Operational Implications and Proposed Infrastructure Changes for NAS Integration of Remotely Piloted Aircraft (RPA)

Technical Report, Version 0.1 — December 2014

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Prepared for:
United States Air Force
Aerospace Management Systems Division
Air Traffic Systems branch (AFLCMC/HBAG)
Hanscom AFB, Bedford, MA

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The intent of this report is to provide (1) an initial assessment of National Airspace System (NAS) infrastructure affected by continuing development and deployment of unmanned aircraft systems into the NAS, and (2) a description of process challenges attendant to timely infrastructure changes in response to a growing demand for safe and efficient air traffic control services for unmanned aircraft systems.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
oz	ounces	28.35	grams	g
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
mL	milliliters	0.034	fluid ounces	fl oz
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
g	grams	0.035	ounces	oz
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	Kilopascals	0.145	poundforce per square inch	lbf/in^2

***SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)**

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The intent of this report is to provide the USAF AFLCMC/HBAG with (1) an initial assessment of Federal Aviation Administration infrastructure affected by continuing development and deployment of unmanned aircraft systems into the National Airspace System, and (2) a description of challenges that impede timely infrastructure changes in response to a growing demand for safe and efficient air traffic control services for unmanned aircraft systems.

Generation and refinement of this report's contents was a joint government-industry effort, drawing on UAS subject-matter expertise from personnel at the Volpe Center, Mosaic ATM, Inc., and Aviation Management Associates, Inc.

This report, Version 0.1, is subject to revision based upon government and industry feedback. Any questions and/or comments attendant to this report should be submitted to Jason Glaneuski (Jason.Glaneuski@dot.gov) and Mark Strout (Mark.Strout@dot.gov) of the Volpe Center's Air Traffic Management Systems Division (RVT-73) no later than close of business (COB) Friday, April 17, 2015.

The Volpe Center wishes to thank the USAF AFLCMC/HBAG for their continued support towards mission-critical RPA research and analysis.

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List of Acronyms

Acronym	Definition
4DTBO	4 Dimensional Trajectory Based Operations
A/G	Air to Ground
AAtS	Aircraft Access to SWIM
ABSAA	Airborne Sense and Avoid
ACAS-X	Airborne Collision Avoidance Systems
ADS-B	Automatic Dependent Surveillance–Broadcast
AFP	Airspace Flow Program
AIM	Aeronautical Information Management
AIXM	Aeronautical Information Exchange Model
AMCC	ARTCC Monitor and Control Center
AMS	Acquisition Management System
ANSP	Air Navigation Service Provider
ARM	Airport Resource Management
ARTCC	Air Route Traffic Control Centers
ARTS	Automated Radar Terminal System
ASI	Aviation Safety Inspectors
ASOS	Automated Surface Observing System
ATC	Air Traffic Control
ATCOTS	Air Traffic Control Optimum Training Solution
ATCS	Air Traffic Control Specialist
ATCSCC	Air Traffic Control System Command Center
ATCT	ATC Tower
ATM	Air Traffic Management
ATMRPP	Air Traffic Management Requirements and Performance Panel
ATO	Air Traffic Organization
ATOP	Advanced Technologies and Oceanic Procedures
AUVSI	Association for Unmanned Vehicle Systems International
AWD	Aviation Weather Display
BLOS	Beyond Line of Sight
BOA	Basic Ordering Agreement
BPA	Blanket Purchase Agreement
C2	Command and Control
CANRAD	Canadian Radar
CARTS	Common Automated Radar Terminal System
CAS	Commercially Available Software
CATMT	Collaborative Air Traffic Management Technologies
CDM	Collaborative Decision Making
CDTI	Cockpit Display of Traffic Information
CIWS	Corridor Integrated Weather System
CMTD	Concept Maturity and Technology Development
COA	Certificate of Authorization
COI	Community of Interest
ConOps	Concept of Operations
CoSPA	Consolidated Storm Prediction for Aviation

Acronym	Definition
COTS	Commercial off-the-shelf
CPC	Certified Professional Controller
CPDLC	Controller Pilot Data Link Communication
CRD	Concept and Requirements Definition
CSS-Wx	Common Support Services–Weather
CTOP	Collaborative Trajectory Option Program
CWAF	Convective Weather Avoidance Field
CWAM	Convective Weather Avoidance Model
DAA	Detect and Avoid
DHS	Department of Homeland Security
DoD	Department of Defense
DOJ	Department of Justice
DOT	Department of Transportation
DSP	Departure Spacing Program
DSR	Display System Replacement
DST	Decision Support Tool
EDC	En Route Departure Capability
EFD	Electronic Flight Data
EFS	Electronic Flight Strip
EOL	End of Life
EOM	End of Maintenance
EOSH	Environmental and Occupational Safety and Health
ERAM	En Route Automation Modernization
ERIDS	En Route Information Display Systems
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
ETVS	Enhanced Terminal Voice Switch
EVM	Earned Value Management
EVMS	Earned Value Management System
F&E	Facilities and Equipment
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FBWTG	FAA Bulk Weather Telecommunications Gateway
FDE	Flight Data Elements
FEA	Flow Evaluation Area
FF-ICE	Flight and Flow–Information for a Collaborative Environment
FIA	Final Investment Analysis
FIS-B	Flight Information Service–Broadcast
FISMA	Federal Information Security Management Act 2002
FIXM	Flight Information Exchange Model
FIXM DD	FIXM Data Dictionary
FLM	Front Line Manager
FSDO	Flight Standards District Office
FSIMS	Flight Standards Information Management System
FSM	Flight Schedule Monitor
FSS	Flight Service Station

Acronym	Definition
FTI	FAA Telecommunications Infrastructure
G/G	Ground to Ground
GA	General Aviation
GBSAA	Ground Based Sense And Avoid
GDP	Ground Delay Program
GPS	Global Positioning System
GS	Ground Stop
GUFI	Globally Unique Flight Identifier
HALE	High Altitude Long Endurance
IARD	Investment Analysis Readiness Decision
ICAO	International Civil Aviation Organization
IDA	Investment Decision Authority
IDS	Information Display System
IDS4	Information Display System 4
IFR	Instrument Flight Rule
IGCE	Independent Government Cost Estimate
IIA	Initial Investment Analysis
ISD	In-service Decision
ISR	In-service Review
ISS	Information System Security
IT	Information Technology
ITWS	Integrated Terminal Weather System
JRC	Joint Resources Council
LOS	Line of Sight
MIT	Miles-in-Trail
MOPS	Minimum Operations Performance Standards
MSL	Mean Sea Level
NAC	NextGen Advisory Committee
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NEMS	NextGen Enterprise Messaging System
NEPA	National Environmental Policy Act
NESG	NextGen Enterprise Security Gateway
NetCDF	Network Common Data Format
NEXCOM	NextGen Communications
NEXRAD	Next Generation Weather Radar
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NOTAM	Notice to Airmen
NSWRC	NextGen Surveillance and Weather Radar Capability
NVS	NAS Voice System
NWP	Next Generation Weather Processor
O&M	Operations and Maintenance
OCIP	Operational Capability Integration Plan
OMB	Office of Management and Budget
OPS	Operations

Acronym	Definition
ORD	Operational Readiness Date
OSA	Operational Safety Assessments
PIC	Pilot in Command
PIR	Post-implementation Reviews
PIREP	Pilot Report
PMO	Program Management Office
RAMP	Radar Acquisition and Mosaic Processor
RAPT	Route Availability Planning Tool
RE&D	Research Engineering and Development
RPA	Remotely Piloted Aircraft
RSA	Research for Service Analysis
RTCA	Radio Technical Commission for Aeronautics
SC	Special Committee
SCAP	Security Certification and Authorization Package
SCRB	Support Contract Review Board
SE	System Engineering
SIR	Screening Information Request
SM	Surface Metering
SME	Subject Matter Expert
SMS	Safety Management System
SOA	Service Oriented Architecture
SOP	Standard Operating Procedure
SRMGSA	Safety Risk Management Guidance for System Acquisitions
SS	Surface Scheduling
SSA	Surface Situational Awareness
SSD	System Specification Document
ST&E	System Test and Evaluation
STARS	Standard Terminal Automation Replacement System
SWIM	System Wide Information Management
T&E	Test and Evaluation
TAMR	Terminal Automation Modernization and Replacement
TBFM	Time Based Flow Management
TCAS	Traffic Alert and Collision Avoidance System
TDWR	Terminal Doppler Weather Radar
TFDM	Terminal Flight Data Management
TFM	Traffic Flow Management
TFM-I	The Traffic Flow Management Infrastructure
TFMS	Traffic Flow Management System
TIDS	Terminal Information Display System
TIS-B	Traffic Information Service Broadcast
TMI	Traffic Management Initiative
TMU	Traffic Management Unit
TPAX	Trajectory Prediction and Exchange
TRACON	Terminal Radar Approach Control
TSD	Traffic Situational Display
UA	Unmanned Aircraft

Acronym	Definition
UAS	Unmanned Aircraft System
UHF	Ultra High Frequency
UML	Universal Markup Language
URET	User Request Evaluation Tool
USAF	United States Air Force
VFR	Visual Flight Rule
VHF	Very High Frequency
VMC	Visual Flight Conditions
VoIP	Voice over Internet Protocol
VP	Vice President
VPN	Virtual Private Network
VSCS	Voice System Control Switch
WAAS	Wide Area Augmentation System
WAF	World Aviation Forecast
WARP	Weather and Radar Processor
WINS	Weather Information Network Server
WX	Weather
WXXM	Weather Information Exchange Model
XML	Extensible Markup Language

1. Executive Summary

Background and Challenge

This report of the *Operational Implications and Proposed Infrastructure Changes for NAS Integration of RPA* looks at the major FAA NextGen-related systems and developmental programs that will likely interact with RPA to determine what and to what degree FAA processes and systems are prepared to accommodate new functional interactions driven by RPA business models and user mission requirements. It is envisioned that NAS systems and RPA development must evolve in parallel to achieve seamless NAS integration; however, it is beyond the scope of this report to examine how RPA must adapt to existing infrastructure and airspace in the NAS. A programmatic detail of changes, including effects on costs and schedules, is also beyond the scope of this report.

A previous Volpe Report (DOT-VNTSC-DoD-13-01) that identifies UAS forecast service demands from 2015 to 2035 projects the expected number and type of vehicles as well as their associated missions and business cases. The Volpe Report serves as a basis to identify new ATC operational paradigms needed to accommodate RPA missions and business models with both legacy ATC systems as well as new and future ATC systems functionality (note: "Remotely Piloted Aircraft" is the International Civil Aviation Organization (ICAO) preferred nomenclature for unmanned aircraft). This need, or shortfall, is reflected in the identification and description of current FAA automation and infrastructure programs identified within this report. In addition, this report addresses programmatic program changes needed to accommodate RPA in a timely and efficient manner to ensure continuing ATC system safety, capacity, and efficiency. Of particular concern and interest was to define changes in ATC systems and sub-systems to address air traffic controller workload and workload complexity concerns associated with RPA activities. An adjunct to this need was the requirement to review and address current FAA acquisition processes and to successfully facilitate these required ATC system and sub-system changes in a timely and efficient way.

In the case of RPA, and even commercial space operations, needs assessments are so preliminary that potential future requirements have yet to find their way into the FAA acquisition process. Once initial needs are identified, it can easily take 25 years or more to make changes in NAS systems and sub-systems supporting ATC operations and functions. For example, one of the major FAA NextGen programs, Automatic Dependent Surveillance Broadcast (ADS-B) began in 1985 under the Alaskan Capstone Project with the full second generation system deployment announced in April of 2014. This has been a 30-year journey, but still the system will not be fully deployed and in full use until the ADS-B mandate in 2020. Other FAA programs such as Enroute Automation Modernization (ERAM), Controller Pilot Data Link Communication (CPDLC), and Wide Area Augmentation Systems (WAAS) have similar timescales. Based on limited FAA data, the average period for concept development for completed programs that move forward for deployment is 6.5 years. If standards are required, it adds another 10 years. The development process for FAA infrastructure is 9.5 years. Finally, the average time it takes to move a system from preliminary operations to full field acceptance and deployment is about 4 years. Again, this represents an average 30-year cycle for major programs deemed successful.

This report represents a preliminary identification and assessment of the NAS and NextGen systems affected in efforts to provide timely and seamless integration of RPA into the NAS. There are strong programmatic challenges associated with the identification of detailed requirements, schedules, and costs of modifying the NAS infrastructure that are well beyond the scope of this report.

NAS Change Technical Approach

Congress has afforded the FAA the opportunity to possess its own unique research, development, test, engineering, and support system that is called the FAA Acquisition Management System, or AMS. The

AMS provides FAA with the full Lifecycle Management processes and tools used to accommodate acquisition and deployment of new systems, including those supporting RPA integration into the NAS. To understand how RPA integration into the NAS will occur requires an understanding of the phases, processes and details of the AMS. This report provides a summary discussion and details covering the relevant sections of the AMS. It is intended to help define the processes, associated challenges, and products needed to introduce technical initiatives in support of RPA into the NAS.

To identify and analyze NAS systems that may be affected by RPA incorporation, it is necessary to provide a framework that defines the FAA processes for identifying, evaluating, developing, acquiring, deploying, operating, and disposing of NAS systems and sub-systems. The technical approach chosen for this report explores the means and methods currently in use by the FAA that support procurement and deployment of NAS hardware as well as software changes that affect NAS systems and sub-systems. This approach allows the report to identify critical areas that may affect a rapid and successful implementation of NAS changes needed to support timely integration of RPA into the NAS. Just as importantly, this analysis permits the report to address challenges, issues, and potential changes in priorities and processes necessary to ensure that RPA integration is timely, efficient, and cost-effective.

Analysis Methodology and Scope

This document is intended to be a high-level overview of the RPA impact on NAS automation. The purpose of the work was to identify key functional and technical areas of potential impact upon current NAS operational and support systems. It was not the intent to determine this impact for all of the NAS automation platforms. Rather, we chose a selected set of NAS systems that are representative of the major NAS functions. From this selected set of systems, the document draws together insights across airspace domains (airport, terminal, enroute) as well as the supporting NAS infrastructure systems.

Acquisition Management System

The FAA's AMS defines the basis for action to make needed investments in the NAS. There are a number of processes defined by AMS to provide for FAA acquisition requirements ranging from new technology to technical refresh of current technologies to facilities to support services. The selection of process or entry to the appropriate process is critical to an FAA development and deployment schedule.

This paper is a preliminary identification of the FAA systems and sub-systems that need to be analyzed to determine whether they need to be modified, augmented, or replaced to meet future FAA requirements to support full and seamless integration of RPA into the NAS. In addition, this paper looks ahead to provide insight into the means and methods providing a fast track for needed technology insertion into the current NAS acquisition processes.

Strategic Management Process

The FAA supports future system requirements through a strategic management process that forecasts the future aviation environment and captures goals, objectives, and performance targets in its strategic plan. FAA strategic planning links the long-range vision and goals for the agency directly to the service needs of customers and defines top-level performance measures and multi-year performance targets.

An initial part of the AMS is the FAA capital investment process that develops an annual 5-year Capital Investment Plan (CIP). The Strategic Plan articulates the most important goals for improving performance in the delivery of aviation services. These goals guide the Agency in upgrading NAS systems and operating procedures to meet the demands of future growth.

The FAA Modernization and Reform Act of 2012 mandates the creation and publication of a five-year roadmap that details regulations, policy, procedures, and training requirements to support safe and efficient RPA operations in the NAS. Additionally, the FAA has designated six operational test sites and has begun research and development at the William J. Hughes Technical Center (WJHTC) to support RPA integration. However, at the time of this report's publication, there is not yet a formal effort by the FAA to move forward within the approved structure of the AMS to begin to identify and to accommodate future FAA air traffic system needs supporting RPA.

Services and Systems Affected by RPA Integration into the NAS

This report identifies selected NAS systems and automation programs that are affected by the developing demand for RPA services from the NAS. The ability of the FAA to accommodate new business models as defined by their mission requirements is critical for both the emerging NAS system user as well as the FAA for continuing successful sustainment of safety and performance of the NAS.

Each program identified in this report briefly discusses a description of the program, its major functions supporting the NAS, the RPA needs affecting the program, and finally high-level considerations for program changes needed to effectively accommodate RPA in the NAS. This section focuses on how RPA integration will affect air traffic controller workload and workload complexity if programmatic changes are not made. Increases in air traffic controller workload can reduce overall system capacity while increased complexities have a bearing on ATC safety performance.

Detect and Avoid

Depending upon architecture and functionality, DAA for RPA could have a profound effect on a variety of FAA systems and infrastructure. DAA can be airborne-based and can affect ADS-B In and ADS-B Out and an associated Cockpit Display of Traffic Information (CDTI). DAA can also affect Traffic Alert and Collision Avoidance System (TCAS) functionality, including designs for the new Next Generation Airborne Collision Avoidance Systems (ACAS-X). GBSAA that leverages ASR-11 Surveillance Radars and STARS or TAMR also demands automation and surveillance system modification to provide this capability. Additional analysis of portable primary three-dimensional radars integrated in the NAS will also be required.

2. Background and Challenge

The National Airspace System

The Federal Aviation Act of 1958 established the Federal Aviation Administration (FAA) and made it responsible for the control and use of navigable airspace within the United States. The FAA created the National Airspace System (NAS) to protect persons and property on the ground and to establish a safe and efficient airspace environment for civil, commercial, and military aviation. The NAS is made up of a network of air navigation facilities, Air Traffic Control (ATC) facilities, airports, technology, and appropriate rules and regulations that are needed to operate the system to provide necessary services for the safe, orderly, and expeditious movement to the users of this system, from commercial air transport to business aviation to general aviation and the military. These services will eventually need to be extended to include support for RPA.

NextGen

The Next Generation of the National Airspace System (NextGen) infrastructure has been developed to enable a shift to satellite-based digital technologies, and new procedures that combine to make air travel more convenient, predictable, and environmentally friendly.

As the nation's largest airports continue to experience congestion, NextGen improvements will enable the FAA to guide and track aircraft more precisely on more direct routes. NextGen efficiency promises to enhance safety, reduce delays, save fuel, and lessen aircraft exhaust emissions. NextGen is also vital to preserving aviation's significant contributions to our national economy.

NextGen enables the sharing of real-time data about weather, the location of aircraft and vehicles, and conditions throughout the NAS. NextGen gets the right information to the right people at the right time, helping controllers and operators to make better decisions and to improve on-time performance.

NextGen capabilities in place today are the foundation for continually improving and accommodating future air transportation needs while strengthening the economy locally and nationally with one seamless, global sky. There is no doubt that RPA and their timely integration into the NAS are critical components of NextGen.

RPA Effect on NAS and NextGen

This report looks at the major FAA NextGen-related systems and developmental programs that will likely interact with RPA to determine what and to what degree FAA processes and systems are prepared to accommodate new functional interactions driven by RPA business models and user mission requirements. Although RPAs must evolve in parallel to the NAS, it is beyond the scope of this report to examine how RPA must adapt to existing infrastructure and airspace in the NAS.

A previous Volpe Report (DOT-VNTSC-DoD-13-01) that identified RPA forecast service demands from 2015 to 2035 defined the expected number and type of vehicles as well as their associated missions and business cases. The Volpe Report served as a basis to identify new ATC operational paradigms needed to accommodate RPA missions and business models with new ATC systems functionality. This need, or shortfall, is reflected in the identification and description of current FAA automation and infrastructure programs identified within this report. In addition, this report addresses programmatic program changes needed to accommodate RPA in a timely and efficient manner to ensure continuing ATC system safety, capacity, and efficiency. Of particular concern and interest was to define changes in ATC systems and sub-systems to address air traffic controller workload and workload complexity concerns associated with RPA activities.

An adjunct to this need was the requirement to review and address current FAA acquisition processes and to successfully facilitate these required ATC system and sub-system changes in a timely and efficient way.

Another rationale for this assessment is to provide assistance to the FAA in meeting and achieving its objectives for accommodation of RPA, the need to understand the technical and operational impediments to seamless integration of RPA operations into the NAS, and the compelling commercial arguments for RPA integration. In the case of RPA, and even commercial space, needs assessments are so preliminary that potential future requirements have yet to find their way into the FAA acquisition process. Once initial needs are identified, it can easily take 25 years or more to make changes in NAS systems and sub-systems supporting ATC operations and functions.

The FAA Modernization and Reform Act of 2012 required the Secretary of Transportation to publish a final rule on allowing small RPA to fly in the airspace by mid-2014. It further mandated the safe integration of all civil RPA by September 30, 2015. Industry advocates, including the Association for Unmanned Vehicle Systems International (AUVSI), have expressed strong support for advancement toward these objectives (N.B.: small RPA rules are still under development, with an initial draft expected by the end of 2014). "The UAS industry believes the pending rule is urgently needed and will provide meaningful guidance to manufacturers and end users for design, construction and operation of small UAS to safely operate and deliver crucial services to law enforcement, agriculture and other sectors of the American economy," said AUVSI's Toscano in a letter to the Department of Transportation. (AUVSI, 2012) Toscano added "UAS will be the next big revolution in aviation; however, before this industry can really take off, we need rules from the FAA on how to safely operate alongside manned aircraft."

AUVSI's analyses project the creation of more than 70,000 jobs in the first three years of integration in the United States with an economic impact of more than $13.6 billion. AUVSI further projects that this benefit will grow through 2025 to more than 100,000 jobs created and an economic impact of $82 billion. (AUVSI, 2013) Based on the FAA's own data, these projections clearly represent a material impact to the overall contribution of aviation to the economy. (Federal Aviation Administration, 2011)

3. NAS Change Technical Approach

To identify and analyze NAS systems that may be affected by RPA integration, it is necessary to provide a framework that defines the FAA processes for identifying, evaluating, developing, acquiring, deploying, operating, and disposing of NAS systems and sub-systems. The technical approach chosen for this report explores the means and methods currently in use by the FAA that support procurement and deployment of NAS hardware as well as software changes that affect NAS systems and sub-systems. This approach allows the report to identify critical areas that may affect a rapid and successful implementation of NAS changes needed to support timely integration of RPA into the NAS. Just as importantly, this analysis permits the report to address challenges, issues, and potential changes in priorities and processes necessary to ensure that RPA integration is timely, efficient, and cost-effective.

In addition to the AMS, the FAA relies upon other processes and tools to define and describe the NAS. This includes the NAS System Architecture that defines and describes ATC automation and infrastructure systems and sub-systems that make up the ATC system. NAS architecture depicts system and sub-system connectivity and relationships and provides a framework for establishing system functionality. Additional functional disciplines, such as System Engineering, supplement the NAS architecture and provide the necessary tools for engineering changes into the NAS, such as process improvements and technology insertion.

4. Analysis Methodology and Scope

Performing an impact assessment and gap analysis requires understanding the context of a future RPA in the NAS operation. This context is still emerging; it can be envisioned by reading RPA-related documents that the FAA has released in recent years, from gaining an understanding of today's RPA operations under Certificate of Authorization (COA), and from participating in the previous work efforts of Radio Technical Commission for Aeronautics (RTCA) Special Committee (SC) 203 and the ongoing SC-228. Furthermore, this document neither presents nor summarizes a description the operational context or concepts of operations for the RPA in the NAS. Rather, it has been necessary to assume that the reader has a basic understanding and background of the emerging RPA concept of operation and use.

The steps taken to determine the scope of the RPA impact are as follows:

a. Develop a current and summary description each of the selected NAS systems.
b. Highlight the major ATC-related functions performed by the NAS system.
c. Using Subject Matter Experts (SMEs), summarize the related RPA needs as pertains to the ATC role that the system supports.
d. Draw high-level conclusions that point to or express the areas where change(s) will need to be addressed.

The following NAS systems and programs are covered in Section 6:

- 6.1 En Route Automation Modernization (ERAM)
- 6.2 Traffic Flow Management System (TFMS)
- 6.3 National Voice System (NVS)
- 6.4 Terminal Automation Modernization and Replacement (TAMR)
- 6.5 Terminal Information Display System (TIDS) & En Route Information Display Systems (ERIDS)
- 6.6 System Wide Information Management (SWIM)
- 6.7 Flight Information Exchange Model (FIXM)
- 6.8 Air Traffic Control Optimum Training Solution (ATCOTS)
- 6.9 Future Facilities
- 6.10 Next Generation Weather Processor (NWP) and Weather and Radar Processor (WARP)
- 6.11 Terminal Flight Data Management (TFDM)
- 6.12 Detect and Avoid (DAA)

5. Acquisition Management System (AMS)

The FAA's AMS defines the basis for action to make needed investments in the NAS. There are a number of processes defined by AMS to provide for FAA acquisition requirements ranging from new technology to technical refresh of current technologies to facilities to support services. The selection of process or entry to the appropriate process is critical to an FAA development and deployment schedule.

This paper is a preliminary identification of the FAA systems and sub-systems that need to be analyzed to determine whether they need to be modified, augmented, or replaced to meet future FAA requirements to support full and seamless integration of RPA into the NAS. In addition, this paper looks ahead to provide insight into the means and methods providing a fast track for needed technology insertion into the current NAS acquisition processes.

Growth of RPA operations can easily be enhanced if automation can be deployed quickly and effectively to reduce ATC workload. Reduced ATC workload will improve sector capacity and better accommodate RPA operations.

5.1 Strategic Management Processes

The FAA supports future system requirements through a strategic management process that forecasts the future aviation environment and captures goals, objectives, and performance targets in its strategic plan. FAA strategic planning links the long-range vision and goals for the agency directly to the service needs of customers and defines top-level performance measures and multi-year performance targets.

An initial part of the AMS is the FAA capital investment process that develops an annual 5-year Capital Investment Plan (CIP). The Strategic Plan articulates the most important goals for improving performance in the delivery of aviation services. These goals guide the Agency in upgrading NAS systems and operating procedures to meet the demands of future growth.

The NAS Concept of Operations (ConOps) specifies the operational capabilities that the NAS will have over time. Together, the FAA strategic plan and NAS ConOps set the primary context for the FAA Enterprise Architecture and all lower-level plans and budgets within the agency. FAA lines of business and staff offices align their planning to the goals and objectives in FAA strategic planning. Service organizations within the lines of business in turn align their business and operating plans to line-of-business planning. These relationships are illustrated in Figure 1.

Figure 1: Strategic Planning, Management, and Budgeting

Service organizations develop integrated business plans and budgets across all appropriations to achieve full lifecycle support of service delivery. Success or failure in achieving performance goals influences future planning and budgeting decisions. Resources are dedicated to key activities such as service analysis, concept and requirements definition, and investment analysis.

Each year, every program is required to submit a request for funding with justification and details concerning cost, schedule, and benefits. Programs must be consistent with the NAS Architecture and with any approved baselines. A Capital Investment Team composed of representatives from budget and finance, and, as appropriate, representatives of Air Traffic Organization (ATO) vice-presidents and other FAA organizations, reviews these requests to determine whether the program should be funded.

The Chief Financial Officer formulates the budget across lines of business and staff offices, tracks actual performance against planned execution based on input from these organizations, records the approved resource adjustments to FAA plans and budgets, and incrementally moves FAA planning and budgeting forward each year. The Chief Financial Officer also develops the Facilities and Equipment (F&E); Research, Engineering, and Development (RE&D); and Operations (OPS) budget requests.

The Administrator approves the FAA strategic plan; the NextGen Management Board approves the NAS ConOps; and the Joint Resources Council (JRC) approves Capital Investment Plan and the FAA Enterprise Architecture. The consolidated budget request is then reviewed and approved by the Joint Resources Council (JRC) prior to submittal to the Office of the Secretary of Transportation (OST), OMB and finally Congress as part of the President's budget request.

5.2 Acquisition Categories Supporting Investment Decision-making and Governance

Acquisition categories are used to ensure that the appropriate level of oversight and artifact requirements is applied to each FAA investment program. This process applies to all investment programs, appropriations, and FAA organizations. This includes all capital investments in the NAS and FAA administrative and mission support systems and services.

For purposes of RPA NAS integration, it is envisioned that the FAA's investment will predominantly fall under **New Investments**, requiring research, design, development, and implementation to facilitate a new FAA system or service. This program typically introduces new capabilities or provides new or improved functionality to an existing program (e.g., Pre-Planned Product Improvement [P3I]). It is not inconceivable that RPA investments will need to be made as a Facility initiative that addresses new construction, replacement, modernization, repair, remediation, lease, or disposal of FAA's manned and unmanned facility infrastructure(s) to accommodate expansion for new positions of operations or new automation, communications, command, or control infrastructure. Such an initiative may result in new safety or security implications. Further, it is expected that contracts for **Support Services** will also need to be provided that includes contracts associated with procuring technical, engineering, scientific, professional, managerial, and administrative expertise, advice, analysis, studies, or reports in support of RPA integration into the NAS.

To the degree possible, investments in FAA systems and sub-systems should be determined to fall under Pre-Planned Program Improvements, allowing current programs to introduce new related capabilities or to provide improved functionality to an existing program, such as improved flight plan filing capabilities for RPA within ERAM. However, this process does not respond well to urgent programmatic needs. A revised lifecycle management process that better defines and enables technology insertion and spiral development on established FAA programs is necessary.

While not defined within the AMS, available moneys and acceptable processes may be available and fast-tracked through the use of NextGen Pre-implementation Funding. Pre-implementation investments as managed through the NextGen Offices provide for the exploration of new concepts and the evaluation of alternatives to reduce uncertainty and programmatic risks associated the development and deployment of NextGen capabilities.

For example, a pre-implementation activity would be used to mature program requirements to support a final investment decision (FID). Beginning in FY2008 the FAA has been using a management tool called a Project Level Agreement (PLA) to transfer NextGen funds to an organization designated to preform engineering activities supporting the FID.

While the use of a PLA may provide relatively rapid access to funding in support of technology insertion in development programs to meet RPA FAA mission needs, there is no defined process to accomplish this inside or outside the AMS in an accelerated manner or method.

5.3 Key Elements of Acquisition Management

Acquisition management policy is structured to apply FAA investment resources to the cost-effective delivery of safe and secure services to its customers. The delivery of these services is accomplished through service organizations, which are responsible and accountable for lifecycle management of service delivery. The overarching goal is continual improvement in the delivery of safe, secure, and efficient services over time. Furthermore, the application is flexible and may be tailored by the Acquisition Executive or JRC. Figure 1 is a graphical representation of the Lifecycle Management Process and shows the logical sequence of phases and decision points of a program's lifecycle.

5.3.1 Acquisition Lifecycle Management

Figure 1: The FAA Lifecycle Management Process (FAA)

The lifecycle process begins with research and systems analyses. In this phase, programs are analyzed to identify how they align with long-term FAA plans. This phase governs selection and execution of the RE&D portfolio.

After research and systems analysis, a program moves into the Concept and Requirements Definition where operational needs are translated into operational requirements and a solution concept of operations for the capability is developed. It also quantifies the service shortfall in sufficient detail for the definition of realistic preliminary requirements and estimation of potential costs and benefits. Finally, concept and requirements definition identifies the most promising alternative solutions able to satisfy the service need, one of which must be consistent with the conceptual framework in the enterprise architecture.

Following the Concepts and Requirements Definition phase comes the Investment Analysis phase. Investment analysis is conducted in the context of the enterprise architecture and FAA strategic goals and objectives. Such plans serve as guides to prioritize current and future investment analyses. Investment analyses, in turn, help to refine and mature those plans by providing decision-makers with a clear picture of investment opportunities and their risks and value. Affordability, accurate cost, and schedule estimates are important factors in the decision to approve a new investment program. The results of investment analysis help the JRC to determine which potential investments will improve operations across the air transportation system and by how much. The outcome of investment analysis can be used to make individual, portfolio, and prioritization decisions.

Solution implementation begins at the final investment decision when the JRC approves and funds an investment program or segment, establishes the acquisition program baseline for variance tracking, and authorizes the service organization to proceed with implementation. Solution implementation ends when a new service or capability is commissioned into operational use at all sites.

The in-service decision (ISD) authorizes deployment of a solution into the operational environment. It occurs after demonstration of initial operational capability at the key test site(s) and before initial operational capability at any non-key site or waterfall facility. The decision is made following completion of the certification of compliance with testing, information security, and safety requirements. In-Service Management

The final phase of the lifecycle management process is in-service management. This entails operating, maintaining, securing, and sustaining systems, products, services, and facilities in real time to provide the level of service required by users and customers. It also entails periodic monitoring and evaluation of fielded products and services and feedback of performance data into service and investment analysis as the basis for revalidating the need to sustain deployed assets or taking other action to improve service delivery.

5.4 NAS Enterprise Architecture

The NAS Architecture is the preeminent documentation that describes the systems and sub-systems that comprise the NAS, as illustrated in Figure 2. This architecture depicts and defines the hardware as well as connectivity and relationships between NAS system components and their functionality in supporting ATC operations.

Understanding this architecture is critical to determining what system design is needed to accommodate changes in the NAS driven by RPA customer and business model needs, and when that design is needed. This understanding in conjunction with the processes of the FAA's AMS create a picture of not only what needs to be done to facilitate RPA-driven changes in the NAS, but how those changes need to be made. The FAA's System Engineering referenced in Appendix B further support this effort.

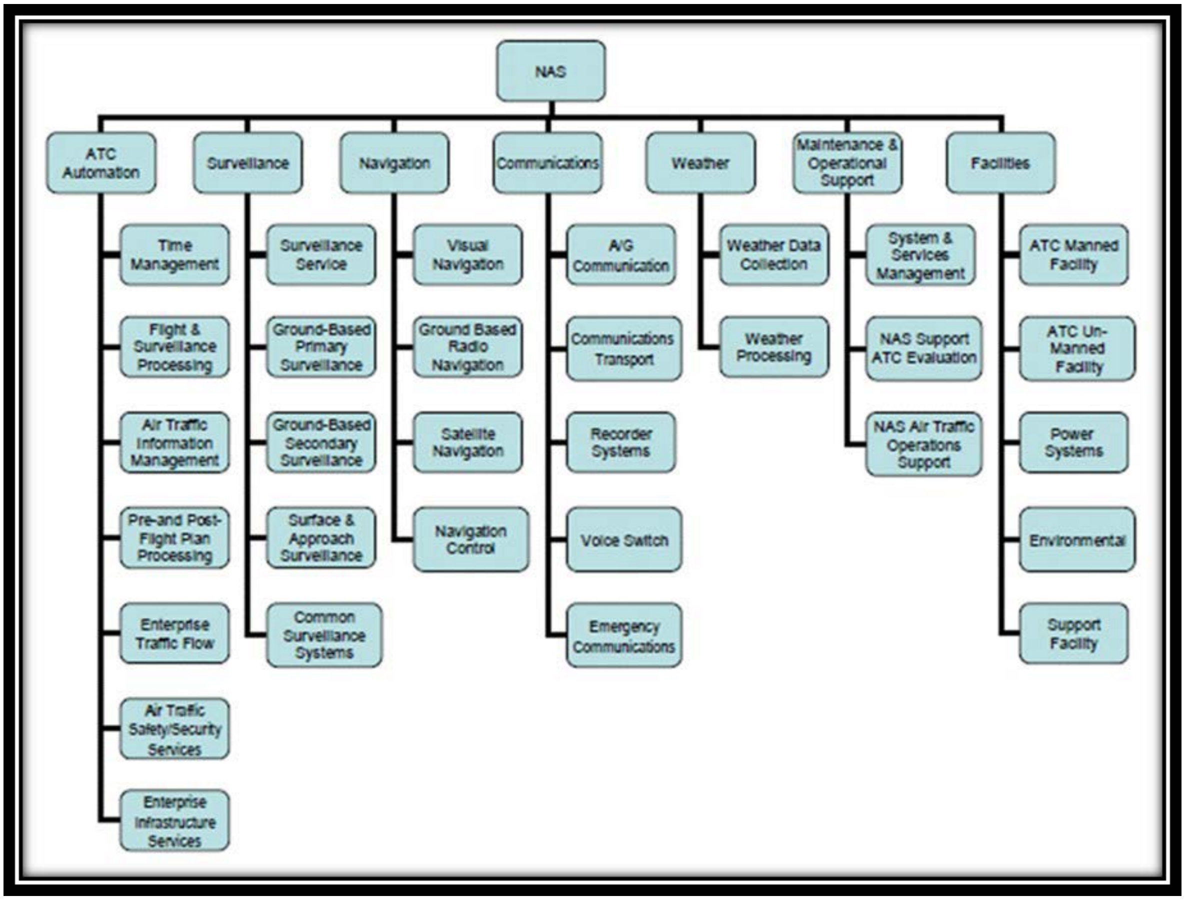

Figure 2: NAS Hierarchy to the System, Element, and Sub-element Levels (FAA)

The NAS hierarchy contains seven elements organized around the NAS Enterprise Architecture roadmaps. These elements represent the seven major functional groupings that comprise the NAS. These are Air Traffic Control Automation, Surveillance, Navigation, Communications, Weather, Maintenance & Operational Support, and Facilities. Each element is further broken down into sub-elements. (FAA, 2012).

- The term element refers to a major functional grouping, product or service of the NAS.
- The term sub-element refers to a collection of sub-systems equipment and/or services that fulfills a common purpose—these may or may not be collocated and may be leased from a vendor.
- The term sub-system refers to an individual device or several integrated sets of devices that are a relatively independent, identifiable entity within a sub-element, such as Standard Terminal Automation Replacement Systems (STARS), Mode-S Sensor, etc.

These sub-systems perform a cleanly and clearly separated function, involving similar technical skills or a separate supplier. All of the NAS sub-systems, functionality, and interfaces of an element are contained within one of its sub-elements. Figure 2 shows the partitioning of the NAS into the seven elements and their successive sub-elements.

Description of NAS System Hierarchy Elements

The following sub-sections describe the elements of the NAS hierarchy in terms of their sub-elements and their main functions. The sub-elements providing the functional capabilities of each element are in turn described in terms of their main functionality and interfaces with other sub-elements. Finally, the detailed view of the NAS Hierarchy diagram depicts NAS sub-systems organized within their respective sub-elements based on their primary function. Where applicable, the NAS Hierarchy also depicts NAS sub-system variants; key components and functions are identified as "V—Variant Name," "C—Component Name," and "F—Function Name."

5.4.1 Air Traffic Control Automation Element

The ATC Automation element provides ATC functions including air traffic control, flight service, traffic management, time management, and information management functions. It includes seven sub-elements to support air traffic controller operations and pilot situational awareness. These sub-elements perform their functions by receiving and processing data from the Surveillance, Navigation, and Weather sub-systems. The ATC Automation sub-systems rely on the Communications sub-systems to send and receive both voice and data transmissions.

The seven sub-elements within the ATC Automation element are as follows:

- Time Management;
- Flight & Surveillance Processing;
- Air Traffic Information Management;
- Pre- and Post-Flight Plan Processing;
- Enterprise Traffic Flow;
- Air Traffic Safety and Security Services; and
- Enterprise Infrastructure Services.

The Time Management sub-element transmits accurate timing source data to sub-systems across the NAS that are critical to ATC services. Accurate timing is necessary for capability synchronization between systems and recording of historical/legal information.

The Flight & Surveillance Processing sub-element consists of NAS sub-systems that manage flight plans and associate them with live radar reports from Surveillance sub-systems in near-real-time. NAS sub-systems provide the position of airborne traffic detected in the terminal and en route airspace to air traffic controllers and pilots for use in controlling air traffic.

The Air Traffic Information Management sub-element consists of NAS sub-systems that collect and disseminate local and NAS-wide non-tactical air traffic information (e.g., Notices to Airmen [NOTAMs], aeronautical data, facility information, and administrative documentation) to air traffic controller positions without relying on manual methods (such as pen and paper) or computers that are not located in the controllers' primary work area.

The Pre and Post-Flight Plan Processing sub-element consists of NAS sub-systems that create, process, and disseminate NAS information (e.g., weather briefings, NOTAMS) to Visual Flight Rule (VFR) pilots who are not normally under ATC. These sub-systems process NAS information to aid pilots with pre-flight plan preparation and managing the flight.

The Enterprise Traffic Flow sub-element consists of NAS sub-systems that monitor and analyze air traffic demand on airports or airspace sectors. The Enterprise Traffic Flow sub-element is used to optimize NAS-wide traffic flow by rescheduling air traffic when situations arise (e.g., inclement weather, closed runways, and inoperable navigation or ATC equipment), which reduces airspace or airport capacity. Traffic Management Specialists at the Air Traffic Control System Command Center (ATCSCC) in collaboration with FAA air traffic field facilities and airline dispatch offices use these NAS sub-systems to adjust the demand on the NAS that could result in departure delays or the rerouting of aircraft for severe weather avoidance. These actions adjust the airspace/airport demand to available airspace/ airport capacity. Weather forecasts and other analysis tools are used to support the Traffic Management Initiative (TMI) decisions.

The Air Traffic Safety and Security sub-element consists of NAS sub-systems that collect and analyze safety and security-related data, conduct hazard analysis, and implement risk mitigation approaches.

The Enterprise Infrastructure Services sub-element consists of NAS sub-systems that provide enterprise-level service-oriented architecture that enables information sharing between the FAA NAS sub-systems and between FAA and external users. This sub-element provides a uniform single point of entry for Communities of Interest (COIs) to publish and subscribe to NAS Services and NAS data.

5.4.2 Surveillance Element

The Surveillance element is composed of five sub-elements that detect and report the presence and location of targets (i.e., aircraft) in the air and on the airport surface movement areas. The data collected and created by the Surveillance element support users such as pilots and air traffic controllers via integration and data sharing with sub-elements within the ATC Automation element.

The five sub-elements within the Surveillance element are as follows:

- Surveillance Service;
- Ground-based Primary Surveillance;
- Ground-based Secondary Surveillance;
- Surface and Approach Surveillance; and
- Common Surveillance Systems.

The Surveillance Service sub-element consists of NAS sub-systems that provide both air and ground aircraft position information and other air traffic management information for pilot situational awareness and ATC. This includes information such as azimuths and trajectories, traffic information service-broadcast (TIS-B), and flight information service-broadcast (FIS-B).

The Ground-based Primary Surveillance sub-element consists of NAS sub-systems that detect and report the presence and location of targets (i.e., aircraft) in the terminal and en route airspace.

The Ground-based Secondary Surveillance sub-element consists of NAS sub-systems that detect and report the presence and location of targets (i.e., aircraft) in the terminal and en route airspace through interaction with aircraft transponders that reply and provide identification and altitude data of the transponders. The aircraft identification and position information is forwarded to the appropriate ATC automation subsystems.

The Surface and Approach Surveillance sub-element consists of sub-systems that serve to monitor and control the movement and position of aircraft and other vehicles on the airport surface movement area.

The Common Surveillance Systems sub-element includes sub-system equipment that is part of the Surveillance Facility but is not exclusive to a specific radar variant/model.

5.4.3 Navigation Element

The Navigation element is composed of four sub-elements that provide visual and instrument-based guidance to pilots during all phases of flight operations including airport surface navigation. The Surveillance element shares surface movement radar data with the Navigation element to aid pilots in navigating safely through airport surface, departure, and arrival operations.

The four sub-elements within the Navigation element are as follows:

- Visual Navigation;
- Ground-based Radio Navigation;
- Satellite Navigation; and
- Navigation Control.

The Visual Navigation sub-element consists of sub-systems that use lights as the primary means to enable pilots to visually identify and navigate along approach paths, runways, and surrounding air traffic controlled runway environments (airport movement areas).

The Ground-based Radio Navigation sub-element consists of ground-based sub-systems, such as VORs, that transmit radio signals to aircraft avionics that in turn provide pilots with visual and aural indications to aid en route navigation, airport approach, and precision landing operations.

The Satellite Navigation sub-element consists of sub-systems that use Global Positioning System (GPS) Satellite-Based Augmentation technology that interact with GPS-based aircraft avionics to enable aircraft to determine their 3-dimensional position with an accuracy that will support precision and non-precision approaches and reduced longitudinal separation throughout the NAS.

The Navigation Control sub-element consists of sub-systems that monitor and control airport navigation, lighted aids, and power systems.

5.4.4 Communications Element

The Communications element is composed of five sub-elements that perform transmission or recording functions for voice and data communications within and external to the NAS. These communications support connectivity between the following five sub-elements within the Communications element and are as follows:

- Air/Ground Communications;
- Communications Transport;
- Recorder Systems;
- Voice Switch; and
- Emergency Communications

The Air/Ground Communications sub-element is composed of sub-systems that support wireless air-to-ground communications for both voice and data communications. Individually, these systems handle different types of communications (i.e., voice vs. data); have varying interfaces (i.e., human users vs. integration with other data systems); and serve widely varying purposes.

Aggregated, these systems handle all aspects of the air-to-ground communications link, from user interface to transmission to display.

The Communications Transport sub-element is made up of sub-systems and networks that carry voice and data communications between other sub-systems and NAS facilities. Some of these communications are contained completely within the NAS, while others involve external systems. The sub-systems within the Communications Transport sub-element handle the NAS' interfaces to external systems, including security, data validation, and other interface functions.

The Recorder Systems sub-element is responsible for handling the recording, archiving, and retrieval of voice communications that originate from or are received by the NAS. Due to their nature, these sub-systems are generally tightly integrated with NAS facilities.

The Voice Switch sub-element is made up of ground-to-ground voice switching sub-systems that provide air traffic controllers with ground-to-ground voice switching intra-facility (intercom) and inter-facility communications and remote control access to air-to-ground radio equipment for controller-to-pilot communications.

The Emergency Communications sub-element is made up of sub-systems that provide back-up communications for manned ATC facilities.

5.4.5 Weather Element

The Weather element is composed of two sub-elements that are responsible for acquiring, aggregating, processing, and distributing weather-related data to other sub-elements within the NAS. Weather-related data includes all meteorological and environmental information that contributes to pilot and air traffic controller situational awareness. The NAS hierarchy differentiates between weather-related sub-systems contained fully within the NAS and those provided by third-party service providers.

The two sub-elements within the Weather element are as follows:

- Weather Data Collection
- Weather Processing

The Weather Data Collection sub-element is composed of sub-systems that collect weather data through instrumentation. These sub-systems include radar, visual range indicators, ceiling indicators, wind shear indicators, and other sub-systems and components intended to detect and collect weather information. The Weather Data Collection sub-element relies on the Communications Transport sub-element to distribute weather information to the Weather Processing sub-element and other parts of the NAS that use the weather data.

The Weather Processing sub-element is composed of sub-systems that manage weather data received from the Weather Data Collection sub-element and external weather service providers. This includes the aggregation, analysis, distribution, and display of weather data. The Weather Processing sub-element is the primary means by which human-usable weather data is presented to users. This sub-element also relies heavily on the Communications Transport sub-element to receive weather data.

5.4.6 Maintenance & Operational Support Element

The Maintenance & Operational Support element provides support services to other elements of the NAS. This element also provides the capability to accomplish performance monitoring, certification, and control of FAA facilities from centralized work centers.

The three sub-elements within the Maintenance & Operational Support element are as follows:

- System and Services Management
- NAS Support ATC Evaluation
- NAS Air Traffic Operations Support

The System and Services Management sub-element represents the enterprise-wide maintenance and system management function. It monitors the health of all system elements and responds to failures and degradations of service in conjunction with Remote System and Services Management. Additionally, it restores service and provides logistics and preventative maintenance services to minimize system outages and degradation of services. It also monitors the health of external entities critical to the success of collaborative operations.

The NAS Support ATC Evaluation sub-element includes both real-time and off-line analysis of information gathered throughout the NAS system and from external entities. It is used to assess overall NAS system health and performance and also supports investigations.

The NAS Air Traffic Operations Support sub-element includes sub-systems that provide operations support to ATC operations and configurations support for sub-systems across the NAS (e.g., airport configurations analysis, procedures analysis, and route and obstruction analysis).

5.4.7 Facilities Element

The implementation of the NAS Architecture will result in significant change to airport environments, major buildings and structures, and remote facilities buildings. Airport operator plans, agency-developed airport master plans, and alternate designs of proposed structures will reduce the environmental impact on functional equipment facilities. The consolidation and relocation of facilities and equipment as proposed in the NAS Architecture will greatly reduce the total number of buildings and structures required to house and support the NAS elements. In-depth analysis of power, lighting, sound level, heating, and cooling requirements of facilities will result in cost-effective, energy-efficient facilities.

The five sub-elements within the Facilities element are as follows:

- ATC Manned Facility
- ATC Unmanned Facility
- Power Systems
- Environmental
- Support Facility

The ATC Manned Facility sub-element includes those facilities that house ATC personnel and critical NAS sub-systems contained within the Automation, Communications, Weather Information Management, and Maintenance & Operational Support NAS Elements.

The ATC Unmanned Facility sub-element includes those unmanned facilities that house critical NAS sub-systems contained within the Automation, Communications, Weather Information Management, and Maintenance & Operational Support NAS Elements.

The Power Systems sub-element encompasses the primary and secondary systems that generate or deliver power to the other NAS sub-systems and facilities. These include direct current systems, generators, alternate power sources, distribution grids, and commercial power provisioning.

The Environmental sub-element includes the ATC facilities environmental and fire control systems.

The Support Facility sub-element includes those support facilities that provide operation control centers, logistics, training, and testing support for critical NAS sub-systems contained within the other NAS Elements.

5.5 System Engineering (SE) Services

The FAA has several Systems Engineering (SE) guidance documents that describe SE processes, procedures, and reviews and provide for documentation content. These are methods and practices consistent with the development of large-scale systems in the Department of Defense (DoD) and other agencies. A summary of this material has been provided in Appendix B.

6. Services and Systems Affected by RPA Integration into the NAS

6.1 En Route Automation Modernization (ERAM)

6.1.1 Program Description

The ERAM system is the foundation of the FAA ATC environment. The ERAM system processes, coordinates, distributes, and tracks information on aircraft movements throughout domestic and international airspace. The ERAM system is key to the FAA's ability to implement new services and concepts to users.

The ERAM program has installed a modernized computer system that provides the essential automation infrastructure of the NAS. ERAM, which replaces the existing Host computer system, is the primary system for managing flights plans and controlling aircraft in en route airspace. ERAM processes primary and secondary radar data, matches that data to flight plans to create flight tracks, and provides these flight tracks to the radar display systems that allow en route air traffic controllers to safely and efficiently manage en route airspace. In addition to the radar display systems, ERAM includes an Electronic Flight Strip (EFS) system that provides flight strip-based textual flight plan data.

While the revised ERAM deployment will occur over FY 2011–FY 2015, the program has accepted and installed the system hardware at all 20 Air Route Traffic Control Centers (ARTCCs). ERAM will serve as the infrastructure hub for future automation capabilities to be deployed from the NextGen portfolio. During FY 2012 and FY 2013, ERAM developed software functionality to support the upcoming Initial Operating Capability of the Airborne Reroute and Ground Interval Management Spacing capabilities.

6.1.2 Major ATC Functions

Key ERAM functions include the following:

- *Flight Plan Processing (Input, Editing, and Removal*). ERAM accepts flight plans from NAS users and allows air traffic controllers to enter flight plans as needed. In addition, ERAM provides adaptable automated flight plan editing, e.g., assign preferential routes to flights between city pairs. Air traffic controllers can also, as needed, manually edit flight plans. When the proposed time of a flight plan approaches, ERAM activates the flight plan and sends it to the terminal automation system at the origin airport. Filed flight plans that go unused are automatically removed from ERAM when a timeout period is reached. Air traffic controllers can also manually remove flight plans.
- *Flight Tracking.* ERAM assigns transponder codes to flights to match radar position data to flight plans. The fused flight plan and track data provide the information that drives the radar display systems that air traffic controllers use to provide separation to aircraft in positive control airspace was well as to perform traffic management procedures that increase NAS efficiency. In addition, ERAM provides the capability for automated handoffs of flights between sectors.
- *Flight Data Management.* ERAM's EFS capabilities allow controllers to manage flight data without the use of paper flight progress strips. Paper strips are maintained by ERAM as a backup.
- *Conflict Alerts and Conflict Probe.* ERAM provides tactical conflict alerts in instances of potential loss of separation, as well as longer-term, strategic conflict probe capabilities.
- *Traffic Management System Integration.* ERAM maintains data interfaces with traffic management systems and provides traffic management information on the radar display systems of air traffic controllers.

6.1.3 Related RPA Needs

Enhancements to the ERAM system in support of RPA operations in the NAS are dependent on changes to policies and procedures beyond the scope of ERAM system upgrades. For example, changes to the NAS and International Civil Aviation Organization (ICAO) flight plan formats involve organizations from around the globe. Coordination of the changes is required to ensure interoperability across international airspace boundaries and systems. Further, enhancements to the ERAM system to support NAS and ICAO flight plans format changes will in turn require changes to external systems, such as commercial flight plan filing systems. Likewise, the identification of RPA aircraft on ATC systems such as EFS systems and radar display systems will require consideration of ATC procedures. If RPA are identified on ATC systems, then air traffic controllers need to know what actions are required of them. If no actions are required, then the purpose of the display of the information is in question. Unconventional flight plans, such as loitering and flying on-station operations, raise additional questions, such as where such operations are permitted. Finally, issues such as the need for additional ultra-high sectors for RPA operations are dependent on predictions of number and type of future RPA operations. Developing the capability to accommodate demand that doesn't materialize could result in the inefficient use of limited resources.

The policy implications for ATC procedures are also substantial. All of these issues are predicated on the assumption of the widespread adoption of RPA. A key step for preparing ERAM for RPA operations is a preliminary analysis conducted by the Volpe Center technical report "UAS Service Demand: 2015-2035" which characterizes the extent and types of RPA operations that can be expected in the foreseeable future. Another key step is the establishment of inter-organizational committees to begin working out the implementation issues from policies and procedures down to data format and system integration.

This NAS area requires the investment of additional requirement analysis and SE to fully understand the scope of the changes being discussed in this brief summary. It is strongly recommended that additional study resources be made available for this purpose.

It is also recommended that early controller workload studies be initiated to review alternative controller approaches. This would involve review of results achieved in National Aeronautics and Space Administration (NASA) studies that have touched the controller workload issues.

6.1.4 Conclusions and Recommendations

For RPA to operate safely and efficiently in the NAS, several enhancements to the ERAM system will be required:

- ERAM modifications will be driven by the need to accept, process, and display lengthy and complex RPA flight plans that include automated flight profile contingencies to the air traffic controller.
- ERAM must be modified to display the next 20 minutes of an aircraft's projected flight trajectory on a controller's display suite.
- ERAM must incorporate the ability to display, review, modify, and approve a RPA flight plan request originating in an en route center, including underlying terminal, airspace environment as a 24-hour file and fly replacement to the current constrained COA process now in use to approve domestic RPA operations.
- NAS flight plans and ICAO flight plans will require modification of FIXM to include a variety of changes responsive to RPA and ATC needs. These include RPA nomenclatures to label hundreds of latitude and longitude coordinates sequentially with associated estimated times and flight profile contingencies associated with each fix or node.

- NAS flight plans and ICAO flight plans and processing systems will need to be enhanced to accommodate unconventional flight plans accommodating FIXM requirements for RPA. Most notably, RPA orbits need flight planning definitions to determine orbit origin, radius and period of orbit.
- As RPA operations proliferate in the NAS, ERAM may have to be adapted to identify and manage the use of predefined airspace for holding/loitering flights or flights performing convoluted routes for survey or other missions. This includes means and methods for routinely defining and rapidly revising altitude blocks and lateral areas of airspace in support of RPA mission requirements.
- The performance characteristics of RPA aircraft classes and types will need to be added to the ERAM adaptation.
- The conflict probe and conflict alert models may need to be modified to account for the performance characteristics and/or reaction speed of RPA aircraft. This is especially true if the implementation of ground or airborne detect and avoid has impact on air traffic controller duties or authorities of responsibilities.
- RPA High Altitude Long Endurance (HALE) may drive a need to create ultra-high sectors for RPA operations.

6.2 Traffic Flow Management System (TFMS)

6.2.1 Program Description

The Traffic Flow Management System (TFMS) is the primary automation system used by FAA traffic managers for monitoring and assessing large-scale air traffic congestion and delay in the NAS. It houses a suite of decision-support tools that identify imbalances between capacity and demand, and furthermore allow the FAA to take action to mitigate these imbalances. TFMS relies heavily on departure delay procedures to constrain demand on overloaded NAS assets, or reroutes to better balance available airspace and airport capacity.

The FAA must maintain mission essential operations at its 81 TFMS-equipped ATC facilities for its customers and continue to provide enhanced TFM services. NextGen initiatives include modernization of the Traffic Flow Management Infrastructure (TFM-I), development of Collaborative Air Traffic Management Technologies (CATMT), technology refreshment, and development of new decision support tools. The automation and communication mechanisms provided by the TFMS support the decision-making process used to adjust flight schedules and/or routes as necessary. When the NAS is impacted by severe weather, congestion, and/or outages, TFMS has unique capabilities to predict chokepoints and to facilitate the collaboration and execution of mitigation initiatives with stakeholders, using common information displays and tools, to minimize NAS delays.

6.2.2 Major ATC Functions

NextGen capabilities identify, analyze, model, and prototype various aspects of the traffic flow management functionality and these are being implemented in TFMS. In addition, a TFM Roadmap and initial TFM Gap Analysis have been developed to assess the need for additional concept engineering activities. CATMT is the investment package for deploying NextGen mid-term TFM capabilities.

Key TFMS functions include the following:

- *Situational Awareness.* TFMS allows traffic managers to monitor traffic flows. The geographical display feature of TFMS, the Traffic Situational Display (TSD), allows traffic managers to create custom map displays for various purposes. Users can, for instance, monitor the arrival or departure flow into an airport or Center. They also can create a custom geographical shape (a line, a polygon, etc., including altitude ranges) called a flow evaluation area (FEA) and monitor all flights predicted to traverse the shape. Users can create multiple maps and monitor multiple flows on each one. A wide range of options for color coding flights and displaying text-based information are available to users.

- *Airport/Airspace Capacity Management.* Localized, sector-based congestion issues are monitored via the Monitor Alert function of TFMS. Monitor Alert provides traffic managers with warnings when the number of aircraft in a sector is predicted to exceed sector capacity. For larger en route capacity/demand imbalances, often the result of convective weather, TFMS provides the ground delay program (GDP) and airspace flow program (AFP) functionalities to traffic managers.

  When airport or airspace demand exceeds capacity—such as during periods of peak demand or inclement weather—traffic managers will institute GDPs and AFPs via the TFMS Flight Schedule Monitor (FSM) component, or alternatively issue National Reroutes to restructure en route flows bound for specific airports. GDPs assign departure times to flights bound for a capacity-constrained airport, while AFPs assign departure times to flights needing to traverse a capacity-constrained airspace boundary. The collaborative decision making (CDM) process allows flight operators to assign priorities across their flights impacted by a GDP or AFP. While GDPs, AFPs, and Reroutes address the majority of the capacity/demand imbalances, their precision at the arrival airport is often inadequate to fully solve the problem. Traffic Management Initiatives (TMI) such as miles-in-trail (MIT) restrictions and time-based metering (TBM), executed by other NAS automation capabilities, are then used more locally in concert with GDPs to smooth out smaller-scale traffic flow discrepancies.

6.2.3 Related RPA Needs

The existing TFM toolset will need to overcome the following challenges to meet the FAA's mission and customer expectations for successful RPA integration: continued timely development and integration of sophisticated decision support tools (DSTs) to minimize NAS delays and improve efficiency, obsolescence of existing TFM system software architecture, near-term sustainment limitations of existing TFM Infrastructure, and fiscal pressures forcing a reduction in the cost of ownership.

The impact of RPA flights' TFMS functionality is largely dependent on the types and volume of their operations. If the volume is low, then the impact will be minimal and likely can be handled by exception. However, if the volume is, as expected, substantial, then the types of RPA flights will determine the priority of the impacts on TFMS. If most RPA traffic will originate and end at low-demand airports, then the primary impacts will be in the en route environment. On the other hand, if RPA traffic includes a large cargo component, then the impacts on the busiest airports, and the TFMS systems such as TBFM and FSM that are used to manage that traffic, will be substantial. Understanding and being proactive to the nature of future RPA flights is the key to planning for their impacts on TFMS.

It is expected that RPA flights, like traditional piloted flights, will be subject to TMIs when they compete for constrained NAS resources. TMIs can impact flights at the origin airport, in en route airspace, and in the arrival phase of flight. To maintain the efficiency and effectiveness of TMIs, traffic managers and TFMS will have to adapt to the key distinguishing characteristics of RPA flights.

6.2.4 Conclusions and Recommendations

For RPA to integrate efficiently into the existing TFM process, several enhancements to the TFMS system will be required.

- The performance characteristics of RPA aircraft classes and types will need to be incorporated into the TFMS. Mission-driven performance requirements may alter baseline TFMS assumptions and functionality and flight trajectory modeling. Similar to ERAM, lengthy RPA flight plans will need to be handled by TFMS.
- RPA aircraft mission needs will likely impact sector capacity and thus the TFMS Monitor Alert functionality; RPA impact on sector capacity will have to be studied, and the Monitor Alert function may have to be modified to account for the presence and nature of the RPA aircraft missions.
- Non-standard flight patterns, such as holding represented by orbiting or loitering flights, could also impact sector capacity and the Monitor Alert functionality of TFMS. Further, the situational awareness functionality of TFMS would need to be able to display such operations as well as their operating areas.
- Some RPA flights will likely be unscheduled and will be generated on a 24-hour or less notification; as a result these flights will impact how pop-up flight traffic is modeled in GDPs, AFPs, and CTOPs. It may be that RPA flights simply increase the volume of pop-up traffic, but it is also possible that RPA flights will require special consideration.
- Given the complexity of RPA missions, there may be a need to establish a 24-hour file and fly notification or request system that would allow an originating Instrument Flight Rule (IFR) facility to review and approve a RPA flight profile and timing 24 hours in advance of a mission conducted within high-density airspace environments.
- Due to the current lack of understanding of future RPA operations in the NAS, it is difficult to determine which TFMS functions will be most impacted.
- There are a few shortfalls that can be identified now, including (1) the ability for the TFMS Traffic Situation Display (TSD) to identify and annotate RPA flights, including flights flying non-traditional flight plans; (2) the ability for TFMS to model RPA flight characteristics; (3) the ability for TBFM to model RPA time-based metering capabilities; and (4) the ability for GDPs, AFPs, and CTOPs to account for RPA demand.

6.3 NAS Voice System (NVS)

6.3.1 Program Description

The current switch infrastructure within the NAS consists of 17 different types of switches. Each type of switch has a different logistical support structure, resulting in an extensive inventory of parts needed to support each system as well as an engineering workforce that is capable of maintaining each switch type. This infrastructure is aging, with some switches being more than 20 years old and experiencing obsolescence issues. This requires engineering analysis and modification of systems to continue to operate these systems. As they age, the systems are experiencing increasing failures of parts and increasing site visits for repairs, resulting in higher maintenance costs. Additionally, the current inventory of switches does not support the future ATC operations as outlined by NextGen. These switches cannot be networked to allow for the flexibility that will be needed for future NAS operations, including dynamic re-sectorization, facility backup, and resource re-allocation.

NVS will provide voice communications services to Air Traffic Control Specialists (ATCS), supervisors, and ancillary ATC operators in support of continuous ATC operations in the terminal and en route domains of the NAS. Voice communications connectivity will be provided to aircraft flight crews and RPA operators through air-to-ground radio circuits or equivalent network connections. Voice communications connectivity between ATCS, supervisors, and traffic managers will be provided through access to intra-facility and inter-facility ground-to-ground voice circuits or equivalent network connections. The future ATC voice switching systems must be able to provide timely and direct pilot-to-controller voice and data communications via Voice over Internet Protocol (VoIP). [Technical Report Version 0.1, September 2013, DOT-VNTSC-DoD-13-01]

The NAS Voice Switch program will allow FAA to achieve voice switching modernization objectives, such as a network-based infrastructure, as well as to evolve toward a flexible communications routing architecture that supports dynamic re-sectorization, resource reallocation, airspace redesign, and the NextGen vision (e.g., improving flow capacity).

Today's ATC-related voice switching system is composed of the following components:

- Integrated Communications Switching Service;
- Small Tower Voice Switch;
- Rapid Deployment Voice Switch;
- Enhanced Terminal Voice Switch (ETVS);
- Interim Voice System Replacement;
- Voice Switch Bypass;
- Voice System Control Switch (VSCS); and
- VSCS Training and Backup Switch.

Although these components use digital technology today, they will be replaced by the NVS, which offers state-of-the-art data networking approaches such as VoIP. However, the full system replacement may not be fully accomplished until 2027. The program has been envisioned in two segments. Segment 1 provided a demonstration of the technical requirements. This included the initial technical requirements to perform VoIP call connections and channel bridging. The work plan of Segment 2 will perform the first article testing, evaluation, and then deployment.

6.3.2 Major ATC Functions

Air traffic controller-to-pilot communication systems are used for strategic, tactical, and informational exchanges between an air traffic controller and a pilot. This communications link may be part of an airport, terminal area, en route, or oceanic airspace. Today, in domestic airspace, the open and close of a communications exchange takes place in seconds even though the channel is a shared, common access radio channel. Pilots listen for a "close" before keying their radio to start a new call. Once a radio is keyed (push-to-talk), other parties on the shared channel are in effect jammed from speaking, but can hear the other pilots' exchange with th24e controller. In doing so, there is a party line situational awareness afforded to the pilot as to the actions of other aircraft in the same sector. This communication system enables the controller to provide clearances and to request changes in the aircraft's flight path in order to maintain safe separation.

6.3.3 Related RPA Needs

Today's air traffic controller-to-pilot communications are exchanged over Very High Frequency (VHF) or Ultra High Frequency (UHF) analog voice radios. In the future, this voice will be augmented by a VHF data link known as the FAA Data Communications Program (Data Comm). These communications are routed over ground landlines to remote air-to-ground communication sites where radio transmitter and receivers are located to broadcast communications directly to the aircraft and pilot. These are referred to as Line of Sight (LOS) communications. Communications are limited by the power of the transmitters, sensitivity of the receivers, the distance of the aircraft from these ground transceivers, and the direct or clear view of the aircraft's antennas from the radio transceivers. This is the nature of the terrestrial communications network used by ATC.

In the case of RPA, the LOS means communicating not with the RPA but with the pilot located on the ground in reasonably close proximity to the radio transceiver. When this distance increases, communication is relayed through the RPA. This relay can use VHF or UHF to the RPA and then be rebroadcast using a number of other means or methods to reach to and from the pilot's location on the ground. This communications relay is referred to as Beyond Line of Sight (BLOS). Other means or methods for two-way communications relay may mean any combination of analog or digital voice via satellite or terrestrial communication systems.

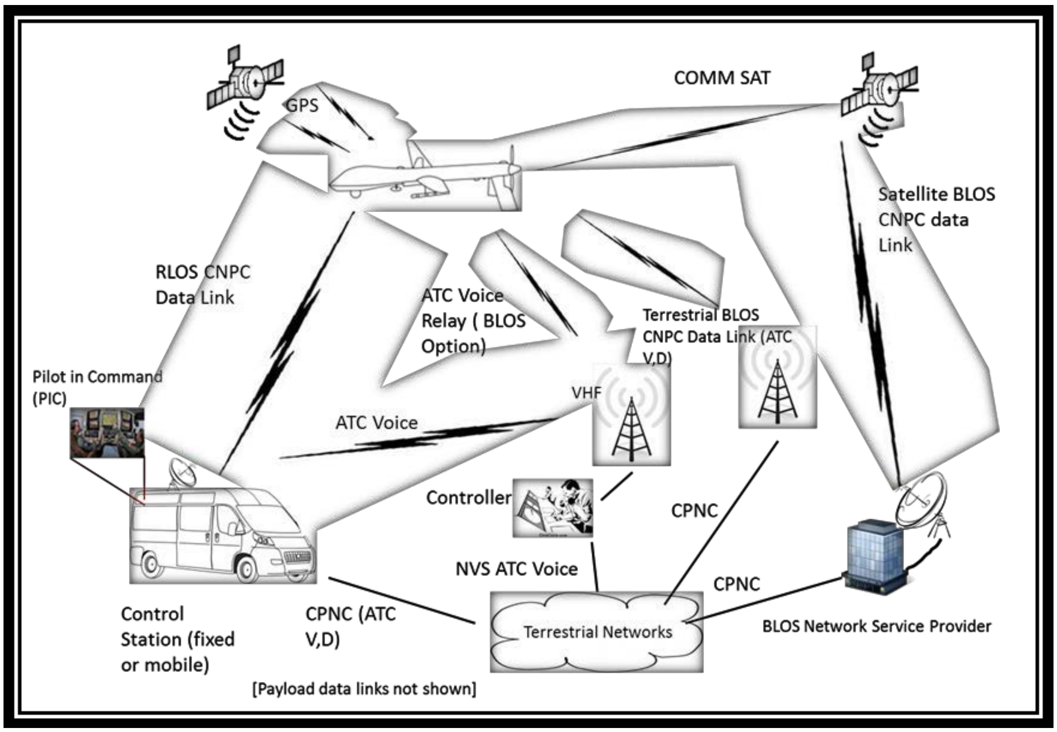

Figure 3: RPA Connectivity for ATC Communications and Control Non-Payload Communications

The RPA NAS integration ConOps, depicted in Figure 3, is still in draft status. At this time the following potential shortfalls can be identified. These may have been intended to be resolved as the NVS design proceeds, and additional discussions with the FAA NVS program are required. At this time, these are items for further analysis:

- The RPA NAS integration ConOps is not yet finalized, which could delay introduction.
- The call establishment process needs to be reviewed for possible use and transfer of directory updates. It also is assumed that many Pilots in Command (PICs) will connect through mobile service providers.
- How will the controller know the connection number for the pilot, and will the pilot be able to reach the proper controller (needed for drop out or failure recovery)? It is assumed that the pilot phone number as well alternative pilot numbers will be provided in the flight plan filing process. This contact number information should be presented in the controller display (or on the data block). The intercom selection could be automatically set to dial out to the pilot when a

handoff is occurring. The tail numbers, flight IDs, or ICAO addresses need to be matched to VoIP pilot numbers. How the handoff is to be performed between VoIP calls and controller across sectors is not clear.

- Connection changes for airport to terminal to en route and the use of VoIP techniques is not clear.
- It is expected that calls will need to go through a secure gateway to separate NAS and non-NAS network connections.
- RTCA SC-228 C2 Minimum Operation Performance Standards (MOPS) that include the NVS approach will need to interoperate and adopt FAA NVS requirements. The current forecast for the MOPS publishing is 2018.
- The sector-to-sector handoff requirements will require interaction with the ATC supporting systems (e.g., ERAM, STARS).
- Monitoring of radio guard per sector of flight must be included.

For the envisioned NextGen future, which will have RPA operations in high-density controlled airspace, it is necessary to make the RPA ATC voice communication capabilities an imbedded functionality of the NVS. During the transition from RPA accommodation to NAS integration, and in sectors for which there are fewer RPA operations, the use of relayed LOS or terrestrial networks with UA relay can be used. However, the controller voice intercom will have to be able to distinguish which connection method the RPA is using.

As part of the NVS Segment 1 work efforts, the FAA has conducted a Controller Working Group activity to set possible solution approaches for addressing RPA voice connection. These were guided by an effort to make no changes in controller workload. The work of this group set direction for the items listed in the above bullets.

Finally, as described above, there is not any ongoing planning for the construction of a wide area communication service using ground networks either by a private service provider or by government support. The only solution in this case would be for each RPA to procure or install an infrastructure. Each of these approaches would have to be separately certified as part of the RPA applicant's certification process.

It is noted that the FAA has performed a preliminary RPA and radio network demonstration project [A.R. Murray, "Voice Communications Solution for RPA Integration in the NAS," The Journal of Air Traffic Control, Spring 2014, Volume 56, No.1]. However, the approach demonstrated would require additional planning and a finding for an FAA-provided common use system.

Voice communication is only one of the several communication and networking areas related to FAA future development in supporting RPA within the NextGen Infrastructure. The major upgrades planned for NextGen include the Data Comm Program, the ground radio infrastructure under the NEXCOM, and the FAA Telecommunications Infrastructure (FTI) upgrades to supports the SWIM architecture including functions such as NEMS and the NextGen Enterprise Security Gateway (NESG). Another FAA project in the earlier concept validation phase is the Aircraft Access to SWIM (AAtS). AAtS may have useful features to connect NAS information to the pilot. However, the envisioned implementation would be via connectivity and information system functionally offered by a non-government service provider.

Another important communications issue to RPA is in defining who will install and provide a terrestrial communications network to the RPA operators when they are operating in a BLOS mode. This has a companion issue in how radio frequencies already assigned to the FAA to support a nationwide air-to-ground connection by the communications network will be assigned to civil operator use.

NVS is critical to the future success of RPA integration into the NAS. Communications between pilots and controllers have remained one of the three major legs of technology (i.e., communications, navigation, and surveillance) that ensures ATC continuity of performance.

Effective RPA operations will need a ground-based connection between the pilot and controller for voice communications. NVS implementation of pilot to controller voice will be the only cost-effective method to integrate a ground-to-ground connection service.

In the FAA RPA ConOps, the FAA specifies that ATC communications be separate from the Command and Control (C2) Communications.

Additional analysis is needed to resolve not only the shortfall issues but also larger strategic communication issues and policies.

6.3.4 Conclusions and Recommendations

Although a continuation of the use of VHF and UHF radios between air traffic controllers and RPA pilots talking directly in a local airport environment is indistinguishable from manned aircraft, any RPA operations requiring communication relay through the RPA poses significant communications challenges in terms of communications availability, latency, and quality and the opportunity to sustain party line communications deemed critical to pilot situational awareness. These concerns drive the following NVS requirements to safely and efficiently accommodate RPA:

- Future ATC voice switching systems must be able to provide timely and direct ground-to-ground pilot-to-controller voice and data, including text messaging and communications via VoIP. This includes methodologies for enabling an automated transfer of communication for the RPA pilot between different control sector frequencies as well as a broadcast of communication over ATC radios to ensure that party line communications are maintained.
- Future communications must be secure. Authentication is considered a bare minimum requirement. Encryption may also be a high priority for C2 and payload communications.
- NVS must consider the parallel use of voice recognition to digitize and relay communications as textual messages in addition to traditional voice messaging.

6.4 Terminal Automation Modernization and Replacement (TAMR)

6.4.1 Program Description

Terminal Automation systems are essential for controllers to manage the operations at the nation’s busiest airports. The automation systems rely on information from radar and weather sensors, along with flight plan information for each aircraft to inform controllers of the aircraft’s location and intended flight path so they can safely and efficiently maintain aircraft separation at or near airports.

Terminal Automation Modernization and Replacement (TAMR) is an FAA effort that addresses technology to replace and modernize systems in such a manner that safety, capacity, and aging/obsolescence concerns with existing systems are resolved. The TAMR program provides a phased approach to modernizing the automation systems at the FAA’s TRACON facilities and their associated ATCTs throughout the NAS. TAMR addresses the common ARTS at 103 TRACONs and associated ATCT facilities with STARS to meet NextGen mid-term goals. TAMR will include a potential new, scalable system that will meet requirements for NextGen and other enhancements. (FedBizOpps, 2009)

6.4.2 Major ATC Functions

Terminal automation systems receive radar data and aircraft flight plan information for air traffic controllers at more than 162 radar control facilities and hundreds of FAA and contract towers. These systems provide air traffic controllers with comprehensive flight situational awareness. Controllers use this automation to provide air traffic services to pilots in the airspace immediately around major airports. The TAMR and STARS services and capabilities include, but are not limited to:

- Separation and sequencing of air traffic
- Target tracking and correlation
- Data integration
- Conflict and terrain recognition and resolution
- Real-time traffic display
- Weather advisories
- Performance modeling
- Trajectory estimation
- Radar vectoring for departing and arriving traffic

Future development may address the need to accommodate 4-dimensional trajectory-based operations (4DTBO) concept of operations with new system requirements and enhanced NAS automation interoperability requirements.

6.4.3 Related RPA Needs

The NAS will require a standard RPA performance database to provide the requisite aeronautical performance characteristic benchmarks. These performance data will provide the necessary computational values to the vector processors performing target tracking and correlation, performance modeling, and trajectory estimation algorithms. These standard data sets will seamlessly integrate with similar manned aircraft data sets that ultimately provide ATC with the means to consider real-time traffic displays, conflict recognition, and conflict resolution strategies.

Ultimately, these performance algorithms will address the need to accommodate 4DTBO. Under the NextGen ConOps, assuming enhanced NAS automation interoperability, RPA operations and interoperability within the NextGen NAS will be able to operate under a comparable body of 'file-and-fly' flight standards. Given the nascent emergence of commercial RPA markets, it seems clear that increased RPA traffic volume and expanded performance envelopes will potentially drive STARS and TAMR functional requirements and performance specifications toward increased processor bandwidth, cache access, and data communication throughput.

From the human factors, procedures, and certification perspective, the current shortfall in supporting RPA needs for STARS and TAMR is substantial. Flight standards for RPA, operational certification, and development certification collectively are at an immature state of development relative to the technical maturity of the RPA systems themselves. Moreover, the FAA must undertake development of extensive training programs for ATC professionals, Flight Standards District Office (FSDO) inspectors, and Aviation Safety Inspectors (ASIs). And of course, the FAA must integrate RPA flight standards into the current Flight Standards Information Management System (FSIMS) in addition to conducting the necessary operational safety assessments (OSAs) to ensure that the NAS maintains an acceptable level of risk.

From the technical side, the current system will need extensive testing and probably substantial modernization to the next generation of hardware and software algorithms to ensure sufficient processor bandwidth, on-board cache, data communication bandwidth, and server throughput to fully accommodate the increased aggregate traffic volumes projected due to growth of RPA, transport, and General Aviation (GA) traffic.

If these upgrades are not addressed, then NAS performance may be impaired. Potential performance degradation may include degraded airspace management efficiency, traffic congestion, compromised accommodation of weather and traffic-induced re-routing requirements, and impaired safety margins. Given the focus of NextGen on the terminal environment, there may need to be considerable effort to modify TAMR in response to the growing recognition of the critical safety, capacity, and efficiency needs within the terminal airspace environment. Considering the forecasted growth of small RPA and their mission needs covering populated areas, it is expected that a new emphasis must be made on creating controller tools and decision aids supporting this environment.

6.4.4 Conclusions and Recommendations

TAMR provides an excellent opportunity to rapidly insert critical RPA needs into the ATC systems to accommodate NAS integration of RPA. TAMR and the STARS platform continue to undergo a spiral development of capabilities that deliver considerable benefits to ATC that can absorb expansion of capabilities in support of RPA operations. These capabilities are listed below.

- TAMR and associated terminal automation systems could display, review, modify, and approve an RPA flight plan "off or on" an airport originating in a terminal airspace environment as a 24-hour file and fly as a replacement to the current constrained COA process now in use. These flight profile requests could be reviewed against airspace segmentation and use critical infrastructure locations, high population density areas, and 15-minute time critical periods to modify and approve low-risk mission profiles.
- With the deployment of Ground Based Sense and Avoid (GBSAA), TAMR may also be able to provide surveillance conformance monitoring for approved RPA flights within a terminal airspace environment. This may be essential for RPA operations conducted from airports when Airborne Sense and Avoid (ABSAA) systems are not active until reaching selected altitudes or airspace environments (e.g., for an RPA after 2020 using ADS-B for ABSAA in an airspace environment where ADS-B is not mandated).
- Terminal radars supporting TAMR and GBSAA, such as 3D primary radars, could be networked and used by the tower and approved RPA operators to provide RPA pilots with situational awareness for self-separation (e.g., local law enforcement using RPA under the FAA/Department of Justice (DOJ) Common Strategy to coordinate with the local air traffic control tower real-time).

6.5 Terminal Information Display System (TIDS) & En Route Information Display Systems (ERIDS)

6.5.1 Program Description

Currently, different Air Traffic domains use different systems for information display. Terminal facilities use either the Information Display System 4 (IDS4) or the Automated Surface Observing System (ASOS) Controller Equipment - Integrated Display System (ACE-IDS). FSS facilities have limited access to these systems as well, but they typically contain little FSS-specific information.

TIDS integrates several NAS weather sensors and operational data onto a single display platform. The information is used by several thousands of air traffic controllers. The IDS-4 system is one of the largest automation systems used by the ATC system and must be sustained in order to continue providing the same level of service to the flying community. However, IDS-4 is one of the NAS systems that is becoming obsolete, increasingly difficult to repair or maintain, and unable to accept new functionality.

ERIDS is a real time, interactive, electronic information display system that is used as a replacement for paper sources of information. ERIDS provides controllers, supervisors, and traffic managers with access to aeronautical data, weather data, airspace charts, NOTMs, PIREPs, and other sources of ATC information. The national deployment of ERIDS will be an important tool for providing the early benefits of improved productivity and efficiency by distributing important information to air traffic controllers electronically. Reducing controller time spent accessing this information and improving the quality control of the information will increase productivity and controller efficiency during periods of increased traffic loads.

6.5.2 Major ATC Functions

The FAA acknowledges information-display automation as a positive step toward shared situational awareness in a more complex NAS capable of handling increasing volumes of air traffic, including RPA. The nationwide deployment of ERIDS at en route air traffic controller workstations is aimed at producing results in the form of improved system safety, system efficiency, reduced workload, and improved air travel experience for the flying public.

The ERIDS architecture leverages existing COTS software and hardware, with the goal of minimizing custom coding and maximizing flexibility. ERIDS integrates data products from various sources including the FAA and other government organizations as complete products. This strategy reduces the ERIDS processing requirements on both the server and client ends and retains original agency data certification in the process.

6.5.3 Related RPA Needs

Information systems that provide air traffic controllers with rapid access to operational information, such as TIDS or ERIDS, are the only near-term source of critical RPA-related operational information. Current flight plan information that supports manned aircraft operations does not provide all of the information that an air traffic controller may need to safely provide ATC services to a RPA in a mixed manned and unmanned aircraft environment.

The enhancement of TIDS and ERIDS is critical and timely given the inability of controllers to query pilots directly via ground-to-ground VoIP until NVS is fully deployed. The major concern is now the reliance on communications relays through the RPA vehicle may not be possible with an associated RPA communication link failure, especially when satellite communication is used.

6.5.4 Conclusions and Recommendations

In recognition of the length and complexity of many RPA missions, the FAA should provide the following capabilities to TIDS and ERIDS to ensure that air traffic controllers have immediate access to RPA flight information that may significantly affect air traffic controllers' duties, authorities, and responsibilities:

- RPA flight plan information related in excess of that provided by ERAM must be readily available to the air traffic controller.
  - This information should include all of the waypoints filed in support of the RPA mission (this could be 500 latitude/longitude fixes that define a mission length of 24 hours or more).
  - Waypoint should be numerically coded in the sequence flown with an associated Estimated Time of Arrival (ETA) for each fix, including orbiting delays.

- The route of flight should be sequenced so it displays the current estimated fix based on real time.
- A real-time display for the next 20 minutes of flight plan route should be optionally displayed to confirm the actual route segment that is being flown.
- Contingencies (one or more) for each waypoint must be available to be optionally selected and displayed by the controller to accommodate for a lost C2 communication link, vehicle or operational anomalies, or system/sub-system derogated modes or failures.

- C2 information supporting an RPA mission must also be readily available to the air traffic controller, including the following:
  - Contact information and means and methods to contact the RPA pilot or operator;
  - Key information if not routine about the mission and mission profiles to enable the air traffic controller to understand mission needs and effects on ATC operations; and
  - Information concerning any performance characteristics or limitations that affect ATC.

6.6 System Wide Information Management (SWIM)

6.6.1 Program Description

Point-to-point data connections and operations characterize today's NAS. In contrast, a SWIM network can enable multiple parties to share information by linking individual systems and creating a common, net-centric data exchange service. To support the NextGen long-term vision of shared common knowledge of situations, SWIM uses an Internet-like network to make information accessible, secure, and usable in real-time for all users. For example, shared networks would enable FAA to share information with the international aviation community, other government agencies, and the aviation industry.

SWIM will help to transition the NAS to network-centric operations by providing the infrastructure and associated policies and instructions to enable NAS-wide information sharing. Underlying this transition is a scalable, standards-based network architecture that seamlessly and securely connects users with the NAS information they need. SWIM provides advanced information distribution and sharing capabilities to support a wide range of ATC activities, such as negotiating and tracking flight plans, tracking aircraft movement via surveillance, and sharing weather information with NAS service providers and users. SWIM must be able to rapidly move critical RPA information around the NAS to provide the right information to the right person at the right time and in the right format.

SWIM is vital to the achievement of Department of Transportation (DOT) and FAA strategic plans and the future evolution of air transportation management in the nation. The current FAA systems and operations cannot support this vision as they are not network-enabled and are characterized by rigidly configured systems (communications lines, computers, and software applications). SWIM contributes to meeting the following NextGen objectives:

- Increase Predictability—SWIM will provide increased machine-to-machine interchange, supporting and disseminating decisions rather than current and less efficient human-to-human interactions. SWIM increases the likelihood that similar decisions will be consistent by enabling them to be based on the same data.
- Reduce Costs—SWIM will help to reduce infrastructure costs by reducing the number and types of interfaces, systems, and, potentially, facilities. Initially, SWIM will provide a common network capability, reducing operation and maintenance costs of the hundreds of current interfaces. New systems will interface with SWIM, saving future development costs and increasing

reusability and interoperability. Ultimately, redundant sources of data will no longer be needed and can be decommissioned.

- Shared Situational Awareness—SWIM will help to provide shared situational awareness so that all appropriate parties are privy to the same complete set of information.
- Collaborative Decision Making (CDM)—SWIM will help to enable CDM, which means that once all parties have access to the same information, they can efficiently make real-time decisions and quickly reach agreements. SWIM will also provide benefit to the FAA resulting from new SWIM Aeronautical Information Management (AIM) functionality resulting in a reduction of staff time through automated processes.

6.6.2 Major ATC Functions

The NAS legacy systems have individually optimized their own external data input and output exchanges and have defined exchange formats and data types. The operators and developers of the legacy systems understand the data handling requirements as well as the exchange rules and nuances as they pertain to their NAS automation platform. To effect the SOA transition, the FAA chose to start with a federated approach. This approach would begin to standardize the method of data exchanges within an overall framework or IT infrastructure of the NAS. With this standardization, the different NAS platforms could then interoperate to continue their legacy missions services while the additional features of a SOA where being added (e.g., features such as security and governance).

Once implemented, automated applications within the NAS systems can be developed with data sharing and interaction that does not require knowledge of the other NAS systems' technical hardware and software implementations. The implementation is phased into two segments. Each segment covers a grouping of the NAS automation platforms and information products. At present many of the NAS systems are publishing SWIM-compliant products. Figure 4 shows a summary of the NAS systems and SWIM. Included in the figure is the NESG. This gateway provides a "firewall" between the private NAS communications infrastructure and the public world of leased lines, Internets, or private networks owned by non-Federal organizations.

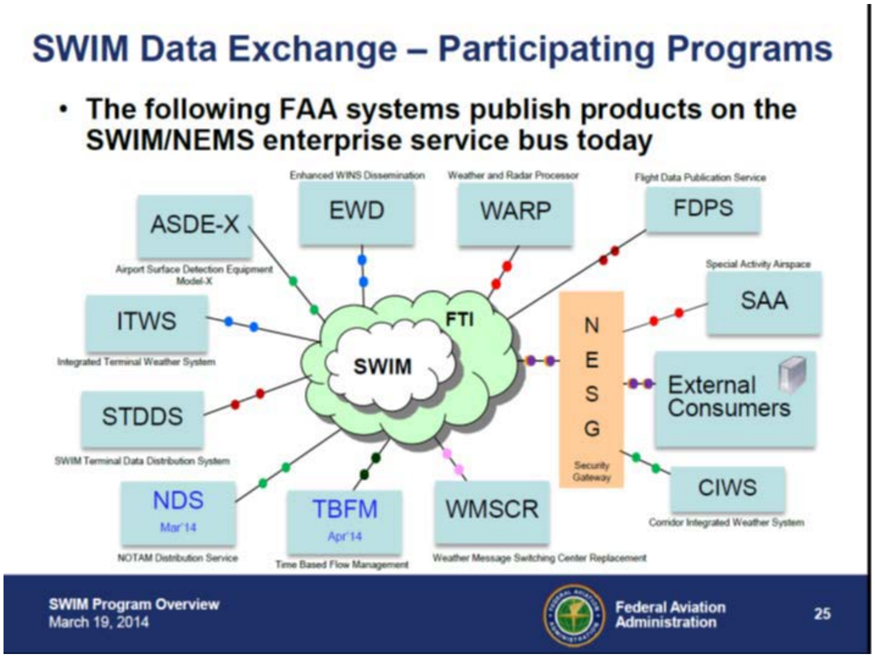

Figure 4: NAS Systems Having SWIM-compliant Products and Showing NESG

Source: FAA Briefing to RTCA NAC, 3-19-14

The SWIM architecture and standards at the top functional level provide the NAS with the following ATC functions:

- Open system protocol standards;
- Addressing Directory;
- Provisioning of Governance;
- Definition of security techniques; and
- Data sharing support for messaging exchanges to handle outage and restoral.

6.6.3 Related RPA Needs

The missions and operations of RPA are considerably different from those of commercial air transport. The missions are potentially lengthy and complex, requiring more detailed information to be presented and available to ATC to ensure safety and to support the service requirements of the broad nature of the RPA missions and their business models. In addition, the diversity of RPA in terms of types of vehicles and performance characteristics are expected to be far greater than that of manned aircraft.

These differences in missions and vehicles will drive greater information requirements for ATC to have the right information at the right place at the right time and in the right format. For example:

- RPA operations will cause changes in Flight Plan data content. These need to be added to the Flight Data Object in the longer term, after any systems handling the flight plans are adapted to the merging FIXM messaging standard.
- The pilot in command (PIC) will require connectivity to NOTAMs and other aeronautical information sources. Today these can be obtained for FSS or other publically provided sources.
- For safety reasons and to assist in maintaining the “well-clear” condition, providing a surveillance data connection to the RPA Control Segment needs to be reviewed. This could augment the TIS-B and or ADS-B IN for areas where reception on the ground is not possible.

6.6.4 Conclusions and Recommendations

SWIM must be able to provide both publishers and subscribers of RPA data with timely information and an information exchange that would be readily available to air traffic controllers and their support staff, including the following:

- User-provided detailed flight plan information associated with each RPA flight operation, including flight contingencies;
- User-provided information concerning mission needs and requirements to assist ATC in understanding how best to support user mission requirements;
- User-provided RPA vehicle information, including its operating characteristics, performance capabilities, and limitations;
- User-provided communications means and methods as well as contact information for pilots and operators; and
- ATC-provided airspace or operational constraints that could affect RPA missions and operations.

Under the standards of the FIXM and other Flight Plan submission changes, NAS internal data sharing is expected to include RPA-specific data elements. The basic FTI/SWIM/NEMS/NESG, in general, will be transparent to data elements exchange, as long they are included in messaging standards. However, how the PIC and the Control systems connect to the NAS communications infrastructure is expected to increase the demand for connections to the NESG.

The cockpit today is considered to be part of the NAS because the voice discussions connect to the NAS systems. The PIC will be supported by a ground-based voice connections infrastructure, by surveillance information, and by CPDLC or other data link messaging in the future. However, all of these connections will flow over public networks and will be considered to be “outside the NAS.” These exchanges will have to be adopted and carried over the FTI/SWIM/NEMS/NESG architecture. The NESG and connection to it are normally performed using VPN and require additional formation security practices to be followed. It is unclear how the PIC and related control will be impacted.

6.7 Flight Information Exchange Model (FIXM)

6.7.1 Program Description

FIXM is a global standard for achieving interoperable exchanges of flight information. The need for FIXM was identified by the ICAO Air Traffic Management Requirements and Performance Panel (ATMRPP) in order to support the flight information exchange as prescribed in the ICAO Document 9965, *“Manual on Flight and Flow – Information for a Collaborative Environment (FF-ICE).”* It is based upon a standardized (yet extensible and dynamic) set of data elements to increase interoperability and data exchange between systems. FIXM is part of a family of technology-independent, harmonized, and interoperable information exchange models and Extensible Markup Language (XML) schemas (alongside Aeronautical Information Exchange Model [AIXM] and Weather Information Exchange Model [WXXM]), designed to support the exchange of flight information between aviation stakeholders.

FIXM provides three main packages:

- The FIXM Conceptual Model that models in Universal Markup Language (UML) the operational language defined in the flight and flow–information for a collaborative environment (FF-ICE) provisions. It captures the operational entities and their relationships expressed in terms understandable by operational stakeholders, ensuring consistency across point-of-view, semantic interoperability, and consolidation/harmonization activities for the whole FF-ICE concept of operations.
- The FIXM Logical Model captures in UML all the constructs that are required for system-to-system exchanges of flight information at global level, including air-ground aspects, in a form that is technology-agnostic. It details the data entities, their attributes, and containment relationships, and may capture additional constraints (business rules) where appropriate. The FIXM Logical Model defines an extension mechanism that allows data entities and attributes to be added to the core model.
- The FIXM XML schemas provide the physical representation in XML of the constructs described in the FIXM Logical Model, but restricted to ground-to-ground exchanges. It does not support flight information exchanges between air-to-ground, although in some cases the information originally comes from the aircraft. The FIXM XML schemas are programmatically derived from the FIXM Logical Model (or from a subset of it).

FIXM supports a “core + extension” mechanism as described below:

- The core part contains Flight Information data that is globally standardized and exchanged between FIXM stakeholders.
- The extensions supplement the core FIXM model in order to support additional requirements from regional stakeholders.

6.7.2 Major ATC Functions

FIXM represents a new international protocol for collecting, processing, and disseminating information related to aircraft flight movements within the United States and around the world. FIXM broadens the amount and detail of information associated with an aircraft and its movements on the ground and in the air to provide for enhanced delivery of ATC services as well as providing for more tailored services optimized for individual aircraft.

6.7.3 Related RPA Needs

Additional RPA Flight Data Elements (FDEs) will be required for data exchange between different ATC systems and ANSPs. The FAA will need to identify these additional requirements and provide updates for inclusion in FIXM. The timeline for FIXM releases is provided in Table 1. According to the current schedule, FDEs for RPA operations are planned for inclusion in FIXM v4.0, scheduled for release in August 2015. As described above, FDEs for current ATC and TFM functions for handling manned aircraft have been added or are in the review phase for inclusion in FIXM. Any additional FDEs that may be required specifically for RPA operations by these systems will need to be identified, reviewed, and proposed for inclusion in a timely manner in order to accommodate the proposed schedule.

Table 1: FIXM Timeline

Ver.	Target Release Date	Version Contents
1.0	Aug 2012	• ICAO FP 2012 • GUFI • NAS Flight Plan Data • Initial ED-133 element inclusions
1.1	Dec 2012	• Hazardous Cargo (Dangerous Goods)
2.0	Aug 2013	• ICAO 2012 ATS (15 remaining messages) • TFM (Strategic) • Fleet prioritization, TFM DE, CDM • Airport CDM (Euro control)
3.0	Aug 2014	• Surface data *(anything not covered in Airport CDM and TFM/CDM elements)* • ANSP to ANSP boundary crossing (tactical) • 4D Trajectories (1st package)
4.0	Aug 2015	• Security elements (1st package) • Unmanned Aircraft Systems (UAS) • 4DT (2nd package)
5.0	Aug 2016	• Flight capabilities (1st package) • Operator Constraints (1st package) • Operator Preferences (1st package) • Security (2nd package)
6.0	Aug 2017	• Operator SOP – TBD • Commercial Space
7.0	Aug 2018	• Inclusion of WX capabilities and constraints

The alternative to the inclusion of the additional RPA FDEs to FIXM is for the ATC and TFM systems to exchange such information in their native data format; however, this approach is inconsistent with the

FAA strategic initiative to support and adopt global standards. Later migration to AIXM/FIXM standards will impose additional costs on industry and FAA programs to respond once RPA-specific data is later released consistent with the global information standards. The longer the period the RPA data is available in a "native data format", the larger the installed base of users will be and the more difficult it will be for the FAA to migrate the RPA data to the global standard without significant external pushback.

6.7.4 Conclusions and Recommendations

FIXM can already support many flight plan elements for RPA such as unlimited number of waypoints with ETA for each, long duration missions, and changes of airspeed and/or altitude associated with designated waypoints. In view of future RPA mission needs and requirements that must be supported by ATC, the FIXM-related data issues need to be explored to extend the AIXM and FIXM datasets for the following:

- Provide the ability to identify a radius of orbit at a holding waypoint. In addition to the orbiting radius, this waypoint would have both an ETA as well as an associated Estimated Time of Departure (ETD) to indicate the period of time of the orbit.
- Provide the ability to denote and link externally to mission-related information such as contingencies (e.g., actions associated with lost link or system failures) that are defined at flight plan waypoints.

6.8 Air Traffic Control Optimum Training Solution (ATCOTS)

6.8.1 Program Description

The Air Traffic Control Optimum Training Solution (ATCOTS) program mission is to develop and maintain the most highly skilled air traffic controller workforce in the world. The ATCOTS program was developed to find a solution to the training needs of Air Traffic Controller candidates and existing Certified Professional Controllers (CPCs). Several factors drove the establishment of the ATCOTS program, including the need to shorten and reduce the cost of the certification process and evolve the training program to prepare for impending technology changes throughout the FAA.

The program goals are as follows:

- **Innovation**: Leverage current industry best practices to develop an innovative training service delivery solution.
- **Efficiency**: Achieve efficiencies by reducing the time and cost it takes to certify professional controllers.
- **Continuous Improvement**: Institute continuous improvement within the training program.
- **Performance Management**: Establish a performance-based contract management process.
- **Safety**: Continue to deliver skilled air traffic controllers to ensure air traffic safety.

6.8.2 Major ATC Functions

The Air Traffic Organization (ATO) is the operational arm of the FAA. It is responsible for providing safe and efficient air navigation services to 30.2 million square miles of airspace. This represents more than 17 percent of the world's airspace and includes all of the United States and large portions of the Atlantic and Pacific Oceans and the Gulf of Mexico (Federal Aviation Administration, 2014).

FAA ATO stakeholders include commercial and private aviation and the military. The ATC employees are the service providers—the 35,000 controllers, technicians, engineers, and support personnel whose daily efforts keep aircraft moving safely through the nation's skies.

6.8.3 Related RPA Needs

ATC training, qualification, and certification is mandatory for professional controllers working in control towers, TRACONs, and En Route Centers. These ATC professionals will need supplemental training and certification to ensure uniform understanding of RPA flight standards and RPA operational conformance against the relevant body of RPA procedural regulations. The mandated introduction of RPA to the NAS makes clear the need to plan, document, and promulgate a uniform policy doctrine regarding RPA operations in the NAS coupled with the requisite safety certification and operational standards.

> **Note:** Each year the FAA publishes a 10-year ATC Workforce Plan. The FAA's most recent plans contain no specific reference to RPA requirements, operational demand, or commercial expectations. The 2013 Report for 2013 to 2022 does not include any reference to unmanned aircraft systems, RPA, RPAs, drones, or robotic aircraft.

One of the key metrics of success for air traffic controllers is their ability to understand the operating characteristics and missions needs of the aircraft that they control. RPA vehicles are an entirely new and emerging challenge and in many cases are significantly different from the commercial air transport, business aviation, and general aviation manned aircraft that comprise the demand on the ATC system today.

6.8.4 Conclusions and Recommendations

In view of the emerging development of RPA and their introduction into the ATC system, there are a number of recommendations provided below to address their safe introduction and integration into the NAS.

- Provide for comprehensive initial and frequent recurrent training emphasizing these RPA topics:
  - Orientation and training on RPA mission types, including needs and requirements from an ATC perspective;
  - Operational or simulated training on new or modified ATC systems that support RPA operations and mission needs and requirements;
  - Training on new ATC policies and procedures covering RPA operations;
  - Orientation and training with emphasis on differing RPA vehicles types, operating characteristics, performance capabilities, and limitations; and
  - Training on RPA communications and C2 means, methods, alternatives, and contingencies.

6.9 Future Facilities

6.9.1 Program Description

Many of the ATC facilities maintained by the FAA are more than 50 years old, and are in need of remediation, replacement, or consolidation into new modern facilities that can advantage economies of scale. NextGen establishes a broad framework for the services, technologies, policies, procedures, and methods of operation that must be implemented by 2025 to achieve the national air transportation goals. This vision includes NextGen facilities as a key component of the strategy for supporting air transportation and enhanced operational decision-making between now and 2025

Since the flexible ground-to-ground and air-to-ground communications networks negate the requirement for proximity of air traffic facilities to the air traffic being managed, NextGen facilities will be sited and occupied to provide for infrastructure security, service continuity, and best deployment and management of the workforce. This includes co-locating several operational domains (e.g., en route, terminal) within a single facility.

Information systems facilitate the monitoring of infrastructure health, remote maintenance, and system resilience to maintain service availability and automatically alert the community about the status of NextGen assets. One key transformation resulting from NextGen is the ability to continue to operate the system with the loss of a limited number of key operational facilities. Network-enabled operations and infrastructure management services provide continuity of operations in the event of a major outage (such as a major hurricane or terrorist event).

6.9.2 Major ATC Functions

Air traffic controllers provide a variety of services to airspace users within the NAS from designated locations. Primary services by manned ATCTs are sequencing and spacing between aircraft to maintain a safe, orderly, and expeditious movement of air traffic. The primary responsibility of TRACONs and En Route Centers is the safe separation between aircraft flying IFR. In addition, these controllers provide additional services for safety and traffic advisories between known airborne aircraft involving aircraft flying VFR. Also, these controllers provide other safety advisories to all aircraft pertaining to weather and ATC systems status.

Most commercial air transport departs from an airport that has a tower that controls aircraft within about a 5-mile radius up to a few thousand feet. The aircraft then transitions to a TRACON, which provides ATC services until the aircraft climbs to about 10,000 feet no further than 60 miles from the departing airport. From there, the responsibility for ATC services is transferred to an ARTCC as the aircraft climbs to cruising altitude until is it ready to begin its descent into the arrival airport where the departure process is reversed.

6.9.3 Related RPA Needs

As previously mentioned, each year the FAA publishes a 10-year ATC Workforce Plan that is affected by future facilities. The FAA's most recent plans contain no specific reference to RPA requirements, operational demand, or commercial expectations. The 2013 Report for 2013 to 2022 does not include any reference to unmanned aircraft systems, RPA, drones, or robotic aircraft.

FAA real estate assets may likely be affected as new RPA-related systems are developed and deployed. RPA NAS integration may drive additional FAA manpower needs for positions of operations, coordination, and management. This may require additional physical footprints and infrastructure to accommodate new positions of operations, personnel, and their supporting systems.

There are very early concerns, as noted in this paper, that future RPA needs will drive FAA infrastructure changes. These changes in ATC system policies and procedures will likely drive changes to FAA's physical plant and infrastructure to house new operational positions and new equipment. Physical effects of RPA integration need to be assessed and planned early in the lifecycle process.

6.9.4 Conclusions and Recommendations

Although plans for large-scale realignments and consolidations are still evolving, the FAA must address key technical, financial, and workforce challenges to successfully implement the plan, including needs to identify and assess future effects in support of RPA integration and operation.

- First, the FAA will need to align ongoing construction projects with a plan to include RPA support since some projects overlap with the recently approved consolidation plans, creating the potential for duplication of effort and waste of funds.
- Second, the FAA will have to make key technical decisions related to areas such as airspace boundaries and automation platforms, which will have a significant impact on the costs and schedules of modernization programs. This will require coordination among the FAA's various modernization programs which the FAA has begun but not yet completed. An assessment of RPA requirements for ATC needs to be included.
- Third, the FAA will need to finalize cost estimates for individual integrated facility projects, given that the initial business case only provided preliminary cost data.
- Finally, the FAA will have to address the wide-ranging impacts that facility consolidations will have on its workforce and affected communities. While FAA is aware of these challenges, it is incumbent upon the Agency to mitigate them to the extent possible as its plans for large-scale consolidations evolve. As past consolidations have shown, not addressing these challenges will pose risks to achieving expected benefits.

More specifically, the FAA must consider the needs for operational systems within the TFM operational area to address RPA liaison and mission planning and approval. This is especially relevant as the FAA transitions from its current encumbered centralized COA process to a future 24-hour file and fly review and approval by originating IFR facilities. This transition would require new automation systems supported by new personnel for ATC RPA operational positions.

6.10 Next Generation Weather Processor (NWP) and Weather and Radar Processor (WARP)

6.10.1 Program Description

The WARP program provides accurate weather data to critical NAS programs such as ERAM, Advanced Technologies and Oceanic Procedures (ATOP), and User Request Evaluation Tool (URET). The current WARP system is operational at 21 ARTCCs and the ATCSCC and provides the following functions: provides the following functions:

- Integrates timely and accurate weather onto air traffic controller displays;
- Supports the TMU and the ATC specialists at the ARTCCs and the ATCSCC;
- Disseminates weather data to critical NAS subsystems;
- Provides current and forecast data to Center Weather Service Unit Meteorologists who support air traffic personnel; and
- Provides processing tools to consolidate weather data from several sources into a single, integrated display that supports air traffic operations.

The WARP program enhances safety, reduces weather-related delays, and improves CDM. The WARP weather functions furnish timely, accurate, and integrated weather products to other NAS systems. All operational WARP systems must stay current with the NAS while continuing to meet DOT/FAA strategic goals by implementing incremental WARP technical refresh activities addressing critical hardware and software obsolescence.

NextGen Weather Processor (NWP)
NWP will provide a common platform for processing aviation-specific weather observations and forecasts for use by ANSPs (including controllers and traffic managers) and NextGen DSTs. NWP will subsume the following weather processing systems:

- **WARP**: Provides en route weather data for use by ARTCC controllers and Traffic Management Coordinators; includes radar mosaic products. NWP will improve on current WARP functionality by incorporating Terminal Doppler Weather Radar (TDWR) and Canadian Radar (CANRAD) on top of the Next Generation Weather Radar (NEXRAD) to increase range and resolution.
- **Corridor Integrated Weather System (CIWS)**: Prototype capability providing 0-2-hour weather information for TFMS and associated users; includes convective observations and forecasts, storm growth and decay trends, and surface winter weather and precipitation products.
- **Integrated Terminal Weather System (ITWS)**: 0-1-hour weather information for TRACON controllers, including terminal area convective activity, winds, and critical safety alerts resulting from detection of hazardous weather.
- **Consolidated Storm Prediction for Aviation (CoSPA)**: Prototype system extending CIWS storm forecasts out to 8 hours using alternate modeling techniques.

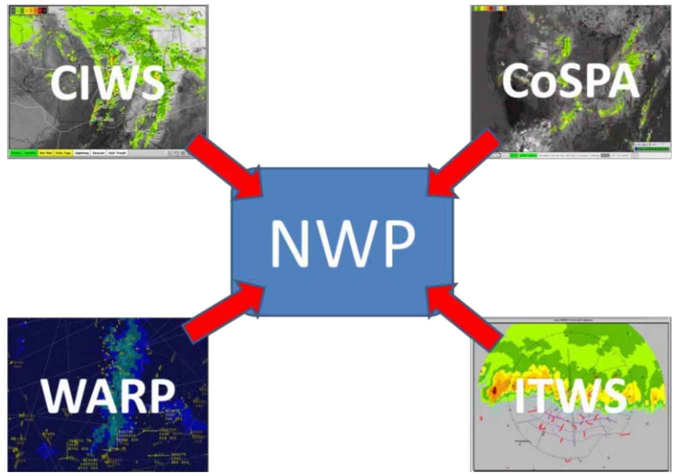

Figure 5: NWP Will Consolidate Weather Processing Functions of CIWS, CoSPA, WARP, and ITWS

NWP will also generate data required to create convective weather avoidance fields (CWAFs) using the Convective Weather Avoidance Model (CWAM).

Common Support Services—Weather (CSS-Wx)

A related component of the NextGen weather vision is CSS-Wx. CSS-Wx will be the single provider of aviation weather information for FAA users and decision support systems and will act as a hub for weather products produced by NWP. CSS-Wx will relay relevant data to NWP for processing. NWP will process the data and return processed weather products to CSS-Wx. CSS-Wx applies appropriate geospatial and temporal filters to the data and generates appropriate CWAFs before distributing the results to subscribers through SWIM. Subscribers can include FAA facilities, commercial aviation operators, and general aviators.[i]

6.10.2 *Major ATC Functions*

Both forecast and real-time weather information is critical to the safety, efficiency, and capacity of the NAS. Weather remains the number one cause of ATC delays and one of the major causes of aircraft accidents.

The FAA plays a major role in the collection, processing, and dissemination of aviation-related weather information to NAS stakeholders. Systems supporting these functions, which include NWP and WARP, serve to provide the FAA with timely weather products to aid in decision-making affecting the safe, orderly, and expeditious movement of air traffic. In addition, these systems are closely tied to TFM systems that monitor and meter the movement of air traffic throughout the NAS.

6.10.3 Related RPA Needs

The removal of a pilot in the cockpit also removes the ability to "see" from a traditional pilot's perspective. This affects many aspects of flight safety associated with detection and avoidance of hazardous weather based on direct visual and physical (e.g., turbulence) observations by a pilot in a manned cockpit.

Determination of flight visibility is one such factor. An unmanned aircraft may need to rely on electronic data and reports from nearby piloted aircraft to determine its own visibility to those aircraft. Simultaneously, the criteria for RPA Visual Meteorological Conditions (VMC) may need to be adjusted to account for the fact that sensors on the aircraft may maintain visibility of the surrounding airspace when a pilot's visibility is reduced.

Similarly, RPA operators will not have the visibility of a piloted aircraft when navigating around or through convective weather. RPA operators will be unable to "feel" wind shear or turbulence and will have to rely on electronic data (ground observations/forecasts along with on-board sensor feedback) and reports from other aircraft. It should also be noted that many of the RPA flying in the NAS today have a very low tolerance to hazardous weather such as turbulence and icing, which increases the reliance on accurate forecasts and real-time weather data.

Some RPA are able to stay aloft for extended periods of time—in some cases, longer than 24 hours. This is a significant increase in the planning horizon relative to manned aircraft. As a result, RPA operators may need weather forecasts that look 24 hours or more into the future to support flight planning.

NWP and CSS-Wx are primarily efforts to consolidate existing weather processing and dissemination capabilities into a single processing platform (NWP) and a single SWIM-compatible dissemination platform (CSS-Wx). All of the NWP and CSS-Wx functionalities available to piloted aircraft operators will also be available to RPA operators via the web-based AWD interface or SWIM subscription. The system specifications require that NWP be designed and developed to allow integration of additional processing functions. However, there is no indication that any weather products specifically addressing RPA needs are currently part of any planned future releases. The NWP Screening Information Request (SIR) documents do not include the terms "unmanned" or "RPA."[ii]

NWP and CSS-Wx address, in a limited way, RPA needs related to lack of direct visual and physical pilot observation. CWAFs will assist RPA operators in avoiding convective weather but will likely require a wider buffer around convection than can be achieved through visual observation. Increased coverage and resolution from the integration of multiple radar systems into a single mosaic may provide some benefit. Current ITWS data related to terminal area winds and wind shear will be available. No new data will be generated—the primary improvement will be in accessibility. Consolidating the data onto a single platform and disseminating with CSS-Wx will provide RPA operators with easier access. However, RPA operators will still be limited in their ability to assess visibility, turbulence, icing, etc., beyond what can be determined from sensors on the airframe.

Extended flight planning will be supported in part by the extension of the forecast horizon for most products to 8 hours. This will not cover the full planning horizon for RPA with the ability to stay aloft for longer periods of time. These RPA operators will likely have to seek new or alternative sources for weather information or implement capabilities for short-term periodic updates and integrate a capability to rapidly alter the active RPA flight.

The NextGen Surveillance and Weather Radar Capability (NSWRC) is a planned replacement for many legacy weather and traffic radar systems. NSWRC is anticipated to improve forecast and visualization models through increased accuracy, resolution, and update rate.[iii] This would allow for better use of radar-based NWP products in piloting RPA in the presence of convection. With a deployment date no earlier than 2023; however, this is unlikely to impact mid-term RPA operations.

CSS-Wx has completed its initial investment decision and is scheduled for deployment in 2016. Ongoing incorporation of additional weather dissemination functionalities and replacement of legacy weather dissemination systems will continue through 2022.

NWP will be implemented through a succession of work packages. The first work package, which will replace CIWS and CoSPA and implementing CWAM WAF models, is scheduled for an initial operational deployment in 2017. The second NWP work package will replace WARP and centralized ITWS functionalities with full deployment completed by 2022. This will also include consolidation of similar products (e.g., terminal and en route convective forecasts), improved resolution of gridded products, and extension of capabilities to cover CONUS+, Alaska, and Hawaii. Future FAA work packages are planned to replace the localized functionalities specific to individual ITWS sites.[iv]

None of this work specifically addresses any unique RPA weather requirements or means or methods of processing or disseminating weather information critical to RPA requirements or missions.

6.10.4 Conclusions and Recommendations

The following items outline perceived weather-related products and services that will be required to safely, effectively, and efficiently support RPA integration and operation in the NAS:

- Provide new aviation weather products that have extended forecast periods with means and methods for automated updates and alerts of changes in previous forecasts.
- Develop weather products that provide greater weather spatial and temporal granularity, which may be needed due to the RPA vehicle design parameters, including greater sensitivity to hazardous weather, such as turbulence and icing, and extended flight times, including loiter.
- Conduct an analysis of current weather requirements for flight visibilities and ceiling needs to be conducted in consideration of weather requirements for unmanned aircraft and their sensor systems' equivalency to manned capabilities.
- Conduct an analysis of needs to install on larger RPA weather sensors or systems capable of deriving or detect critical weather parameters, such as icing, turbulence, visibilities, and wind speed and direction. Included in this analysis should be a consideration to routinely broadcast these weather parameters to other nearby aircraft as well as a downlink to meteorological forecast centers for processing on systems such as NWP.

6.11 Terminal Flight Data Management (TFDM)

6.11.1 Program Description

When RPA flights operate to or from the busiest airports in the NAS, they will impact the terminal automation systems at those facilities. As with other NAS systems, RPA flights generally will be treated the same as manned-flights, but some accommodations for unmanned flights are likely. Currently the automation in ATCTs consists of a number of unintegrated narrow-use systems, but the FAA is planning to address this shortfall through the TFDM program. The TFDM program is designed to provide an integrated platform for existing and future terminal automation capabilities. TFDM is currently undergoing the FAA's investment analysis process, and in the spring of 2014 it passed the initial investment decision. The final investment decision is expected in late 2014.

6.11.2 Major ATC Functions

Because TFDM is still undergoing FAA investment analysis, it is impossible to definitively define the functionality that will be included in the TFDM system; however, according to the most recently published information from the TFDM program office, the TFDM system will include the following key elements:

- **Electronic Flight Data**. Electronic Flight Data (EFD) replaces the paper flight progress strips currently in use in the terminal environment. EFD will provide the capability to display flight-specific information and traffic management impacts on specific flights. EFD will also provide the capability for flight-specific inputs and actions from terminal traffic managers to be automatically transmitted to internal TFDM processes as well as to external systems
- **Surface Scheduling**. Surface Scheduling (SS) provides predictions of resource times (e.g., movement area entry time, departure time, arrival fix time, and arrival time) for flights operating at an airport. These predictions will take into account such things as aircraft characteristics, separation and wake vortex constraints, arrival and departure demand, and active and planned TMIs.
- **Surface Situational Awareness**. Surface Situational Awareness (SSA) provides a configurable surface/terminal-based geographical display of the surface operation. In addition, SSA will provide configurable text-based displays based on the SS predictions.
- **Surface Metering**. Surface Metering (SM) will provide a departure metering capability that will control the departure queue length, reducing fuel burn, and increasing surface efficiency by assigning movement area entry times to flights based on predicted departure demand and existing CDM procedures.
- **Airport Resource Management**. Airport Resource Management (ARM) provides tools for managing airport resources, e.g., runways, to maximize airport efficiency. ARM will use the predictions from SS and other sources and make recommendations regarding runway configuration changes and the usage of other terminal airspace resources, such as taxiways and arrival and departure fixes.

6.11.3 Related RPA Needs

Since the TFDM system is only a proposed system that is not yet operational, the related RPA needs are difficult to define at the time this report is written. However, a review of the most recent TFDM System Specification Document (SSD) published by the TFDM program does not mention RPA in any way. As a result, our analysis assumes that RPA operations are not a major consideration attendant to the TFDM investment analysis process at this time.

Since the TFDM system development process has yet to begin, the two alternatives that exist are to incorporate RPA operations into the ongoing design and development process as soon as possible, or to delay the integration of RPA requirements until the initial TFDM deployment has been completed. Each option has its own associated challenges. For instance, incorporating RPA operations into TFDM as soon as possible is likely to delay the development schedule. Alternatively, waiting until after initial system deployment will likely result in increased system cost in the long term.

6.11.4 Conclusions and Recommendations

The concept of TFDM, which integrates and automates a number of ATC functions, provides an excellent opportunity to analyze surface and terminal requirements to accommodate integration of RPA into the NAS. The following items are presented for consideration in addressing RPA needs inherent in TFDM:

- Review EFS requirements to ensure that information supporting the safe movement of RPA on the surface as well as on departure and arrival is provided. This may be an expansion of flight plan elements as discussed in FIXM to the ability of TFDM to support information needs identified previously in this paper for ERAM, TAMR, and SWIM.
- SS and SM will need to consider operational performance for RPA as it differs from manned aircraft operations. This includes divergent RPA type, operating characteristics, performance capabilities, and limitations.
- Develop an acceptable method of surface movement to support ground RPA operations. This may include ground escort vehicles, remote surface radar to RPA pilots or operators, the use of optical or other sensors in the RPA that are remotely displayed to the pilot, or any combination of these.
- Look at fully automated ground movement being preprogrammed, or dynamically upload taxi instructions given by the RPA pilot or operator or conceivably by ATC controlled from the ATC ground control position.

6.12 Detect and Avoid (DAA)

6.12.1 Description

Depending upon architecture and functionality, DAA for RPA could have a profound effect on a variety of FAA systems and infrastructure. DAA can be airborne-based and can affect ADS-B In and Out and an associated Cockpit Display of Traffic Information (CDTI). DAA can also affect Traffic Alert and Collision Avoidance System (TCAS) functionality, including designs for the new Next Generation Airborne Collision Avoidance Systems (ACAS-X). GBSAA that leverages ASR-11 Surveillance Radars and STARS also demands automation and surveillance system modification to provide this capability. Additional future work on portable primary three-dimensional radars integrated in the NAS will also be required

Many of the elements of the concepts below need to be validated through an aggressive research agenda as well as vetted with operational personnel though simulation or in an actual operational environment. This assumes that theses perspectives are reasonable and have a valid technical foundation.

Although there are numerous concepts and associated scenarios that can be put forward for analysis and subsequent validation, the one chosen below represents a preliminary concept that minimizes workload and complexity for air traffic controllers. The following scenario is presented in an initial stage of development, but with future efforts, this scenario can hopefully validate that the concept and the associated critical systems and aircraft performance can be achieved in a cost-effective way.

6.12.2 Major ATC Functions

The fundamental challenge of RPA integration into the NAS is that there are no longer humans to look out of the cockpit windows to “see and avoid” other aircraft as required by federal regulations. The ability to provide alternative means to a successful detect and avoid capability is critical to RPA integration into the NAS.

The second major factor is the chain of command, control, and communication in RPA as compared with manned aircraft. The pilot in the manned aircraft communicates directly with ATC, accepts control instructions, and physically interfaces with the aircraft’s C2 systems. RPA pilots must also communicate with ATC as relayed through the RPA, since direct ground-to-ground communications are not yet available, as well as remotely communicate to the RPA to provide C2 instruction.

The third major consideration is the nature of the RPA mission. Traditional and conventional air transport moves people and cargo from point A to point B in a few hours, whereas RPA missions are characterized as going from point A and returning to point A after some cases lengthy (more than 24 hours) and complex (hundreds of waypoints with associated altitude changes and orbits, circling, or holding) missions.

The fourth major issue that differentiates many RPA from manned aircraft is the design of airframe, powerplant, and sensors to optimize mission needs and requirements such as reduction of aircraft robustness for turbulence to carry more fuel for greater mission endurance.

All of these factors must be weighed and considered, carefully developing and adopting technologies that integrate RPA operations within the NAS with minimum disruption.

One of the preliminary requirements is for a component of the RPA (e.g., human operator, automated capability, or some combination) to file a flight plan, communicate with ATC, and operate under IFR. Conceptually, this includes RPA that weigh more than 55 pounds and operate above 500 feet above ground level excluding takeoff and landing. Since this segment will be receiving ATC separation services, concerns focus on the DAA aspect of flying in an airspace environment that permits VFR operations and has aircraft not participating in the ATC system. Non-participating aircraft will not be communicating with ATC or receiving ATC services, including safety alerts and traffic advisories[v], and may or may not be equipped with avionics that support electronic surveillance, such as transponders or ADS-B. Non-participating VFR operations may occur in airspace known as Class E and G, when weather conditions permit, between the surface and Flight Level 180 (approximately 18,000 feet MSL). It is in this airspace environment that DAA is needed so that an RPA can use electronic alternatives to the human eye to see and maneuver to avoid conflicting VFR traffic.

An RPA, such as the MQ-1 Predator type, will likely operate from a traditional airport that provides ATC services. These services require two-way communications with all pilots to provide takeoff and landing clearances, flight plan clearances, taxi instructions, airport and traffic advisories, and airborne sequencing and spacing within airport traffic areas of Class B, C, and D airspace. The airport traffic areas are generally concurrent with the nominal size of Class D airspace, a four nautical-mile radius from the airport center up to 2,500 feet above the ground with a speed limit of 200 knots indicated airspeed or less. In this airspace environment the tower will provide arrival, departure, and traffic pattern guidance to assist an RPA with DAA to remain well clear of any conflicting traffic. This does depend upon favorable meteorological conditions to enable the control tower to see the operational environment. If the weather is below VFR minima of 1,000-feet ceilings and three-mile visibilities, VFR aircraft should not be operating unless under a Special VFR clearance. The tower will provide RPA IFR services up to the limits of its airspace or until the RPA has had a transfer of communications to an ATC IFR facility, such as a TRACON or ARTCC.

If the RPA is operating from an uncontrolled airport or at a time when the tower is closed, RPA operators must provide visual observers on the ground as a replacement for the loss of ATC advisory services. Further, GBSAA may be used as a substitute for ABSAA or DAA, provided that GBSAA can sustain an equivalent DAA level of safety to identify and avoid VFR aircraft until such time the RPA is under control of the appropriate IFR ATC facility.

Once under an IFR facility's control, the facility will provide separation from other IFR aircraft consistent with their standards. This normally means 3 nautical miles in a terminal radar environment and 5 nautical miles in an en route radar environment. As the RPA transitions to its requested altitude above 18,000 feet MSL, it is subject to a maximum speed of 250 knots indicated until reaching 10,000 feet MSL[vi]. This speed restriction aids and abets DAA by reducing the speeds of the potential collision encounters. Most VFR aircraft not participating in the ATC system are small general aviation aircraft operating at speeds well less than 200 knots indicated airspeeds and at altitudes below 10,000 feet MSL.

A critical consideration for DAA's effect on the ATC systems is the determination of the minimum conflict avoidance distance established by "well-clear." Well clear has its basis in FAR rules pertaining to visibility and maneuvering distances needs to safely see and avoid other aircraft as well as aviation hazards[vii]. The more modest this distance the less it potentially affects the ATC system. The Traffic Collision Avoidance System (TCAS II) is a good example of a conflict avoidance technology that provides last-minute vertical maneuvers to avoid imminent airborne collision between aircraft and minimizes impact on the ATC system. The nature of these maneuvers, which are near to the ATC minimum radar separation standards, conform to FAA rules that do not require an ATC approval or clearance before executing a TCAS directed maneuver.

In the same sense, if the execution of a DAA maneuver occurred with less than the minimum radar separation standard for the airspace environment involved; the FAR provisions for see and avoid that allows an IFR aircraft to maneuver to remain well clear to avoid collision with VFR aircraft without violating an ATC clearance could be met as defined in FAR 91.123 and FAR 91.181[viii].

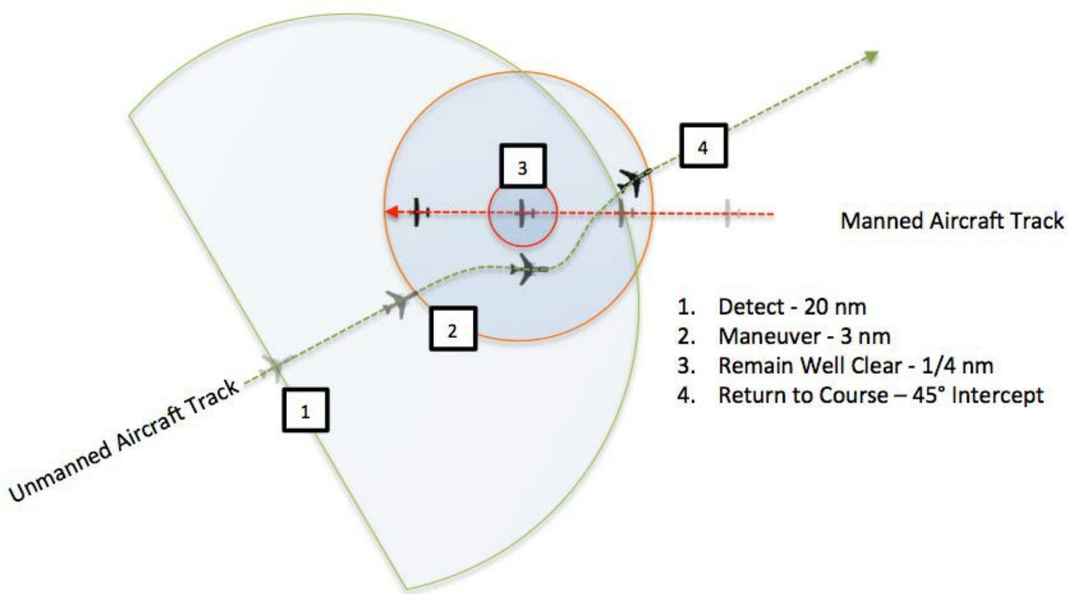

Figure 6: An Airborne Detect and Avoid Scenario

From an air traffic control perspective, ATC will provide separation between IFR aircraft by at least the IFR separation minima of 3 nautical miles. ATC will also provide separation or advisory and alerting service to participating VFR aircraft depending upon the airspace environment. FAA will not provide services to non-participating and non-communicating VFR traffic known or unknown. Under these circumstances, if ATC fails to provide separation or advisories to the RPA pilot by a closest approach of 3 nautical miles or less, it can be assumed the conflicting aircraft is not an IFR or participating VFR aircraft, and automated DAA maneuvers shall be made to remain well clear of the conflicting aircraft.

The key to the success of this approach in Figure 6 is the determination or definition of the minimum distance for well clear. Given that VFR non-participating aircraft are expected to be small, relatively slow moving general aviation aircraft, one-quarter mile or 1,500 feet laterally seems to be both a reasonable and acceptable well clear distance, provided an RPA aircraft can successfully maneuver within 3 nautical miles or 5 nautical miles to remain at least 1,500 feet laterally from a non-participating VFR aircraft. This depends upon a number of factors, including environmental conditions of wind speed and direction, aircraft performance differentials[ix], error budgets for detection, positioning[x] and maneuvering systems, as well as the collision geometry.

It is expected that a minimum DAA range and detection with high probability, 2 sigma or better, would be approximately 20 nautical miles. A determination of a DAA maneuver that would be made at 20 nautical miles can continually be updated with any necessary lateral maneuver being executed at the appropriate IFR ATC minimum radar separation standard either 3 nautical miles or 5 nautical miles, depending upon the airspace environment.

The probability of a perfect collision juxtaposition that cannot be resolved by a DAA maneuver is no doubt notably small. However, this eventuality must be considered and resolved. If preliminary DAA calculations determine, at 20 nautical miles from point of closest approach, that a minimum well clear distance of 1,500 feet cannot be established and maintained, then the pilot must coordinate with ATC for route deviation that can be executed prior to the normal DAA 3-nautical-mile or 5-nautical-mile maneuver boundary distances.

One of the DAA issues that needs to be addressed is the standard of nautical miles versus time for purposes of establishing separation between conflicting vehicles. While the airborne TCAS II system utilizes time parameters (Tau – time to closest point of approach (CPA) in seconds between two aircraft), the ATC ground-based system uses distance. To meet ATC operational needs for a mileage requirement for separation assurance, DAA must vary the time in seconds to correspond to an ATC required separation minima in mileage depending upon the speeds of the vehicles involved in any potential conflict.

A key consideration in the success of DAA will be how the pilot interacts and communicates with the RPA systems, including sensors and flight management and control systems. Also how the RPA pilot interacts with ATC is a major metric determining DAA success. It is assumed for safety and efficiency purposes that the RPA pilot will be “on-the-loop” as opposed to “in-the-loop” as shown in Figure 7. This means that DAA is an automated system that will detect and maneuver the RPA without pilot intervention, albeit the pilot has the option to intervene at any time. This also means that the DAA is fully functional and continues to operate in a predictable manner in the case of loss of pilot C2. This obviates the need to carry additional collision avoidance systems, such as TCAS. The pilot is alerted in a timely manner as close as possible to the detection threshold of 20 nautical miles to all impending DAA events and alerted to the calculated and intended DAA maneuver. The pilot then may choose to (1) allow the automated systems to accomplish the DAA maneuver and return to course; (2) manually maneuver the RPA within the DAA automated parameters to select options for climb or descent, airspeed changes, or lateral maneuvers; or (3) coordinate with ATC for alternative maneuvers outside of the DAA boundaries, which may be driven by the fact automated maneuvers, even if manually flown, cannot guarantee a conflict is avoided by well clear minimum distances, or the pilots wants or needs to alter the intended automated maneuver to route of flight.

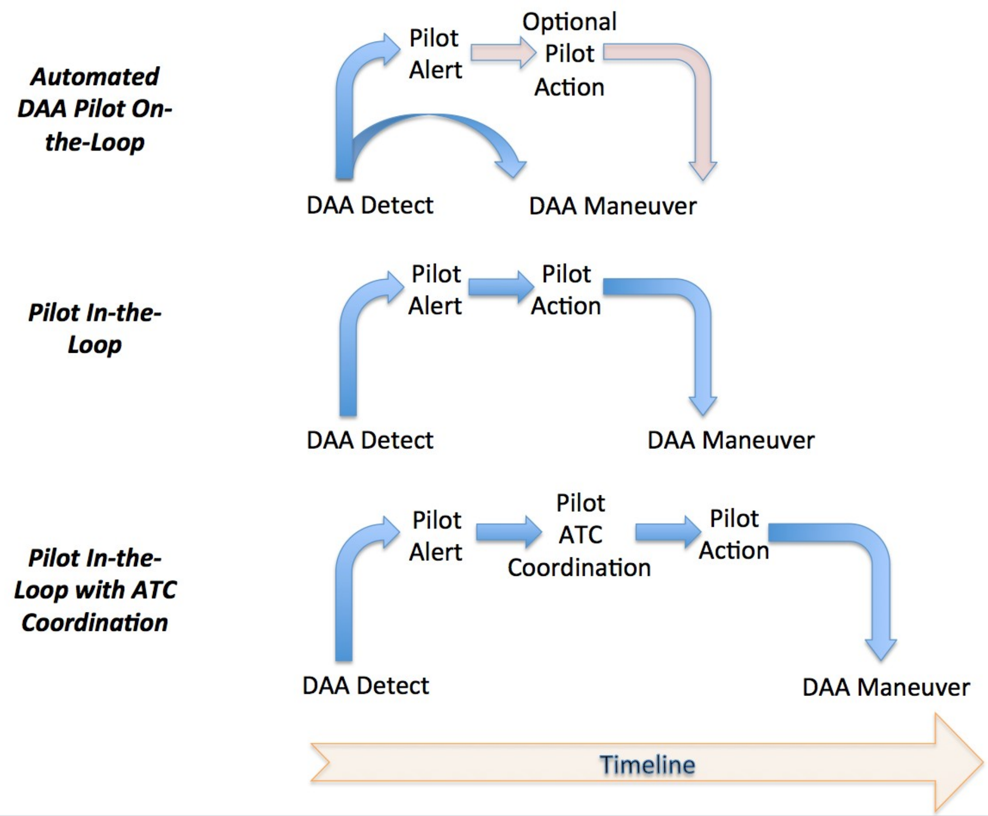

Figure 7: DAA Modes

As a result of the communications loop, manual intervention in response to a DAA alert by the RPA pilot affects the time needed for an RPA maneuver. DAA coordination of maneuvers with ATC also affects the timeliness of maneuvers, extending the entire DAA timeline sequence. This timeline can create a major impact to ATC in terms of increased workload and workload complexity. Designing and assessing DAA is a major concern. If DAA distances or times become extended, it may prove impractical to implement DAA into the ATC system, especially for RPA operating under IFR clearances that begin to require frequent ATC coordination.

While there has been a focus on lateral DAA maneuvers, there is no reason that DAA could not combine modest changes in rates of climb or descent, including a temporary altitude hold, or changes in airspeed. Modest changes in rates of climb, such as 250 feet per minute or a temporary leveling off, would have little to no effect on ATC. A 10% increase or decrease in airspeed would also have little to no effect on ATC. These modest airspeed or climb or descent rate adjustments could be made as early as 20 nautical miles from the closest calculated distance of approach without disrupting ATC and could be used in conjunction with lateral maneuvers made at less than the applicable ATC radar separation standards. One or more of these maneuvers could all but make DAA maneuvers unnoticeable and without impact to current to ATC duties, authorities, and responsibilities.

Depending upon architecture and functionality, DAA for RPA could have a profound effect on a variety of FAA systems and infrastructure. DAA can be airborne-based and affect ADS-B In and Out and an associated CDTI and TCAS functionality, including designs for the new ACAS-X. GBSAA that leverages ASR-11 Surveillance Radars and STARS or TAMR also demands automation and surveillance system modifications to provide this capability. Additional future work on portable primary three-dimensional radars integrated in the NAS will also demand system concept, architectural and functional development.

The implementation of DAA, also referred to as See and Avoid, into the FAA ATC systems has many implications for driving change in the NAS. First, the business model for RPA is far different from that of commercial air transport that has served as the foundation of ATC services since 1936. The nature of the RPA business model is driven by mission needs and requirements that affect the NAS infrastructure in ways previously discussed in this report. However, there is potential for an even greater effect upon ATC procedures and air traffic controller workload and associated complexity. In order to dramatize this change, a review of RPA operational scenarios that support a concept of operations is warranted to explain the why, what, where, and how of future RPA operations in the NAS.

6.12.3 Related RPA Needs

There are a number of areas requiring research efforts to allow a safe and efficient integration of RPA into the NAS. The focus of the agenda items below is on work needed to further support and/or validate both requirements and solution sets for DAA.

Validation of Airspace Environments

One of the first questions is: What is the airspace environment from the ground to 18,000 feet MSL that a RPA using DAA will operate? If the assumption is that a RPA will operate under IFR, then the consideration of DAA is to provide separation assurance from those aircraft operating under VFR and not participating in the ATC system.

There are other questions to address, as well. Where do these non-participating aircraft fly and at what altitudes and speeds? Are there any predominant flight patterns or profiles for non-participating aircraft? Are there observable tracks to indicate response to the See and Avoid mandate? If so, what are the separation assurance maneuvers—when, where, and how much—in response to potentially conflicting aircraft? What is the density of this airspace by altitude and traffic mix? A 12-month survey and assessment of the high-density airspace in portions of Florida and California may be most helpful in creating a risk profile for DAA.

The thesis that needs validation is that the greatest collision risk for RPA and the major need for DAA would be at altitudes below 10,000 feet MSL. These are altitudes where it is most likely to find the types of aircraft that are non-participating VFR manned aircraft. It is expected these aircraft are small, relatively slow moving single-engine general aviation aircraft, such as a Cessna 172.

Depending upon the results of this assessment, it may be appropriate to have a DAA standard for RPA specifically designed for an airspace environment below 10,000 feet MSL that could be used by a RPA under both IFR as well as well as VFR operations.

Vehicle Performance Parameters

A second major question is: What is the performance envelope below 10,000 feet MSL and at 10,000 feet MSL and above of the RPA needed to successfully use DAA? Assuming that an RPA will not begin to maneuver to establish itself well clear by a minimum of 1,500 feet of a conflicting aircraft before a 3 nautical mile closest approach distance, what are the minimum and maximum RPA speeds, turn rates, environmental conditions (wind speeds and wind directions), climb and descent rates, and encounter geometries for a successful maneuver?

There is an assumption that those RPA weighing less than 55 pounds, as may be proposed by the FAA's Small RPA Rule, will not be subject to the requirements of an airborne DAA.

From an aircraft performance perspective it is assumed that speed ranges for an RPA can be between 60 knots and 250 knots indicated airspeed below 10,000 feet MSL and up to 600 knots above 10,000 feet MSL; turn rates can nominally be 3 degrees per second; and rates of climb and descent can be from 250 feet per minute to 1,000 feet per minute. The question will be: What are the performance standards that will be required for an RPA to complete a successful DAA maneuver below 10,000 feet MSL and at or above 10,000 feet MSL? These values may likely define future regulatory requirements for RPA carrying DAA.

Detection Systems

A third major question is: What is the collision detection system(s) that must be carried by an RPA operating with DAA? This is a challenging question given the wide range of RPA types, sizes, and missions.

Assuming that the focus is on U.S. domestic operations of RPA weighing greater than 55 pounds, the obvious post-2020 answer is that ADS-B Out is the cooperative surveillance system of choice. The small size, low cost, precision positioning information, and ubiquitous use where mandated is a perfect DAA solution. Unlike the impracticality of airborne radar, ADS-B provides 360-degree vehicle coverage and alerting.

ADS–B Out will be required for all aircraft operating in Class A, B, and C airspace within the NAS; above the ceiling and within the lateral boundaries of a Class B or Class C airspace area up to 10,000 feet MSL; and Class E airspace areas at or above 10,000 feet MSL over the 48 contiguous United States and the District of Columbia, excluding the airspace at and below 2,500 feet above the surface. In addition, the rule also requires that aircraft meet these performance requirements in the airspace within 30 nautical miles of certain identified airports from the surface up to 10,000 feet MSL. In addition, the rule requires that aircraft meet ADS–B Out performance requirements to operate in Class E airspace over the Gulf of Mexico at and above 3,000 feet MSL within 12 nautical miles of the coastline of the U.S.

While the 2020 mandate for ADS-B is not universal, it is worthwhile to note that the greatest mission value for RPA may indeed be within the airspace environment requiring ADS-B equipage. For those areas outside of this ADS-B equipage requirement, GBSAA may serve the detection and alerting role for DAA. This integration of DAA with GBSAA is a strong research need.

DAA Standards and Algorithms

Research is needed to validate the threshold parameters for initiation of DAA maneuvers (i.e., 3 nautical miles) as well as the acceptability of the well clear boundary (i.e., 1,500 feet). In addition, metrics need to be validated for the surveillance detection and maneuvering error budgets, including communications loop if required, to determine target values for well clear. In other words, a well clear calculation and trajectory targeting 2,000 feet will actually achieve 1,500 feet or more within a 2 or 3 sigma deviation. Also, work is needed to develop and validate overall vehicle performance including hardware and software in response to an end-to-end timeline for DAA events.

RPA Marking and Lighting

Research must be conducted in regards to RPA marking and lighting to make the aircraft as visible as possible to other pilots. This is of particular importance when the manned aircraft is overtaking or converging on an RPA from the rear quarters. In these circumstances the DAA should maintain its course, speed, and heading and allow the overtaking or converging manned aircraft to maneuver to avoid it, assuming it can be seen.

One thought is to create a unique strobe light pattern spelling out and repeating “RPA” in Morse code. The strobe would be located in the tail of the RPA and be activated in response to the conflicting aircraft's ADS-B position. If the RPA is outside of ADS-B mandated equipage area, the GBSAA could activate the alert.

If properly implemented, DAA should be seamless and transparent to ATC operations. Workload generated as a result of RPA DAA should be virtually equivalent to manned aircraft. However, it is expected that occasional coordination would occur when DAA cannot successfully resolve an automated DAA. This would require the notified RPA pilot to coordinate with ATC for a route deviation, vector, or altitude change in advance of the normal DAA maneuver initiation boundary. Ground-to-ground RPA pilot-to-controller VoIP communications should be seamless and timely once implemented. In the interim RPA pilot-to-controller communications via satellite will have a latency of about 0.8 seconds, longer than the normal air-to-ground 0.25 seconds for VHF/UHF manned and unmanned pilot communications.

As previously outlined, there will be a number of RPA standards that will require development, adoption, and implementation to enable fully integrated RPA operations.

6.12.4 Conclusions and Recommendations

This analysis of DAA addresses an approach that minimizes DAA effects on ATC in terms of workload and workload complexity. These are important considerations if the FAA is to achieve a timely and seamless integration of RPA into the NAS. While there may be alternative strategies and technological approaches for DAA, technology alone cannot drive itself into the NAS by ignoring basic paradigms essential to NAS operations.

The concepts put forward in this paper diverge from other efforts and approaches with the following key differences:

- RPA operations may be conducted either VFR or IFR within appropriate airspace environments.
- RPA operations conducted under IFR must minimize operational effects on ATC. This requires minimized coordination and communication needs between RPA pilots and air traffic controllers to keep workload on both pilot and controller as low as possible. In addition, DAA actions must be innocuous, seamless, and transparent enough not to create air traffic controller workload complexity.
- DAA will be driven by ATC mileage separation requirements at the point of closest approach. Mileage requirements will be converted by DAA into varying time parameters as a basis for DAA maneuvers.
- Use of TCAS data to establish DAA performance is non sequitur. DAA must baseline appropriate airspace and vehicle information relevant to its uses and risks.
- Selective design and use of DAA may be an importance step in NAS integration of RPA. For example, a DAA concept that addresses its use within ADS-B-mandated airspace below 10,000 feet MSL might provide the greatest near-term benefit, coupled with the most effective and efficient DAA deployment strategy.
- DAA must be able to function with GBSAA as an integrated solution for separation assurance. GBSAA can provide non-cooperative 3D primary radar surveillance in areas below or outside ADS-B-mandated airspace and provide RPA separation detecting and alerting until a RPA with ADS-B surveillance is wholly contained and operating within ADS-B-mandated airspace.
- DAA sensors may include radar, electro-optical, infrared, and others. Their performance to be able to detect and track conflicting traffic will be critical to their acceptability and use.

- The concept of a DAA maneuver threshold coincidental with ATC radar separation minima is critical to the acceptability of DAA not to pejoratively affect the efficiency, capacity, and ostensibly the safety of the ATC system.
- Well clear distances are predicated on FAR VFR minimum flight visibility requirements and distances clear of cloud. This assumes that these standards have been judged as adequate by FAA to exercise See and Avoid maneuvers between conflicting aircraft.

7. Conclusions and Recommendations

The conclusions and recommendations below summarize (1) the revision to processes for timely deployment of needed ATC improvements through technology insertion or continuing spiral development to integrate RPA into the NAS, and (2) the RPA issues identified and associated with each ATC system or sub-system that needs to be modified or replaced to facilitate timely integration of RPA into the NAS.

Of overriding importance is the need to ensure that future RPA activities and growth do not degrade the capability of the NAS by introducing additional air traffic controller workload or workload complexities not already associated with manned aircraft. An increase of controller workload for RPA because of the lack of system design and associated procedures could likely mean a decrease in ATC capacity to handle traditional manned aircraft and its associated projection of growth.

7.1 Acquisition Lifecycle Management

One of the major challenges to the timely and full integration of RPA into the NAS is the need to modify the current FAA infrastructure to accommodate the safe, orderly, and efficient movement of RPA seamlessly and with NAS transparency. Infrastructure changes to automation, navigation, communication, and facilities entail capital investments driven by the FAA AMS. This system defines a cradle-to-grave lifecycle process for the acquisition of systems requiring capital investments.

In the past, the FAA has advocated an accelerated and iterative process of spiral development and responsive technology insertion, but the AMS recognizes neither of these as a valid part of lifecycle management.

An additional acquisition process complexity attendant to AMS is the OMB Exhibit 300 (Appendix C). Exhibit 300s establish policy for planning, budgeting, acquisition and management of major information technology (IT) capital investments outside and in addition to the requirements established within the FAA's AMS. The vast majority of FAA programs with an automation component subject to OMB Exhibit 300 managing and reporting.

The following proposals are presented for consideration:

- As an adjunct to the AMS, approved processes must be developed and implemented to respond to critical and timely needs to provide for technology insertion into the NAS to respond to and accommodate the needs of new entrants driving FAA capital investments. These needs would be represented as accelerated and abbreviated by Six Sigma "leaned" processes that are viewed as essential in the context of modification of a fielded system or a system under Program Management Office (PMO) implementation.
- Technology insertion initiatives that affect current FAA capital investment programs should be driven and controlled consistent with newly established AMS directives by the PMO in conjunction with support from NextGen offices. These may include the modification and use of NextGen Project Level Agreements (PLA).
- Additional review needs to be provided to better define "spiral development" of FAA capital investment programs and to establish processes that support this concept of continual program improvement. This is extremely important to recognize new business models and missions that must be support by ATC and the NAS infrastructure and to be able to react so not to create a barrier to social and economic benefits.

7.2 En Route Automation Modernization (ERAM)

For RPA to operate safely and efficiently in the NAS, several enhancements to the ERAM system will need to be made:

- ERAM modifications will be driven by the need to accept, process, and display lengthy and complex RPA flight plans that include automated flight profile contingencies to the air traffic controller.
- ERAM must be modified to display the next 20 minutes of an aircraft's projected flight trajectory on a controller's display suite.
- ERAM needs to incorporate the ability to display, review, modify, and approve an RPA flight plan request originating in an en route center, including underlying terminal, airspace environment as a 24-hour file and fly replacement to the current constrained COA process now in use to approve domestic RPA operations.
- NAS flight plans and ICAO flight plans will require modification of FIXM to include a variety of changes responsive to RPA and ATC needs. These include RPA nomenclatures to label hundreds of latitude and longitude coordinates sequentially with associated estimated times and flight profile contingencies associated with each fix or node.
- NAS flight plans and ICAO flight plans and processing systems will need to be enhanced to accommodate unconventional flight plans accommodating FIXM requirements for RPA. Most notably, RPA orbits need flight planning definitions to determine orbit origin, radius and period of orbit.
- As RPA operations proliferate in the NAS, ERAM may have to be adapted to identify and manage the use of predefined airspace for holding/loitering flights or flights performing convoluted routes for survey or other missions. This includes means and methods for routinely defining and rapidly revising altitude blocks and lateral areas of airspace in support of RPA mission requirements.
- The performance characteristics of RPA aircraft classes and types will need to be added to the ERAM adaptation.
- The conflict probe and conflict alert models may need to be modified to account for the performance characteristics and/or reaction speed of RPA aircraft. This is especially true if the implementation of ground or airborne DAA has impact on air traffic controller duties, authorities, or responsibilities.
- RPA HALE may drive a need at ultra-high altitudes for airspace redesign to create ultra-high sectors for RPA operations.

7.3 Traffic Flow Management System (TFMS)

For RPA to integrate efficiently into the existing TFM process, several enhancements to the TFMS will be required:

- The performance characteristics of RPA classes and types will need to be incorporated into the TFMS. Mission-driven performance requirements may alter baseline TFMS assumptions and functionality.
- RPA mission needs will likely impact sector capacity and thus the TFMS Monitor Alert functionality; RPA impact on sector capacity will have to be studied, and the Monitor Alert function may have to be modified to account for the presence and nature of the RPA aircraft missions.

- Non-standard flight patterns, such as holding represented by orbiting or loitering flights, could also impact sector capacity and the Monitor Alert functionality of TFMS. Further, the situational awareness functionality of TFMS would need to be able to display such operations as well as their operating areas.
- Some RPA flights will likely be unscheduled and will be generated on a 24-hour or less notification; as a result these flights will impact how pop-up flight traffic is modeled in GDPs, AFPs, and CTOPs. It may be that RPA flights simply increase the volume of pop-up traffic, but it is also possible that RPA flights will require special consideration.
- Given the complexity of RPA missions, there may be a need to establish a 24-hour file and fly notification or request system that would allow an originating Instrument Flight Rule (IFR) facility to review and approve an RPA flight profile and timing 24 hours in advance of a mission conducted within high-density airspace environments.
- There are a few shortfalls that can be identified now, including (1) the ability for the TFMS Traffic Situation Display (TSD) to identify and annotate RPA flights, including flights flying non-traditional flight plans; (2) the ability for TFMS to model RPA flight characteristics; (3) the ability for TBFM to model RPA time-based metering capabilities; and (4) the ability for GDPs, AFPs, and CTOPs to account for RPA demand.

7.4 National Voice System (NVS)

Although a continuation of the use of VHF and UHF radios between air traffic controllers and RPA pilots talking directly in a local airport environment is indistinguishable from manned aircraft, any RPA operations requiring communication relay through the RPA poses significant communications challenges in terms of communications availability, latency, and quality and the opportunity to sustain party line communications deemed critical to pilot situational awareness. These concerns drive the following NVS requirement to safely and efficiently accommodate RPA:

- Future ATC voice switching systems must be able to provide timely and direct G/G pilot-to-controller voice and data, including text messaging and communications via VoIP. This includes methodologies for enabling an automated transfer of communication for the RPA pilot between different control sector frequencies as well as a broadcast of communication over ATC radios to ensure that party line communications are maintained.
- Future communications must be secure. Authentication is a barest minimum requirement. Encryption may also be a high priority for C2, as well as payload communications.
- NVS must consider the parallel use of voice recognition to digitize and relay communications as textual messages in addition to traditional voice messaging.

7.5 Terminal Automation Modernization and Replacement (TAMR)

TAMR, which is an ongoing FAA technology insertion program, provides an excellent opportunity to rapidly insert critical RPA needs into the ATC systems to accommodate NAS integration of RPA. The STARS and TAMR platform continues to undergo a spiral development of capabilities that deliver considerable benefits to ATC that can absorb expansion of capabilities in support of RPA operations. These capabilities are listed below:

- TAMR or associated terminal automation systems could display, review, modify, and approve a RPA flight plan “off or on” an airport originating in a terminal airspace environment as a 24-hour file and fly as a replacement to the current constrained COA process now in use. These flight profile requests could be reviewed against airspace segmentation and use critical infrastructure locations, high population density areas, and 15-minute time critical periods to modify and approve low-risk mission profiles.

- With the deployment of Ground Based Sense and Avoid (GBSAA), TAMR may also be able to provide surveillance conformance monitoring for approved RPA flights within a terminal airspace environment. This may be essential for RPA operations conducted from airports when Airborne Sense and Avoid (ABSAA) systems are not active until reaching selected altitudes or airspace environments (e.g., for a RPA after 2020 using ADS-B for ABSAA in an airspace environment where ADS-B is not mandated).
- Terminal radars supporting TAMR and GBSAA, such as 3D primary radars, could be networked and used by the tower and approved RPA operators to provide RPA pilots with situational awareness for self-separation (e.g., local law enforcement using RPA under the FAA/Department of Justice (DOJ) Common Strategy to coordinate with the local air traffic control tower real-time).

7.6 Terminal Information Display System (TIDS) & En Route Information Display Systems (ERIDS)

In recognition of the length and complexity of many RPA missions, the FAA should provide the following capabilities to TIDS and ERIDS to ensure that air traffic controllers have immediate access to RPA flight information that may significantly affect air traffic controllers' duties, authorities, and responsibilities:

- RPA flight plan information related in excess of that provided by ERAM must be readily available to the air traffic controller.
- This information should include all of the waypoints filed in support of the RPA mission (this could be 500 latitude/longitude fixes that define a mission length of 24 hours or more).
- Waypoint should be numerically coded in the sequence flown with an associated ETA for each fix, including orbiting delays.
- The route of flight should be sequenced so it displays the current estimated fix based on real time.
- A real-time display for the next 20 minutes of flight plan route should be optionally displayed to confirm the actual route segment that is being flown.
- Contingencies (one or more) for each waypoint must be available to be optionally selected and displayed by the controller to accommodate for lost C2 communication link, vehicle or operational anomalies, or system/sub-system derogated modes or failures.
- C2 information supporting a RPA mission must also be readily available to the air traffic controller, this includes the following:
    - Contact information and means and methods to contact the RPA pilot or operator.
    - Key information, if not routine, about the mission and mission profiles to enable the air traffic controller to understand mission needs and effects on ATC operations.
    - Information concerning any performance characteristics or limitations that affect ATC.

7.7 System Wide Information Management (SWIM)

SWIM must be able to provide both publishers as well as subscribers of RPA data with timely information and an information exchange that would be readily available to air traffic controllers and their support staffs, including the following:

- User-provided detailed flight-plan information associated with each RPA flight operation, including flight contingencies;

- User-provided information concerning mission needs and requirements to assist ATC in understanding how best to support user mission requirements;
- User-provided RPA vehicle information, including its operating characteristics, performance capabilities, and limitations;
- User-provided communications means and methods as well as contact information for pilots and operators; and
- ATC-provided airspace or operational constraints that could affect RPA missions and operations.

7.8 Flight Information Exchange Model (FIXM)

FIXM can already support many flight plan elements for RPA such as unlimited number of waypoints with ETA for each, long duration missions, and changes of airspeed and/or altitude associated with designated waypoints. In view of future RPA mission needs and requirements that must be supported by ATC, the FIXM-related data issues need to be explored to extend the AIXM and FIXM datasets for the following:

- Provide the ability to identify a radius of orbit at a holding waypoint. In addition to the orbiting radius, this waypoint would have both an ETA as well as an associated Estimated Time of Departure (ETD) to indicate the period of time of the orbit.
- Provide the ability to denote and link externally to mission-related information such as contingencies (e.g., actions associated with lost link or system failures) that are defined at flight plan waypoints.

7.9 Air Traffic Control Optimum Training Solution (ATCOTS)

In view of the emerging development of RPA and their introduction into the ATC system, there are a number of recommendations provided below to address their safe introduction and integration into the NAS.

- Provide for comprehensive initial and frequent recurrent training emphasizing the RPA topics below:
  - Orientation and training on RPA mission types, including needs and requirements from an ATC perspective;
  - Operational or simulated training on new or modified ATC systems that support RPA operations and mission needs and requirements;
  - Training on new ATC policies and procedures covering RPA operations;
  - Orientation and training with emphasis on differing RPA vehicles types, operating characteristics, performance capabilities, and limitations; and
  - Training on RPA communications and C2 means, methods, alternatives, and contingencies.

7.10 Future Facilities

Although FAA's plans for large-scale realignments and consolidations are still evolving, the Agency must address key technical, financial, and workforce challenges to successfully implement the plan, including needs to identify and assess future effects in support of RPA integration and operation.

First, FAA will need to align ongoing construction projects with a plan to include RPA support since some projects overlap with the recently approved consolidation plans, creating the potential for duplication of effort.

Second, FAA will have to make key technical decisions related to areas such as airspace boundaries and automation platforms, which will have a significant impact on the costs and schedules of modernization programs. This will require coordination among FAA's various modernization programs, including NextGen, which FAA has begun but not yet completed.

Third, FAA will need to finalize cost estimates for individual integrated facility projects, given that the initial business case only provided preliminary cost data.

Finally, FAA must address the wide-ranging impacts that facility consolidations will have on its workforce and affected communities. While FAA is aware of these challenges, it is incumbent upon the Agency to mitigate them to the extent possible as its plans for large-scale consolidations evolve. As past consolidations have shown, not addressing these challenges will pose risks to achieving expected benefits.

More specifically, FAA must consider the needs for operational systems within the TFM operational area to address RPA liaison and mission planning and approval. This is especially relevant as FAA transitions from its current encumbered centralized COA process to a future 24-hour file and fly review and approval by originating IFR facilities. This transition would require new automation systems supported by new personnel for ATC RPA operational positions.

7.11 Next Generation Weather Processor (NWP) and Weather and Radar Processor (WARP)

The following items outline weather-related products and services that will be required to safely, effectively, and efficiently support RPA integration and operation in the NAS:

- Provide new aviation weather products that have extended forecast periods with means and methods for automated updates and alerts of changes in previous forecasts.
- Provide new products that provide greater weather spatial and temporal granularity, which may be needed due to the RPA vehicle design parameters, including greater sensitivity to hazardous weather, such as turbulence and icing, and extended flight times, including loiter.
- Conduct an analysis of current weather requirements for flight visibilities and ceiling needs to be conducted in consideration of weather requirements for unmanned aircraft and their sensor systems' equivalency to manned capabilities.
- Conduct an analysis of needs to install on larger RPA weather sensors or systems capable of deriving or detect critical weather parameters, such as icing, turbulence, visibilities, and wind speed and direction. Included in this analysis should be a consideration to routinely broadcast these weather parameters to other nearby aircraft as well as a downlink to meteorological forecast centers for processing on systems such as NWP.

7.12 Terminal Flight Data Management (TFDM)

The concept of TFDM, which integrates and automates a number of ATC functions, provides an excellent opportunity to analyze surface and terminal requirements to accommodate integration of RPA into the NAS. The following are presented for consideration in addressing RPA needs inherent in TFDM:

- Review EFS requirements to ensure that information supporting the safe movement of RPA on the surface as well as on departure and arrival is provided. This may be an expansion of flight plan elements as discussed in FIXM to the ability of TFDM to support information needs identified previously in this paper for ERAM, TAMR, and SWIM.

- SS and SM will need to consider operational performance for RPA as it differs from manned aircraft operations. This includes divergent RPA type, operating characteristics, performance capabilities, and limitations.
- Develop an acceptable method of surface movement to support ground RPA operations. This may include ground escort vehicles, remote surface radar to RPA pilots of operators, the use of optical or other sensors in the RPA vehicle that are remotely displayed to the pilot, or any combination of these.
- Look at fully automated ground movement being preprogrammed, or dynamically upload taxi instructions given by the RPA pilot or operator or conceivably by ATC controlled from the ATC ground control position.

7.13 Detect and Avoid (DAA)

This analysis of DAA addresses an approach that minimizes DAA effects on ATC in terms of workload and workload complexity. These are important considerations if the FAA is to achieve a timely and seamless integration of RPA into the NAS. While there may be alternative strategies and technological approaches for DAA, technology alone cannot drive itself into the NAS by ignoring basic paradigms essential to NAS operations.

The concepts put forward in this paper diverge from other efforts and approaches with the following key differences:

- RPA operations may be conducted either VFR or IFR within appropriate airspace environments.
- RPA operations conducted under IFR must minimize operational effects on ATC. This requires minimized coordination and communication needs between RPA pilots and air traffic controllers to keep workload on both pilot and controller as low as possible. In addition, DAA actions must be innocuous, seamless, and transparent enough not to create air traffic controller workload complexity.
- DAA will be driven by ATC mileage separation requirements at the point of closest approach. Mileage requirements will be converted by DAA into varying time parameters as a basis for DAA maneuvers.
- Use of TCAS data to establish DAA performance is non sequitur. DAA must baseline appropriate airspace and vehicle information relevant to its uses and risks.
- Selective design and use of DAA may be an importance step in NAS integration of RPA. For example, a DAA concept that addresses its use within ADS-B-mandated airspace below 10,000 feet MSL might provide the greatest near-term benefit, coupled with the most effective and efficient DAA deployment strategy.
- DAA must be able to function with GBSAA as an integrated solution for separation assurance. GBSAA can provide non-cooperative 3D primary radar surveillance in areas below or outside ADS-B-mandated airspace and provide RPA separation detecting and alerting until an RPA with ADS-B surveillance is wholly contained and operating within ADS-B-mandated airspace.
- DAA sensors may include radar, electro-optical, infrared, and others. Their performance to be able to detect and track conflicting traffic will be critical to their acceptability and use.
- The concept of a DAA maneuver threshold coincidental with ATC radar separation minima is critical to the acceptability of DAA not to pejoratively affect the efficiency, capacity, and ostensibly the safety of the ATC system.
- Well clear distances are predicated on FAR VFR minimum flight visibility requirements and distances clear of cloud. This assumes that these standards have been judged as adequate by FAA to exercise See and Avoid maneuvers between conflicting aircraft.

7.14 Themes for Future Near-term Focus

This paper reveals two emerging themes associated with the timely integration of RPA into the NAS. First is that the information required to safely and efficiently operate RPA in the NAS will be far greater in volume and content than that of conventional manned aircraft. This is due to the fact that RPA are designed around missions with business cases that are different than virtually all manned aircraft operating in the NAS today. This drives RPA designs that will possess a broad divergence from traditional manned aircraft operating in the NAS of aircraft types, operating characteristics, performance capabilities, and limitations—all of which will drive the need for more information delivered to the right place at the right time and in the right format. In addition, the fact that the pilot is not collocated in the aircraft presents considerable communications, command, and control challenges that add complexity to the operation of the NAS, also adding an information burden.

The second major theme is that the processes established by the FAA in their AMS contain obstacles that hinder the FAA's ability to deploy or modify capital investments in NAS infrastructure in a sufficient timeframe.

In view of these challenges, considerable work needs to be undertaken to begin to detail a more comprehensive vision with associated concepts, architectures, and functional requirements that can be translated into engineering designs and system requirements, which would be modeled and simulated to iterate and validate means and methods to successfully operate RPA in the NAS. Coincidentally this also means identifying and removing policy, procedural, and process barriers that impede timely and responsible actions and activities to move quickly and effectively to integrate RPA into the NAS.

Perhaps one of the most effective ways to build to an overall system design is to attack its critical elements and to seek solutions that will integrate into a larger system of systems solution set. Three critical and unresolved issues are as follows:

- The integration of mission and flight planning for RPA is a considerable challenge for ATC. A plethora of waypoints in latitude-longitude format, each with the possibility of an associated action of altitude changes and/or orbiting delays, provides a new complexity that translates into heavy workloads for air traffic controllers. The need to sequentially number waypoints and to provide ETAs and possibly departure times from these waypoints also adds to workload complexity that characterizes RPA operations.
- The overwhelming need to provide accountability for RPA operations in the NAS, especially of small RPA, is a critical need because small RPA operations in metropolitan areas are exploding in number throughout the NAS. This may range from filing notification of operations for some RPA flights to requiring a preapproved mission profile under a COA replacement for a 24-hour file and fly.
- There is also a need to provide a structured communications concept and policy for C2 with supporting procedures to accommodate the needs of small RPA that, due to mission or safety requirements, find the use of public unlicensed spectrum ill advised.

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Appendix A: FAA Acquisition Management System

A.1 FAA Acquisition Management System

The AMS establishes policy and guidance for all aspects of lifecycle acquisition management for the FAA. It defines how the FAA manages its resources, money, people, and assets to fulfill its mission. The objectives of the policy are to increase the quality, reduce the time, manage the risk, and minimize the cost of delivering safe and secure services to the aviation community and flying public. According to FAA, Acquisition Management policy promotes these objectives to ensure that FAA plans, programs, and budgets address priority aviation needs.

Table 2: Lifecycle Processes and Functional Discipline Matrix

Lifecycle Processes					
Mission Analysis (including Research for Service Analysis) 6 – 16 years		**Investment Analysis 2 years**		**Solution Implementation 10 years**	**In-Service Management 4 years**
Service Analysis	Concept and Requirements Definition	Initial Investment Analysis	Final Investment Analysis		
Functional Disciplines Supporting Major Lifecycle Processes					
			Configuration Management	Configuration Management	Configuration Management
Real Property	Real Property	Real Property	Real Property	Real Property	Real Property
Integrated Logistics	Integrated Logistics	Integrated Logistics	Integrated Logistics	Integrated Logistics	Integrated Logistics
				Test and Evaluation	
				Independent Operational Assessment	
				Deployment Planning	
		Human Factors	Human Factors	Human Factors	
			Environmental, OSHA and Energy	Environmental, OSHA and Energy	
Information Technology	Information Technology	Information Technology	Information Technology	Information Technology	Information Technology
System Engineering	System Engineering	System Engineering	System Engineering	System Engineering	
Security	Security	Security	Security	Security	Security
System Safety Management	System Safety Management	System Safety Management	System Safety Management	System Safety Management	System Safety Management
Risk Management	Risk Management	Risk Management	Risk Management	Risk Management	Risk Management
				Data Standardization	Data Standardization
					Post Implementation Review
		Earned Value Management	Earned Value Management	Earned Value Management	

The full understanding and use of the AMS is critical to providing an acceptable process for NAS systems and sub-systems changes to optimize the accommodation of RPA into the NAS.

The FAA AMS is broken into major areas of Policy, Lifecycle Phases and Decisions, and Practices that cover all aspects of the FAA system acquisition. However, the major interest of this paper is to focus on the viability of technology insertion and migration in response to new customer business models that drive new operational paradigms for ATC systems and sub-systems. This means looking at FAA lifecycle acquisition processes and supporting disciplines to understand the challenges and timelines involved in introducing new needed functionality into ATC systems. Table 2 defines those lifecycle processes and functional disciplines of greatest interest in seeking successful methods to provide for rapid technology insertion and system migration to needed new functionality.

If the integration of RPA into the NAS requires NAS infrastructure changes, then those changes, once identified, need to follow FAA-approved processes as defined by the AMS to be successfully integrated through FAA systems and sub-systems that define the NAS infrastructure. These processes will effect requirements and their associated technical risks, costs, and schedules and may represent the true time and costs for full NAS integration of RPA.

Of the all-inclusive AMS Policy, the two sections defined below contain critical processes for introducing RPA-related changes in the NAS that must be understood and supported.

The Acquisition Management Policy is organized as follows:

- Section 1: AMS policy and defined key management elements
- Section 2: Phases and decision points of FAA's lifecycle management process
- Section 3: Procurement policy
- Section 4: Policy for critical lifecycle management functions and disciplines
- Section 5: Acquisition career management policy
- Appendix A: Roles and responsibilities for key FAA organizations
- Appendix B: Policy for AMS planning documents
- Appendix C: Terms used in the policy
- Appendix D: Glossary of acronyms
- Appendix E: Laws and executive branch policy applicable to FAA

The Lifecycle Phases and Decisions are organized as follows:

- Section 1: Research for Service Analysis
- Section 2: Service Analysis and Strategic Planning
- Section 3: Concept and Requirements Definition
- Section 4: Investment Analysis
- Section 5: Solution Implementation
- Section 6: In-Service Management
- Section 7: Decisions/Reviews/Standard Milestones
- Section 8: Investment Decision Authority Processes
- Section 9: Acquisition Categories

In addition, there are a number of functional areas of disciplines defined that apply to one or more of the major lifecycle functional areas of (1) Mission Analysis, (2) Investment Analysis, (3) Solution Implementation, and (4) In-Service Management.

A.2 Acquisition Management System Policy

The FAA executes its acquisition management policy by means of the lifecycle management process, which is organized into a series of phases and decision points as shown in Figure 8. The circular representation conveys the principle of seamless management and continuous improvement in service delivery over time. Application is flexible and may be tailored appropriately. A continuing dialog with and feedback is maintained throughout the process.

Figure 8: The FAA Lifecycle Management Process (FAA)

A.2.1 Acquisition Categories Supporting Investment Decision-making and Governance

Acquisition categories are used to ensure that the appropriate level of oversight and artifact requirements is applied to each FAA investment program. This process applies to all investment programs, appropriations, and FAA organizations. This includes all capital investments in the NAS and FAA administrative and mission support systems and services.

First, a proposed FAA investment program will be classified into an Investment Type (New Investment, Technology Refreshment, Facility, Variable Quantity, or Support Contract). Second, the investment program will be further classified based on the designation criteria. Programs will be assigned to the highest level that meets one or more of the designation criteria. Designation criteria include factors such as total Facilities and Equipment (F&E) costs; single year F&E costs; Operations and Maintenance (O&M) costs; and factors such as complexity, risk, political sensitivity, safety, and security. During concept and requirements definition (CRD), the sponsoring service organization recommends a category and classification to the Acquisition Executive Board, which makes the categorization decision and notifies the JRC. These decisions are finalized before the investment analysis readiness decision (IARD).

For purposes of RPA NAS integration, it is envisioned that the FAA's investment will predominantly fall under New Investments, requiring some research, design, development, and implementation to facilitate a new FAA system or service. This program typically introduces new capabilities or provides new or improved functionality to an existing program (e.g., Pre-Planned Product Improvement [P3I]). It is not inconceivable that RPA investments will need to be made as a Facility initiative that addresses new construction, replacement, modernization, repair, remediation, lease, or disposal of FAA's manned and unmanned facility infrastructure(s) in an effort to provide for expansion to accommodate new positions of operations or new automation, communications, command, or control infrastructure. Such an initiative may result in new safety or security implications. Further, it is expected that contracts for Support Services will also need to be provided, including contracts associated with procuring technical, engineering, scientific, professional, management, and administrative expertise, advice, analysis, studies, or reports in support of RPA integration into the NAS.

The tables below outline the designation criteria, Governance Investment Decision Authority (IDA), reviewing organizations and key artifacts required during Concept and Requirements Definition (CRD), Initial Investment Analysis (IIA) and Final Investment Analysis (FIA) for program investments as reference in identifying the steps necessary to consider NAS investments for RPA integration.

The tables below detail and describe the AMS Support Services Acquisition Categories, Governance and Artifacts.

Table 3: AMS Support Acquisition – New Investment

Acquisition Category	Designation Criteria	Governance IDA	Reviewed By	Key Artifacts		
				CRD	*IIA*	*FIA*
New Investment 1 (1NI)	1. Program has total F&E costs **greater than $800M** 2. Program has a single year of F&E funding **greater than $200M** 3. Program has O&M costs **greater than $500M** 4. For Non-NAS IT Programs: a. FAA Enterprise-wide impact OR b. Critical to Mission Support functions of the FAA 5. The aggregate rating of the following factors is **high**: a. Complexity b. Risk c. Political Sensitivity d. Safety e. Security	JRC	JRC Executive Secretariat Engineering Services (NAS Programs) Chief Technology Officer (NAS Regulatory/ Non-NAS Programs) Investment Planning & Analysis	Shortfall Analysis/ Quantification Solution ConOps Functional Analysis EA Products/Views Safety Assessment Preliminary Program Requirements Specialty Engineering Assessments (e.g., Spectrum, Human Factors) Range of Alternatives ROM Costs ACAT Determination Investment Analysis Plan	Initial Program Requirements Initial Business Case Initial Implementation Strategy and Planning Document Final Investment Analysis Plan	Final Program Requirements Final Business Case Final Implementation Strategy and Planning Document Acquisition Program Baseline In-Service Review Checklist

Acquisition Category	Designation Criteria	Governance IDA	Reviewed By	Key Artifacts		
				CRD	*IIA*	*FIA*
New Investment 2 (2NI)	1. Program has total F&E costs **greater than $300M but less than $800M** 2. Program has a single year of F&E funding **greater than $100M but less than $200M** 3. Program has O&M costs **greater than $250M but less than $500M** 4. For Non-NAS IT Programs: a. FAA Enterprise-wide impact OR b. Critical to Mission Support functions of the FAA 5. The aggregate rating of the following factors is **medium to high**: a. Complexity b. Risk c. Political Sensitivity d. Safety e. Security	JRC	JRC Executive Secretariat Engineering Services (NAS Programs) Chief Technology Officer (NAS Regulatory/ Non-NAS Programs) Investment Planning & Analysis	Shortfall Analysis/ Quantification Solution ConOps Functional Analysis EA Products/Views Safety Assessment Preliminary Program Requirements Specialty Engineering Assessments (e.g., Spectrum, Human Factors) Range of Alternatives ROM Costs ACAT Determination Investment Analysis Plan	Initial Program Requirements Initial Business Case Initial Implementation Strategy and Planning Document Final Investment Analysis Plan	Final Program Requirements Final Business Case Final Implementation Strategy and Planning Document Acquisition Program Baseline In-Service Review Checklist
New Investment 3 (3NI)	1. Program has total F&E costs **greater than $100M but less than $300M** 2. Program has a single year of F&E funding **greater than $50M and less than $100M** 3. Program has O&M costs **greater than $100M but less than $250M** 4. For Non-NAS IT Programs: a. Significant impact on a single or several FAA LOBs OR b. Impact the Mission Support functions of the FAA 5. The aggregate rating of the following factors is **medium**: a. Complexity b. Risk c. Political Sensitivity d. Safety e. Security	JRC	JRC Executive Secretariat Engineering Services (NAS Programs) Chief Technology Officer (NAS Regulatory/ Non-NAS Programs) Investment Planning & Analysis	Shortfall Analysis/ Quantification Solution ConOps Functional Analysis EA Products/Views Safety Assessment Preliminary Program Requirements Specialty Engineering Assessments (e.g., Spectrum, Human Factors) Range of Alternatives	Initial Program Requirements Initial Business Case Initial Implementation Strategy and Planning Document Final Investment Analysis Plan	Final Program Requirements Final Business Case Final Implementation Strategy and Planning Document Acquisition Program Baseline In-Service Review Checklist

Acquisition Category	Designation Criteria	Governance IDA	Reviewed By	Key Artifacts		
				CRD	*IIA*	*FIA*
				ROM Costs ACAT Determination Investment Analysis Plan		
New Investment 4 (4NI)	1. Program has total F&E costs **greater than $20M but less than $100M** 2. Program has a single year of F&E funding **greater than $20M but less than $50M** 3. Program has O&M costs **greater than $20M but less than $100M** 4. The aggregate rating of the following factors is **medium to low**: a. Complexity b. Risk c. Political Sensitivity d. Safety e. Security	JRC	JRC Executive Secretariat Engineering Services (NAS Programs) Chief Technology Officer (NAS Regulatory/ Non-NAS Programs) Investment Planning & Analysis	Shortfall Analysis/ Quantification Solution ConOps Functional Analysis EA Products/Views Safety Assessment Preliminary Program Requirements Specialty Engineering Assessments (e.g., Spectrum, Human Factors) Range of Alternatives ROM Costs ACAT Determination Investment Analysis Plan	Initial Program Requirements Initial Business Case Initial Implementation Strategy and Planning Document Final Investment Analysis Plan	Final Program Requirements Final Business Case Final Implementation Strategy and Planning Document Acquisition Program Baseline In-Service Review Checklist
New Investment 5 (5NI)	1. Program has total F&E costs **less than $20M** 2. Program has a single year of F&E funding **less than $20M** 3. Program has O&M costs **less than $20M** 4. The aggregate rating of the following factors is **low**: a. Complexity b. Risk c. Political Sensitivity d. Safety e. Security	JRC	JRC Executive Secretariat Engineering Services (NAS Programs) Chief Technology Officer (NAS Regulatory/ Non-NAS Programs) Investment Planning & Analysis	Shortfall Analysis/ Quantification Solution ConOps Functional Analysis EA Products/Views Safety Assessment Preliminary Program Requirements Specialty Engineering Assessments (e.g., Spectrum,	Initial Program Requirements Initial Business Case Initial Implementation Strategy and Planning Document Final Investment Analysis Plan	Final Program Requirements Final Business Case Final Implementation Strategy and Planning Document Acquisition Program Baseline In-Service Review Checklist

Acquisition Category	Designation Criteria	Governance IDA	Reviewed By	Key Artifacts		
				CRD	*IIA*	*FIA*
				Human Factors) Range of Alternatives ROM Costs ACAT Determination Investment Analysis Plan		

Table 4: AMS Support Acquisition – Facility

Acquisition Category	Designation Criteria	Governance IDA	Reviewed By	Key Artifacts		
				CRD	*IIA*	*FIA*
Facility 1 (1F)	**1.** Program has total F&E costs **greater than $800M** a. Based on 5-year estimated costs for recurring programs b. Based on entire program lifecycle costs for discrete programs **2.** Program has a single year of F&E funding **greater than $200M** **3.** Program has O&M costs **greater than $500M** **4.** For Non-NAS IT Programs **a.** FAA Enterprise-wide impact **b.** Critical to Mission Support functions of the FAA **7.** The aggregate rating of the following factors is **high**: a. Complexity b. Risk c. Political Sensitivity d. Safety e. Security	JRC	JRC Executive Secretariat Engineering Services (NAS Programs) Investment Planning & Analysis	Facility Shortfall Analysis/ Quantification Safety Assessment Modified Preliminary Program Requirements ROM Costs Facility Execution Plan - Program Level (recurring programs only) ACAT Determination	No IIA Required	Completed at Project Level

Acquisition Category	Designation Criteria	Governance IDA	Reviewed By	Key Artifacts		
				CRD	*IIA*	*FIA*
Facility 2 (2F)	1. Program has total F&E costs **greater than $300M but less than $800M** **a.** Based on 5-year estimated costs for recurring programs **b.** Based on entire program lifecycle costs for discrete programs 2. Program has a single year of F&E funding **greater than $100M but less than $200M** 3. Program has O&M costs greater than **$250M but less than $500M** 4. For Non-NAS IT Programs a. FAA Enterprise-wide impact OR b. Critical to Mission Support functions of the FAA 5. The aggregate rating of the following factors is **medium to high:** a. Complexity b. Risk c. Political Sensitivity d. Safety e. Security	JRC	JRC Executive Secretariat Engineering Services (NAS Programs) Investment Planning & Analysis	Facility Shortfall Analysis/ Quantification Safety Assessment Modified Preliminary Program Requirements ROM Costs Facility Execution Plan - Program Level (recurring programs only) ACAT Determination	No IIA Required	Completed at Project Level
Facility 3 (3F)	1. Program has total F&E costs **greater than $100M but less than $300M** **a.** Based on 5-year estimated costs for recurring programs **b.** Based on entire program lifecycle costs for discrete programs 2. Program has a single year of F&E funding **greater than $50M and less than $100M** 3. Program has O&M costs **greater than $100M but less than $250M** 4. For Non-NAS IT Programs: a. Significant impact on a single or several FAA LOBs OR b. Impact the Mission Support functions of the FAA 5. The aggregate rating of the following factors is **medium**: a. Complexity b. Risk c. Political Sensitivity d. Safety e. Security	JRC	JRC Executive Secretariat Engineering Services (NAS Programs) Investment Planning & Analysis	Facility Shortfall Analysis/ Quantification Safety Assessment Modified Preliminary Program Requirements ROM Costs Facility Execution Plan - Program Level (recurring programs only) ACAT Determination	No IIA Required	Completed at Project Level

Acquisition Category	Designation Criteria	Governance IDA	Reviewed By	Key Artifacts		
				CRD	*IIA*	*FIA*
Facility 4 (4F)	1. Program has total F&E costs **greater than $20M but less than $100M** **a.** Based on 5-year estimated costs for recurring programs **b.** Based on entire program lifecycle costs for discrete programs 2. Program has a single year of F&E funding **greater than $20M but less than $50M** 3. Program has O&M costs **greater than $20M but less than $100M** 4. The aggregate rating of the following factors is **medium to low**: a. Complexity b. Risk c. Political Sensitivity d. Safety e. Security	JRC	JRC Executive Secretariat Engineering Services (NAS Programs) Investment Planning & Analysis	Facility Shortfall Analysis/ Quantification Safety Assessment Modified Preliminary Program Requirements ROM Costs Facility Execution Plan - Program Level (recurring programs only) ACAT Determination	No IIA Required	Completed at Project Level
Facility 5 (5F)	1. Program has total F&E costs **less than $20M** **a.** Based on 5-year estimated costs for recurring programs **b.** Based on entire program lifecycle costs for discrete programs 2. Program has a single year of F&E funding **less than $20M** 3. Program has O&M costs **less than $20M** 4. The aggregate rating of the following factors is **low**: 1. Complexity 2. Risk 3. Political Sensitivity 4. Safety 5. Security	JRC	JRC Executive Secretariat Engineering Services (NAS Programs) Investment Planning & Analysis	Facility Shortfall Analysis/ Quantification Safety Assessment Modified Preliminary Program Requirements ROM Costs Facility Execution Plan - Program Level (recurring programs only) ACAT Determination	No IIA Required	Completed at Project Level

Acquisition Category	Designation Criteria	Governance IDA	Reviewed By	Key Artifacts		
				CRD	*IIA*	*FIA*
Facility Project Sub-ACAT F1	1. Project has total F&E costs **greater than $15M AND** 2. Project includes **new construction** or has an aggregate rating of **high** for the following factors: a. Complexity b. Risk c. Political Sensitivity	JRC	JRC Executive Secretariat Investment Planning & Analysis	Completed at Program Level Safety assessment if required	No IIA Required	Modified Final Program Requirements Modified Final Business Case Modified Final Implementatio n Strategy and Planning Document

Acquisition Category	Designation Criteria	Governance IDA	Reviewed By	Key Artifacts		
				CRD	*IIA*	*FIA*
						Facility Execution Plan - Project Level
Facility Project Sub-ACAT F2	1. Project has total F&E costs **between $1.5M and $15M** **OR** 2. Project has F&E costs **greater than $15M**, but **does not include any new construction and has an aggregate rating of medium or low** for the following factors: a. Complexity b. Risk c. Political Sensitivity	ATO: VP Non-ATO: Director	LOB	Completed at Program Level Safety assessment if required [1]	No IIA Required	Follow LOB review processes and documentation requirements
Facility Project Sub-ACAT F3	1. Project has total F&E cost **less than $1.5M**	ATO: Director Non-ATO: Director	LOB	Completed at Program Level Safety assessment if required [1]	No IIA Required	Follow LOB review processes and documentation requirements

Table 5: AMS Support Acquisition – Support Services

Acquisition Category	Designation Criteria	Governance IDA	Reviewed By	Key Artifacts
Support Services Contract 1 (1SC)	1. Support services contracts with total costs **greater than $100M** that would result in a new contract, agreement, basic ordering agreement (BOA)/blanket purchase agreement (BPA), or other procurement action (lease) 2. Modification actions to existing contracts, orders, or agreements where the individual or combination of modifications: a. Increases the total value of a contract that has been previously reviewed to **$100M** or more b. Results in a significant change to the statement of work for contracts **greater than $100M**	JRC	JRC Executive Secretariat Support Contract Review Board (SCRB)	• SCRB Phase I Form • SCRB Phase II Form • Contract Business Case • Statement of Work • Independent Government Cost Estimate (IGCE)
Support	1. Support services contracts	ATO: VP	Support	• SCRB Phase I Form

Acquisition Category	Designation Criteria	Governance IDA	Reviewed By	Key Artifacts
Services Contract 2 (2SC)	with total costs between **$10M and $100M** that result in a new contract, agreement, basic ordering agreement (BOA)/blanket purchase agreement (BPA) or other procurement action (lease) 2. Modification actions to existing contracts, orders, or agreements where the individual or combination of modifications: a. Increases the total value of a contract that was not previously reviewed to between **$10M and $100M** b. Results in a significant change to the statement of work for contracts between **$10M and $100M**	Non-ATO: Director	Contract Review Board (SCRB)	• SCRB Phase II Form • Contract Business Case • Statement of Work • Independent Government Cost Estimate (IGCE)
Support Services Contract 3 (3SC)	Support services contracts with total costs **less than $10M** that result in a new or modified contract, agreement, basic ordering agreement (BOA)/blanket purchase agreement (BPA) or other procurement action (lease)	ATO: Director Non-ATO: Director	Contracting Officer	• Contract Business Case • Statement of Work • Independent Government Cost Estimate (IGCE)

A.2.2 Strategic Planning, Management, and Budgeting

The Government Performance and Results Act of 1993 requires Federal agencies to have measurable performance targets tied to agency goals and objectives. These targets serve as the basis for planning capital investments and measuring progress.

The FAA supports this requirement through a strategic management process that forecasts the future aviation environment and captures goals, objectives, and performance targets in its strategic plan, currently Destination 2025. FAA strategic planning links the long-range vision and goals for the agency directly to the service needs of customers and defines top-level performance measures and multi-year performance targets.

The NAS ConOps specifies the operational capabilities that the NAS will have over time. Together, the FAA strategic plan and NAS ConOps set the primary context for the FAA Enterprise Architecture and all lower-level plans and budgets within the agency. FAA lines of business and staff offices align their planning to the goals and objectives in FAA strategic planning. Service organizations within the lines of business in turn align their business and operating plans to line-of-business planning. These relationships are illustrated in Figure 9.

Figure 9: Strategic Planning, Management, and Budgeting

Service organizations develop integrated business plans and budgets across all appropriations to achieve full lifecycle support of service delivery. Planning is realistic within budgetary constraints. Success or failure in achieving performance goals influences future planning and budgeting decisions. Resources are dedicated to key activities such as service analysis, concept and requirements definition, and investment analysis.

The Administrator approves the FAA strategic plan, the NextGen Management Board approves the NAS ConOps, and the JRC approves the FAA Enterprise Architecture.

The Chief Financial Officer formulates the budget across lines of business and staff offices, tracks actual performance against planned execution based on input from these organizations, records approved resource adjustments to FAA plans and budgets, and incrementally moves FAA planning and budgeting forward each year. The Chief Financial Officer also develops the F&E, RE&D, and OPS budget requests.

A.2.3 FAA Enterprise Architecture

The FAA Enterprise Architecture defines the operational and technical framework for all capital assets of the FAA. It describes the agency's current and target architectures, as well as the transition strategy for moving from the current to the target architecture. The enterprise architecture is approved annually by the JRC in support of FAA budget and strategic management processes.

The enterprise architecture has two components: the NAS architecture and the non-NAS architecture. The NAS architecture is composed of the systems, people, and procedures necessary for C2 of the NAS. It also includes mission-support systems that manage or design C2 components and air traffic procedures. The non-NAS architecture is composed of the IT operations and investments needed for agency business administration and planning. It includes all mission-support applications, systems, policies, and procedures not directly involved in ATC.

A.2.4 Service Management

Acquisition management policy is structured to apply FAA investment resources to the cost-effective delivery of safe and secure services to its customers. The delivery of these services is accomplished through service organizations, which are responsible and accountable for lifecycle management of service delivery.

A service organization is any organization that manages investment resources, regardless of appropriation, to deliver services. It may be a service unit, program office, or directorate and may be engaged in air traffic services, safety, security, regulation, certification, operations, commercial space transportation, airport development, or administrative functions.

Service organizations bring together the stakeholders and specialists necessary to plan, obtain, manage, and sustain assigned services throughout their lifecycle. A service may be delivered directly to a customer, such as flight planning for general aviation, or to other service organizations that deliver end services to customers. Together, service organizations span the spectrum of FAA activity and responsibility.

Service organizations manage service delivery by means of integrated portfolios of capital investments and operational assets. These portfolios include investment assets under acquisition; fielded equipment, legacy systems, infrastructure, and facilities; and all other types of resources.

Service organizations perform service analysis annually to determine what capabilities must be in place now and in the future to meet agency goals and the service needs of customers and to move planning forward each year. Results are captured in enterprise architecture roadmaps, which are the transition plans for moving the current "as is" architecture to the future "to be" state. These roadmaps are the foundation for line-of-business and staff office business plans, which in turn are the basis for service organization operating plans.

The operating plan of each service organization specifies how it will manage its operational assets and investment initiatives over time to sustain and improve service delivery. Each operating plan is maintained on a continuing basis and updated yearly to reflect progress against plan, Congressional or executive direction, emerging customer needs, and critical aviation incidents. Service organizations track performance, accomplishments, and resource expenditures relative to the operating plan and take corrective action as necessary to achieve agreed goals and objectives.

A.2.5 Portfolio Management

The FAA views and manages its investment and operational assets through multiple levels and groupings of portfolios to ensure that they work together efficiently to achieve agency strategic, mission, and service goals. At the agency level, the entire FAA budget is a portfolio of planned expenditures organized to balance support of existing operational services with investment in new capability. Within this portfolio, the RE&D, F&E, and OPS appropriations are distinct portfolios that allocate research, investment, and operational funding to the most pressing service needs of the aviation community. Similarly, the enterprise architecture is a portfolio with investments and assets that make up the NAS and administrative and mission support IT (non-NAS). The enterprise architecture can be viewed as distinct portfolios segmented in different ways for specific purposes.

Operational capability portfolios are rational groupings of NAS investment programs proceeding through the AMS lifecycle management process that have critical interdependences that must be taken into account when making investment decisions for individual components of the portfolio.

The JRC uses portfolio management in conjunction with strategic planning, the enterprise architecture, and outcome-based performance measures when making investment decisions and managing selected groupings of investments.

AMS policy does not create a universal definition for the term "portfolio management." It establishes the definition and policy for several standard agency-wide portfolios and for operational capability portfolios. This policy does not preclude other types of portfolios within the agency, nor does it provide policy or guidance for managing them.

The FAA implements agency-wide portfolio management at multiple organizational levels and within a unified functional framework. The FAA, through the JRC and other means, manages the overall agency investment portfolio with the following tools:

Enterprise Architecture: The enterprise architecture portrays the "as is" and "to be" state of FAA operational assets along with roadmaps that lay out over time what investments will be made to achieve the end-state configuration. The enterprise architecture is developed and updated annually by analyzing the functions that the FAA needs to provide based on identified gaps in needed services over time. This view of the corporate-level portfolio is presented to the JRC each year for approval.

FAA Budget: The budget is developed using a strategic management process that ties it to the needs in the enterprise architecture and the goals in the FAA strategic plan to create a unified performance-based budget. The budget is reviewed each year considering several corporate-level portfolio measures, including progress in meeting FAA strategic goals, budget allocations relative to strategic planning targets, and assessments of under-performing programs using Earned Value Management (EVM). This information is presented to the JRC annually when it reviews the agency budget submission.

Each line of business and staff office oversees, coordinates, and integrates the service portfolios of its service organizations to achieve the greatest overall contribution to agency strategic goals and targets. Service organizations (e.g., terminal services, en-route and oceanic services, regulatory services, certification services) manage integrated sets of investment and operational assets to optimize service delivery over time. The NextGen organization oversees investment portfolios that cut across service organizations to provide fully integrated operational capabilities for the NAS in such areas as precision-based navigation and improved runway operations. More than one service organization may be involved with implementation and in-service management of these investment packages. The NextGen organization oversees investment packages that cut across service organizations to provide fully integrated functional capability for the NAS in such areas as weather, surveillance, communications, automation, and navigation. More than one service organization may be involved with implementation and in-service management of these investment packages.

The JRC oversees the FAA investment portfolio as expressed in the enterprise architecture, FAA budget, and individual service portfolios. It evaluates the performance of all investment programs and operational assets within each service against quantified baseline measures. Planned initiatives for new investment are discussed along with proposals to remove, replace, or improve operational assets with declining performance that no longer satisfy service needs or are nearing the end of their service life. The JRC aligns and coordinates investment activity across the lines of business through annual review and approval of the enterprise architecture and agency budget submissions to Congress.

Line of business portfolio governance aligns and coordinates investment activity across service organizations within a line of business or staff office. This governance ensures that investment and operational resources support priority FAA strategic and performance goals; ensures that there is no overlap, redundancy, or gap in service delivery; and reviews progress, tracks baseline variances, and monitors remedial planning and execution within service portfolios. Specifically, ATO governance oversees, reviews, and coordinates service portfolios related to the NAS and the provision of ATC services (e.g., terminal, en-route, and technical operations). NextGen (ANG) and Aviation Safety (AVS) governance oversee and recommend investment portfolios within their line of business.

Service organizations manage service delivery within their service area of responsibility. They evaluate service demand on a continuing basis and recommend changes to the service portfolio over time to optimize service delivery.

The FAA has standard criteria for selecting, controlling, and evaluating its investment portfolio. The JRC uses the standard criteria when evaluating new investment opportunities for inclusion in a service portfolio, when evaluating the status of ongoing investment programs, and when evaluating the efficiency and effectiveness of operational assets.

The three categories of portfolio management criteria are listed below.

Selection criteria: The JRC applies the following standard quantitative and judgmental selection criteria to assess the relative contribution of investment options for inclusion in an investment portfolio: benefits, lifecycle cost, benefit-to-cost ratio, consistency with the enterprise architecture, impact on FAA strategic goals, and risk.

Control criteria: The FAA employs EVM, risk management, and testing to determine how efficiently developmental, modernization, and enhancement investment programs are performing relative to plan during solution implementation. For investment programs that do not involve development, modernization, or enhancement, the FAA applies multiple control techniques such as independent review of program cost and schedule estimates, comparison of spend plans against budget authorization, comparison of actual cost and schedule results against planning estimates, and periodic program and data reviews against planning. These management controls identify and quantify variances to baseline cost, schedule, and performance measures as the basis for corrective action. Service organizations test and evaluate the products of investment programs against requirements in the program requirements document to determine whether they are satisfied.

Evaluation criteria: The FAA periodically measures the efficiency (technical quality) and effectiveness (business value) of operational assets to determine whether they should be upgraded, replaced, or removed from service. Service directorates evaluate in-service assets by means of Post-implementation Reviews (PIRs) and operational analyses. PIRs determine whether performance, cost, schedule, and benefit goals are being attained. They provide the basis for corrective action, as well as lessons learned for improving agency investment management processes. Operational analysis determines trends in such factors as reliability, maintainability, supportability, obsolescence, and O&M costs. They are the basis for validating continued support for fielded assets or some other action such as upgrade, replacement, or removal from service.

The NextGen Management Board establishes operational capability portfolios to achieve priority NAS performance and operational goals subject to concurrence by the JRC. When an individual investment increment of the portfolio comes before the JRC for investment decisions, the portfolio manager is present so decisions are made within context of the entire portfolio and overall corporate framework.

An operational capability portfolio may contain materiel (e.g., hardware or software deliverables) and non-materiel (e.g., airspace redesign or procedures) components. Each investment increment must receive an acquisition category designation from the Acquisition Executive Board and is managed through the AMS lifecycle according to its designation.

An operational capability integration plan (OCIP) approved by the executives responsible for each investment increment of an operational capability portfolio defines the critical interdependencies between investment increments, how they will be managed, and their interaction with each other and the overall portfolio. The OCIP specifies how cost, schedule, or performance issues will be communicated to other portfolio investment increments and how they will be resolved corporately for the benefit of the portfolio. A standard template is used to develop the OCIP, which includes measures for tracking and evaluating the portfolio (e.g., portfolio costs and benefits).

Acquisition categories ensure that the appropriate level of oversight and documentation requirements are applied to each FAA investment program. Acquisition categories apply to all investment programs, appropriations, and FAA organizations. This includes all capital investments in the NAS and FAA administrative and mission support systems and services. The JRC is the investment decision authority for all acquisition categories.

Investment programs are classified by investment type (new investment, technology refreshment, variable quantity, facility initiative, or support service contract) and then categorized based on qualitative and quantitative criteria.

The sponsoring service organization recommends an acquisition category to the Acquisition Executive Board, which makes the categorization decision and notifies the JRC for confirmation through the JRC Executive Secretariat. The designation of acquisition category is made before the investment analysis readiness decision. A standard readiness process applies to all acquisition category levels for AMS decision points.

Table 6: Lifecycle Management Decision-making

Decision	Decision Body	Decision Chair
Concept and requirements definition readiness decision	FAA Enterprise Architecture	None
Investment analysis readiness decision	JRC	Acquisition Executive
Initial and final investment decisions	JRC	Acquisition Executive
Product demonstration	Delegated	Delegated
Production	Delegated	Delegated
In-service	Delegated	Delegated
Program baseline change	JRC	Acquisition Executive
F&E, RE&D, and OPS budget approvals	JRC	Acquisition Executive
FAA Enterprise Architecture changes	JRC	Acquisition Executive

Table 6 specifies the decision authority for each AMS lifecycle management decision point. The JRC is the FAA senior investment review board. It makes corporate-level resource decisions, including authorization and funding for investment programs, and approves changes to the enterprise architecture. The JRC selects for approval and funding those investment opportunities having the highest potential for contributing to FAA strategic and performance goals, improving service delivery, increasing aviation safety, lowering operating costs, or otherwise providing value to the FAA and its customers. The JRC may approve, disapprove, modify, or terminate an investment initiative at any AMS decision point.

The JRC approves investment resources, regardless of appropriation, in useful and manageable segments (e.g., development, demonstration, production, deployment, and operations). Each segment is managed within cost, schedule, and performance targets in the acquisition program baseline approved by the JRC at the final investment decision. The portfolio manager attends all lifecycle management decision points involving each investment increment of an operational capability to disclose the impact on an end-state capability of not approving an investment increment.

The service team or program office must complete all phase activities and artifacts to qualify for a decision to proceed to the next lifecycle management phase, but can return to the JRC at any time including the next decision point if the recommendation is to terminate the effort.

The Air Traffic Services Committee reviews all JRC investment decisions for procurement of ATC equipment of $100,000,000 or more in facilities and equipment costs.

A.3 Acquisition Management System Lifecycle Phases and Decisions

Lifecycle acquisition management is built around a logical sequence of phases and decision points (Figure 19). The FAA uses these phases and decision points to determine and prioritize its needs, make sound investment decisions, implement solutions efficiently, and manage services and assets over their lifecycle. The overarching goal is continuous improvement in the delivery of safe, secure, and efficient services over time. Application is flexible and may be tailored by the Acquisition Executive or JRC.

Figure 10: The FAA Lifecycle Management Process (FAA)

The lifecycle management process is the FAA's Capital Investment Planning and Control Process. Service analysis and investment analysis constitute the select process. Solution implementation is the control process. In-service management is the evaluation process.

A.3.1 Research for Service Analysis

Research and systems analysis are often required during service analysis to mature operational concepts, reduce risk, or define requirements before a decision is rendered to proceed further in the lifecycle management process. Research for service analysis (RSA) policy also applies when research and systems analysis are required to develop NAS architecture products to meet the criteria to enter concept and requirements definition. In addition, AMS portfolio management policy applies when alignment across related initiatives is necessary to mature concepts to move through the AMS lifecycle.

During RSA, the FAA engages in two general areas of applied research activity:

- RE&D, and
- Concept Maturity and Technology Development (CMTD).

The RE&D process governs selection and execution of the RE&D portfolio. This portfolio includes systematic studies to gain knowledge or understanding of concepts, products, or procedures that could potentially benefit the aviation community with or without specific application or means by which a specific need may be met, such as research related to materials and human factors. These activities inform FAA strategic planning, the NAS architecture, and CMTD activities, but do not lead directly to concept and requirements definition.

The CMTD process governs activities directed toward the production of useful materials, devices, systems, and methods, as well as advances the maturity of new concepts. Typical activities include concept feasibility studies, technical analysis, prototype demonstrations, and operational assessments that identify, develop, and evaluate opportunities for improving the delivery of NAS services. These efforts reduce risk, define requirements, demonstrate operational requirements, inform concept and requirements definition activities, and generate information required to support agency investment decisions and product lifecycle management.

RSA activities related to the NAS are performed in coordination with the NextGen organization to ensure alignment with the enterprise-level technical strategy as reflected in the NAS architecture.

A.3.2 Research, Engineering, and Development Process

The RE&D process supports aspects of aviation with research on materials and human factors to support development of new products, services, and procedures. These aspects include regulation, certification, and standards for aircraft, air operators, manufacturers, aircrews, and other aviation personnel; airports; commercial space transportation; environment; modernization, operation, and maintenance of the NAS; and aerospace policy formulation, planning, and analysis.

RE&D activity across FAA is coordinated through the RE&D portfolio process. The RE&D executive board develops the RE&D portfolio each year using strategic planning in the National Aviation Research Plan as a guide. This plan links FAA research activities to broader strategic planning in the NAS ConOps, NextGen Implementation Plan, the NAS Architecture, and the functions of a Joint Planning Development Office. The RE&D executive board is supported by program planning teams assigned to prepare and manage specific research areas.

Program managers execute research programs. They work closely with research sponsors (business units that own or share the RE&D requirement) to ensure that results meet customer needs. Annual evaluations determine whether research results are meeting performance targets and supporting FAA strategic goals. Evaluations also determine whether FAA strategic planning is leading the RE&D portfolio in the right direction.

The RE&D Advisory Committee and its associated subcommittees review the RE&D portfolio twice a year, first during budget formulation and later during portfolio evaluation. The outputs and products are the FAA RE&D portfolio, budget formulation documentation, National Aviation Research Plan, and research products addressing the needs of the FAA and aviation community. JRC approves the RE&D budget, and the Administrator approves the National Aviation Research Plan.

Activities

Both the Service Organization as well as the NextGen Organization as outlined below does supporting activities.

Service organizations:

- Identify, justify, and manage research, study, and analysis within their service area of responsibility;
- Prepare budget formulation documents for research programs approved for inclusion in the RE&D portfolio;
- Submit research, study, and analysis proposals to the RE&D portfolio development process for evaluation and possible inclusion in the RE&D portfolio;
- Facilitate peer reviews by subject-matter experts to improve the quality and timeliness of ongoing research programs; and
- Maintain documentation of research methodology, activities, and results.

NextGen organization:

- Manages the RE&D planning and budget process;
- Coordinates annual development of the National Aviation Research Plan;
- Ensures that the RE&D portfolio is aligned with FAA strategic goals and the NAS architecture;
- Coordinates annual updates to the NAS architecture and ensures that concept RE&D activities are properly depicted;
- Identifies and analyzes potential solutions to service need, including feasibility analyses;
- Evaluates prototypes and conducts feasibility demonstrations to validate and refine initial requirements, operational concepts, and potential solutions;
- Integrates FAA research activity with research sponsored or conducted by industry, universities, and other Government organizations;
- Interfaces with Office of the Secretary of Transportation, Office of Management and Budget (OMB), Congress, trade associations, international organizations, and other state and federal government organizations for agency-level research issues;
- Identifies, justifies, and manages research, study, and analysis programs;
- Coordinates with the lines of business to develop the FAA RE&D portfolio each year;
- Reviews and approves the non-NextGen-funded portion of RE&D portfolio each year; and
- Coordinates sequential review of the RE&D portfolio with the Chief Operating Officer, Associate and Assistant Administrators, and JRC.

A.3.3 Concept Maturity and Technology Development Process

The concept maturity and technology development process governs conduct of NAS activities such as feasibility studies, technical analysis, prototype demonstrations, and operational assessments that identify, develop, and evaluate potential concepts for improving service delivery by the FAA. These activities may be for a single initiative or multiple initiatives related to a single concept or portfolio. They may play a role in the development of service analysis products. Key outputs are mature, beneficial concepts that can progress toward entry into the NAS ConOps and NAS architecture and then into concept and requirements definition phase of AMS.

The CMTD process supports concept maturity through the following three stages:

- Concept Exploration identifies promising concepts with sufficient definition to begin development of a concept of operations and plan follow-on activities. Work starts with the collection of a broad and varied range of potential approaches for meeting agency strategic goals, objectives, and service needs and organizes them into candidate concepts. Outputs are promising and feasible concepts that warrant further maturation and development.

- Concept Development matures and evaluates promising concepts to determine which should continue further development. Activities include modeling, simulation, and detailed analysis.
- Concept Evaluation confirms that a concept has great promise toward meeting the needs of the agency and begins to determine operational and technical feasibility. Concept evaluation can include concept integration, evolution, or scalability. Representative activities include prototyping and field demonstration. Individual projects reside in one of the stages, but may not pass sequentially through each, depending on the maturity level of the concept and the progress of related initiatives.

CMTD activities are selected according to their relative potential for achieving needed operational improvements identified in the NAS ConOps and NAS architecture. CMTD activities include development of mid-term operational concepts, concept evaluation studies, human factors analysis, preliminary requirements development for individual concepts, prototypes, demonstrations, and concept development. These activities generate information supporting the validity of identified capability shortfalls, future service needs, capability requirements, expectations of benefits, and design alternatives. See CMTD guidance for a list of products and how CMTD supports the development of those products.

CMTD encompasses activities designed to validate concepts for improving performance. A concept is a broad area of potential operational improvement to be explored for applicability to agency strategic goals and objectives. Concepts are evaluated for technical and operational feasibility as they progress through the CMTD process where they are prepared for entry into the NAS ConOps and NAS architecture, and eventually on to concept and requirements definition.

Individual projects are discrete efforts that evaluate specific aspects of the concept and provide data necessary to assess technical maturity and operational feasibility. The objective of each project must be defined, have definitive deliverables, and have clear success criteria. An individual project is most often completed during one stage of the CMTD process and is always conducted in accordance with a project-level or portfolio-level agreement. Several CMTD projects may need to be completed for a concept to be deemed mature enough to continue with service analysis or enter concept and requirements definition.

The following flowchart describes the steps that projects move through during the CMTD process. The steps are cyclic and apply to each stage of the process.

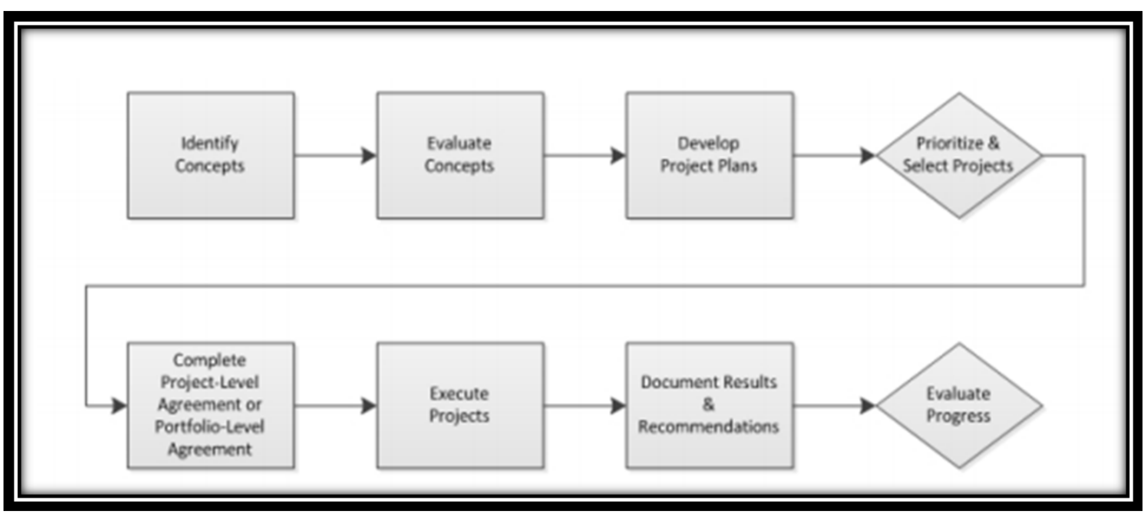

Figure 11: Concept Maturity and Technology Development Process

- Identify Concepts. All potential concepts for satisfying immediate or future priority service or performance needs are gathered and acknowledged. The FAA strategic plan, NAS architecture, NAS ConOps, NextGen Implementation Plan, and prior research are various sources from which to identify concepts.
- Evaluate Concepts. Concepts are evaluated annually to determine which have the greatest potential for improving performance and service and which need to mature in the near future. The NAS architecture links operational improvements to strategic goals and identifies when they are needed.
- Develop Project Plans. A project plan is completed for each potential project. The plan defines project goals and objectives; explains how it will mature the research concept; identifies interdependencies, related projects, risks, and safety concerns; and documents expected outputs and measures for success.
- Prioritize and Select Projects. The portfolio manager collects all project plans and prioritizes them based on immediate needs, dependencies, and projected results. Highest priority research projects are selected to be carried out based on available funding. Projects not selected return to the identify concepts step of the CMTD process for the next funding cycle.
- Complete Project-Level Agreement or Portfolio-Level Agreement. The project team completes the project-level or portfolio-level agreement, which is reviewed by the portfolio manager. This document builds on the project plan and defines project objectives, scope, schedule, deliverables, measures of success, and resources.
- Execute Projects. The project team carries out the research in accordance with the project-level or portfolio-level agreement.
- Document Results and Recommendations. The project team documents all findings and products completed during the research. Depending on the stage, findings could be a refined concept of operations, preliminary requirements, the identification of alternative solutions, the analysis of multiple alternatives, the feasibility and scalability of a single alternative, or the demonstration of a proposed concept. The project team also recommends what should happen next based on the findings. Depending on which stage the concept is in, recommendations could consist of the following: continue working on the concept, the concept is mature, or terminate further consideration of the concept.
- Evaluate Progress. Individual projects are evaluated periodically, and project results are used to develop documentation for service analysis and concept and requirements definition. Often, completion of multiple projects through many cycles will be required to mature a concept from exploration to evaluation. When a concept is deemed mature, the initiative may continue in service analysis or progress to concept and requirements definition.

The CMTD output and products are project plans and the project level portfolio agreements. They also include project results and recommendations and information that validate new ideas and concepts strategically, operationally, and financially for inclusion in the NAS ConOps. The responsibilities fall on the NextGen Organization as well as the Service Organizations. Their work must ultimately be approved for the JRC for budget inclusion.

A.3.4 Service Analysis and Strategic Planning

Service analysis and strategic planning determine what capabilities must be in place now and in the future to meet agency goals and the service needs of customers. Results are captured in the “as is” and "to be" states of the enterprise architecture, as well as the roadmaps for moving from the current to the future state. Results are also captured in line-of-business business plans and service organization operating plans, which specify how each will manage its RE&D, F&E, and OPS resources over time. These plans integrate new investment initiatives with the operation and support of fielded assets and other necessary actions to optimize service delivery. Continuing analysis keeps planning current with changes in the service and operational environment.

Industry best practices (e.g., technology and service demand forecasting, portfolio management, and customer surveys) are employed during service analysis to align service outcomes with actions and activities necessary and sufficient to realize benefits for the FAA and its customers. Service analysis may lead to the refocus, reduction, or elimination of ongoing investment programs and may identify new and more productive ways of doing business. It may also identify alternative paths for achieving service goals in a dynamic environment and may identify opportunities for improving FAA strategic planning when the service environment evolves in ways not anticipated. Some investment opportunities may require research and development to demonstrate operational concepts, reduce risk, or define requirements before proceeding further in the lifecycle management process.

The key activities of service analysis and strategic planning develop the information necessary for determining which service shortfalls or new ideas for improving service delivery are approved for inclusion in agency strategic planning documents. When a service shortfall impacts the NAS, it enters the NAS ConOps change development and decomposition process to determine how it fits within the NAS.

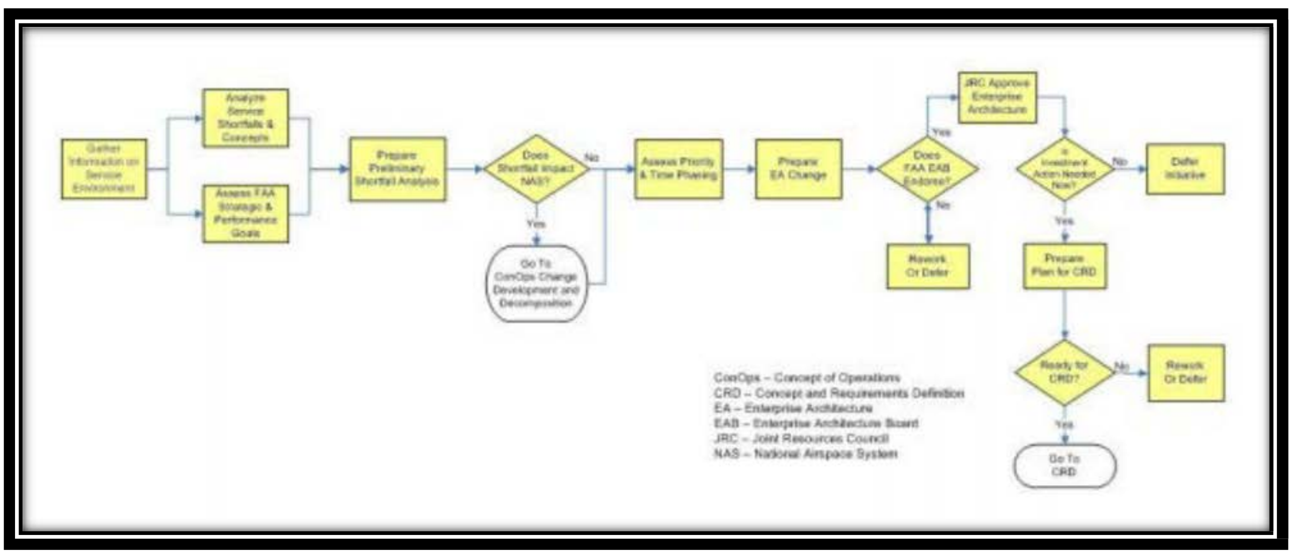

Figure 12: Key Activities of Service Analysis and Strategic Planning

- Gather Information on the Service Environment. Service organizations analyze forecasts for aviation service needs and stay abreast of opportunities for improving service delivery, as a basis for determining and prioritizing service needs and shortfalls. A continuing dialog with and feedback from customers (e.g., commercial air carriers, general aviation, air transport industry, and state and local airport authorities) and users (air traffic and technical operations) are crucial, as is the supportability and operational outlook for fielded assets.
- Analyze Service Shortfalls and Concepts. Lines of business use service environment performance information to identify shortfalls and ideas for improving service delivery within

their domain. Aviation research by NASA and other industry and government organizations may also identify emerging service shortfalls or technological opportunities for improving service delivery. This activity identifies business, technology, organizational, process, and personnel issues that affect service outcomes, as well as assumptions, risks, and dependencies.

- Assess FAA Strategic and Performance Goals. Service shortfalls or new ideas for improving service delivery should support current services or fulfillment of FAA strategic and performance goals. When they do not, the shortfall or new idea must be shown to have sufficient merit to warrant inclusion in agency strategic planning documents. Agency strategic plans and performance goals may also define service shortfalls that must be addressed in lower-level agency planning.
- Prepare Preliminary Shortfall Analysis. The service organization analyzes the shortfall or new idea as a foundation for understanding the problem and its urgency and impact. The shortfall is the difference between future service need and current capability. A service shortfall is usually addressed by a sustainment action for existing assets or a new service delivery idea or concept for predicted gaps. A new idea or concept should deliver existing services more efficiently or provide new services of value to the FAA and aviation industry. At this stage, the service shortfall is expressed as levels of service improvement, not by specific performance values.
- Does Shortfall Impact the National Airspace System? A new service need or shortfall that impacts the NAS is assessed by means of the NAS ConOps Change Development and Decomposition Process to determine whether or how the NAS ConOps should be changed. Once NAS needs or shortfalls have been appropriately included in the NAS ConOps as operational improvements or sustainments, they move forward with non-NAS shortfalls to determine how they should be integrated within the FAA enterprise architecture.
- Assess Priority and Time-Phasing. A new service shortfall or need must be shown to have sufficient merit to warrant inclusion in the enterprise architecture when evaluated against other service needs of the agency. The line of business works with the Technical Review Board (NAS) or the Architecture Review Board (non-NAS) and other lines of business to determine how a new service need, technology refresh, or sustainment activity should be planned, time-phased, and integrated within the architecture relative to all other agency service needs. This activity may require rework of existing shortfalls and improvements already in the architecture.
- Prepare Enterprise Architecture Change. The service organization prepares change documents reflecting the service need or shortfall and submits them to the FAA Enterprise Architecture Board for endorsement. NAS service needs and shortfalls are expressed as operational improvements and operational sustainments.
- Does FAA Enterprise Architecture Board Endorse the Change? The FAA Enterprise Architecture Board determines whether and how to integrate new service needs within the enterprise architecture and its roadmaps. In making this determination, the board analyzes and assesses the new service need against all other service needs of the FAA using such criteria as contribution to agency strategic goals, monetary or performance benefits, compatibility with the enterprise architecture, risk, and political sensitivity. The decision to endorse and place a new service need, improvement, or sustainment within the enterprise architecture validates that this service need is an agency priority and warrants further action.

- Joint Resources Council Approves the Enterprise Architecture. The JRC approves the FAA Enterprise Architecture annually. No service need can proceed further in the AMS lifecycle management process unless it is in the enterprise architecture approved by the JRC. Emergency needs not contained in the JRC-approved architecture may be presented to the FAA Enterprise Architecture Board by exception.
- Rework or Defer. Service needs, shortfalls, improvements, and sustainments not approved for inclusion in the enterprise architecture are reworked or deferred according to the direction of the FAA Enterprise Architecture Board or JRC, as appropriate.
- Is Investment Action Needed Now? The investment increment enters concept and requirements definition at the appropriate time as determined by its time-phasing in the appropriate enterprise architecture roadmap.
- Defer Initiative. Investment action is deferred when action is not needed now to meet agency plans and schedules.

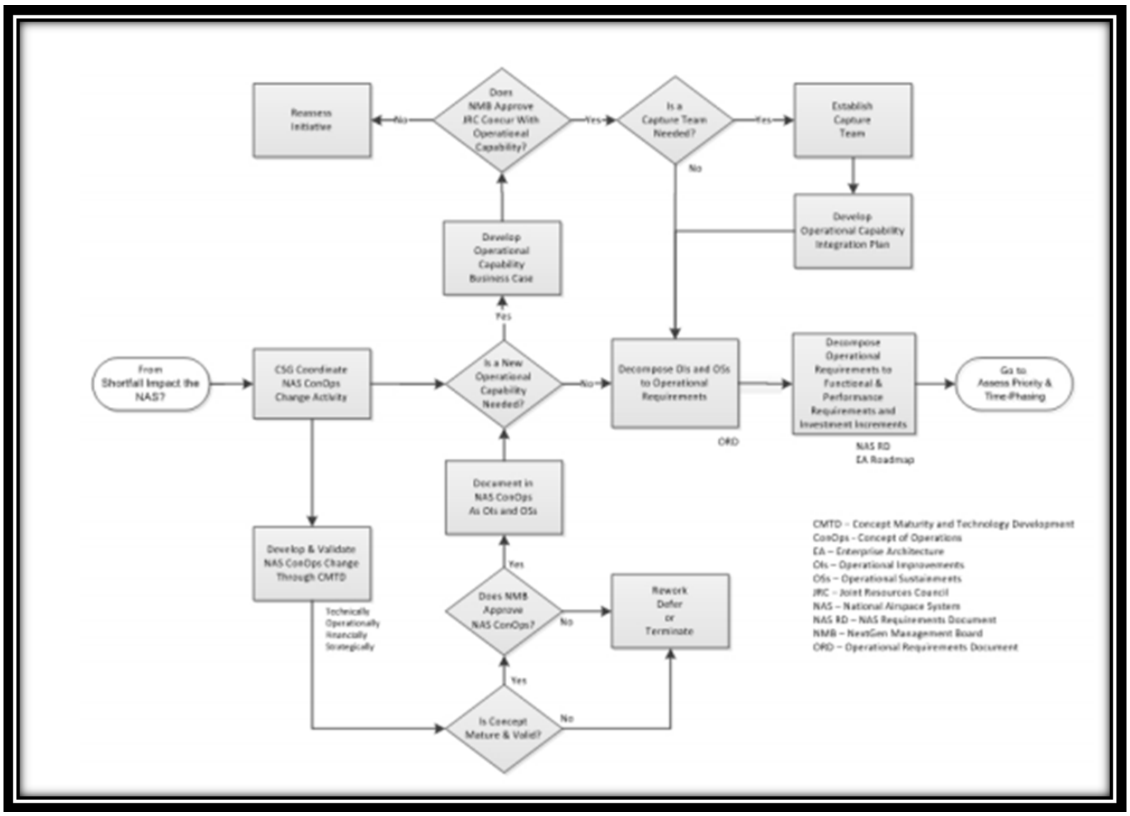

Figure 13: NAS ConOps Change Development and Decomposition Process

- Prepare Plan for Concept and Requirements Definition. NAS Systems Engineering Services (NAS) or AIT Information Technology Research & Development (non-NAS) works with the implementing and operating service organizations to prepare a plan for concept and requirements definition. This plan (1) specifies how tasks will be accomplished, (2) defines roles and responsibilities of participating organizations, (3) defines outputs and exit criteria, (4) establishes a schedule for completion, and (5) specifies needed resources. By signing the plan for concept and requirements definition, organizations that will do the work agree to provide the necessary resources.

- Ready for Concept and Requirements Definition? The FAA Enterprise Architecture Board makes the decision to enter concept and requirements definition or directs other action.
- Rework or Defer. The investment initiative is reworked or deferred when planning or organizational support is not sufficient to enter concept and requirements definition.
- Concept Steering Group Coordinates NAS ConOps Change Activity. The Concept Steering Group reviews the preliminary shortfall analysis to determine whether the service shortfall or new idea is addressed in the NAS ConOps. New shortfalls or ideas that are already within the scope of the NAS ConOps move to decomposition into operational requirements and investment initiatives after determining whether they should be incorporated into a new or existing operational capability. For shortfalls and ideas not addressed in the NAS ConOps, the Concept Steering Group coordinates discussion with the sponsor and the lines of business to determine what development or validation activity is needed.
- Develop and Validate NAS ConOps Change Through Concept Maturity and Technology Development. New ideas for improving NAS service or eliminating a shortfall must be validated to be technically and financially feasible, strategically aligned with agency goals and objectives, and have significant operational benefit to warrant inclusion in the NAS ConOps. The Concept Steering Group coordinates activity to develop and validate new ideas and concepts. Typically, the concept maturity and technology development process is applied to the point where technical risk is sufficiently low and potential benefits sufficiently high to justify inclusion. This activity includes a safety assessment to identify and characterize any hazards associated with the idea or concept.
- Is Concept Mature and Valid? The NAS ConOps is a stable document that evolves over time. Only the best high-value new concepts and ideas are added. The Concept Steering Group assesses development and validation results and records their findings and recommendations in a memorandum to the NextGen Management Board, which approves all changes to the NAS ConOps.
- Concept Steering Group Coordinates NAS ConOps Change Activity. The Concept Steering Group reviews the preliminary shortfall analysis to determine whether the service shortfall or new idea is addressed in the NAS ConOps. New shortfalls or ideas that are already within the scope of the NAS ConOps move to decomposition into operational requirements and investment initiatives after determining whether they should be incorporated into a new or existing operational capability. For shortfalls and ideas not addressed in the NAS ConOps, the Concept Steering Group coordinates discussion with the sponsor and the lines of business to determine what development or validation activity is needed.
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- Is Concept Mature and Valid? The NAS ConOps is a stable document that evolves over time. Only the best high-value new concepts and ideas are added. The Concept Steering Group assesses development and validation results and records their findings and recommendations

in a memorandum to the NextGen Management Board, which approves all changes to the NAS ConOps and investment increment to achieve the operational capability. The objective is informed, integrated, and coordinated decision-making by all parties.

- Establish Capture Team. Each line of business that must contribute to achieve the operational capability provides an empowered representative to the capture team. The capture team monitors development, integration, and deployment of all elements of the operational capability, as well as plan and oversee a post-implementation evaluation to confirm that forecast benefits are being achieved or to define and implement corrective action when they are not.
- Develop Operational Capability Integration Plan. The team works with the portfolio manager to develop an OCIP that specifies responsibilities and agreements among all team members and organizations. The OCIP also defines the lifecycle plan, performance goals and measures, and operational benefits that will accrue from implementation of the operational capability.
- Decompose Operational Improvements and Operational Sustainments to Operational Requirements. A cross-organizational team with members from all lines of business and led by Advanced Concepts and Technology Development decomposes the NAS ConOps narrative of operational improvements and operational sustainments into NAS operational requirements. These requirements are recorded in the NAS Operational Requirements Document.
- Decompose Operational Requirements to Functional and Performance Requirements and Investment Increments. A cross-organizational team decomposes NAS operational requirements to NAS functional and performance requirements. These requirements are specified with sufficient detail for allocation to investment increments that will be undertaken to achieve the operational improvements and sustainments in the NAS ConOps. The goal is clear and unambiguous traceability of requirements from the NAS ConOps to the NAS Operational Requirements Document to the NAS Requirements Document and then to the program requirements document of specific investment increments. Each investment increment enters concept and requirements definition at the appropriate time as determined by their time phasing in the enterprise architecture roadmap.

The output and products include a preliminary shortfall analysis that describes qualitatively the service need, shortfall, and legacy assets; enterprise architecture change notices, products, and amendments; updates to the enterprise architecture; and a plan for concept and requirements definition. Key work products are verified and validated according to the FAA AMS Verification and Validation Guidelines before the CRD readiness decision.

NAS ConOps Change Development and Decomposition initiatives include white papers, research reports, and outputs from concept maturity and technology development; updates to the NAS ConOps; operational capability business case; operational capability; capture team; operational Capability Integration Plan; updates to the NAS Operational Requirements Document; and updates to the NAS Requirements Document. Key work products are verified and validated according to the FAA AMS Verification and Validation Guidelines before the CRD readiness decision.

The organizations involved in the Service Analysis and Strategic Planning involve the Service Organizations, the Advanced Concepts and Development Office, NextGen Lifecycle Integration Office, the Lines of Business, AIT Information Technology Research and Development Office, Technical Review Board, Architecture Review Board, and FAA Enterprise Review Board. NAS ConOps Change and Development has an equally large group of offices involved in these processes.

The approval authorities for Service Analysis and Strategic Planning include NextGen Lifecycle Office, Director of the service organization with the need, FAA Enterprise Architecture Board, ATO VPs or Directors of non-ATO service organizations with the service need, and the operating service and the FAA Enterprise Architecture Board Chair, as well as the JRC. The approval authorities for the NAS ConOps Change Development and Decomposition include the NextGen Management Board, NextGen Systems Analysis and Modeling Office, ATO Operational Concepts, Validation and Requirements Office, and the NAS Engineering Service.

The concept and requirements definition readiness decision occurs when an enterprise architecture roadmap indicates that action must be taken to address a critical service shortfall or opportunity. At this decision, the FAA Enterprise Architecture Board verifies that (1) the service shortfall, operational improvement, or operational sustainment is in an enterprise architecture roadmap; and (2) planning and resources for concept and requirements definition are in place. The readiness decision is the gateway between service analysis and strategic planning and concept and requirements definition.

Service shortfall, operational improvement, or sustainment is in an enterprise architecture roadmap and represents a compelling need of the FAA; and the Plan for concept and requirements definition approved by the FAA Enterprise Architecture Board are required for the concept and requirements definition readiness decision. Ultimately the FAA Enterprise Architecture Board makes the decision to enter concept and requirements definition phase.

A.3.5 Concept and Requirements Definition

All investment opportunities that require funding outside the scope of an approved acquisition program baseline undergo concept and requirements definition. This includes upgrades or replacements to existing capability without approved investment funding.

Concept and requirements definition translates priority operational needs in the enterprise architecture into preliminary requirements and a solution concept of operations for the capability needed to improve service delivery. It also quantifies the service shortfall in sufficient detail for the definition of realistic preliminary requirements and the estimation of potential costs and benefits. Finally, concept and requirements definition identifies the most promising alternative solutions able to satisfy the service need, one of which must be consistent with the conceptual framework in the enterprise architecture.

Planning for concept and requirements definition begins when a roadmap in the enterprise architecture specifies that action must be taken to address a priority service or infrastructure need. These needs typically relate to existing or emerging shortfalls in the "as is" architecture or essential building blocks of the "to be" architecture. Should a service organization wish to pursue an investment opportunity not in an enterprise architecture roadmap, it must first develop architectural change products and amendments and get endorsement from the FAA Enterprise Architecture Board and approval by the JRC.

The FAA may undertake research activity or employ research by other agencies or industry to define the operational concept, develop preliminary requirements, demonstrate and refine computer-human interfaces, reduce risk, or achieve customer buy-in to potential solutions to service need.

When the investment initiative entering concept and requirements definition is an element of an operational capability (NAS only), the capture team responsible for achieving the operational capability (if established) participates in and contributes to CRD activity. The capture team is populated with representatives from each service team or program office that will provide an increment of the overall operational capability. These team members ensure that all preliminary alternatives emerging from concept and requirements definition for each investment increment fit within the strategy for obtaining the capability and can provide the necessary performance and functionality.

A non-materiel solution that emerges during concept and requirements definition may proceed to solution implementation upon approval of implementation and resource planning, provided it satisfies the need, can be achieved within approved budgets, and is acceptable to users and customers. This determination is made by the Vice President or Director of the service organization with the service need with the concurrence of the FAA Enterprise Architecture Board. The key activities of concept and requirements definition are shown in Figure 14. They apply to all investment initiatives seeking investment funding, whether a standalone investment initiative or an element of a complex operational capability.

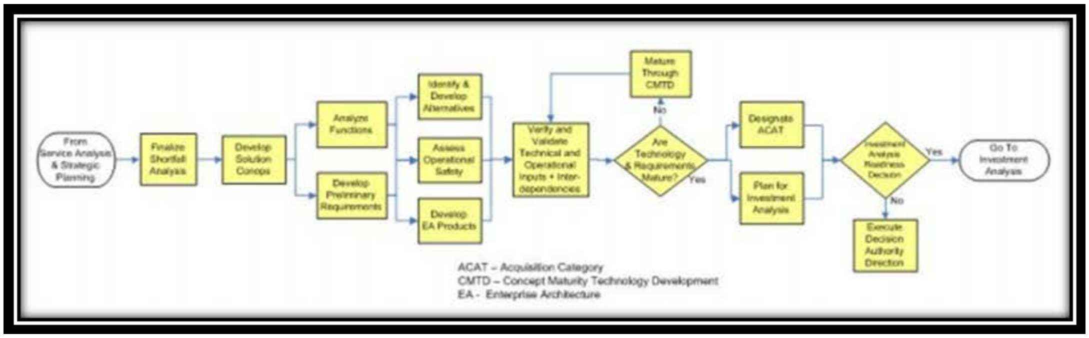

Figure 14: Key Activities of Concept and Requirements Definition

The plan for concept and requirements definition must be approved by the Vice Presidents (ATO) or Directors (non-ATO) of the service organization with the service need and the operating service organization and by the FAA Enterprise Architecture Board chairperson before the start of any CRD activity. Roadmap planning in the enterprise architecture specifies when concept and requirements definition activity must begin.

- Finalize Shortfall Analysis. The service organization or program office updates, refines, and quantifies the preliminary shortfall identified during service analysis in sufficient detail to serve as the basis for (1) clearly understanding the nature, urgency, and impact of the service need; (2) defining preliminary requirements; (3) determining realistic and economic alternative solutions; and (4) quantifying likely program costs and benefits.
- Develop Solution Concept of Operations. The solution ConOps describes how users will employ the new capability within the operational environment and how it will satisfy service need. The solution ConOps defines the roles and responsibilities of key participants (e.g., controllers, maintenance technicians, and pilots); explains operational issues that system engineers must understand when developing requirements; identifies procedural issues that may lead to operational change; and establishes a basis for identifying alternative solutions and estimating their likely costs and benefits. More than one solution ConOps may be required if proposed alternative solutions differ significantly from each other.
- Analyze Functions. The service organization or program office translates stakeholder needs in the shortfall analysis, solution ConOps, and NAS Requirements Document (NAS only) into high-level functions that must be obtained to achieve the desired service outcome. These are then decomposed into sequentially lower-level functions. For NAS investment initiatives, this decomposition may have been done during service analysis when operational improvements

and sustainments in the NAS. The plan for concept and requirements definition must be approved by the Vice Presidents (ATO) or Directors (non-ATO) of the service organization with the service need and the operating service organization and by the FAA Enterprise Architecture Board chairperson before the start of any CRD activity. Roadmap planning in the enterprise architecture specifies when concept and requirements definition activity must begin.

- Finalize Shortfall Analysis. The service organization or program office updates, refines, and quantifies the preliminary shortfall identified during service analysis in sufficient detail to serve as the basis for (1) clearly understanding the nature, urgency, and impact of the service need; (2) defining preliminary requirements; (3) determining realistic and economic alternative solutions; and (4) quantifying likely program costs and benefits.
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- Analyze Functions. The service organization or program office translates stakeholder needs in the shortfall analysis, solution ConOps, and NAS Requirements Document (NAS only) into high-level functions that must be obtained to achieve the desired service outcome. These are then decomposed into sequentially lower-level functions. For NAS investment initiatives, this decomposition may have been done during service analysis when operational improvements and sustainments in the NAS when technological risk is too high or when requirements are not mature or the investment initiative may be deferred or terminated.
- Mature Through Concept Maturity and Technology Development (NAS only). The Technical Review Board recommends further development for NAS initiatives when technological risk is too great or requirements are not sufficiently known. Prescribed activity may take the form of simulation, analysis, operational prototyping, or field demonstration in a controlled operational environment. See the Guidelines for Concept Maturity and Technology Development for more information.
- Designate Acquisition Category. The service team or program office prepares an acquisition category determination request based on preliminary financial data, as well as subjective assessments of complexity, risk, political sensitivity, safety, and security. The request is vetted through NAS Systems Engineering Services (NAS) or AIT Information Technology Research and Development (non-NAS) and submitted to the Acquisition Executive Board for a designation.
- Plan for Investment Analysis. The plan for investment analysis (1) defines scope and assumptions, (2) describes alternatives and their associated rough lifecycle costs, (3) describes planned activities and specifies how tasks will be accomplished, (4) defines output and exit criteria, (5) establishes a schedule for completion, (6) defines roles and responsibilities of participating organizations, and (7) estimates resources needed to complete the work. By signing the plan for investment analysis, the organizations that will conduct the analysis agree to provide the resources necessary to complete the work. This activity includes development of the investment analysis readiness decision package and pre-briefings to decision-makers.

The output and products from this effort include: solution ConOps; preliminary program requirements document, architecture products and amendments; realistic alternatives with rough cost estimates, detailed shortfall and functional analyses; safety risk assessment, shortfall analysis report, acquisition category designation request, and an investment analysis plan.

The organizations involved in these processes include the implementing organization; NAS systems Engineering Services, IT Research and Development; Chief Technology Office; NAS Lifecycle Integration Office, Program Management Office, Line of Business Operating Service; IT Research and Development; and Capture Team, if applicable. The approving organizations are the Acquisition Executive Board with JRC concurrence and authorities found in the Service Analysis and Concepts and Requirements Definition Guidelines.

The investment analysis readiness decision determines whether the solution ConOps, preliminary requirements, architecture products and amendments, and preliminary alternatives are sufficiently mature to warrant entry into investment analysis. The decision is made within context of all ongoing and planned investment activities to sustain and improve service delivery. It ensures that proposals for new investment are consistent with overall corporate needs and planning. A preliminary program requirements document, realistic alternative solutions, architecture products and amendments, approved shortfall analysis report, and signed plan for investment analysis are required for the investment readiness decision. The full list of work products that may be required for the investment analysis readiness decision is found on the JRC Secretariat website. The JRC makes the decision to enter investment analysis.

A.3.6 Investment Analysis

Investment analysis is a disciplined process that supports sound capital investment decisions. Investment analysis is conducted in the context of the enterprise architecture and FAA strategic goals and objectives. Such plans serve as guides to prioritize current and future investment analyses. Investment analyses, in turn, help to refine and mature those plans by providing decision-makers with a clear picture of investment opportunities and their risks and value.

NAS and non-NAS roadmaps in the enterprise architecture establish when an operational capability or service need must be in place. This, in turn, determines when investment analysis should be complete to allow sufficient time to acquire and deploy a suitable solution. The key is to balance timeliness, complexity, and size of the investment analysis with the rigorous development of quantitative data needed by the JRC to make an informed investment decision.

Affordability and accurate cost and schedule estimates are important factors in the decision to approve a new investment program. The results of investment analysis help the JRC to determine which potential investments will improve operations across the air transportation system and by how much. The outcome of investment analysis can be used to make individual, portfolio, and prioritization decisions.

When the investment initiative is an element of an operational capability (NAS only), the capture team for the capability (if established) participates in and contributes to investment analysis activity. The capture team is populated with representatives from each service team or program office that will provide an increment of the overall operational capability. They ensure that the alternative emerging from initial investment analysis for each increment fits within the strategy for obtaining the operational capability and can provide the necessary performance and functionality.

A non-materiel solution that emerges during investment analysis may proceed to solution implementation upon approval of solution requirements and implementation and resource planning if it meets the following criteria: satisfies the need, can be achieved within approved budgets, and is operationally acceptable to the user.

This determination is made by the Vice President or Director of the service organization with the service need with the concurrence of the FAA Enterprise Architecture Board. All proposed investments must answer the same basic questions: What is the problem that needs to be addressed or resolved? What is the range of alternatives that could address this problem? What are the costs, benefits, and risks associated with each alternative? And, based on the above, what is the recommended course of action?

Figure 15 illustrates the phases and decision points of investment analysis. Initial investment analysis evaluates alternative solutions to service needs and recommends the most promising for further development. Final investment analysis develops detailed cost and benefits estimates, detailed plans, and final requirements for the most promising alternative. The level of activity required during investment analysis is based on the acquisition category assigned to the investment opportunity. In general, the larger and more complex an investment, the greater the level of effort required during investment analysis.

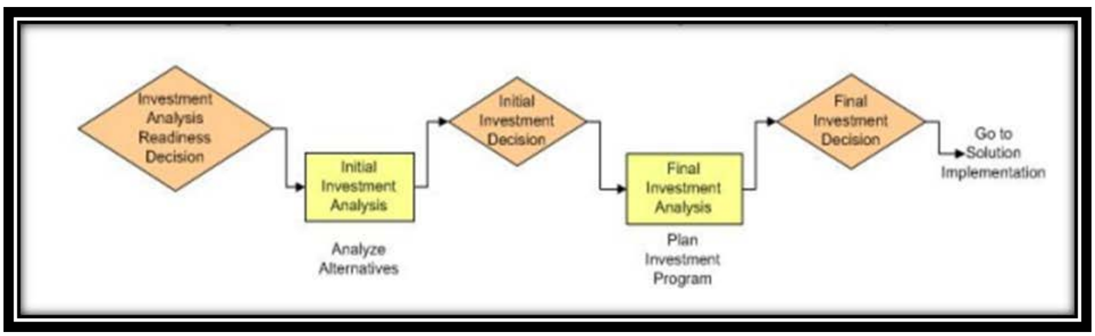

Figure 15: Phases and Decision Points of Investment Analysis

Very complex investment programs are structured into manageable, lower-risk segments and approved incrementally by the JRC. When sequential segments are required to fully implement an investment opportunity, the service organization conducts final investment analysis for each segment and brings planning and baseline documents to JRC for approval.

Figure 16 defines the key activities that must be completed during initial investment analysis. The Investment Analysis Process Guidelines on FAST describe the full range of activities that may be required.

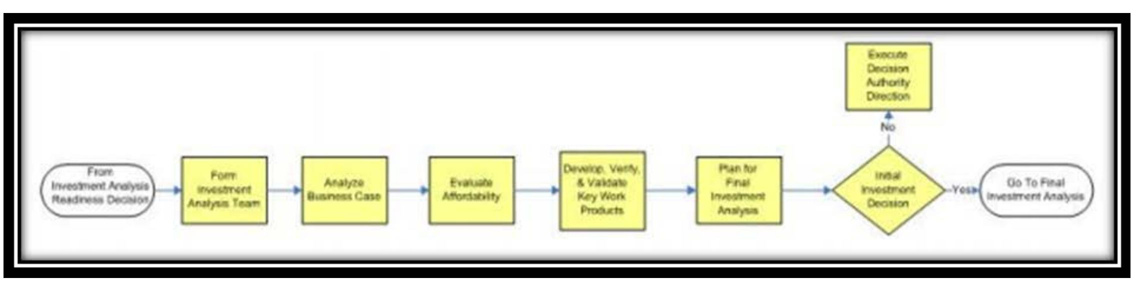

Figure 16: Key Activities of Initial Investment Analysis

- Form Investment Analysis Team. An investment analysis team is formed and scaled to the size and complexity of the analysis. Team membership is flexible depending on the needs of the analysis, but typically includes system, technical, logistics, specialty engineering and operational subject-matter experts, and business case analysts. Security and regulatory specialists are team members when potential solutions involve facility, asset, personnel, or information security; hazardous materials; emergency operations; or when they impact aircraft, airspace, or the public.
- Analyze Business Case. The business case focuses on those key factors that demonstrate value and worth of a proposed investment initiative to the FAA and the aviation industry. This includes updating the preliminary requirements document to reflect any changes resulting from the investment analysis. When the investment initiative is an increment necessary to achieve an operational capability, the impact on achieving the capability is also a key factor of the business case. See the Business Case Analysis Guidance for more details.
- Evaluate Affordability. FAA Finance assesses the budget impact and relative contribution to agency goals of each alternative against other ongoing and proposed investment programs in the FAA financial baseline. The impact assessment may shape subsequent deliberations of the investment analysis team.
- Develop, Verify, and Validate Key Work Products. Validation of the business case is described in the Business Case Evaluation and Assessment Guide. Verification and validation for all other documentation is described in the FAA AMS Lifecycle Verification and Validation Guidelines. The full list of work products that may be required for the initial investment decision is found on the JRC Secretariat website.
- Plan for Final Investment Analysis. The plan for final investment analysis defines work activities, resources, schedules, roles and responsibilities, and products. It also specifies exit criteria and a planning date for the final investment decision.

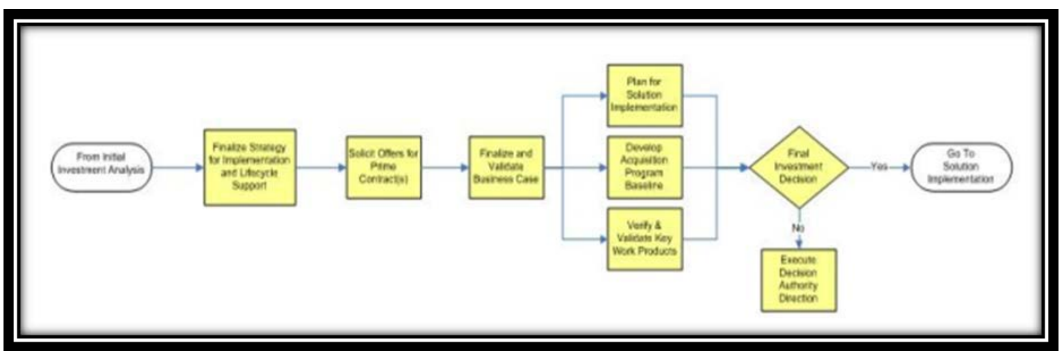

Figure 17: Key Activities Completed during Final Investment Analysis

- Finalize Strategy for Implementation and Lifecycle Support. The implementing service organization or program office develops a detailed strategy for procuring, implementing, and supporting the solution over its service life with input from the investment analysis team. This strategy is the foundation for a request for offer to industry for procurement of the solution and all subsequent program planning.
- Solicit Offers for Prime Contract(s). The implementing service organization or program office prepares an independent government cost estimate, releases a request for offers, and evaluates industry responses for completeness, technical suitability, and compliance with the

statement of work. The most acceptable industry response forms the basis for the final business case and acquisition program baseline.

- Finalize and Validate Business Case. The business case and supporting documents are prepared according to the ACAT designation for the solution. These requirements are found in the appropriate business case template located on the investment analysis page in FAST. This includes preparation of the final requirements document.
- Plan for Solution Implementation. The investment analysis team develops a realistic plan for solution implementation using the FAA standard work breakdown structure and a tailored in-service review checklist. Planning must cover all key aspects of obtaining the solution so costs are reflected in resource documents and the acquisition program baseline. Planning is recorded in the implementation strategy and planning document.
- Develop Acquisition Program Baseline. The acquisition program baseline establishes the cost, schedule, and key performance baselines for the investment initiative. It is the agreement between the implementing service organization or program office and the JRC concerning the performance that will be obtained and the timeframe and resources agreed to by the agency. For some investment types (e.g., facilities, service contracts, and variable quantities), an execution plan is developed in lieu of an acquisition program baseline.
- Verify and Validate Key Work Products. Investment Planning and Analysis validates the business case as described in Business Case Evaluation and Assessment Guide. Verification and validation for all other program work products is according to the FAA AMS Lifecycle Verification and Validation Guidelines. The full list of work products that may be required for the final investment decision is found on the JRC Secretariat website.

The principal output for initial investment analysis is information that enables the JRC to select the best alternative that meets the required performance and offers the greatest value to the FAA and its customers. The following are required products: updated program requirements document, initial business case, initial implementation strategy and planning documents for each alternative, and plan for final investment analysis. Key work products are verified and validated according to the FAA AMS Verification and Validation Guidelines before the initial investment decision.

The responsibilities for this work include an investment analysis team, the Implementing service organization or program office, the Investment Planning and Analysis Office, stakeholder organizations and only a capture team for NAS programs. Approval varies based on investment type and associated costs and risks.

At the initial investment decision, the JRC selects the best alternative for implementation or rejects all alternatives and specifies what action is needed next. If the JRC approves an alternative, it selects an alternative for implementation, approves entry into final investment analysis, approves funding for any analytical or developmental work related to the selected alternative, and designates a service organization to lead final investment analysis and to be responsible for solution implementation.

Alternatives can be rejected if the technology is not mature or when requirements are not sufficiently defined. If rejected, the JRC can approve such actions as research, further analysis, development, or termination.

When the initial investment decision involves an investment initiative that is an element of an operational capability, the portfolio manager attends to explain the interrelationships among capability elements and the impact of not approving the initiative on the overall operational capability.

The JRC uses the following standard selection criteria when making the investment decision: lifecycle costs, benefits, risk, benefit-to-cost ratio, consistency with the FAA enterprise architecture, and impact on FAA strategic goals.

The JRC makes the final investment decision. If the JRC disapproves the recommendation, it returns the investment package with specific instructions for further work or terminates the effort. If the JRC accepts the recommendations, it approves the investment program for implementation and delegates responsibility to the appropriate service organization or program office; approves the final program requirements document, final business case, and the implementation strategy and planning document; approves the acquisition program baseline; commits the FAA to funding the program segment, as specified in the acquisition program baseline; approves updated architecture products and amendments; and approves adjustments to FAA plans and budgets to reflect the investment decision.

Before the JRC approves documents at the initial or final investment decisions, the documents require approval from other officials, as can be found in AMS Appendix B, Acquisition Planning and Control Documents. When a final investment decision involves an investment initiative that is an element of an operational capability, the portfolio manager attends to explain the interrelationships among capability elements and the impact of not approving the initiative on the overall operational capability.

A.3.7 Solution Implementation

Solution implementation begins at the final investment decision when the JRC approves and funds an investment program or segment, establishes the acquisition program baseline for variance tracking, and authorizes the service organization to proceed with implementation. Solution implementation ends when a new service or capability is commissioned into operational use at all sites.

Detailed program planning, including the solicitation and evaluation of offers for prime contract(s), occurs during final investment analysis and before the final investment decision. This ensures that accurate contract costs, risks, and schedules are reflected in the acquisition program baseline and program planning documents. These plans and baselines are revalidated, and updated if necessary, after contract award to ensure that they can realistically serve as the management construct for program implementation. They are kept current throughout solution implementation.

The overarching goal of solution implementation is to satisfy requirements documented in the final requirements document and to achieve the benefit targets in the business case. To achieve this, the service organization must work with users and stakeholders throughout solution implementation to resolve issues as they arise. Actions outside the direct control of the service organization (e.g., regulatory changes) are recorded in the implementation strategy and planning document and tracked at program reviews throughout solution implementation.

The activities undertaken during solution implementation vary widely and are tailored for the solution or capability being implemented. FAST contains tailored process flowcharts for representative types of investment program (systems and software, facilities, services) and functional disciplines (e.g., human factors, information systems security, configuration management, integrated logistics support). These flowcharts identify actions and activities that the service organization may need to execute to achieve projected capability, value, and benefits. Instructions, templates, best practices, good examples, and lessons learned are attached to many activities in the flowcharts to assist lifecycle management specialists as they plan and execute activities that make sense for their investment program.

Although service organizations are empowered to implement investment programs and manage them over their lifecycle, they must adhere to built-in checks and balances. The acquisition program baseline establishes the performance, cost, and schedule boundaries within which the service organization is authorized to operate. The service organization must report all negative variances from cost, schedule, and performance baseline measures and undertake corrective action in accordance with AMS Section 1.2.3. The assessment of critical performance requirements must be regularly reported during solution implementation and at completion.

The service organization monitors cost, schedule, and performance status against targets in the acquisition program baseline on a continuing basis and takes corrective action when variances from planning objectives arise. The service organization also reports program status at acquisition quarterly program reviews. The focus of these reviews is to identify high-risk issues requiring resolution and to ensure that all actions necessary to achieve projected value and benefits are being executed satisfactorily, particularly those outside the control of the service organization. The service organization applies the principles of EVM to development, modernization, and enhancement investment programs, and when applicable, uses audits to ensure that contract costs are proper and allowable.

The service organization captures expenditures consistent with the program baseline work breakdown structure fashioned during final investment analysis.

For those NAS investment programs progressing through solution implementation as elements of an operational capability, capture team members assess and report progress of each investment increment monthly to the portfolio manager. The portfolio manager reports status of the overall capability to the NextGen Management Board quarterly. These reviews focus on cost, schedule, or performance issues associated with every element of the operational capability. The portfolio manager recommends action for correction of cost, schedule, or performance shortfalls and may propose the transfer of funding from one investment increment to another when necessary to improve the health and prognosis of the overall capability. The JRC evaluates proposed baseline changes among investment increments at acquisition quarterly program reviews. Each service team or program office works with the capture team to ensure that each investment increment provides the functionality and performance necessary to achieve the operational capability.

Solution implementation is organized into the activities shown in Figure 18. These activities are tailored to the special requirements of each investment program.

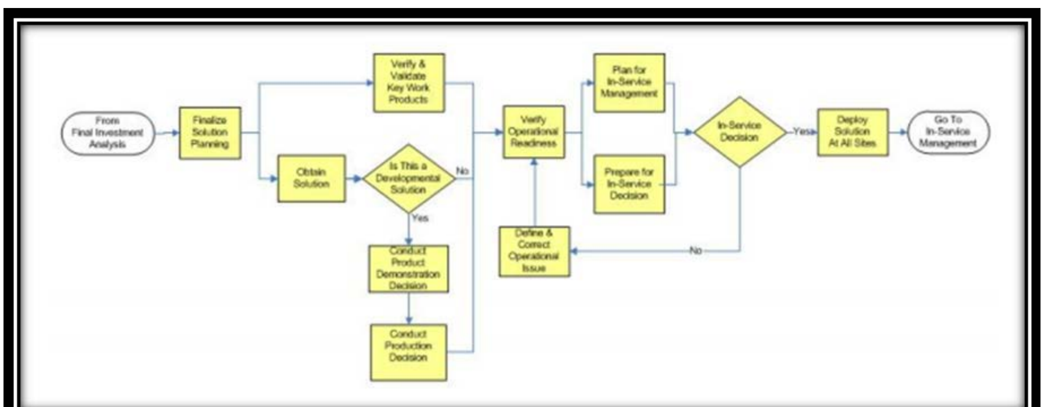

Figure 18: Key Activities of Solution Implementation

- Finalize Solution Planning. The service organization or program office reviews and updates program planning completed during final investment analysis (e.g., implementation strategy and planning document, work breakdown structure, and In Service Review (ISR) checklist). Key stakeholders participate in this activity to ensure that planning is complete and realistic. For example, if new systems are to be installed or existing facilities modified, service organization planners work with service-area offices so people and resources will be available when needed.
- Obtain the Solution. The service organization or program office oversees and coordinates execution of tasks and activities necessary to achieve the benefits projected for the investment program within approved cost and schedule baselines. This includes such activities as contract award, contract administration, program management, resource management, risk management, systems engineering, logistics support, T&E, and site acquisition and adaptation. It may involve developing operational procedures and standards; obtaining physical, personnel, and information security; modifying the physical infrastructure; and coordinating collateral action by the aviation industry.
- Is This a Developmental Solution? Investment programs that develop, modernize, or enhance systems or software follow the knowledge-based product development process shown in Figure 19. The following two decisions are intended to ensure that the knowledge base is sufficiently mature to warrant proceeding to the next stage of implementation.
- Conduct Product Demonstration Decision. Figure 28 defines the timing, decision authority, and decision criteria for authorizing full development and demonstration of the product.

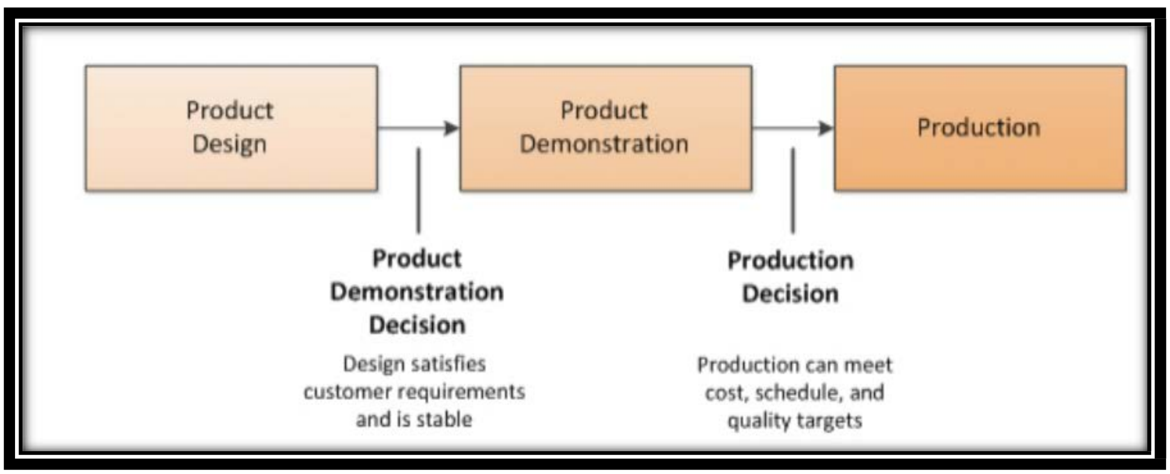

Figure 19: FAA Knowledge-based Product Development Process

The decision authority for Solution Implementation resides with the Vice President or Director of the implementing service organization unless otherwise designated by the JRC. These responsibilities include the following:

- Verify and Validate Key Work Products and Products. The service organization or program office incrementally verifies and validates key work products and products of solution implementation, including the contract to obtain the capability, design documents, specifications, and actual product/product components. Verification and validation activity supports contract award, product demonstration decision, production decision, product acceptance, and the in-service decision.

- Verify Operational Readiness. The service organization or program office manages all activities necessary to install the solution at a designated test site(s) and tests it thoroughly to verify operational readiness. Operational readiness encompasses operational effectiveness and operational suitability. Operational effectiveness measures how well the solution satisfies mission need and operational requirements. Operational suitability measures how well a product can be integrated and employed for field use, considering such factors as compatibility, reliability, human performance factors, maintenance and logistics support, safety, and training. For designated programs, operational readiness is also assessed by an independent operational assessment. The solution may be installed, as necessary, at the FAA Academy, FAA Logistics Center, and William J. Hughes Technical Center before the in-service decision. In rare cases and with proper justification, the service organization may request authority to install at other specific sites. This authorization does not affect the regular in-service review process culminating in a final in-service decision, which must be adhered to before a product can be placed into operational service through the declaration of operational readiness date (ORD) and commissioning.
- Plan for In-Service Management. The service organization or program office plans how it will sustain and manage deployed assets throughout their full lifecycle. This includes in-service logistics support; PIR; and other evaluations of operational assets to measure performance, collection of performance data in support of acquisition quarterly program reviews, product sustainment strategy, and action.
- Prepare for In-Service Decision. The service organization or program office completes all activities necessary for the in-service decision. This includes resolution of all support issues identified by the operating service organization and integrated logistics management team, completion of management actions arising from the in-service review checklist and the independent operational assessment report (designated programs only), resolution of stakeholder issues, development of the in-service decision briefing and action plan, and concurrence of key stakeholders.
- In-Service Decision Approved? The in-service decision authority reviews operational test results, the status of in-service checklist items, the independent operational assessment (designated programs only), the perspective of key stakeholders, and other information deemed relevant to the in-service decision. If the in-service request is approved, deployment of the solution may begin. If the request is not approved, the service organization must correct any deficiency and return for the in-service decision upon verification that all outstanding issues have been resolved.
- Define and Correct Operational Issues. The service organization or program office takes whatever corrective action is necessary to resolve all remaining operational issues. This may involve a return to concept and requirements definition, if correcting the issue involves a change to program requirements, or to investment analysis if operational issues require a change to the acquisition program baseline.
- Deploy the Solution at All Sites. The service organization or program office manages all activities necessary to deploy the solution at each site. This includes transportation and delivery of equipment, installation and checkout, contractor acceptance and inspection, integration, field familiarization, declaration of initial operational capability, joint acceptance and inspection, dual operations, declaration of operational readiness, and removal and disposal of obsolete equipment. PIRs are conducted at deployment sites to ensure that user needs are satisfied; to identify systemic problems that must be corrected; and to determine

whether cost, schedule, and benefits objectives are being achieved. The transition from solution implementation to in-service management extends over time, occurring at each site upon declaration of operational readiness or commissioning.

The primary outcome of solution implementation is a fully deployed and supported operational capability that satisfies requirements (including program requirements and designated specifications), is accepted by users, is compatible with other products and services in the field, and realizes the benefits in the final business case by fully addressing requirements in the final program requirements document. The following are typical products of solution implementation that support the fielding of a satisfactory operational capability: annual updates of the OMB Exhibit 300 for designated programs; continuous evaluation of progress against targets in the acquisition program baseline (including status of critical performance requirements); contracts that achieve investment objectives (i.e., cost, schedule, performance, and benefits); successful operational test and evaluation, including a final report on the status of critical operational issues and requirements in the final program requirements document and passing status of critical performance requirements; successful independent operational assessment and report for designated programs; in-service decision, including the in-service decision briefing and action plan; declaration of operational readiness and commissioning at each site; program reviews and reports (e.g., baseline management, variance tracking; financial, schedule, performance; earned value, logistics measures, and risk management); in-service management plan; monthly capture team assessments, when applicable; and acquisition quarterly program reviews.

Key work products are verified and validated according to the FAA AMS Verification and Validation Guidelines before the in-service decision.

The offices responsible for meeting these requirements include the performing service organization or program office; operating service organization; key stakeholder organizations; Vice President of the service organization, Director of Policy and Performance; ATO Safety and Technical Training; Information Technology Shared Services Committee; AIT Information Technology Program and Portfolio Organization; and Portfolio Manager.

The approval organizations include JRC; Chief Information Officer; Chief Financial Officer; Acquisition Executive; and Vice President or Director of implementing service organization, unless otherwise designated by the JRC at the final investment decision.

The in-service decision (ISD) authorizes deployment of a solution into the operational environment. It occurs after demonstration of initial operational capability at the key test site(s) and before initial operational capability at any non-key site or waterfall facility. The decision is made following completion of the certification of compliance with testing, information security, and safety requirements. It establishes the foundation for operational readiness to be declared at subsequent sites. The ISD uses results from T&E that report on the verification and validation of performance requirements, critical performance requirements, critical operational issues, and operational readiness (e.g., safety, effectiveness, and usability). The in-service review (ISR) checklist is used by the service organization to identify and resolve readiness issues before the ISD and to obtain concurrence from stakeholder organizations.

The JRC is the ISD authority. At the final investment decision, the JRC may delegate ISD authority to appropriate FAA officials. For any solutions or products that affect multiple organizations, a joint ISD authority may be designated. This decision is documented in the final investment record of decision.

Depending on the implementation strategy of the solution (e.g., phased implementation, segments, multiple releases, several smaller programs executed separately as a part of one solution), multiple ISDs may be required to ensure the operational readiness of each specific component of the overall solution. The ISD strategy is developed by the service team with help from the ISD Executive Secretariat, approved by the JRC, and documented in the implementation strategy and planning document. The ISD authority must approve follow-on revisions to the ISD strategy.

The ISD is recorded in the record of decision. Action plans for resolving remaining operational readiness issues are included as an attachment to the record of decision. Status of action plans is tracked and reported to the ISD Executive Secretariat until all issues are resolved. Once all action plans are satisfactorily completed, the ISD Executive Secretariat provides a closeout memorandum. The ISD Authority approves the ISD strategy for phased or segmented deployments, agrees to the action plans, makes the ISD, and approves the Record of Decision. The following artifacts are required for each in-service decision: operational test report(s), independent Operational Assessment Report for designated programs, ISR Checklist completed or action plans for those remaining open, Safety Risk Management Document approved, information security certification and authorization or certification and authorization, stakeholder concurrence on readiness for the ISD, and ISD briefing and action plans.

A.3.8 In-Service Management

Activity during in-service management supports execution of the FAA mission of providing ATC and other services. This entails operating, maintaining, securing, and sustaining systems, products, services, and facilities in real time to provide the level of service required by users and customers. It also entails periodic monitoring and evaluation of fielded products and services and feedback of performance data into service and investment analysis as the basis for revalidating the need to sustain deployed assets or taking other action to improve service delivery.

Service organizations are responsible and accountable for managing service delivery within their area of responsibility throughout in-service management. They bring together the multiple engineering, logistics, and other management specialists necessary to operate and sustain fielded systems, services, products, and facilities. This includes managing resources within specific geographic areas and may involve emergency sustainment actions in response to natural disasters or other unanticipated events.

Service organizations have flexibility to sustain and enhance fielded capability. They may implement pre-planned product improvements or block upgrades as stipulated at the investment decision and may use sustainment resources to upgrade components of fielded products as needed (e.g., printers or processors).

In-service management planning documents focus on actions and activities that support continued O&M of deployed assets. The documents clearly define in-service management activities such as configuration management, preventive and corrective maintenance, training, infrastructure support, and logistics support, along with planned activities to support PIRs and operational analyses.

Service organizations evaluate the safety, efficiency, and effectiveness of operational assets throughout in-service management as a basis for improving service delivery over time. This process begins with a PIR at one or more early operational sites to determine whether a new investment program is achieving its performance and benefit targets and whether it is meeting the service needs of customers. The primary objective is useful information on how best to eliminate flaws and optimize performance and benefits before deployment at additional sites. This evaluation process continues throughout in-service management with the periodic evaluation of operational assets to determine whether they are continuing to contribute to agency safety, performance, and cost goals or whether they should be modernized, replaced, or removed from service. These operational analyses are the basis for out-year planning in the service organization business plan, which integrates ongoing and planned investment activity with resources for the operation and sustainment of fielded assets over their service life. The overarching goal is the continued best use of agency resources to achieve FAA strategic and performance goals.

When a fielded capability is projected to be unable to satisfy service demand or when another solution offers improved safety, lower cost, or higher performance, the service organization initiates action to enter the service analysis process leading to a new investment decision. The key is to look far enough into the future so there is enough time to approve and implement a solution before the existing capability fails or becomes obsolete.

Service organizations must remove and dispose of fielded assets and services when they are no longer needed. This includes restoration of sites where obsolete products or services were deployed, disposal of government property, recovery of precious metals, and cannibalization of useful assets. The cost of removal and restoration is included in the acquisition program baseline of the replacement program. If there is no replacement program, the cost must be otherwise factored into the service-area operating plan.

Figure 20 portrays the activities undertaken during in-service management. They are organized to deliver, sustain, and evaluate operational assets and to take corrective action when they are projected to be unable to satisfy the service needs of users and customers or when they are becoming unsupportable or obsolete. The workflow includes actions to verify and validate achievement of projected benefits from an operational capability resulting from completion and integration of multiple investment increments.

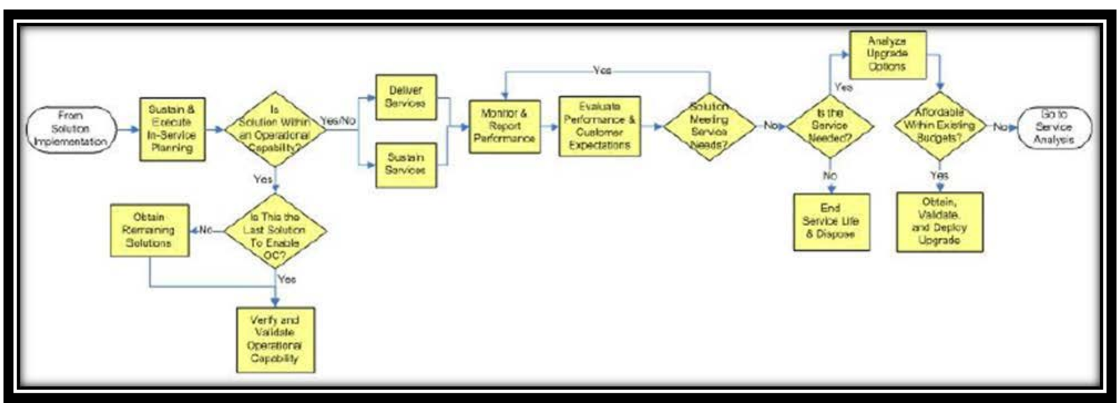

Figure 20: Key Activities of In-Service Management

- Sustain and Execute In-Service Planning. Service organizations review and update in-service planning documents as needed. This includes updating the OMB Exhibit 300 each year for designated programs. Annual updates reflect program changes and move the budget submission forward one year. The OMB Exhibit 300 must continue to achieve a passing score from the OMB.
- Is Solution Within an Operational Capability? When a recently deployed solution is not an increment necessary to achieve a complex operational capability, it is operated and sustained during in-service management as a standalone capability. When it is part of an operational

capability, the agency validates that the projected benefits of the operational capability are being achieved once all supporting investment increments are in service.

- Is This the Last Solution to Enable an Operational Capability? If the recently deployed solution is the last investment increment necessary to implement an operational capability, a PIR is planned and executed to determine whether the performance and benefits projected for the operational capability are being achieved and to identify what corrective action is needed and when none is needed.
- Obtain Remaining Solutions. All investment increments necessary to achieve the operational capability are obtained and deployed before verifying and validating that the performance and benefits of the operational capability are being realized.
- Verify and Validate Operational Capability. When the last investment increment of an operational capability is deployed and approved for operational service, the capture team oversees the integration of investment elements necessary to achieve the operational capability and verifies achievement of operational and performance benefits in the operational capability business case. Typically, a PIR will be planned and executed for this purpose. Results are presented to the NextGen Management Board, which determines whether performance of the operational capability meets agency expectations or whether further action is necessary.
- Deliver Services. The operational workforce provides ATC and other business services using infrastructure, procedures, and other assets as assigned and funded. This includes all safety-related quality assurance actions such as inspecting flight, certifying aircraft, establishing safety standards for operations, monitoring safety performance, issuing and maintaining certificates and licenses, and developing and revalidating procedures such as approach and landing procedures. Emergency sustainment actions are planned and executed whenever required. During emergencies, highest priority services are sustained even if performance goals for lower priority services cannot be met. In addition, physical, personnel, and information security are maintained at all FAA facilities. This includes environmental threat and facility assessment and accreditation in accordance with FAA internal security planning.
- Sustain Services. A variety of actions are undertaken by the FAA workforce during in-service management to ensure that operational assets remain in good working order. These include the following:
  - Corrective and preventive maintenance, supply support, second-level engineering, depot-level repair, modification of hardware and software to improve performance, test and support equipment, and transportation of supplies.
  - Management and engineering actions to sustain and improve service delivery, correct deviations from cost and performance standards, and improve quality. These actions include modifications to hardware and software to solve latent or discovered technical problems, process changes to improve performance, planned block upgrades and product improvements, and sustainment actions that lower operating costs. It involves the management of personnel, information systems, money, logistics support, spare parts, technical resources, and other assigned assets. Management techniques include fiscal and workforce planning; contract award and administration; fiscal and program control; and process management to achieve cost, performance, and benefit objectives. All modifications to fielded assets must be in accordance with the enterprise architecture. If a planned modification requires a change to the architecture, appropriate amendments and products must be developed and approved.

- Management and control of the configuration of all services and service components. This includes submission of NAS change proposals to the appropriate approval board to baseline, install, and manage changes to NAS systems, software, and equipment. It requires coordination with the appropriate systems engineering organization to ensure that changes are compatible with and reflected in the enterprise architecture.
  - Sustainment of utilities, buildings, grounds, structures, roads, telecommunications, handling of hazardous materials, lightning protection, bonding, grounding, heating, cooling, and special access.
  - Participation in cross-organizational planning to review, integrate, and prioritize the allocation of operational resources to fielded services and assets. The objective is to continue support for high-ranking service needs and reduce or terminate support for low-value or redundant assets. Recommendations are presented to the JRC for approval.
  - Acquisition and management of FAA-owned and leased properties, as well as management of non-Federal facilities with external sponsors. This activity may involve the purchase or lease of buildings, structures, and grounds, as well as removal and disposal of no longer used equipment, systems, services, products, facilities, real property, and resources.
- Monitor and Report Performance. PIR(s) at early deployment sites help to determine whether performance and benefits are being achieved. When projections are not being realized, corrective action is planned and implemented. Periodic operational evaluations of fielded assets continue throughout in-service management to identify performance shortfalls, determine trends in the cost of ownership, identify adverse support trends, and solve systemic operational or support problems.
- Evaluate Performance and Customer Expectations. Operational evaluations are the basis for revalidating the merit of sustaining investment assets or the need for other action. Findings are fed back into service analysis, where it is determined whether to continue to sustain existing assets or recommend new investments to solve systemic problems in the service environment.
- Solution Meeting Service Needs? If the solution is meeting service needs and no supportability issues have emerged, the operational workforce continues to operate and sustain the solution, as well as monitor and evaluate it periodically. If supportability issues are emerging or the solution is projected to be unable to satisfy the service need, corrective action is initiated once it is verified that the service is supported by the NAS ConOps during timeframe in question.
- Is the Service Needed? The operating service organization determines whether the service provided by the solution is still needed. In making this determination, the service organization reviews the NAS ConOps and enterprise architecture roadmaps to confirm that the service will continue to be required in the timeframe that any upgrade to the operational asset would cover.
- End Service Life and Dispose of Unneeded Assets. When an operational asset is replaced by new capability, the program office installing the new capability removes and disposes of replaced assets. When there is no replacement asset, the operating service organization removes and disposes of unneeded assets. Removal and disposal includes decommissioning, dismantling, and demolishing of systems and equipment; restoring sites including environmental cleanup and disposal of hazardous materials; disposing of Government property; recovering precious metals; and reusing surplus assets.

- Analyze Upgrade Options. When the service is still needed, the service organization investigates ways to upgrade at-risk assets within existing operating budgets and determines whether additional investment funds are needed.
- Affordable Within Existing Budgets? When the operational asset can be modernized within existing budgets (e.g., a planned and funded product improvement, operational funds), the upgrade is obtained, validated, and deployed. When new funds outside the scope of available resources are needed, the service shortfall enters service analysis to begin the search for a solution.
- Obtain, Validate, and Deploy Solution Upgrade. Any modification to fielded assets (e.g., block upgrade, planned product improvement, problem correction) must be accompanied by concomitant changes to key elements of the support infrastructure such as training, documentation, spare parts, and engineering support. This includes training for personnel who directly operate, maintain, or provide support functions. All key work products and products of in-service management, including NAS change proposals (such as actual changes/ improvements to products and product components) and system support directives are verified and validated before an upgrade enters operational service. This includes the modified content of key work products and products that originate in other phases of the lifecycle but are intended for use during in-service management. Verification and validation activity supports decisions to implement and deploy procedural or product improvements.

The output and products from this effort include delivery of FAA enterprise services; PIRs and corrective action as needed to achieve investment performance and benefits; periodic operational analysis of fielded assets, including the effectiveness and efficiency of supply chain management; periodic revalidation of the need to sustain fielded assets; enforcement actions, baseline changes, and investment recommendations to maintain or improve service delivery; change proposals to install systems, software, and equipment and to improve capability, safety, or efficiency in accordance with the enterprise architecture; program technical reports and hardware discrepancy reports to correct hardware and software problems; annual OMB Exhibit 300 submissions (designated programs only); emergency sustainment actions to sustain high-priority capabilities and services; up-to-date configuration records for fielded equipment; annual report on critical operational needs; periodic assessment of facility security enhancements; action plans to remedy cost and performance shortfalls; updated in-service management planning documents if needed; and flight inspections, aircraft certification, and regulatory actions.

The responsible organizations include service organization or program office, AIT Information Technology Program and Portfolio Organizations; PIR Quality Officer; Integrated Logistics Management Team; ATO Technical Operations; William J. Hughes Technical Center; Mike Monroney Aeronautical Center; and Capture Team.

Approval authority includes the Chief Information Officer, Chief Financial Officer, Acquisition Executive, and Vice President or non-ATO Director of the operating service organization.

A.4 Functional Disciplines Supporting FAA Lifecycle Management

A.4.1 Configuration Management

Sound acquisition management requires that service organizations integrate and manage many critical functions and disciplines working to the common purpose of fielding high-quality, trouble-free products and services. These disciplines vary, depending on the type of investment program, but typically include configuration management, real property, integrated logistics support, T&E, independent operational assessment, deployment planning, human factors, environmental, occupational safety and health, and energy considerations, IT, systems engineering, security, system safety management, risk management, and data standardization.

Configuration management applies to all systems, sub-systems, equipment, components, and assets captured in the FAA Enterprise Architecture. This includes all NAS and non-NAS IT hardware, software, firmware, documentation, interfaces, standards, test and support equipment, facility space, spares, training and courseware, and manuals. Configuration management begins with the base lining of requirements documentation and ends with decommissioning of physical assets or the termination of services. Before introducing new equipment or software, the responsible solution provider must prepare a change proposal and have it approved by the appropriate configuration control board. This is required for expenditure of both operations and facilities and equipment funding. Configuration management of FAA systems and equipment complies with all agency safety and security requirements. Detailed lifecycle configuration management policy and procedures are in FAA Order 1800.66.

A.4.2. Integrated Logistics Support

Integrated logistics support is the critical functional discipline that plans, establishes, and maintains an integrated logistics support system for the lifecycle all FAA products and services. The objective is to provide the required level of service to the end user at optimal lifecycle cost to the FAA for new investment programs and the sustainment of fielded products and services.

Logistics elements are addressed during each phase of the AMS lifecycle management process (service analysis, concept and requirements definition, investment analysis, solution implementation, and in-service management). This entails managing the interdependencies among logistics elements, integrating the acquisition and lifecycle management of logistics support with the investment product or service, and adhering to the principles of supply chain management throughout.

A.4.3 Test and Evaluation (T&E)

During service analysis, T&E activities help in the identification and prioritization of the critical FAA needs. During concept and requirements definition, T&E helps to determine the best alternative solutions to those needs. During investment analysis, the criteria for testing operational effectiveness and suitability are expressed as critical operational issues in the program requirements document. T&E strategy and implementation activities are defined in the implementation strategy and planning document. They describe the overall T&E program for verifying achievement of technical performance requirements and development of operationally suitable investment products.

All system/software and facility investment programs follow a structured, disciplined T&E process appropriate to the product or facility being tested. Initially, T&E in solution implementation assesses potential operational, safety, and security risks and identifies opportunities for risk mitigation. Later it examines operational readiness and supplies data to decision-makers in support of the production and in-service decisions.

A typical T&E program consists of developmental test, operational test, site acceptance testing, and field familiarization testing, as well as independent operational assessment for designated programs. T&E of commercial and non-developmental items is tailored to account for test results already available from vendors. For example, an operational capability demonstration may reduce system test requirements.

As part of field familiarization testing, all systems/software products normally require site operational testing and information security testing to support the site operational readiness decision.

The Test and Evaluation Gold Standard and Implementation Guide define standards for the development and implementation of all modifications to the NAS during in-service management. It includes a standardized testing process that lists the phases and detailed activities to be addressed. The Gold Standard processes as designed will support/ensure that the activity of safety risk management is address in the FAA.

The Test and Evaluation Gold Standard Matrix is used as a management tool to record development and test status, improve internal and external communications, and support risk assessment using best business practices.

A.4.4 Independent Operational Assessment

The FAA is committed to verifying that new solutions are operationally effective, suitable, and safe before deployment. The Chief Operating Officer, through the Vice President for Safety and Technical Training, designates solutions on which to conduct independent operational assessment. The decision to designate a solution for independent operational assessment is based on such factors as complexity, operational criticality, lifecycle cost, interoperability, and safety risk.

During the early stage of solution implementation, the Independent Safety Assessment Team identifies potential operational and safety risks and communicates them to the acquisition organization. Once acquisition test activities are complete, the Vice President of the acquisition organization will declare in writing to the Vice President of Office of Safety and Technical Training, via the Independent Operational Assessment Readiness Declaration, the readiness of the solution to enter independent operational assessment. Independent operational assessment provides decision-makers with an independent determination of operational readiness in support of production and in-service decisions.

A.4.5 Deployment Planning

Deployment planning prepares for and assesses the readiness of a solution to be implemented into the NAS. Deployment planning is part of a continuous in-service review process that begins early in the lifecycle management process, usually during the development of requirements. All programs undergo some degree of deployment planning to ensure that key aspects of fielding a new capability are planned and implemented, as well as to ensure that the deployment does not create a critical deficiency in the NAS. The level of authority for deployment readiness assessment and ISD may vary from the service organization leader to the JRC, chaired by the head of the sponsoring line of business.

The conduct of deployment planning involves coordination among and participation by many critical functional disciplines. Trade-offs among cost, schedule, performance, and benefits relative to these functional disciplines must also include the impact of deployment and implementation considerations. Deployment planning tools (such as a tailored in-service review checklist) must be used to assist in identifying, documenting, and resolving deployment and implementation issues. Methods and techniques include, but are not limited to, a tailored application of generic tools, the integration of checklist issues with other emerging issues (such as program trouble reports from T&E), development of action plans for resolution of checklist and other items, and documentation of the results of issue resolution and mitigation. Consistent deployment planning must be visible in the contractor statement of work and associated efforts. The status of deployment planning (and issue resolution) activities are briefed periodically (e.g., at service-level reviews), presented at the ISD meeting, summarized in the ISD memorandum, and audited during the PIR. The implementing service organization is responsible for the successful completion of deployment planning activities. The operating service organization provides guidance and technical expertise related to ISR issues or other factors that may affect the ability to deploy and support the intended service, product, or requirement. All lines of business will resolve and close their respective ISR issues.

A.4.6 Human Factors

Human factors are a critical aspect of aviation safety and effectiveness. Service organizations must ensure that planning, analysis, development, implementation, and in-service activities for equipment, software, facilities, and services include human factors engineering to ensure that performance requirements and objectives are consistent with human capabilities and limitations. Human factors engineering should be integrated with the systems engineering and development effort throughout the lifecycle management process, starting with concept and requirements definition and continuing through solution implementation and in-service management (Human Factors Guidelines).

A.4.7 Environmental, Energy, and OSHA Management

FAA investment programs shall comply with relevant federal, state, and local regulations; FAA orders, specifications, and standards pertaining to environmental and occupational safety and health (EOSH) requirements; and energy and water requirements. FAA lines of business and staff offices must comply with all applicable requirements of the National Environmental Policy Act (NEPA) in accordance with the current version of FAA Order 1050.1, Environmental Impacts: Policies and Procedures. Service organizations responsible for implementing investment programs must consider EOSH and energy and water requirements and address them throughout the lifecycle management process in order to achieve the following results:

- Ensure that the installation and operation of systems, equipment, facilities, and related program activities will not adversely impact personnel safety and health or the environment; and
- Ensure that the acquisition program baseline of the investment initiative reflects the schedule and cost of EOSH requirements.

A.4.8 Information Technology

Information technology represents a significant financial investment for the FAA, as well as a set of essential tools and services that support multiple FAA missions, functions, and activities. To develop, deploy, and manage IT effectively, service organizations must apply sound information and engineering principles to the lifecycle planning and acquisition of IT. Service organizations must also continually involve users in the development, operation, and maintenance of information and application systems. Service area plans should leverage corporate IT capabilities such as FAA telecommunications, emphasize the use of open systems and shared data, implement recognized IT standards, and take advantage of economies of scale.

A.4.9 System Engineering Guidance

Systems engineering management is conducted and documented throughout the lifecycle management process at all levels of management and integration, from individual investment programs to the NAS as a whole. At the NAS-level, systems engineering management integrates across investment programs to achieve an efficient and fully interoperable NAS. At the program level, it optimizes performance, benefits, operations, and lifecycle cost.

All organizations responsible for the development, implementation, and lifecycle management of FAA investment programs shall develop and institute a systems engineering management program consistent with guidance in FAST (system engineering guidance). This includes organizations responsible for integrating investment programs into larger “system of systems” such as the NAS. The systems engineering management program of each organization shall apply systems engineering activities such as functional analysis, requirements management, synthesis, and validation and verification throughout the lifecycle management process, consistent with the specific functions and responsibilities of the organization.

A.4.10 Security

Service organizations and program offices must allow sufficient time and resources to address security laws, policies, and orders including the cost of implementing required security controls into acquired components. Security policy within the FAA is divided into information security; physical, facility, and personnel security; and sensitive information and personally identifiable information. There is overlap between the disciplines (for example, physical security is employed to protect classified materials), so all areas of security policy must be evaluated to ensure full compliance with the various orders and policies.

Information Security Policy

The Federal Information Security Management Act, 2002 (FISMA), Office of Management and Budget Circular A-130, Management of Federal Information Resources, National Institute of Standards and Technology (NIST) guidance, and other federal, departmental, and agency-level guidance and standards as amended, describe information system security (ISS) needed for all FAA information systems. FAA information systems reside in one of three domains: NAS, mission support/administrative, and research and development. They may consist of government-owned/managed components, contractor-owned/managed components, or combinations of these types. They are segregated into infrastructure for air traffic operations and infrastructures for IT administrative support. The infrastructures exchange information via authorized security gateways.

FAA ISS requirements are derived from NIST Special Publications and Federal Information Processing Standards. Because the NAS is classified as critical infrastructure, NAS systems must comply with additional ISS requirements as defined by ATO Policies. These ATO policies can be found on the FAA’s web site under Policy and Guidance and are designated with the letters “JO.”

To receive a successful in-service decision, all FAA investment programs must undergo a security authorization that assesses outputs and products against mandatory security requirements. The security authorization process is defined in FAA Order 1370.82, Information Systems Security Program. The Security Authorization Handbook details the process for compliance with ISS requirements. Investment programs should consult the Security Authorization Handbook and coordinate with the ISS manager for their line of business at each phase of the AMS lifecycle to ensure that information security requirements and related information are included in acquisition artifacts and to ensure that the investment program is on track for a successful security authorization.

Physical, Facility, and Personnel Security Policy

The FAA must conform with national policy related to physical security of the aviation infrastructure, including leased and owned facilities, the security of all information associated with operation of the

FAA and aircraft operations, and personnel security. The FAA is also obligated to protect proprietary information to which it has access. Physical security is directly applicable to aviation industry operations and activities and to supporting infrastructure such as communications, sensors, and information processing. FAA Order 1600.69, Facility Security Management Program, establishes both policy and guidance for physical security.

FAA Orders 1600.1, Personnel Security Program, establishes both policy and guidance for FAA personnel security. In addition, detailed guidance to implement personnel and physical security with respect to contractors is in FAA Order 1600.72, Contractor and Industrial Security Program.

Sensitive Information and Personally Identifiable Information Policy

The FAA is required by Executive Orders 13526 to protect classified national security information from unauthorized disclosure. The FAA Office of Security and Hazardous Materials Safety in accordance with FAA Order 1600.2, Safeguarding Classified National Security Information, manages systems containing or processing classified data. The FAA is also required under 49 CFR Part 15 to protect sensitive unclassified information from public disclosure. FAA Order 1600.75 Protection Sensitive Unclassified Information provides both policy and guidance.

The Privacy Act of 1974 and the E-Government Act of 2002 (Public Law 107-347) mandate protection of an individual’s right to privacy and the prevention of unauthorized dissemination of personal information. FAA Order 1280.1, Protecting Personally Identifiable Information, establishes both policy and guidance. In addition it establishes the position of FAA Privacy Officer with respect to IT.

A.4.11 System Safety Management

When new capital investments are determined to have an effect on the safety of the NAS, safety management shall be conducted and documented throughout the lifecycle of a product or service in accordance with the FAA SMS. The SMS requires use of safety risk management to identify safety risks to the NAS and to conduct product development at a rigor commensurate with the severity of the resultant hazard should that product experience failure. For software-intense systems, the establishment of a development assurance program in accordance with RTCA Document (DO) 278A, Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management Systems, RTCA, Inc., is one acceptable means demonstrating that a software product was developed at the appropriate level or rigor.

Critical safety issues identified during service analysis are further addressed in (1) an operational safety assessment, (2) a system safety assessment of alternative solutions to mission need reported in the business case, and (3) when service organizations provide program-specific safety risk management planning in the implementation strategy and planning document.

Each service organization involved in acquisition management shall institute a system safety program that includes, at a minimum, hazard identification, hazard classification (severity of consequences and likelihood of occurrence), measures to mitigate hazards or reduce risk to an acceptable level, verification that mitigation measures are incorporated into product design and implementation, and assessment of residual risk. Status of system safety shall be presented at all decision points and investment reviews. Detailed guidelines for safety management are found in FAST, FAA SMS manual, SRMGSA, and RTCA DO-278A.

A.4.12 Risk Management

Risk management is applied throughout the lifecycle management process to identify and mitigate risks associated with achieving FAA goals and objectives. Each line of business shall institute risk management processes that (1) identify and assess risk areas, (2) develop and execute risk mitigation or elimination strategies, (3) track and evaluate mitigation efforts, and (4) continue mitigation activity until risk is eliminated or its consequences are reduced to acceptable levels.

Risk management applies to all levels of FAA activity, from small projects to large programs. It applies to such risk areas as cost, schedule, technical, system safety, all security disciplines, human factors, operability, producibility, supportability, benefits, management, funding, and stakeholder satisfaction (e.g., Congressional and aviation community priorities, union concerns).

A.4.13 Data Standardization and Management

The FAA applies data standards to facilitate data sharing across systems, programs, government agencies, and industry. Data standardization improves the transportability of data, facilitates cost-effective development while re-engineering and improves the quality, utility, and integrity of FAA information products and resources. The FAA data management program consists of data registration, data standardization, data certification, and lifecycle data management. Policy is in FAA Order 1375.1, FAA Information and Data Management. Guidelines and tools are in FAST.

A.4.14 Post-implementation Review and Operational Analysis

Post-implementation Review
The PIR is typically a one-time review to determine the following:

- Are actual costs, performance, and benefits achieving baseline expectations and if not, why not?
- Is the asset enabling the agency to provide the intended service, or do we need to make changes?
- Are there any systemic issues that need to be fixed before widespread deployment?
- Are there process or implementation issues we need to strengthen or improve?

The scope and content of the PIR depends on the acquisition category to which the investment program is assigned. The PIR may include the examination of risks, requirements, customer feedback, and cost/ schedule performance. The output is a comparison of actual program costs, schedule, performance, and benefits as specified in the business case and acquisition program baseline or execution plan, and actual results as deployed. PIRs may also be conducted on families of related programs intended to achieve composite service outcomes, as directed by the JRC or Director of the performing organization.

The PIR is typically conducted 6 to 24 months after an asset first goes into operational service or as determined by the JRC for families of related programs. The Director of the performing organization funds the review, determines the factors and sub-factors that comprise the review based on acquisition category, staffs the review team, plans the review, and executes PIR processes. The Director of the performing organization develops a plan of action and milestones to address findings of the review and reports PIR exceptions, which cannot be managed by Directorate resources, to the JRC, vice-president or equivalent, and/or key stakeholder organizations, as appropriate.

The PIR Quality Officer ensures that the review is planned and conducted in an unbiased manner and consistent with agency standards. The PIR Quality Officer participates in PIR processes and maintains agency records of PIR strategies, plans, reports, exception reports, and plans of action and milestones.

Operational Analysis

Operational analysis is the process by which FAA evaluates the ability of in-service assets to continue to provide the service for which they were procured. It answers the following questions:

- Are actual operating costs comparable to estimates in the business case analysis report?
- Is the asset operating with a sustainable design?
- Can the asset continue to meet the business needs and performance goals of the agency?
- Is the asset continuing to meet stakeholder needs?

Operational analysis consists of gathering and analyzing reliability, maintainability, and availability data (using the National Airspace System Performance Analysis System); managing supportability information to determine whether an operational asset can continue to provide the expected service for its intended life; monitoring cost data to ensure that actual costs are in line with planned costs; and managing asset viability against stakeholder needs. Results are fed into the FAA's planning and investment analysis processes by the Directorate, when warranted, as a basis for determining whether an asset may need to be modernized, replaced, or removed from service. Operational analysis begins when an asset first goes operational and continues until it is removed from service. Operational analysis data is also used in the evaluation of asset readiness status. Operational analysis is the responsibility of the Directorate of the performing/service organization

A.4.15 Earned Value Management

All organizations responsible for FAA capital investment programs that involve development, modernization, or enhancement are required to develop and implement an EVM system consistent with guidance in FAST. The objective is integration of all related management disciplines (e.g., systems engineering, cost estimating, procurement, scheduling, and risk management) using EVM to effectively support program execution. EVM provides the FAA with timely, accurate, and integrated cost, schedule, and technical performance information for both the total investment program and individual supporting contracts. It continuously measures the quantity and value of completed work and enables the forecast of reliable estimates of future performance.

Program Requirements

Development, modernization, and enhancement programs must use an EVM system based on the guidelines in American National Standard ANSI/EIA-748, Earned Value Management Systems, for the total program effort, including both government and contractor work, according to the following table. Program EVM must be consistent with the acquisition strategy in the implementation strategy and planning document, section 3.2, Program Control. Major investment programs are those required by the OMB to submit an OMB Exhibit 300. The JRC or appropriate investment decision authority designates non-major programs required to have an EVMS.

Table 7: EVMS Requirements

EVMS Requirements	Program Type Major	Program Type Non-Major	Program Type Other
Exhibit 300	R	T	O
Integrated Master Schedule	R	T	O
Integrated Baseline Review	R	T	O
EVM Standard Compliance	R	R	O
EVM System Certification	R	O	O

R = Required by approving authority
T = Tailored: requirement may be tailored by program
O = Optional

Contract Requirements

Contractor EVM implementation must be consistent with the strategy in the implementation strategy and planning document, Section 2.8, Contract Management. All capital investment programs must use the following table to determine the application of EVM to the development, modernization, and enhancement work assigned to contractors. The requirements apply to all Acquisition Management Policy - 1/2014 3 contract types. On an exception basis, low-risk contractor efforts, i.e., firm fixed-price production, may implement EVM within an FAA program office at the program level. Contractor EVM implementation must be based on an assessment of the cost, schedule, and technical performance risk of each contract.

Table 8: Contract EVMS Requirements

[redacted]

Certification Requirements

Capital investment programs required to use an EVM system in accordance with AMS Section 4.16.1 must be certified as meeting the guidelines of ANSI/EIA-748. The EVM Focal Point (ATO-A) assesses and validates EVM implementation and monitors application to ensure compliance. The AIT Value Management Office (AIT) certifies program EVM systems.

FAA contractors required to use an EVM system in accordance with AMS Section 4.16.2 must be certified as meeting the guidelines of ANSI/EIA-748. Contractor EVM implementation must be validated by the Contracting Officer, assisted by the EVM Focal Point. The EVM Focal Point determines whether a contractor requires an EVMS certification review or whether an existing certification and EVM surveillance process are acceptable. The EVM Focal Point will establish agreements with other government agencies to recognize contractor EVM certifications and surveillance reports.

Appendix B: FAA System Engineering

System Engineering (SE) is a powerful approach to organizing and conducting complex programs, such as those in the National Airspace System (NAS). SE is an overarching process that trades off and integrates elements within a system's design to achieve the best overall product and/or capability known as a system. Although there are some important aspects of program management in SE, it is still much more of an engineering discipline than a management discipline. SE requires quantitative and qualitative decision-making involving tradeoffs, optimization, selection, and integration of the results from many engineering disciplines. SE is iterative—it derives and defines requirements at each level of the system, beginning at the top (the NAS level) and propagating those requirements through a series of steps that eventually leads to a physical design at all levels (i.e., from the system to its parts). Iteration and design refinement lead successively to preliminary design, detail design, and final approved design.

At each successive level, there are supporting lower level design iterations that are necessary to gain confidence for decisions. During these iterations, many concept alternatives are postulated, analyzed, and evaluated in trade studies, resulting in a multi-tier set of requirements. These requirements form the basis for structured verification of performance. SE closely monitors all development activities and integrates the results to provide the best solution at all system levels.

System

A system is an integrated set of constituent parts that are combined in an operational or support environment to accomplish a defined objective. These integrated parts include people, hardware, software, firmware, information, procedures, facilities, services, and other support facets. People from different disciplines and product areas have different perspectives on what makes up a system. For example, software engineers often refer to an integrated set of computer modules as a system. Electrical engineers might refer to a system as complex integrated circuits or an integrated set of electrical units. The FAA has an overarching system of systems called the NAS that includes, but is not limited to, all the airports; aircraft; people; procedures; airspace; communications, navigation, and surveillance/air traffic management systems; and facilities. It is difficult to agree on what comprises a system since it depends entirely on the focus of those who define the objective of the system.

As a "how to" manual for System Engineering (SE), the System Engineering Manual defines the constituent SE elements (Figure 36) to be performed throughout the program lifecycle. The term "program" is intended to mean projects of all sizes and complexity, ranging from the National Airspace System (NAS) to individual parts. While the SEM is primarily directed at NAS modernization, it is recommended that individual programs tailor the application of processes, tools, and techniques according to program requirements. Further, implementation of these processes is to be directed by the appropriate program or SE management authority designated in the NAS System Engineering Management Plan (SEMP).

The SEM defines the FAA SE elements as well as the work products generated from each SE element. The 12 (actually 13) elements appear in Figure 36 with each element's purpose or function. The 13th element listed provides for process management and maintenance of the other 12 elements.

System Engineering	Abbrev.	Purpose of Element
Integrated Technical Planning	ITP	Plans the SE efforts and products.
Requirements Management	RM	Identifies and manages the requirements that describe the desired characteristics of the system.
Functional Analysis	FA	Describes the functional characteristics (what the system needs to do) that are used to derive requirements.
Synthesis	SYN	Transforms requirements into physical solutions.
Trade Studies	TS	Assists decision making by analyzing and selecting the best-balanced solutions to requirements.
Interface Management	IM	Identifies and manages the interactions between segments within a system or interactions with other peer systems.
Specialty Engineering	SpecEng	Analyzes the system, requirements, functions, solutions, and/or interfaces using specialized skills and tools. Assists in derivation of requirements, synthesis of solutions, selection of alternatives, and validation and verification of requirements.
Integrity of Analyses	IA	Ensures that analyses provide the required level of fidelity and accuracy.
Risk Management	RSK	Identifies, analyzes, and manages the uncertainties of achieving program requirements by developing strategies to reduce the severity or likelihood of those uncertainties.
Configuration Management	CM	Establishes and maintains consistency and manages change in the system performance, functional, and physical attributes.
Validation and Verification	V&V	Validation determines if system requirements are correct. Verification determines that the solution meets the validated requirements.
Lifecycle Engineering	LCE	Identifies and manages requirements for system lifecycle attributes, including real estate management, deployment and transition, integrated logistics support, sustainment/technology evolution, and disposal.
Maintain System Engineering Process	MSE	Manages and maintains SE processes to meet FAA goals. Gains agency-wide skill and standardization by continuously improving the effectiveness and efficiency of SE processes and tools.

Figure 21: System Engineering Elements

There are several definitions of System of Systems (SOS) as opposed to the component systems that comprise an SOS, depending on the domain or application of interest. The overall objective for developing a system of systems is to satisfy capabilities that can only be met with a mix of multiple, autonomous, and interacting systems. The mix of constituent systems may include existing, partially developed, and yet-to-be-designed independent systems.

An SOS should be treated and managed as a system in its own right and should therefore be subject to the same SE processes and best practices applied to individual systems. The NAS can be characterized as a "system of systems" by any of these measures. The FAA defines the NAS as the overall environment in which aircraft operate, including aircraft, pilots, tower controllers, terminal area controllers, en route controllers, oceanic controllers, maintenance personnel, and airline dispatchers, as well as the associated infrastructure (facilities, computers, communications equipment, satellites, navigation aids, and radars). For the purposes of this SEM, the NAS will be treated as a system, recognizing that the SOS characteristics above require specific treatment, especially at the NAS level.

Hierarchy

SE first defines the system at the top level, ensuring focus and optimization at that level. It then proceeds to increasingly lower levels of detail until the system is completely decomposed to its basic elements.

A system may include hardware, software, firmware, people, information, techniques, facilities, services, and other support items. Each system item may have its own associated hierarchy. For example, the various software programs/components that may reside in a system have a commonly accepted hierarchy in that a system/subsystem may have multiple Computer Software Configuration Items. The depths of this common hierarchy may be adjusted to fit the complexity of the system. Simple systems may have fewer levels in the hierarchy than complex systems and vice versa. Because there may be varying hierarchal models referenced in the realm of SE, it is important for those who define the objective or function of a given system/subsystem to also lie out the hierarchal levels of the system in order to define the system's scope.

Following are definitions for succeeding levels within the system/subsystem hierarchy used in the FAA System Engineering Manual (SEM):

· **System.** An integrated set of constituent parts that are combined in an operational or support environment to accomplish a defined objective. These parts include people, hardware, software, firmware, information, procedures, facilities, services, and other support facets.

· **Subsystem.** A system in and of itself (reference the system definition) contained within a higher-level system. The functionality of a subsystem contributes to the overall functionality of the higher-level system. The scope of a subsystem's functionality is less than the scope of functionality contained in the higher-level system.

- **Element.** An integrated set of components that comprise a defined part of a subsystem (e.g., the fuel injection element of the propulsion subsystem).
- **Component.** Composed of multiple parts – a clearly identified part of the product being designed or produced.
- **Part.** One, two, or more pieces joined together to make a component; the lowest level of separately identifiable items within a system—are not normally subject to disassembly without destruction or impairment of designed use.

- **Software.** A combination of associated computer instructions and computer data definitions required enabling the computer hardware to perform computational or control functions.
- **Computer Software Configuration Item (CSCI).** An aggregation of software that is designed for configuration management and treated as a single entity in the Configuration Management process.
- **Computer Software Component (CSC).** A functionally or logically distinct part of a CSCI, typically an aggregate of two or more software units.
- **Computer Software Unit.** An element specified in the design of a CSC that is separately testable or able to be compiled.
- **Module.** A program unit that is discrete and identifiable with respect to compiling, combining with other units, and loading.

SYSTEM ENGINEERING IN THE ACQUISITION MANAGEMENT SYSTEM PROGRAM LIFECYCLE

There are relationships between the System Engineering (SE) milestones and the phases and lifecycle management decisions of the Acquisition Management System (AMS). The inputs and outputs for each SE element are related to each (AMS) phase through the SE milestones shown in Figure 37, and the elements and products are associated with the AMS decision points.

SE Element / AMS Lifecycle Phase	Integrated Technical Planning	Requirements Management	Functional Analysis	Synthesis	Trade Studies	Interface Management	Specialty Engineering	Integrity of Analyses	Risk Management	Configuration Management	Validation and Verification	Lifecycle Engineering	Maintain System Engineering
Mission Analysis	X	X	X	X	X	X	X	X	X		X	X	
Investment Analysis	X	X	X	X	X	X	X	X	X	X	X	X	X
Solution Implementation	X	X	X	X	X	X	X	X	X	X	X	X	X
In-Service Management	X	X	X	X	X	X	X	X	X	X	X	X	X
Disposal	X				X	X	X		X	X		X	

Figure 22: SE Element Mapped to AMS Phase

The FAA's System Engineering Manual (SEM) reflects industry and government SE standards, methodologies, and best practices. It recognizes that the current state of the referenced AMS, SE documents, and processes herein may not be in total agreement because that documentation and the SEM are in different update cycles.

Associated SE Milestones With AMS Phases

SE reviews and milestones are associated with and support various AMS decision points. These SE milestones are the primary means to measure a program's progress. These are:

- **Mission Need Decision (AMS-1).** In support of the AMS-1 decision point, analysis is conducted to determine what capabilities must be in place now and in the future to meet agency goals and the service needs of stakeholders. The primary analysis output is a service-level mission need for each service organization. The major SE input to this decision is a recommendation on candidate technologies to be considered and an identification of the shortfall to be addressed. The candidate technology recommendation is an output of a Technology Readiness Assessment (TRA).

- **Investment Analysis Readiness Decision (AMS-2).** Subsequent to the AMS-1 decision, a concept and requirements development activity is conducted, which results in an Investment Analysis Readiness Decision (IARD). SE provides inputs to this decision through the results of an SE Investment Analysis Review (SIAR), which determines if there is sufficient SE data available for a viable decision.
- **Initial Investment Decision (AMS-3).** The initial investment effort explores possible alternative technology or operational solutions to satisfy the mission shortfalls identified in AMS-1. The AMS-3 decision evaluates the most promising solution(s) for further refinement before a final decision. SE conducts a Functional Baseline Review (FBR) to support the Initial Investment Decision and establishes the functional baseline for the investment.
- **Final Investment Decision (AMS-4).** Completion of the Investment Analysis effort is marked by an investment decision. This decision point selects the actual solution in which to invest. A System Requirements Review (SRR) is conducted to validate that the program requirements are sufficient to support the investment decision.
- **In-Service Decision (AMS-5).** The In-Service Review checklist is reviewed by the appointed decision authority as part of the In-Service Decision. Several SE milestones, such as the Preliminary Design Review (PDR) and Critical Design Review (CDR), are established as quality gates leading up to this decision point.

Appendix C: OMB Exhibit 300

Exhibit 300s establish policy for planning, budgeting, acquisition and management of major information technology (IT) capital investments. The Office of Management and Budget (OMB) provides procedural and analytic guidelines for implementing specific aspects of these policies described in OMB Circulars and their associated appendices.

Exhibit 300s are companions to an agency's Exhibit 53. Exhibit 300s and the Exhibit 53, together with the agency's Enterprise Architecture program, define how to manage the IT Capital Planning and Control Process. Exhibit 53A is a tool for reporting the funding of the portfolio of all IT investments within a Department while Exhibit 300A is a tool for detailed justifications of major "IT Investments." Exhibit 300B is for the management of the execution of those investments through their project life cycle and into their useful life in production. By integrating the disciplines of architecture, investment management, and project implementation, these programs provide the foundation for sound IT management practices, end-to-end governance of IT capital assets, and the alignment of IT investments with an agency's strategic goals. As architecture-driven IT investments are funded in the "Invest" phase, they move forward into the implementation phase where system development life cycle processes are followed and actual versus planned outputs, schedule, and operational performance expenditures are tracked utilizing performance-based management processes. New for the FY 2013 budget process, Exhibit 300B requires agencies to provide more detailed benchmarks for the management and performance of projects and operational assets associated with a major investment.

The policy and budget justification principles in this Exhibit apply to all agencies of the Executive Branch of the Government subject to Executive Branch review. Exhibit 300A&B must be submitted for each major IT investment for CIO Council agencies in accordance with this section, parallel requirements for other agencies are addressed in separate guidance. Major IT investments also must be reported on the agency's Exhibit 53.

The Federal Government must effectively manage its portfolio of capital assets to ensure scarce public resources are wisely invested. Capital programming integrates the planning, acquisition and management of capital assets into the budget decision-making process and is intended to assist agencies in improving asset management and in complying with the results-oriented requirements of:

• **The Clinger-Cohen Act (CCA) of 1996, Public Law 104 – 106**, legislatively mandates that IT investments be prudently managed. CCA requires federal agencies to focus on the results achieved through IT investments while streamlining the federal IT procurement process. Congress and OMB have clearly stated that each agency must actively manage its IT program to provide assurances that technology expenditures are necessary and shall result in demonstrated improvements in mission effectiveness and customer service.

• **The Federal Acquisition Streamlining Act of 1994, Title V (FASA V**), which requires agencies to establish cost, schedule and measurable performance goals for all major acquisition programs, and achieve on average 90 percent of those goals.

• **Security:** For IT investments, agencies should maintain up-to-date tracking of systems in the FISMA inventory to the appropriate IT investment. Costs for security are collected in both the Exhibit 53A and 53B.

• **Enterprise Architecture (EA):** The IT investment must be included in the agency's EA and Capital Planning and Investment Control (CPIC) process and mapped to and supporting the Federal Enterprise Architecture (FEA). The business case must demonstrate the relationship between the investment and the business, performance, data, services, application, and technology layers of the agency's EA.

Terminology

Alternatives Analysis refers to an analysis of alternative approaches addressing the performance objectives of an investment, performed prior to the initial decision to implement a solution, and updated periodically as appropriate to capture changes in the context for an investment decision. Alternatives analysis details should be available upon request.

Asset refers to anything that has value to an organization, including, but not limited to: computing device, information technology (IT) system, IT network, IT circuit, software (both an installed instance and a physical instance), virtual computing platform (common in cloud and virtualized computing), and related hardware (e.g., locks, cabinets, keyboards). Assets are the lowest level at which information technology is planned, acquired, implemented and operated.

Capital assets means land, structures, equipment, intellectual property (e.g., software), and information technology (including the output of IT service contracts) used by the Federal Government and having an estimated useful life of two years or more. See Appendix One of the Capital Programming Guide for a more complete definition of capital assets.

Capital investment means the planning, development, acquisition of a capital asset and the management and operation of that asset through its usable life after the initial acquisition. IT Capital investments may consist of one or more assets, the planning, development and acquisition of which are managed through projects, and which then provide useful components in an operational (production) environment.

Capital programming means an integrated process within an agency for planning, budgeting, procurement and management of the agency's portfolio of capital assets to achieve agency strategic goals and objectives with the lowest overall cost and least risk.

Cost means the expenditure of funds or use of property to acquire, produce, operate or maintain an asset. Examples include, but are not limited to: sunk costs, operational costs, acquisition costs and disposition costs (including variable costs such as labor hours).

Cost saving represents the reduction in actual expenditures to achieve a specific objective (as defined in OMB Circular A–131). Cost savings should be cited in descriptions, and may be included as a benefit in alternative analyses.

Cost avoidance represents results from an action taken in the immediate time frame that will decrease costs in the future (as defined in OMB Circular A–131). Cost avoidance should be cited in descriptions, and may be included in alternative analyses.

Dependency means the identification of relationships between projects and operational assets within an investment, and identification of relationships between investments. Identification of dependencies is critical to the management of project, program, and portfolio risk.

Development, Modernization and Enhancement (DME) Costs are costs for projects leading to new IT assets/systems and projects that change or modify existing IT assets to: substantively improve capability or performance; implement legislative or regulatory requirements; or to meet an agency leadership request. Capital costs as part of DME can include hardware, software development and acquisition costs, COTS acquisition costs, government labor costs, and contracted labor costs for planning, development, acquisition, system integration, and direct project management and overhead support.

Disposition Cost for an asset refers to the cost of retiring a capital asset once its useful life is completed or it has been superseded by a replacement asset, and may be included in operational costs.

Earned Value Management (EVM) is a project management tool effectively integrating the project scope of work with schedule and cost elements for optimum project planning and control. The qualities and operating characteristics of earned value management systems (EVMS) are described in American National Standards Institute (ANSI)/Electronic Industries Alliance (EIA) Standard –748–1998, Earned Value Management Systems, approved May 19, 1998. It was reaffirmed on August 28, 2002.

Enterprise Architecture (EA) is the explicit description and documentation of the current and desired relationships among business and management processes and information technology of an organization. It describes the "current architecture" and "target architecture" to include the rules and standards and systems life cycle information to optimize and maintain the environment which the agency wishes to create and maintain by managing its IT portfolio. The EA must also provide a strategy to enable the agency to support its current state and also act as the roadmap for transition to its target environment. The EA will define principles and goals and set direction on such issues as the promotion of interoperability, open systems, public access, end user satisfaction, and IT security. The agency must support the EA with a complete inventory of agency information resources, including personnel, equipment, and funds devoted to information resources management and information technology, at an appropriate level of detail.

Federal Acquisition Certification for Program and Project Managers (FACP/PM) was established to ensure general training and experience requirements for program and project managers are clearly identified for civilian agencies. The FAC-P/PM focuses on essential competencies needed for program and project managers; the program does not include functional or technical competencies, such as those for information technology or agency-specific competencies. Defense agencies have a similar certification program under the Defense Acquisition Workforce Improvement Act (DAWIA). Agencies were required to be compliant with FAC-P/PM starting in FY 2008. Available levels are Entry/Apprentice, Mid/Journeyman and Expert/Advanced for FAC-P/PM and 1, 2 and 3 for DAWIA.

Federal Enterprise Architecture (FEA) is a business-based documentation and analysis framework for government-wide improvement. The FEA allows agencies to use standardized methods to describe the relationship between an agency's strategic goals, business functions, and enabling technologies at various levels of scope and complexity. The FEA is comprised of documentation in six domain areas (strategic goals, business services, data and information, systems and applications, infrastructure, and security) and six reference models areas that are designed to facilitate standardized analysis, reporting, and the identification of duplicative investments, gaps, and opportunities for collaboration within and across federal agencies.

Federal Segment Architecture Methodology (FSAM) is to become the "Federal Solution Architecture Methodology" in October 2011 and will serve as a scalable and repeatable process for solution architecture at the application, system, segment, enterprise, sector, government-wide, national, and international levels of scope. Consistent use of the FSAM should result in more complete and consistent architecture products by helping architects engage system owners, program offices, and executive sponsors to deliver value-added plans for improved mission delivery. Specifically, FSAM includes guidance to help architects establish clear relationships among strategic goals, detailed business / information management requirements, and measurable performance improvements within each area of the agency's enterprise architecture.

Full Funding means appropriations are enacted sufficient in total to complete an asset or useful component (see definition below) of a capital asset before any obligations may be incurred for the component. Incrementally funding the planning and acquisition of capital assets or (useful components) without certainty if or when future funding will be available can result in poor planning, inadequate justification of assets acquisition, higher acquisition costs, project delays, cancellation of projects, the loss of sunk costs, and inadequate funding to maintain and operate the assets. Budget requests for full acquisition of capital assets must propose full funding.

Funding means providing the budgetary resources to plan for, acquire, develop, sustain, or operate an asset.

Information Technology means any equipment or interconnected system or subsystem of equipment that is used in the automatic acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission or reception of data or information by an executive agency. Information Technology is related to the terms Capital Asset, IT Investment, Program, Project, Sub-project, Service, and System.

Integrated Program Team (IPT) means cross-functional or multidisciplinary group of individuals organized and collectively responsible for the specific purpose of delivering a project/product/or process to an external or internal customer. Each IPT should include experts in program and project management, resource management, procurement, and systems engineering, security, and other disciplines, as necessary, to evaluate all aspects of the project. An IPT must always include, but is not limited to: a qualified fully-dedicated IT program manager, a contract specialist, an Information technology specialist, a security specialist and a business process owner before OMB will approve this program investment budget. Key members of the IPT will also be co-located during the most critical junctures of the program, to the maximum extent possible. Agencies should establish integrated program team members individual performance goals to hold team members accountable for both individual functional goals and overall program success. IPT should be defined in a program or an IPT charter.

Interagency Acquisition means the use of the Federal Supply Schedules, a multi-agency contract (i.e., a task order or delivery order contract established by one agency for use by government agencies to obtain supplies and services, consistent with the Economy Act, 31 U.S.C. 1535), or a government-wide acquisition contract (i.e., a task-order or delivery-order contract for information technology established by one agency for government-wide use operated by an executive agent designated by OMB pursuant to Section 11302(3) of the Clinger-Cohen Act of 1996).

Federal IT Dashboard: The purpose of the Dashboard is to provide information on the effectiveness of government IT programs and to support decisions regarding the investment and management of resources. The Dashboard is now being used by the Administration and Congress to make budget and policy decisions.

IT Investment means the expenditure of IT resources to accomplish mission objectives. An IT investment may include a project or projects for the development, modernization, enhancement, or maintenance of a single IT asset or group of IT assets with related functionality and the subsequent operation of those assets in a production environment. While each asset or project would have a defined life cycle, an investment that covers a collection of assets intended to support an ongoing business mission may not have a defined life cycle.

IT Program Managers and IT Project Managers are defined by OPM in the Job Family Standard for Administrative Work, in the Information Technology Group (series 2200 in the Federal Classification and Job Grading Systems). IT Program Managers will be responsible for major investments and will lead the required Integrated Program Team for the investment.

Investment Title as defined in Guidance for Exhibit 53 (See Section 53.8).

Life-cycle costs include all investment costs (including government FTE), independent of the funding source, i.e., revolving fund, appropriated fund, working capital fund, trust fund, etc. (see Capital Programming Guide of OMB Circular A-11 and OMB Circular A-131).

Maintenance is the activity necessary to keep an asset functioning as designed during its operations and maintenance phase of an investment. Maintenance costs include costs needed to sustain an IT asset at the current capability and performance levels including: corrective hardware/software, voice and data communications maintenance; replacement of damaged or obsolete IT equipment; and associated overhead costs. Where appropriate, maintenance activities that follow agency defined project management methodologies should be managed and reported as projects and reported in Section B of the Exhibit 300B. Examples of maintenance projects include operating system upgrades, technology refreshes, and security patch implementations.

Major IT Investment means a program requiring special management attention because of its importance to the mission or function of the agency, a component of the agency, or another organization; has significant program or policy implications; has high executive visibility; has high development, operating, or maintenance costs; is funded through other than direct appropriations; or, is defined as major by the agency's capital planning and investment control process. OMB may work with the agency to declare other investments as major investments. Agencies should consult with your OMB agency budget officer or analyst about what investments to consider as "major." Investments not considered "major" are "non-major."

Operations mean the day-to-day management of an asset in the production environment and include activities to operate data centers, help desks, operational centers, telecommunication centers, and end-user support services. Operational activities are reported through Section C of the Exhibit 300B. Operations costs include the expenses associated with an IT asset that is in the production environment to sustain an IT asset at the current capability and performance levels including: Federal and contracted labor costs; and costs for the disposal of an asset.

Operations and Maintenance means the phase of an asset in which the asset is in operations and produces the same product or provides a repetitive service. Operations and Maintenance (O&M) is synonymous with "steady state."

Performance-based acquisition management means a documented, systematic process for program management, which includes integration of program scope, schedule and cost objectives, establishment of a baseline plan for accomplishment of program objectives, and use of earned value techniques for performance measurement during execution of the program. This includes prototypes and tests to select the most cost effective alternative during the Planning Phase, the work during the Acquisition Phase, and any developmental, modification, or upgrade work done during the Operational/Steady State Phase. For operational/steady state systems, an operational analysis as discussed in Phase IV of the Capital Programming Guide is required. A performance-based acquisition (as defined in the Federal Acquisition Regulation 37.101) or contract/agreement with a defined quality assurance plan that includes performance standards/measures should be the basis for monitoring contractor or in-house performance of this phase.

Planning means preparing, developing or acquiring the information needed to: design the asset; assess the benefits, risks, and risk-adjusted costs of alternative solutions; and establish realistic cost, schedule, and performance goals, for the selected alternative, before either proceeding to full acquisition of the capital project or useful component or terminating the project. Planning must progress to the point where you are ready to commit to achieving specific goals for the completion of the acquisition before proceeding to the acquisition phase. Information gathering activities may include market research of available solutions, architectural drawings, geological studies, engineering and design studies, and prototypes. Planning may be general to the overall investment or may be a useful component of a project. Depending on the nature of the project, one or more planning components may be necessary.

Program for the purposes of this Exhibit 300 is a group of assets that are planned and managed together to achieve an overall set of related outcomes. IT Investment is frequently used as a synonym for IT program.

Project is a temporary endeavor undertaken to accomplish a unique product or service with a defined start and end point and specific objectives that, when attained, signify completion. Projects are undertaken for development, modernization, enhancement, disposal, or maintenance of an IT asset. Projects are composed of activities.

Project Manager (PM) Level of Experience is the specific certification or the number of years of direct project management experience of the PM. Examples of PM certifications include FAC-P/PM, PMI, or other recognized certifications.

Risk Management is a systematic process of identifying, analyzing, and responding to risk. It includes maximizing the probability and consequences of positive events and minimizes the probability and consequences of adverse events to overall objectives.

Solution Architecture is a standardized method of identifying business requirements and viable technology solutions within the context of a single agency's enterprise architecture, or a multi-agency sector or government-wide/international architecture. Solution architecture includes current and future views as well as transition plans at a number of levels of scope that include applications, systems, segments, enterprise, sector, government-wide, national, and international. The Federal Solution Architecture Methodology (FSAM) is scheduled for release in October 2011 to provide the repeatable process for doing solution architecture.

Shared Service Provider is the provider of a technical solution and/or service that supports the business of multiple agencies using a shared architecture.

Unique Investment Identifier as defined in the guidance for Exhibit 53.

Additional budget terms and definitions are included in the Glossary in Appendix J, "Principles of Budgeting for Capital Asset Acquisitions" and in the guidance for Exhibit 53 (for IT).

Appendix D: End Notes

[i] FAA NAS Enterprise Architecture, Infrastructure Roadmap: Weather, https://nasea.faa.gov/products/roadmap/main/display/8/tab/detail.

[ii] https://faaco.faa.gov/index.cfm/announcement/view/15846

[iii] http://www.ofcm.noaa.gov/wg-mpar/meetings/2012-02/10%20NSWRC%20Cost.pdf

[iv] FAA NAS Enterprise Architecture, Infrastructure Roadmap: Weather, NWP Detail, https://nasea.faa.gov/system/main/display/1208.

[v] **FAA Handbook 7110.65 2–1–6. SAFETY ALERT**

Issue a safety alert to an aircraft if you are aware the aircraft is in a position/altitude which, in your judgment, places it in unsafe proximity to terrain, obstructions, or other aircraft. Once the pilot informs you action is being taken to resolve the situation, you may discontinue the issuance of further alerts. Do not assume that because someone else has responsibility for the aircraft that the unsafe situation has been observed and the safety alert issued; inform the appropriate controller.

2–1–21. FAA Handbook 7110.65 TRAFFIC ADVISORIES

Unless an aircraft is operating within Class A airspace or omission is requested by the pilot, issue traffic advisories to all aircraft (IFR or VFR) on your frequency when, in your judgment, their proximity may diminish to less than the applicable separation minima. Where no separation minima applies, such as for VFR aircraft outside of Class B/Class C airspace, or a TRSA, issue traffic advisories to those aircraft on your frequency when in your judgment their proximity warrants it.

[vi] **§91.117 Aircraft speed.**

(a) Unless otherwise authorized by the Administrator, no person may operate an aircraft below 10,000 feet MSL at an indicated airspeed of more than 250 knots (288 mph).

(b) Unless otherwise authorized or required by ATC, no person may operate an aircraft at or below 2,500 feet above the surface within 4 nautical miles of the primary airport of a Class C or Class D airspace area at an indicated airspeed of more than 200 knots (230 mph). This paragraph (b) does not apply to any operations within a Class B airspace area. Such operations shall comply with paragraph (a) of this section.

(c) No person may operate an aircraft in the airspace underlying a Class B airspace area designated for an airport or in a VFR corridor designated through such a Class B airspace area, at an indicated airspeed of more than 200 knots (230 mph).

(d) If the minimum safe airspeed for any particular operation is greater than the maximum speed prescribed in this section, the aircraft may be operated at that minimum speed.

[vii] **§91.155 Basic VFR weather minimums.**

(a) Except as provided in paragraph (b) of this section and Sec. 91.157, no person may operate an aircraft under VFR when the flight visibility is less, or at a distance from clouds that is less, than that prescribed for the corresponding altitude and class of airspace in the following table:

Airspace	Flight visibility	Distance from clouds
Class A -----------------------------	Not Applicable -------------------	Not Applicable.
Class B -----------------------------	3 statute miles --------------------	Clear of Clouds.

Class C ----------------------------	3 statute miles -------------------	500 feet below. 1,000 feet above. 2,000 feet horizontal.
Class D ----------------------------	3 statute miles --------------------	500 feet below. 1,000 feet above. 2,000 feet horizontal.
Class E: Less than 10,000 feet MSL.	3 statute miles -------------------	500 feet below. 1,000 feet above. 2,000 feet horizontal.
At or above 10,000 feet MSL.	5 statute miles -------------------	1,000 feet below. 1,000 feet above. 1 statute mile horizontal.
Class G: 1,200 feet or less above the surface (regardless of MSL altitude).		
Day, except as provided in Sec. 91.155(b).	1 statute mile ---------------------	Clear of clouds.
Night, except as provided in Sec. 91.155(b).	3 statute miles -------------------	500 feet below. 1,000 feet above. 2,000 feet horizontal.
More than 1,200 feet above the surface but less than 10,000 feet MSL		
Day ----------------------------------	1 statute mile ---------------------	500 feet below. 1,000 feet above. 2,000 feet horizontal.
Night --------------------------------	3 statute miles -------------------	500 feet below. 1,000 feet above. 2,000 feet horizontal.
More than 1,200 feet above the surface and at or above 10,000 feet MSL.	5 statute miles -------------------	1,000 feet below. 1,000 feet above. 1 statute mile horizontal.

(b) *Class G Airspace.* Notwithstanding the provisions of paragraph (a) of this section, the following operations may be conducted in Class G airspace below 1,200 feet above the surface:
(c) Except as provided in Sec. 91.157, no person may operate an aircraft beneath the ceiling under VFR within the lateral boundaries of controlled airspace designated to the surface for an airport when the ceiling is less than 1,000 feet.
(d) Except as provided in Sec. 91.157 of this part, no person may take off or land an aircraft, or enter the traffic pattern of an airport, under VFR, within the lateral boundaries of the surface areas of Class B, Class C, Class D, or Class E airspace designated for an airport--
(1) Unless ground visibility at that airport is at least 3 statute miles; or
(2) If ground visibility is not reported at that airport, unless flight visibility during landing or takeoff, or while operating in the traffic pattern is at least 3 statute miles.
(e) For the purpose of this section, an aircraft operating at the base altitude of a Class E airspace area is considered to be within the airspace directly below that area.

[viii] **§91.123 Compliance with ATC clearances and instructions.**

(a) When an ATC clearance has been obtained, no pilot in command may deviate from that clearance unless an amended clearance is obtained, an emergency exists, or the deviation is in response to a traffic alert and collision avoidance system resolution advisory. However, except in Class A airspace, a pilot may cancel an IFR flight plan if the operation is being conducted in VFR weather conditions. When a pilot is uncertain of an ATC clearance, that pilot shall immediately request clarification from ATC.

(b) Except in an emergency, no person may operate an aircraft contrary to an ATC instruction in an area in which air traffic control is exercised.

(c) Each pilot in command who, in an emergency, or in response to a traffic alert and collision avoidance system resolution advisory, deviates from an ATC clearance or instruction shall notify ATC of that deviation as soon as possible….

§91.181 Course to be flown.

Unless otherwise authorized by ATC, no person may operate an aircraft within controlled airspace under IFR except as follows:

(a) On an ATS route, along the centerline of that airway.

(b) On any other route, along the direct course between the navigational aids or fixes defining that route. However, this section does not prohibit maneuvering the aircraft to pass well clear of other air traffic or the maneuvering of the aircraft in VFR conditions to clear the intended flight path both before and during climb or descent.

[ix] There as yet are no defined RPA performance parameters that provide for minimum as well as maximum values to be considered to complete a successful DAA maneuver. This includes minimum and maximum airspeed, rates of turn, rates of climb, rates of descent

[x] The FAA ADS-B Mandate of 2020 will provide dependent surveillance with precise position determination that will greatly enhance the ability to reduce margins required to establish a modest and workable “well clear” safety margin between two aircraft. The final rule prescribes ADS–B Out performance requirements for all aircraft operating in Class A, B, and C airspace within the NAS; above the ceiling and within the lateral boundaries of a Class B or Class C airspace area up to 10,000 feet MSL; and Class E airspace areas at or above 10,000 feet MSL over the 48 contiguous United States and the District of Columbia, excluding the airspace at and below 2,500 feet above the surface.

The rule also requires that aircraft meet these performance requirements in the airspace within 30 nautical miles of certain identified airports that are among the nation’s busiest (based on annual passenger enplanements, annual airport operations count and operational complexity) from the surface up to 10,000 feet MSL. In addition, the rule requires that aircraft meet ADS–B Out performance requirements to operate in Class E airspace over the Gulf of Mexico at and above 3,000 feet MSL within 12 nautical miles of the coastline of the U.S.