabled Operations (NEO). The MCNA extends voice and data information services defined in the NAS System Wide Information Management (SWIM) concept to all mobile elements of the NAS, including aircraft during all phases of flight. Transition to this future MCNA would begin in the 2009 – 2015 time period, and the useful life of the system should be at least 20 to 30 years.

The information received in response to this RFI will be used by NASA GRC in support of a collaborative MCNA Study with the Federal Aviation Administration (FAA) (as part of the Global Communication, Navigation, and Surveillance System (GCNSS) Phase II contract with the Air Traffic Management Division of Boeing Corporation). The FAA/NASA GRC MCNA Study will help to define MCNA requirements and evaluate them against existing and planned communications capabilities in the NAS to identify gaps and/or inconsistencies that must be addressed either through the enhancement of current systems and capabilities or the development of new MCNA systems. The study includes the evaluation of the requirements, architecture and associated transition plans.

NASA GRC responsibilities include the identification of U.S. national capabilities needed to validate the 2015 mobile communications network architecture for use in NEO and SWIM. This RFI is intended to provide input for conducting Task 2.5: Simulation, Emulations, Demonstrations, where candidate simulation models and tools and emulation environments are required to validate proposed MCNA concepts, strategies and enabling technologies. This includes identification of unique facilities and capabilities that exist or are planned within the U.S. at NASA Centers, FAA Facilities, federally-funded organizations, and companies. The Boeing Corporation is under contract with the FAA to assist NASA GRC in the identification of simulation, emulation, and demonstration capabilities. They and other direct contractors of NASA and the FAA for this effort (including but not limited to ITT Industries, Honeywell, Avaliant LLC, and Tectura Corp.) will have access to the information submitted, but only for the specific purpose of helping NASA to develop plans for validating the performance and operational scenarios of integrated communications infrastructure architecture and identification of concepts for demonstrations (in the relevant environment) of the capabilities enabled by the MCNA.

It is desirable that information provided to describe relevant simulation, emulation and demonstration capabilities relevant to aeronautical mobile communications include:

- A technical description of the simulation, emulation, and demonstration capability including but not limited to: tool name, vendor, capability description, hardware supported, and operating system.
- Description of existing application(s) of the tool to support simulation, emulation, and demonstration for the purposes of validating concepts, strategies, and/or technologies in the context of an air traffic management (ATM) environment (in particular the National Airspace System – NAS) and/or aeronautical network enabled environment. This would include descriptions of specific ATM/NAS related models, some discussion/details of how they have been used, and a brief

history of the process and for what purpose they were developed. Sample outputs, screenshots, and other graphical samples would be useful.

- A description of the level of fidelity of the tool/capability with regards to the actual ATM/NAS and/or NEO related system(s) it simulates, emulates, or demonstrates, and whether or not and how the tool/capability has been validated by the FAA, NASA, or other recognized authority.
- Availability of the tool to support future aeronautical MCNA design and development.
- Technical maturity of the simulation, emulation and demonstration capability and areas/timeframe for planned upgrades and improvements.

For the purposes of providing clarity in the scope of responses desired, the following list of examples is included. These examples are intended to be representative of the types of capabilities solicited in the RFI and are not fully inclusive.

- Modeling (software simulation and representation of MCNA or various aspects)
  - Modeling tools for evaluating:
    - Network and datalink protocol performance and interactions
    - PHY performance in multipath, mobile environment
    - Communication system capacity estimation
    - Spectrum utilization and optimization …
  - Models previously developed to represent aeronautical communications such as:
    - VDLm(A,2,3,4,E), UAT, Inmarsat Aero-H, Swift-64, Swift-BGAN, 802.X, P25, P34, 3G, 1090ES, HFDL, VDL-B, B-VHF, ADL
    - Network protocols applicable to MCNA such as (ATN, CPDLC, MIPv6, NeMo, SCTP…)
    - Datalink message sets and applications such as (CPDLC, CM, ADS, FIS…)
- Emulation & Demonstration (Laboratory experiments including hardware in the loop testing eventually leading to flight demonstrations)
  - Wireless and SatCom link emulation
  - Avionics system emulation (CMU, FMC, VHF, HF, SatCom, MCDU …)
  - Ground system emulation (DSP functions, FANS/ATN gateways …)
  - Ground ATM application emulation (ATOP, URET, STARS, CTAS …)
  - Existing testbeds
  - Aviation platforms designed for test and experimentation

Submittal Instructions:

1. Please send relevant literature and information to:

   E-mail address: David.A.Buchanan@nasa.gov

   NASA-Glenn Research Center

   Attn: David A. Buchanan

   21000 Brookpark Road, Mail Stop: 86-5

   Cleveland, OH 44135-3191

   (216) 433-5228

2. Such information shall include as a minimum, a brief description of your company capabilities, products and services, history, ownership, financial capabilities and other specific information as requested in this RFI. As part of your information package, please include company Technical Point(s) of Contact including address, telephone number and e-mail address.

3. At its discretion, NASA may request further discussions and/or clarification of the information submitted. If agreeable to both parties, such discussions may take place via teleconferencing or on-site visit to NASA Glenn Research Center in Cleveland, Ohio at the responder's expense. If they do occur, discussions will be constrained to a two hour time duration, and will consist of vendor presentations and subsequent discussions of the presented material only. Representatives from NASA and its Contractors, and the FAA and its Contractors, may be present for such discussions.

THIS RFI IS ISSUED SOLELY FOR INFORMATION AND PLANNING PURPOSES AND DOES NOT CONSTITUTE A SOLICITATION. Contractors of NASA and the FAA that are assisting in the performance of the MCNA Study will have access to the information submitted for the sole purpose of planning future simulation, emulation and demonstration activities. Responses to this RFI will not be returned. Responders are solely responsible for all expenses associated with any response to this RFI.

THIS SYNOPSIS SHALL NOT BE CONSTRUED AS A COMMITMENT BY THE GOVERNMENT, NOR WILL THE GOVERNMENT PAY FOR THE INFORMATION SOLICITATED. RESPONDERS WILL NOT BE NOTIFIED OF ANY REVIEWS RESULTING FROM THIS RFI.

Appendix B. Acronyms

Term	Definition
A/A, A/A	Air-Air
ACARS	Aircraft Communications Addressing and Reporting System
ACFS	Advanced Concepts Flight Simulator
ADL	Aeronautical Data Link
ADS-A, B, C	Automatic Dependent Surveillance-addressable, broadcast, contract
A-G, A/G	Air-Ground
ASDE	Airport Surface Detection Equipment
ASDE-X	Airport Surface Detection Equipment Model X
ASR	Airport Surveillance Radar
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATOP	Advanced Technology and Oceanic Procedures
BGAN	Broadband Global Area Network (aka SwiftBroadband)
BRITE	Bright Radar Indicator Tower Equipment
B-VHF	Broadband - VHF
CAASD	Center for Advanced Aviation Systems Development
CLNP	Connectionless Network Protocol
CMU	Communications Management Unit

Term	Definition
CNS	Communication, Navigation, Surveillance
COTS	Commercial-Off-The-Shelf
CPDLC	Controller-Pilot Data Link Communications
CTAS	Center-TRACON Automation System
CVSR	Crew Vehicle Systems
CVSRF	Crew Vehicle Systems Research Facility
DSP	Departure Spacing Program
ES	Extended Squitter
ESCAPE	Eurocontrol Simulation Capability and Platform Experimentation
ETOS	Enhanced Tower Simulator
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FCS	Future Communication Study
FFSim	Free Flight Simulation
FIS	Flight Information Service
FIS-B	Flight Information Services - Broadcast
FMC	Flight Management Controller
FREER	Free-Route Experimental Encounter Resolution
FTI	Future Telecommunications Infrastructure
G/G	Ground-Ground

Term	Definition
GCNSS	Global Communication Navigation and Surveillance System
GRC	Glenn Research Center
HF	High Frequency
HMI	Human Machine Interface
IATS	Initial Academy Training System
IP	Internet Protocol
LAAS	Local Area Augmentation System
MCDU	Multifunction Control-Display Unit
MCNA	Mobile Communication Network Architecture
MIPv6	Mobile IP version 6
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NEO	Network Enable Operations
NFM	National Flow Model
NLR	National Aerospace Laboratory (The Netherlands)
OASIS	Operational And Supportability Implementation System
PSTN	Public Switched Telecommunication Network
QoS	Quality of Service
RF	Radio Frequency
RTM	Regional Traffic Model

Term	Definition
SatComm	Satellite Communications
SED	Simulation, Emulation, Demonstration
SEM	Systems Engineering Manual
SIMMOD	Airport & Airspace Simulation Model
SLIC	System Level Integration Concepts
SoSE	Systems-of-Systems Engineering
SSR	Secondary Surveillance Radar?
STARS	Standard Terminal Automation Replacement System
SWIM	SWIM
SWIM	System Wide Information Management
SYSCO	System-to-System Coordination
TAAM	Total Airspace & Airport Modeler
TCAS	Traffic Allert and Collision Avoidance System
TFM-M	Traffic Flow Management Modernization
TIS	Traffic Information Services
TIS-B	Terminal Information Service--Broadcast
TIS-B	Traffic Information Services - Broadcast
TMX	Target Aircraft Generator
UAT	Universal Access Transceiver
URET	User Request and Evaluation Tool

Term	Definition
URL	Universal Resource Locator
VAMS	Virtua Airspace Modeling and Simulation
VAST	Virtual Airspace Simulation Technology
VAST-RT	VAST-Real Time
VDL	VHF Digital Link
VDL-B	VHF Digital Link - Broadcast
VHF	Very High Frequency
VMS	Vertical Motion Simulator
VSCS	Voice Switching Communication System
WAAS	Wide Area Augmentation System

Active Page Record

Page Numbers	Revision Level	Revision Type (Added, Deleted)

Page Numbers	Revision Level	Revision Type (Added, Deleted)

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Revision Record

Revision Letter **A**

Changes in this Revision Type text here.

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