FAA Telecommunication Infrastructure Review Panel

Report on November 19, 2009 Outage

Federal Aviation Administration

Washington, D.C.

April 20, 2010

FAA Telecommunication Infrastructure Review Panel

Report on November 19, 2009 Outage

Federal Aviation Administration

Washington, D.C.

April 20, 2010

Acknowledgements

The FTI Review Panel wishes to acknowledge the efforts of the many people who assisted us in conducting our review. These include staff from the FAA's System Operations Group - Air Traffic Organization, the FAA's Technical Operations Group – Air Traffic Organization and the FAA's Telecommunication Services Group. We also received valuable input from staff at Gartner, Inc., and the US Department of Defense. We specifically want to acknowledge the efforts of the FAA Telecommunications Infrastructure (FTI) Internet Protocol (IP) Analysis Team (FIAT) in providing us with their technical findings and recommendations. Finally, we want to acknowledge the staff in the Government Communications Systems Division of the Harris Corporation, whose willingness to cooperate, provide information, host our site visit and answer our questions facilitated completion of this report.

Washington, D.C.
January 28, 2010

Review Panel Approval

DAVE BOWEN
Assistant Administrator for Information Services and Chief Information Officer
Federal Aviation Administration

NANCY BROWN
Former Director of Command, Control, Communications and Computer Systems, Joint Staff; Vice Admiral, United States Navy (Ret.)

ANEESH CHOPRA
Assistant to the President and Chief Technology Officer
Office of Science and Technology Policy, Executive of the President

STEVE COOPER
Air Traffic Control Organization Chief Information Officer
Air Traffic Control Organization
Federal Aviation Administration

AMR ELSAWY
President and Chief Executive Officer
Member, Board of Trustees
Noblis

PATRICIA MCNALL
Assistant Chief Counsel
Acquisition and Commercial Law Division
Federal Aviation Administration

NITIN PRADHAN
Chief Information Officer
Office of the Secretary
Department of Transportation

FAA Telecommunication Infrastructure Review Panel

Report on November 19, 2009 Outage

Table of Contents

Executive Summary

This is the first of two reports by the FAA Telecommunications Infrastructure (FTI) Review Panel (the "Panel"), commissioned by the FAA Administrator, to address a significant telecommunications outage of the FTI network on November 19, 2009. This report deals with the outage itself; causes, factors, remediation and recommendations for actions to prevent a reoccurrence. The second report will deal with the broader issue of the reliability of contractor-provided Internet Protocol (IP) based networks such as FTI, to carry the critical navigation, communications and other data which will result from the implementation of the FAA's Next Generation Air Transportation System (NextGen).

The Panel found that the FTI, provided to FAA through a service contract with the Harris Corporation, is highly reliable and meets most of the FAA-defined service availability criteria. It found that the architecture of the dedicated optical backbone, to which Harris has recently transitioned the FTI, represents industry best practice and provides the FAA with significant improvements in reliability and capacity for future growth. It also found that Harris has a staff training program capable of providing staff with necessary skill sets, but may not have had adequate staffing distributed across all shifts. The FAA's contract with Harris aligns Harris's and FAA's objectives to provide and operate a reliable telecommunications network.

Not withstanding the above, the Panel found that the outage of November 19, 2009 was the product of a cascading series of events which resulted from errors introduced into the Harris network maintenance and network monitoring processes. These errors not only caused the outage, but also significantly impacted Harris's ability to rapidly diagnose and correct them. The report makes recommendations in the areas of people, process and technology for Harris and the FAA to address in order to reduce the likelihood of a similar outage reoccurring.

This report details the Panel's recommendations for improving the reliability of the FTI and for improving FAA's internal communications and procedures to deal with an FTI outage.

1. Consider using automated tools to implement router configuration changes and to support independent verification procedures.
2. Review maintenance operations and associated checklist design from a human factors and risk reduction perspective to help minimize the potential for human errors. Consider using the FAA's Aviation Safety (AVS) and external experts in this review.
3. Implement end-to-end situational awareness of the network, both Local Area Networks (LANs) and the FTI, as well as including appropriate applications.
4. Implement a capability to report network and application service outages and describe the impact to FAA customers (internal and external) using a common language.
5. Consider developing a functional model of the FAA's FTI network to simulate and test configuration changes and upgrades.
6. Consider a needs assessment of the FTI workforce staffing and skill levels to ensure adequate levels of network technical support at all times.
7. Consider modifying the FTI contract award fee and/or performance incentive structure based on the observations in this report.
8. Provide an alternate means for rapid and standardized entry of flight plan information into the National Airspace System (NAS) to mitigate failures in the flight plan filing system.

9. Evaluate the Automatic Dependent Surveillance - Broadcast (ADS-B) and FTI network architectures to determine the viability of using each as potential back-up for selected services of the other.
10. Perform a review of currently identified essential services and categorize them according to priorities in support of NAS safety and capacity.

Introduction

On November 19, 2009, maintenance work to replace and upgrade a network routing device in the FAA's FTI network caused a bottleneck in the network and resulted in a significant blockage of data transmissions across certain portions of the network from 5:10 AM EST to 8:59 AM, nearly 4 hours. The FTI network is provided to the FAA through a contract with the Harris Corporation, of Melbourne, Florida. There were a variety of FAA services impacted (see Appendix I), but the most notable impact to the flying public was the inability of the FAA to process electronic flight plan data (sent by the airlines and other users) through the FTI network. As a result, these flight plans had to be entered into the FAA air traffic control systems manually, causing the delay of over 800 flights that morning. Air traffic separation was never affected, and safety of the flying public was never compromised.

Flight delays have been an item of heightened concern by the flying public as the Nation's airspace has become more congested over the last several years. Disruptions due to weather and congestion at certain airports such as JFK, Chicago and Newark have had an effect of rippling through the air traffic system and causing delays across the country. While some disruptions are unavoidable, disruptions caused by equipment breakdowns are regarded as preventable and call into question the FAA's ability to manage the current air traffic system while migrating to NextGen.

As a result of the November 19, 2009 communication outage, the Chairman of the House Transportation and Infrastructure Committee, Representative Oberstar (D., Minn.) and the Chairman of the House Subcommittee on Aviation, Representative Costello (D., Ill.) have called upon the Inspector General of the Department of Transportation to investigate the Harris Corporation's provision of services to the FAA, in a letter that reads in part:

> "Given the recent outage and its cascading effects, we request that your office undertake a 60-day study to examine the causes of the problem and whether FAA's corrective action plan will prevent future problems. Also, we ask that you examine FAA's ability to conduct oversight of FTI, and the implications for other critical modernization systems that will not be owned or operated by the Federal Government, such as the FAA's Automatic Dependent Surveillance - Broadcast satellite-based surveillance system."

In order to assure that all appropriate steps are taken to avoid similar disruptions in air travel, FAA Administrator J. Randolph Babbitt chartered a panel of experts (the "Panel") from within and outside of the FAA to look into the outage and review the provision of services by FAA mission-critical service providers (the "Review").

The Panel was chartered to provide two reports: a report on the causes of the November 19, 2009 outage, with recommendations for preventing a reoccurrence, and a report on the suitability of contractor-provided IP based networks such as FTI, to support an increasing number of mission-critical services as NextGen is implemented. This report details the findings of the Panel with regard to the communications outage of November 19, 2009 and the recommendations of the Panel to reduce the chance of a similar outage re-occurring.

Panel Composition

The Panel chartered by Administrator Babbitt is comprised of the following members:

- Aneesh Chopra – Assistant to the President and Chief Technology Officer, Office of Science and Technology Policy, Executive Office of the President;
- Nitin Pradhan - Chief Information Officer, US Department of Transportation;
- David Bowen - Chief information Officer, Federal Aviation Administration;
- Steven Cooper - Chief Information Officer, Air Traffic Organization, Federal Aviation Administration;
- Amr ElSawy – President and CEO, Noblis;
- Patricia McNall - Assistant Chief Counsel – Federal Aviation Administration, and
- Nancy Brown – Former Director of Command, Control, Communications and Computer Systems, Joint Staff; Vice Admiral, United States Navy (Ret.).

Biographies of the Panel members are shown in Appendix III.

Panel Objectives

The Panel's Review had the following objectives:

- Determine the root cause(s) of the outage of November 19, 2009;
- Determine if the Harris Corporation, in providing the FTI, has the adequate people, processes and technology deployed to provide a robust communications network, with adequate security, backup and fail-over capabilities, to meet the needs of the FAA;
- Determine the degree to which the Harris Corporation is using industry best practices in the architectural design, management and operation of the FTI, and if necessary, make suggestions for improvements;
- Assess the maturity of the processes and technology used within the Air Traffic Organization to monitor and oversee FTI, and make suggestions for improvements;
- Determine the degree to which the FAA is using industry best practices to manage FTI, and make suggestions for improvements, and
- Determine the degree to which findings from this Review are relevant for the provision of other critical services to the FAA and as appropriate, recommend their adoption by other critical service providers.

Panel Tasks and Activities

The Panel completed the following tasks to meet its objectives for this report:

- Determined the exact circumstances surrounding the network outage of November 19, 2009;
- Determined the root causes surrounding the network outage of November 19, 2009;
- Reviewed proposed corrective actions by the FAA and by the Harris Corporation to correct the causes of the outage;
- Evaluated those actions against best practices in network infrastructure management, drawn from the Department of Defense (DoD) and other public as well as private sectors;
- Evaluated the architecture of the network infrastructure provided by the Harris Corporation and its ability to provide protection against similar outages occurring in the future;
- Evaluated the processes used by the Harris Corporation to manage and make changes to the FTI, the degree to which they are consistent with industry best practices and the degree to which they are followed by Harris and FAA Air Traffic Organization (ATO) personnel;
- Evaluated the Harris personnel assigned to the FTI, their numbers, locations and skill sets;
- Evaluated the processes used by the FAA to provide oversight to the Harris Corporation in maintaining the FTI, and the degree to which they are consistent with industry best practices;
- Reviewed other planned and existing critical service providers to determine their use of industry best practices in architecting, securing, managing and operating their services and make recommendations as necessary, and
- Published a report of its findings.

The panel conducted the following activities to meet its objectives for this report:

- Discussions with FAA and Harris personnel;
- Review of architectural diagrams;
- Visits of FAA and Harris sites with associated briefings;
- Reviews of incident reports;
- Reviews of operating process and procedure documents;
- Reviews of hardware and software activity logs;
- Reviews of training documentation;
- Reviews of contract documentation;
- Reviews of industry best practice, and
- Reviews of input from selected technical experts.

The November 19, 2009 Outage – Chronology

A general description of the outage circumstances is as follows:

Event Overview

As of November 19, 2009 the transition to the new optical backbone from the legacy Asynchronous Transfer Mode (ATM) was largely complete (estimated 95%), with very few locations left to transition. During the transition period, both the optical and (ATM) networks were operating concurrently:

- Transition from the ATM to optical backbone required hardware and software changes to routers on both networks;
- Harris had established manual procedures and checklists to guide the technicians through the router upgrade procedure. The execution of the procedures was not properly verified;
- During an earlier transition of the Salt Lake City router from the ATM to the optical backbone on October 21, 2009, a routing table error was introduced into Los Angeles and Albuquerque routers, which defined an incorrect route between Salt Lake City and Los Angeles. The error remained dormant and did not impact the operational networks until the Los Angeles router was restarted on November 19, 2009;
- In general, Harris did not use automated tools to manage the transition of their router table configurations and maintenance changes to them nor validated them against a master router table;
- On November 19, 2009, Harris was also doing more complex FTI maintenance in Herndon, Virginia;
- On November 19, 2009, the upgrade of the Los Angeles router was not part of the optical backbone transition, and as a result, had a lower level of technical support than it would have had if it were included in the optical backbone transition;
- Harris had installed a monitoring system in the FTI routers and programmed it to generate an alert if any single router exceeded 60% utilization for more than 10 minutes. There was a low-capacity router in the FAA's Atlantic City Technical Center that routinely ran at these levels and was due for replacement. To prevent false alerts from the Atlantic City router, the monitoring system was programmed to ignore alerts from the Atlantic City Router. *In doing so, the monitoring system was inadvertently programmed to ignore alerts from all network routers, thus effectively disabling this alarm function.* Harris did not know this;
- The Harris system that reports router processor utilization levels was not routinely monitored at Harris's Primary Network Operations Center (PNOCC) and had to be initiated and accessed by a technician, and
- The FAA Telecommunications Infrastructure (FTI) Internet Protocol (IP) Analysis Team (FIAT) did a graphical depiction of the FTI network events before and during the service outage. It is shown in Appendix II.

Timeline of Events - November 19, 2009

Time(EST)	Event
05:04 EST November 19	Replacement of Los Angeles router began (scheduled start time 0200 local time). As part of routine maintenance procedures the Los Angeles router table errors were copied over to the new router.
05:07-05:09	Interface on old Los Angeles router was disabled and interface on new router was enabled.
05:09	Harris Corporation started maintenance in Herndon, Virginia on the FTI network connection to the FAA's Command Center. (The maintenance window for both Los Angeles and Herndon was the same, but the detailed plan was to do Los Angeles first and start the Herndon maintenance when Los Angeles was complete).
05:10-05:11	In activating the new Los Angeles router, the erroneous router table became active.
05:10-05:11	The Los Angeles router then initiated a *preferred route* between the Los Angeles and Salt Lake City routers and in doing so caused all network traffic to flow over this preferred route.
05:10-05:11	The new Los Angeles router also promulgated the erroneous route across the network, forcing a large amount of digital communication traffic to be routed to Los Angeles and then to Salt Lake City, irrespective of its origination or destination. The resulting traffic increase on the Los Angeles to Salt Lake City route exceeded the capacity of the network and the Los Angeles router began dropping communication packets.
05:10-05:11	The erroneous route effectively blocked approximately 75% of the IP routes over the optical backbone network and slowed traffic flow over the ATM backbone.
05:10-05:11	Multiple calls to the Harris Primary Network Operations Command Center (PNOCC) from multiple FAA locations indicated a problem.
05:10-05:11	Harris began problem diagnosis
05:11	Network monitoring systems at the FAA detected a problem
05:11	Harris Corporation engineers first believed the Herndon, Virginia maintenance was the source of the network congestion and as a result began to pursue resolution based on this belief.
05:50	Harris opened up a conference line with FAA and multiple FAA facilities.
05:11– 08:10	Harris engineers conducted router utilization level checks, beginning with major nodes in the East and expanding across the network. Because the high utilization alerts had been inadvertently disabled, Harris technicians were not made aware of high utilization levels on the Salt Lake City or Los Angeles routers
08:13	A Harris technician detects high processor utilization levels on the Salt Lake City router and conducts a reset. FTI field technician is dispatched to Salt Lake City.
08:13– 08:59	Harris PNOCC constantly reset the Salt Lake City router to restore and validate proper data flow across the network. Most services were restored to normal operation during this period.
08:59	FTI technician removed router card in Salt Lake City. This eliminated the need to continuously reset the router in Salt Lake City. Most services were actually restored at 08:13.
08:59–10:30	A few additional services required additional effort to restore, e.g. firewall reset
10:30	All services were restored
Post 10:30	After service restoration, Harris engineers detected and resolved erroneous router table entries in Los Angeles and Albuquerque routers. The Salt Lake router had no configuration errors and was re-installed during a planned maintenance event (see below). Clarification: resetting and removal of the Salt Lake City router temporarily corrected the problem, but the Salt Lake router was not the root cause of the problem. Once the configuration error was corrected in Los Angeles, the Salt Lake router was restored without any changes. The Albuquerque router error had no impact as there was no triggering event to activate the Albuquerque router configuration error.
02:05 November 20	Harris executed maintenance to Salt Lake City router to re-install router card previously removed as it was no longer an issue once erroneous router table entries corrected.

Panel Recommendations and Observations

Recommendation 1 – Consider using automated tools to implement router configuration changes and to support independent verification procedures.

Observations

People

- Complex and intricate maintenance checklists were devised for use by individuals with no independent human back-up (e.g., a second person) or other verification using automation.
- The successful transition of the FTI network to the optical backbone was about 95% complete and the Los Angeles router upgrade was viewed by the Harris staff as a routine, low-risk procedure.
- The upgrade of the Los Angeles router was considered to be not part of the optical backbone transition, and as a result, had a lower level of technical support than it would have if it were considered as part of the optical backbone transition.

Processes

- The maintenance process for the router upgrades was not designed with sufficient error traps and verification procedures to ensure proper installation.
- In general, Harris did not have automated tools to manage the transition of their router table configurations. Changes to them were made manually.
- The potential impact of a router table error was not clearly understood by technician doing the work.
- Routing table changes made during the transition of the Salt Lake City router to the optical backbone were not verified, either by a technician independent of the one making the changes or by an automated tool.
- The Harris system that generated alerts based on elevated router utilization levels was effectively disabled and Harris did not know this.
- There was no process for periodically checking alarm systems.

Technology

- Existing tools to automate router table configuration changes were not being used.
- Tools to manage router configuration control were not used.
- There was no 'model' network to simulate the network change.

Recommendation 2 - Review maintenance operations and associated checklist design from a human factors and risk reduction perspective to help minimize the potential for human errors. Consider using the FAA's Aviation Safety (AVS) and external experts in this review.

Observations

People

- There was an over reliance on human performance in the design of the maintenance checklist process. The design assumed that the maintenance technicians would discover and correct errors by using the checklist during the router maintenance process.
- Maintenance staff were scheduled to work independently in the early morning hours when human performance has the potential to be reduced.

Processes

- FAA's Aviation Safety (AVS) organization has considerable expertise in designing checklists from a human factors and operational safety perspective.
- The maintenance schedule is driven by the need to have maintenance coincide with hours of reduced NAS operations.

Recommendation 3 - Implement end-to-end situational awareness of the network, both Local Area Networks (LANs) and the FTI, as well as including appropriate applications.

Observations

People

- Harris's Primary Network Operations Command Center (PNOCC) staff did not adequately employ systemic processes and diagnostic tools or have the broad situational awareness capacity to quickly determine the problem to resolve the outage.

Processes

- Alarm mechanisms necessary to assist in the diagnosis of emerging problems associated with the router upgrades were deactivated. This delayed the diagnosis of the problem, allowed the outage to expand and delayed the corrective actions to resolve the outage.
- The Harris router processor utilization display was not routinely monitored at the Harris PNOCC.
- Information on network status was available, but Harris did not have a process to regularly review and log situational awareness.

Technology

- Systematic joint-situational network awareness between FAA and Harris command centers and FAA large facilities does not exist.
- There is a need to provide FAA facilities with visibility into the status of the FTI network beyond the service delivery point (SDP) and to provide the FTI PNOCC with the status of applications and local area networks in the centers.
- Programs such as En Route Automation Modernization (ERAM), Center TRACON Automation System (CTAS) and User Request Evaluation Tool (URET) have their own local area networks, but do not share network status with FTI.
- Harris did not have a way to check the network link saturation with telecommunication providers.

Recommendation 4 - Implement a capability to report network and application service outages and describe the impact to FAA customers (internal and external) using a common language.

Observations

People

- While the technical details of outages are sometimes communicated, the operational impact is not always reported or communicated in a way that users can understand.

Processes

- There is no standardized process for communicating FTI service outages.
- The current process is focused on reporting outages of particular facilities or equipment, but do not sufficiently identify specific operational impacts.

Technology

- The FTI Operations Management Tool (OMT) contains the information that is necessary to link technical failures to their operational impacts, but is not sufficiently updated or visible to the FAA operations staff in a timely manner.

Recommendation 5 - Consider developing a functional model of the FAA's FTI network to simulate and test configuration changes and upgrades.

Observations

Processes

- There is no process to simulate network configuration changes in a test environment before being moved to production.

Technology

- Harris has a lab for testing hardware and software functionality.
- Harris uses the FAA Technical Center facility to test data flow across a test network.
- There is no test capability that mirrors the FTI backbone and Air Route Traffic Control Center (ARTCC) routers that can be used to simulate a variety of processes.

Recommendation 6 - Consider a needs assessment of the FTI workforce staffing and skill levels to ensure adequate levels of network technical support at all times.

Observations

People

- There does not appear to be a baseline workforce plan.
- Harris may not have had the proper skill sets on hand at the time of the outage to prevent or rapidly diagnose and fix the problem.

Recommendation 7 - Consider modifying the FTI contract award fee and/or performance incentive structure based on the observations in this report.

Observations

Processes

- Consider using customer input when developing the award fee plan.
- The Reliability Maintainability Availability (RMA) 1 performance level has never been met.
- The incentive provisions of the FTI contract are successful in encouraging Harris to recommend improvements to the FAA.

Recommendation 8 - Provide an alternate means for rapid and standardized entry of flight plan information into the National Airspace System (NAS) to mitigate failures in the flight plan filing systems.

Observations

Processes

- The current backup procedures for flight plan filing are not adequate to support normal system wide demand.
- As a result of the outage, flight plans had to be entered manually which caused significant delays in flights.
- The current backup procedures for filing flight plans allow for multiple transmission methods and formats. This lack of standardization slows the process.

Technology

- Alternate technology such as web-based portals should be analyzed as a back-up strategy for flight plan entry into FAA systems.

Recommendation 9 – Evaluate the Automatic Dependent Surveillance – Broadcast (ADS-B) and FTI network architectures to determine the viability of using each as potential back-up for selected services of the other.

Observations

Technology

- IP network architectures may be leveraged to support each other.

Recommendation 10 - Perform a review of currently identified essential services and categorize them according to priorities in support of NAS safety and capacity.

Observations

People

- There appears to be mismatched performance expectations between the FAA Air Traffic Control (ATC) service providers and ATC service consumers regarding the essential or critical nature of the data services related to flight plan management (and perhaps other essential data services). To some extent, Harris and the FAA's FTI performance contract are caught in the middle between these conflicting expectations.
- Communications between the FAA and DoD need to be strengthened to promote sharing of information. While FAA personnel are embedded in the NORAD Command Center, at the time of this event, that position was not staffed.

Processes

- The reliability and availability of services provided to DoD and Department of Homeland Security (DHS) may not reflect their expectations or actual dependency on the information.
- Essential services necessary to maintain NAS capacity may need expanded infrastructure/attention.

Technology

- Modeling capability or methodology to evaluate the impact on NAS operations of the loss of various essential services might help determine priorities.

Remediation Steps Taken to Date

Harris Corporation has indicated that the following corrective actions have been taken as a result of the November 19th outage:

- Corrected route tables in the Los Angeles router;
- Corrected route tables in the Salt Lake City router;
- Corrected and test elevated processor utilization alerting system;
- Assigned Network Operations Center staff to continuously monitor router processor utilization levels;
- Audited all core router route tables for incorrect entries and resolve any if found (Note: this activity discovered and corrected an additional error in a router in Albuquerque);
- Completed transition to optical backbone network and turn off network links to the old ATM network, and
- Instituted support personnel activity to monitor processor utilization levels of all core routers during replacement or maintenance on any router.

Other changes that have been made that will reduce the impact of future outages include:

- The newly established routing domain segments in the optical backbone will serve to isolate and limit the impact of future outages, and
- The segmentation by operating airspace domains will help simplify network administration and fault isolation and containment.

Appendices

Services Impacted by the FTI Outage	Appendix I
Graphical Network Depiction of Service Outage Events	Appendix II
FTI Panel – Member Biographies	Appendix III
Glossary	Appendix IV

Appendix I – Services Impacted by the FTI Outage

FAA Telecommunications Infrastructure 11-19-09 Service Network Interruption
Reported NAS Impacts

The following table identifies the service impacts associated with the 11-19-09 FTI service interruption. These impacts were reported by the various FAA technical Operations Control Centers and logged in the FAA Remote Maintenance Logging System.

Service Name	Service Description	Reported Impact
CFAD - Composite Flight Data Processing	An umbrella service covering all flight data processing capability within an ARTCC.	9 ARTCCs reported a reduction in service
CTAS - Center TRACON Automation System	Provides automated services to enhance the arrival/departure throughput and efficiency of air traffic operations surrounding major airports.	14 ARTCCs reported impacts ranging from full interruptions to reductions in service.
ETMS - Enhanced Traffic Management Service	Provides information to predict, on national and local scales, traffic surges, gaps, and volume based on current and anticipated airborne aircraft. Traffic Management Personnel evaluate the projected flow of traffic into airports and sectors, and then implement the least restrictive action necessary to ensure that traffic demand does not exceed system capacity.	10 ARTCCs and Potomac Consolidated TRACON reported impacts ranging from full interruptions to reductions in service.
URET - User Request Evaluation Tool	Provides initial conflict probe capability to be used as an advisory tool for strategic planning and clearance decision making.	16 ARTCCs reported full interruptions.
WARP - Weather and Radar Processor	Disseminates NEXRAD and other weather information to controllers, traffic management specialists, and meteorologists. Provides a mosaic display of multiple NEXRAD images and aircraft targets.	10 ARTCCs reported impacts ranging from full interruptions to reductions in service.
AIS - Aeronautical Information System	Provides aeronautical weather information, flight plans, flight movement messages, and Notices to Airmen (NOTAM), and other operational messages for the general and military aviation communities.	2 ARTCCs reported impacts ranging from a full interruption to an informational ticket.
CODAP - Composite Oceanic Display and Planning	Umbrella service covering all oceanic flight data processing and display.	2 ARTCCs reported a reduction in service.
ECG - En Route Communications Gateway	Provides a communications interface between the ARTCC HOST computer processors and surveillance processors. In this context it is used to provide composite surveillance products to DOD and Homeland Security agencies.	3 ARTCCs reported impacts ranging from full interruptions to reductions in service. Associated service interruptions were reported under NDP surveillance services.
NDP Surveillance	Provides surveillance data from FAA Long Range and Short Range radars to Department of Defense Air Defense Sectors and Department of Homeland Security agencies.	All external customers reported impacts ranging from full interruptions to reductions in service.
ERIDS - En Route Information Display System	Supports intra and inter domain information exchange and coordination of aeronautical data products such at ATC documents, messaging products, weather data, and locally generated data.	5 ARTCCs logged full interruptions.
ITWS - Integrated Terminal Weather System	Provides a unified set of planning weather products to air traffic personnel. The ITWS information depicts current conditions and near term forecasts.	4 TRACONs reported impacts ranging from full interruptions to reductions in service.

Appendix I – Services Impacted by the FTI Outage

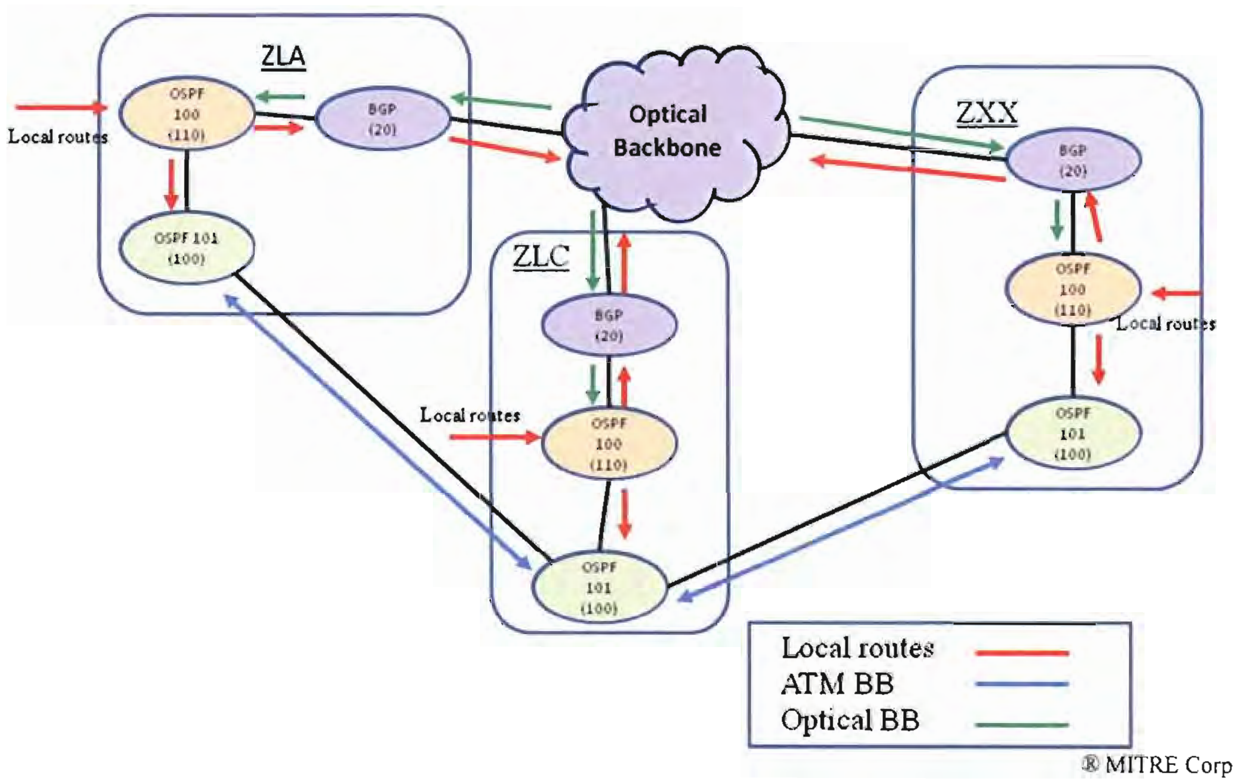
FAA Telecommunications Infrastructure 11-19-09 Service Network Interruption
Reported NAS Impacts

Service Name	Service Description	Reported Impact
NADIN/NMR - National Airspace Data Interchange Network/NADIN Message Switch Rehost	Provides integrated switching and distribution of flight plan data, weather information, NOTAM, and other ATC messages within the NAS.	ARTCCs reported impacts of related NADIN services ranging from full interruptions to reductions in service.
NDP Surveillance	Provides surveillance data from FAA Long Range and Short Range radars to Department of Defense Air Defense Sectors and Department of Homeland Security agencies.	All external customers reported impacts ranging from full interruptions to reductions in service.
NAMS - NADIN Message Transfer Service	Covers the transfer of message data between a NADIN and the NADIN Combined Service Access Point (CSAP) at ARTCCs.	1 ARTCC reported a reduction of service.

Appendix II

Graphical Depiction of the FTI Network Before and During the Service Outage

Routing State Immediately Before LA Router Restart



As shown in the diagram, the routing state before the outage event consisted of various routing processes and the marking or "painting" of specific routes as Local, ATM backbone (BB), or optical BB. The routes are painted so that they may be kept in the proper routing process by the routers. The painting of the routes allows the routers to use routing filters and policies called "route maps" to manipulate which routing process will interact with the network routes. Keeping the network routes properly categorized consistently at each router is imperative in order to keep the network routing working properly across the backbone.

Specifically, the routing state before the outage event was as follows:

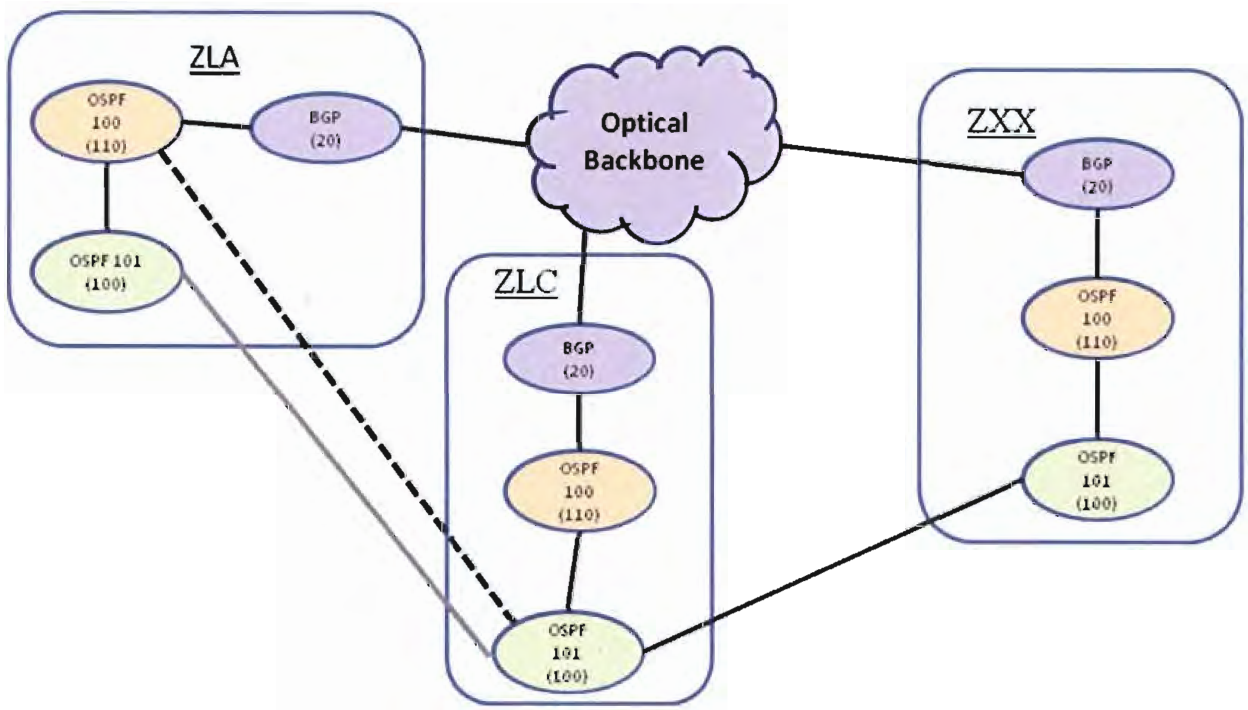
- The diagram above shows the relationships between the routing processes at the various ARTCC networks including LA(ZLA) and Salt Lake City (ZLC).
- *Administrative Distance* shown in parentheses – these are used for to weight routing decisions (i.e., the smallest number is the preferred route)
- All Local routes from each ARTCC are injected into the optical backbone and ATM backbone via the OSPF 100 routing process (red arrows).
- All ATM backbone routes are exchanged between each ARTCC network via the OSPF 101 routing process (blue arrows).
- BGP is the routing process for sending *local* routes to the optical backbone and receiving optical *backbone* routes (green arrows).
- ATM backbone routes are redistributed to the OSPF 100 routing process, but are blocked from being sent via BGP routing advertisements by the "route maps" because they are "painted" blue.

Appendix II

Graphical Depiction of the FTI Network Before and During the Service Outage

Before the ZLA router replacement and restart, all routing was working as expected on the network and all network routes were "painted" and categorized properly.

Routing State Immediately After ZLA Router Restart



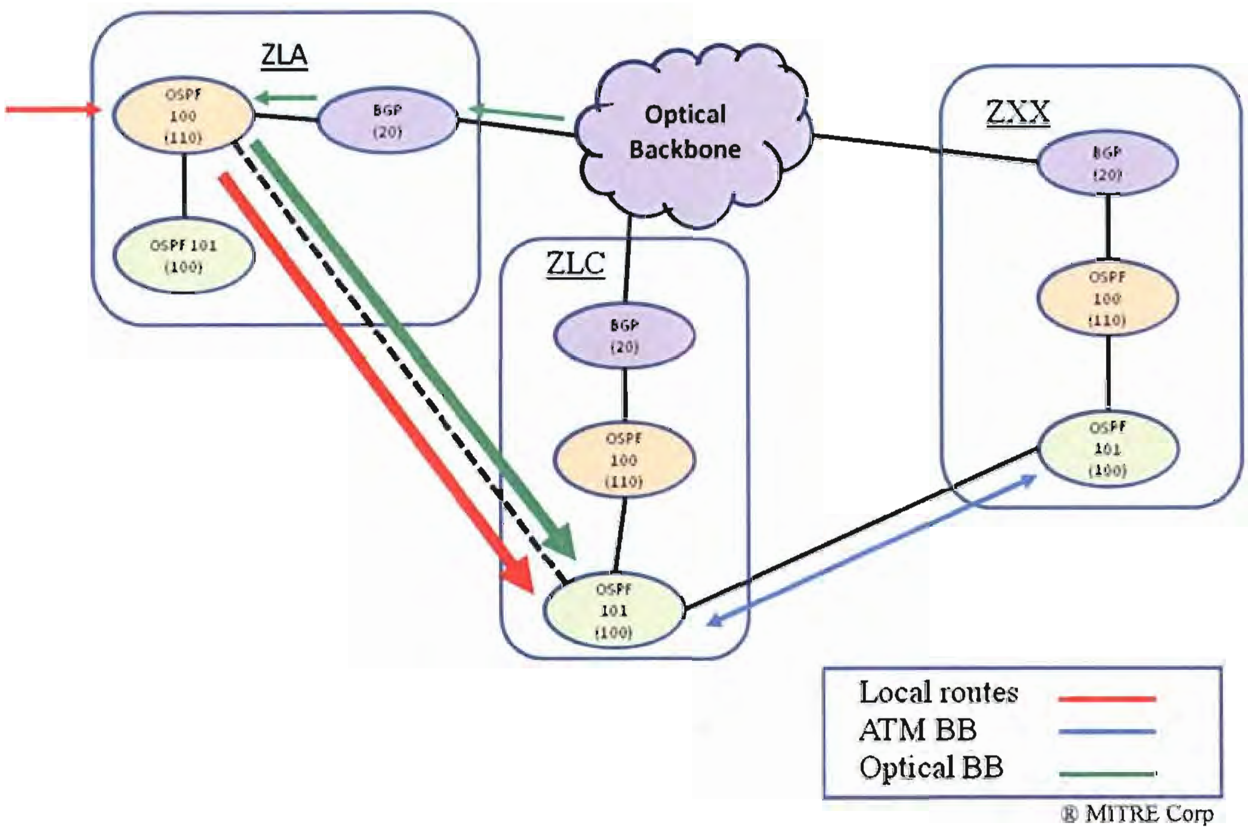
® MITRE Corp

When the new ZLA router was started up and due to the configuration error, the ZLA OSPF 100 routing process started peering directly with the ZLC OSPF 101 routing process. This is shown in the diagram above by the dotted black line denoting the routing relationship between ZLA OSPF 100 and ZLC OSPF 101. The diagram also shows the correct routing relationship (grey line) under nominal operating conditions without the configuration error. The OSPF 100 to OSPF 101 routing relationship is an error and was not a planned part of the transition to the new optical backbone.

Appendix II

Graphical Depiction of the FTI Network Before and During the Service Outage

Routing State Immediately after ZLA Router Restart: Routes coming from ZLA

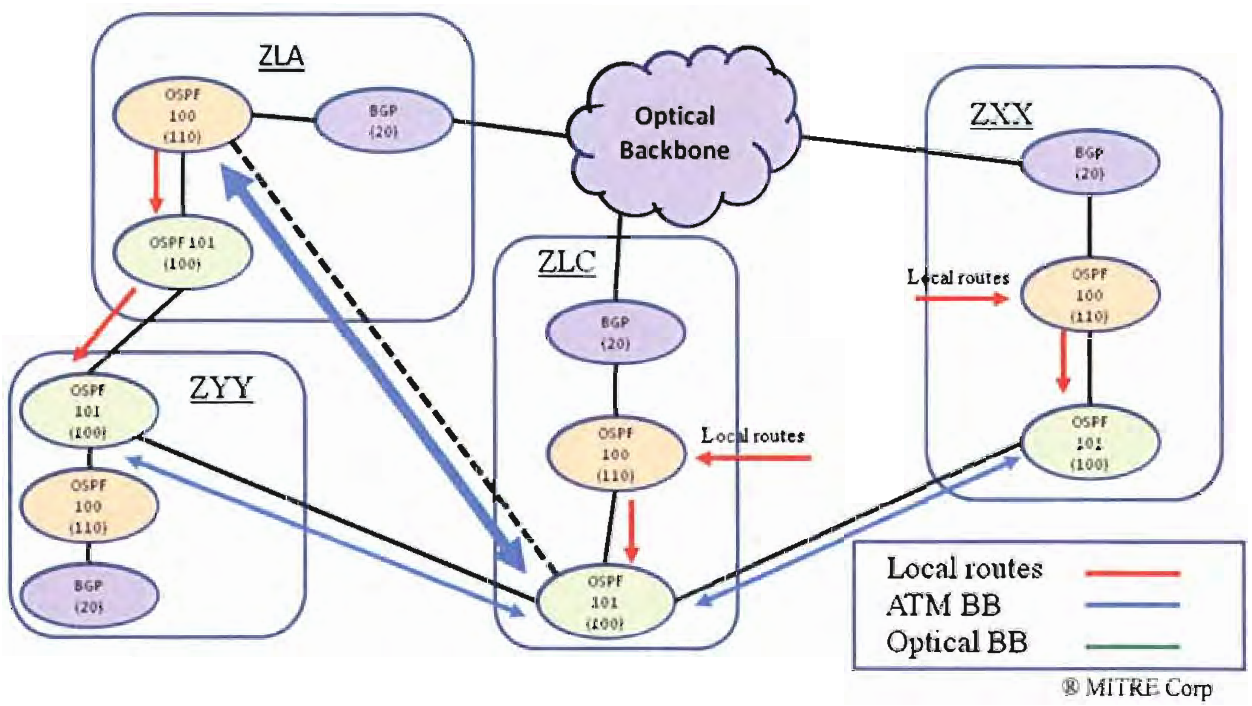


As soon as the ZLA OSPF 100 routing process started exchanging routing with the ZLC OSPF 101 routing process, local routes and optical backbone routes from the ZLA OSPF 100 routing process get injected into the ZLC OSPF 101 routing process. At the ZLC OSPF 101 routing process, both the ZLA *local* (red) and the optical *backbone* (green) routes get "re-painted" as ATM backbone (blue) routes.

Appendix II

Graphical Depiction of the FTI Network Before and During the Service Outage

Routing State Immediately after ZLA Router Restart: Routes coming into ZLA

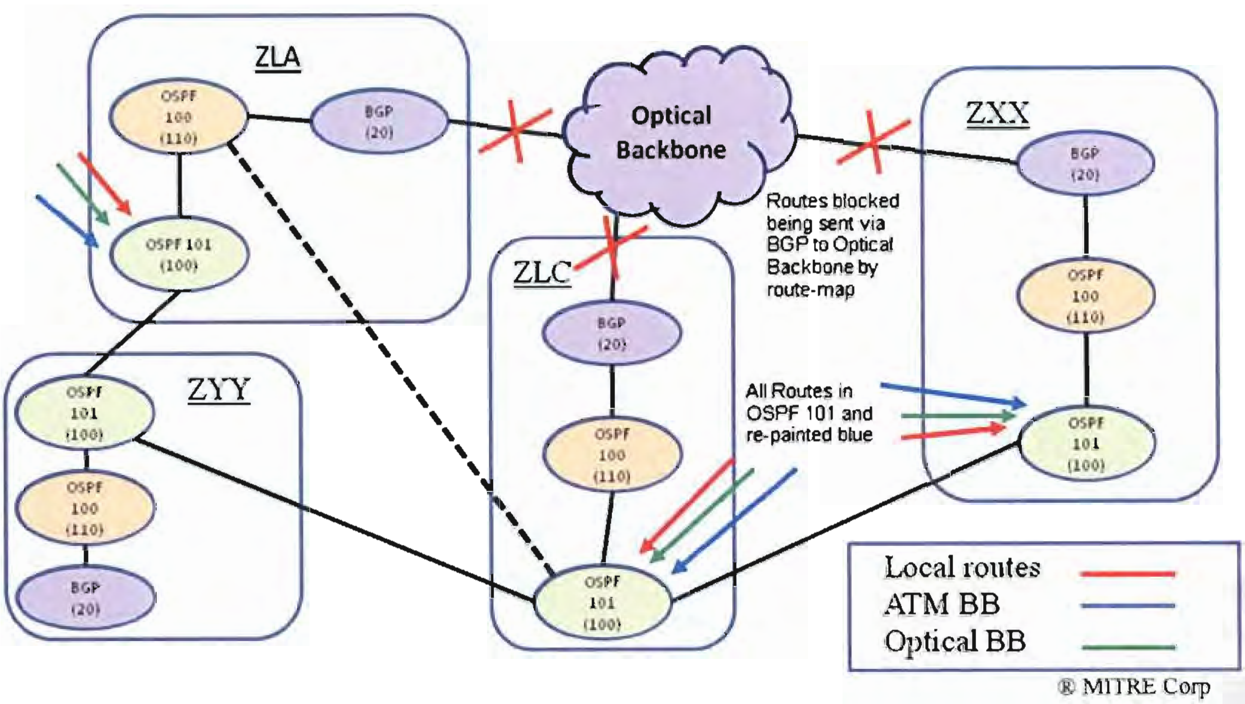


As they normally do under nominal operations, local routes from the ZLC OSPF 100 routing process and the other ARTCC routing processes (represented by ZXX) get injected into the ATM backbone via the OSPF 101 routing process at ZLC. However, once these routes get to ZLC, the ZLC OSPF 101 routing process then injects all ATM backbone routes into the ZLA OSPF 100 routing process over the misconfigured routing relationship. At the ZLA OSPF 100 routing process, all ATM backbone routes get "re-painted" as local routes and redistributed to all ZLA peer ATM backbone OSPF 101 routing processes. This causes all of the other sites on the network to view ZLA as the shortest path or the local connection to all routes on the network. The ZLA OSPF 100 routing process is advertising itself as being connected "locally" to all network routes via the ATM backbone.

Appendix II

Graphical Depiction of the FTI Network Before and During the Service Outage

Routing State Immediately After ZLA Router Restart: Routes Blocked on Optical Backbone

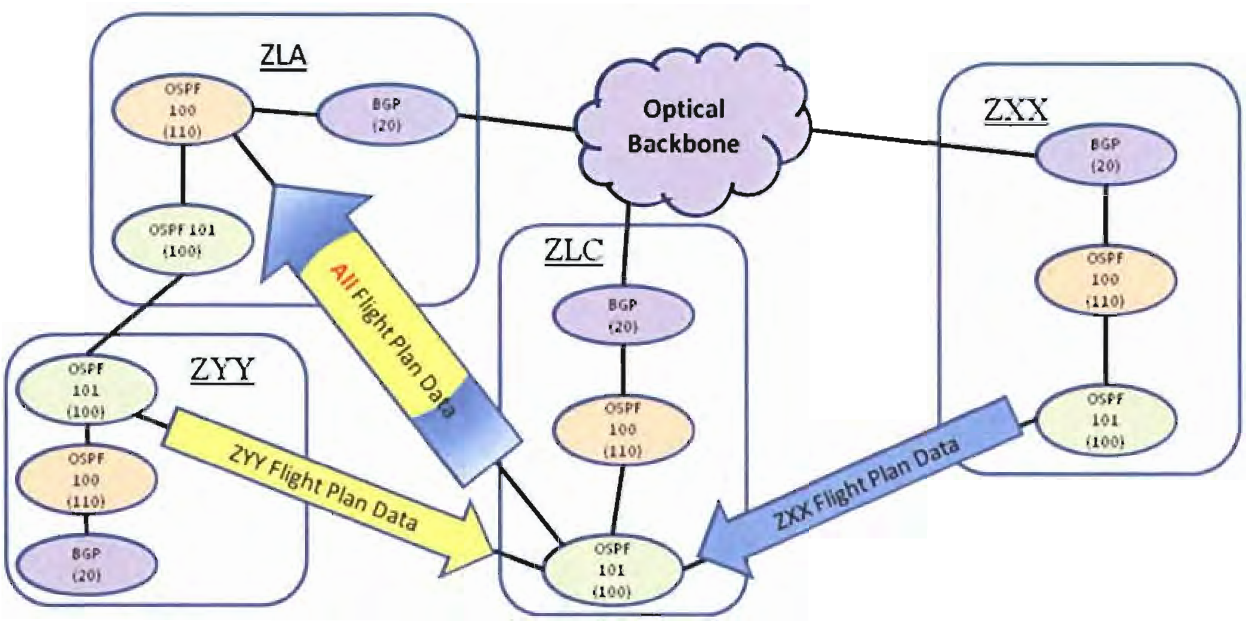


After the ZLA router had claimed to be the shortest path and locally connected to all routes on the network, the preferred routes for the network all resided in the OSPF 101 routing process. This was the result of the OSPF 101 routing process having an "Administrative distance" that was lower than the OSPF 100 routing process (100 vs. 110). Since all of the preferred routes for the network were in the OSPF 101 routing process and painted blue, they were blocked from being advertised via BGP to the optical backbone. Thus, the optical backbone was not the preferred path for network routes and in fact, there were only 25% of the routes being advertised to the optical backbone.

Appendix II

Graphical Depiction of the FTI Network Before and During the Service Outage

Network Data Flows After the LA Router Restart - All Network Data Vectored to the ZLA-ZLC ATM Link



® MITRE Corp

As a result of the ZLA OSPF 100 routing process advertising itself as the local connection for all network routes and the "re-painting" of all ATM backbone routes and optical backbone routes as local routes for ZLA, all network data that needs to traverse the optical backbone between ARTCC's is funneled via the ATM link from ZLC to ZLA. This link has a relatively small 6 Mbps capacity. When all the network data is directed to this link, the ZLC-to-ZLA ATM link is immediately congested and at capacity. In its congested state, network data is blocked, delayed, or dropped on the ZLC-to-ZLA ATM link thus preventing flight plan data from reaching its destination on the network.

Appendix III – Panel Member Biographies

DAVE BOWEN
Assistant Administrator for Information Services and Chief Information Officer
Federal Aviation Administration

Dave Bowen is the Federal Aviation Administration's (FAA) Assistant Administrator for Information Services and Chief Information Officer (CIO). Bowen is responsible for developing, structuring, implementing, and communicating policy and practice as it pertains to the Agency's information technology (IT) investment, management, planning, research and development, and security.

Prior to joining the FAA in February 2006, Bowen spent more than 25 years in healthcare IT management in the provider, payer, consultant, and vendor areas. He most recently served as the Senior Vice President for IT and CIO at Blue Shield of California, a $6.2 billion health plan with more than 2.5 million members. Blue Shield is the second largest not-for-profit healthcare organization in California. While there, Bowen directed Blue Shield's IT, telecommunication, business recovery, and Web implementation resources with an operating budget in excess of $100 million. He sat on Blue Shield's Operations Committee and its Senior Staff.

Prior to Blue Shield, Bowen was Senior Vice President for Information Management and CIO of Catholic Healthcare West (CHW), the fifth largest healthcare delivery system in the United States. His responsibilities included oversight of CHW's Information Management and Telecommunications resources located throughout Arizona, California, and Nevada. He also managed CHW's Year 2000 initiative.

Bowen has also served as the Senior Vice President for Information Systems and CIO at Baptist Health System, Inc., of Birmingham, Ala., a 13-hospital system and the largest integrated healthcare delivery system in Alabama. In addition, he was CIO of its wholly-owned Health Maintenance Organization, Health Partners of Alabama.

He is the former Board Chairman of the Coastside Family Medical Center, former Chairman of the Blue Cross Blue Shield Association IT Roundtable, and member of the Blue Cross Blue Shield Association Interplan Technology Advisory Council.

Bowen has an undergraduate degree in economics from Ursinus College, Collegeville, Pa., and a master's degree in business with distinction from the Johnson Graduate School of Business, Cornell University, Ithaca, N.Y. He is also a CPA, holds an FAA Commercial Pilot certificate, and has more than 30 years of flying experience.

Appendix III – Panel Member Biographies

NANCY E. BROWN
Former Director of Command, Control, Communications and Computer Systems, Joint Staff; Vice Admiral, United States Navy (Ret.)

After completing over 35 years of service Vice Admiral Nancy E. Brown retired from her position as the Director, Command, Control, Communications and Computer Systems, The Joint Staff. Since retiring on 1 October 2009, she has been nominated to serve as an Outside Director of Systematic Software and on the Board of Directors of the United States Naval Institute. She has accepted consulting opportunities with Cypress International and IZ Technologies.

While on active duty her command tours included an assignment as Officer in Charge, Naval Radio and Receiving Facility Kami Seya, Japan, Commanding Officer of the Naval Computer and Telecommunications Station Cutler, Downeast, Maine and Commanding Officer Naval Computer and Telecommunications Area Master Station Atlantic, Norfolk. She was on the National Security Council staff at the White House and was also the Deputy Director, White House Military Office. In August 2004 she deployed to Iraq becoming the first Multi-National Force–Iraq C6 headquartered in Baghdad. Returning in April 2005 she was assigned as the J6 for both North American Aerospace Defense Command and United States Northern Command. In August 2006 she assumed her last active duty position as the Director, Command, Control, Communications and Computer Systems (C4 Systems), The Joint Staff.

Vice Admiral Brown's decorations include the Defense Distinguished Service Medal (with Oak Leaf Cluster), the Defense Superior Service Medal (with two Oak Leaf Clusters), the Legion of Merit (with Gold Star), the Bronze Star Medal, the Defense Meritorious Service Medal (with Oak Leaf Cluster), the Meritorious Service Medal, the Navy and Marine Corps Commendation Medal, the Navy and Marine Corps Achievement Medal, the Iraq Campaign Medal (with two Bronze Stars), the Global War on Terrorism Medal, the Armed Forces Service Medal, and the National Defense Service Medal (with two Bronze Stars).

ANEESH CHOPRA
Assistant to the President and Chief Technology Officer
Office of Science and Technology Policy, Executive of the President

Aneesh Chopra is the Chief Technology Officer and Associate Director for Technology in the White House Office of Science & Technology Policy. He was sworn in on May 22, 2009. Prior to his appointment, he served as Secretary of Technology for the Commonwealth of Virginia from January 2006 until April 2009. He previously served as Managing Director with the Advisory Board Company, a publicly-traded healthcare think tank. Chopra was named to Government Technology magazine's Top 25 in their Doers, Dreamers, and Drivers issue in 2008. Aneesh Chopra received his B.A. from The Johns Hopkins University and his M.P.P. from Harvard's Kennedy School. He and his wife Rohini have two young children.

Appendix III – Panel Member Biographies

STEVE COOPER
Air Traffic Control Organization Chief Information Officer
Air Traffic Control Organization
Federal Aviation Administration

Steven I. Cooper is a founding partner of Strativest (www.strativest.com), a firm focused on identifying emerging technologies applicable to homeland security and emergency response and preparedness, assisting in the development of 'go-to-market' actions, and in providing management advisory services for business strategy and business development, competitive intelligence, and the strategic use of information and communications technology for competitive advantage.

In November 2007, Mr. Cooper joined Fortified Holdings Corporation (www.fortifiedholdings.com) as President. Fortified Holdings is a diversified holding company focused on the development and delivery of solutions to improve situational awareness across the homeland security and first responder communities. In addition to operational responsibilities, he is focused on identifying acquisition targets for the company and helping its business units expand their market reach in effectively delivering its product solutions to emergency management organizations like the Federal Emergency Management Agency, local municipalities, first responders, and government and military agencies, to include the Department of Homeland Security, the US Army, and the US Coast Guard.

From May 2005 to July 2007, he was senior vice president and chief information officer (CIO) of the American Red Cross. Mr. Cooper was responsible for the information technology (IT) assets of the Red Cross and leveraging them to support the humanitarian organization's 35,000 employees and the 300 million Americans they serve. He guided the introduction of a first ever national call center during Hurricane Katrina to provide emergency assistance to the more than 4 Million people displaced from their homes and led the strategic sourcing of the ARC's primary data center.

In February 2003, he was appointed by President George W. Bush as the first CIO of the Department of Homeland Security (DHS). His accomplishments include the implementation of a Homeland Secure Data Network to enable the exchange of classified homeland security information among federal civilian agencies and with the Department of Defense; in partnership, with the Federal Bureau of Investigation (FBI), the deployment of a Homeland Security Information Network to share sensitive information with state and local agencies; first responders, and private sector entities who own critical infrastructure; in developing the department's first IT Strategic Plan, and in standing up the 'day one' IT operations of DHS. Mr. Cooper testified frequently before Congress on matters related to Cyber and Information Security, and the use of Information Technology to achieve homeland security mission objectives.

Earlier, in March 2002, Mr. Cooper was appointed Special Assistant to the President for Homeland Security and also served as senior director for information integration in the White House Office of Homeland Security. In this role, he initiated the integration of the terrorist watch lists, and launched the development of the National Enterprise Architecture for Homeland Security to address information integration within the federal government and the sharing of homeland security information with state, local, and relevant private-sector entities.

Mr. Cooper was named one of the Top 100 CIOs in America by CIO Insight in 2007. He previously was honored by Government Computer News as the Government Civilian Executive of the Year; by the Northern Virginia Technology Council as a Titan of Technology; was a recipient of the Fed 100 Award recognizing the 100 most influential people in Federal Government Technology; and was named by the Washington Post as One of the Five to Watch while serving in the White House.

Mr. Cooper has remained active in his support of the NGO and Not-for-profit sector. Continuing work he did with the Department of Homeland Security in public safety interoperability through his current role as a Board Member of ComCARE (www.comcare.org), he is currently participating in the ComCARE Alliance's Core Services Initiative to provide a nationwide Enterprise Provider Access Directory and Identity Management services for all members of the emergency response community.

As a Board Member of NetHope (www.nethope.org), he is working to extend Information and Communication Technology capability, infrastructure, and innovation across the globe on behalf of NetHope's members, the 23 largest global humanitarian organizations, to 'wire the global village'.

Mr Cooper serves as an executive board member of the National Institute for Urban Search and Rescue, and as a board member of AFCEA International, both not-for-profit organizations dedicated to addressing matters of disaster preparedness and national security at all levels of government and for each citizen and family.

As the first Executive-on-Grounds at the University of Virginia, McIntire School of Commerce, Mr. Cooper brings "real-life" experience in applying technology to the students in the Masters program in the Management of IT.
Prior to his federal government service, Mr. Cooper spent more than twenty years in the private sector as an IT professional and holds a BA degree from Ohio Wesleyan University. He is a former Naval Air Reserve petty officer who served during the Vietnam conflict. He is married and states that being the father of four daughters, and the brother of four sisters, remains the toughest job he's ever had.

Appendix III – Panel Member Biographies

AMR ELSAWY
President and Chief Executive Officer
Member, Board of Trustees
Noblis

As President and Chief Executive Officer, Mr. ElSawy is responsible for the general management and direction of the company's overall technical, financial, and administrative activities. Noblis is a nonprofit science, technology and strategy organization working at all levels of government, in private industry and with other nonprofits in areas that are essential to our nation's well being: national and homeland security, public safety, transportation, health care, criminal justice, energy and the environment, and oceans, atmosphere and space.

Mr. ElSawy was elected Executive Vice President and a member of the Board of Trustees of Noblis in January 2007. He has extensive experience leading organizations and developing innovative solutions to some of the most complex challenges in the public sector.

Prior to joining Noblis, Mr. ElSawy was Senior Vice President and General Manager of MITRE's domestic and international aviation and transportation security work program.

Mr. ElSawy established and ran public-private partnerships. He has earned an international reputation as a leader in aviation. His work experience includes research and development, complex systems engineering, modeling and simulation and informing domestic and international aviation policy.

In 2005, Mr. ElSawy was elected Vice President of Standards and a member of the board of AIAA. He served as Chairman of RTCA from 2004 – 2006, and was a member of the FAA Research and Development Committee (REDAC). He served as the director of the FAA FFRDC from 1999 – 2006.

Prior to 1997, Mr. ElSawy served in various senior management positions and was responsible for strategy development, cross-functional integration, systems engineering, and architecture evolution of programs. He also served as a member of executive panels responsible for oversight of the implementation of large distributed information systems and networks for the Jet Propulsion Laboratory (JPL) and the Advanced Weather Information Processing System of the National Weather Service (NWS).

Mr. ElSawy holds a master's degree in business administration from Georgetown University - 1998, a master's degree in electrical engineering from George Washington University - 1980, and a bachelor's degree in electrical engineering from West Virginia University - 1977. He was inducted in the Computer Science and Electrical Engineering Academy at WVU in 2007.

Appendix III – Panel Member Biographies

PATRICIA A. MCNALL
Assistant Chief Counsel
Acquisition and Commercial Law Division
Federal Aviation Administration

Since 1994, Ms. McNall has been the Assistant Chief Counsel for Acquisition and Commercial Law at FAA. In her 26-year FAA career, Ms. McNall's principal practice has been in the area of Government contracts, but she has served in various other positions, including Acting Deputy Assistant Administrator for Policy, Planning and International Aviation, Deputy Assistant Chief Counsel for FAA's Technical Center, Special Assistant to the Chief Counsel, and acting Deputy Director for the FAA's Office of Acquisitions. In 1995, Ms. McNall worked with a Blue Ribbon Panel of acquisition experts and attorneys to create a new acquisition management system for the FAA. In late 1993, she served as Co-Chair of the Budget and Finance Working Group as part of the Department of Transportation's initiative to create an Air Traffic Control Corporation. She has received numerous awards including a National Performance Review "Hammer" award from the Vice-President, the Federal Bar Association's Transportation Lawyer of the Year, the Secretary's "Gold Medal" award, Outstanding Attorney at FAA for the year, Logistics Service Award, Quality Action Team awards, and numerous Special Achievement Awards.

In 1985, Ms. McNall earned her J.D. from George Washington University. In 1982 she studied law, foreign trade and Chinese language through a Columbia University program held at the Shanghai Law Institute. She also holds a M.A. (1982) in Economics and International Relations from the Johns Hopkins University School of Advanced International Relations, and a B.A. (1979) in International Relations and Asian Studies from Scripps College.

Appendix III – Panel Member Biographies

NITIN PRADHAN
Chief Information Officer
Office of the Secretary
Department of Transportation

Mr. Nitin Pradhan was sworn in on July 6, 2009 as the Chief Information Officer (CIO) for the US Department of Transportation (DOT). In his role of CIO, Mr. Pradhan provides information technology vision, strategy, planning and oversight for DOT's information technology budget. He is also the chief advisor to Secretary Ray LaHood in matters relating to information technology.

Nitin Pradhan is a business strategist, technology expert, coalition builder and change agent with over twenty years of experience including eleven years at CXO level in government, startups, non-profits and private industry. Mr. Pradhan is a strong proponent of building public- private partnerships.

Prior to joining DOT, Mr. Nitin Pradhan was the Chief IT Architect and the Director of the Office of Technology Planning and Assessment and part of the executive leadership of the IT department at Fairfax County Public Schools (FCPS), the 12th largest school district in the USA. The FCPS IT department has been ranked in CIO Magazine's top 100 IT organizations, as well as ComputerWorld's 100 best places to work in the nation.

Prior to joining FCPS, Mr. Pradhan was the Managing Director of Virginia's Center for Innovative Technology (CIT), where his targeted focus was on mentoring and growing technology startups and building research and innovation capabilities and capacity. He has also been the co-founder and interim CEO of a wireless startup.

Mr. Pradhan's educational qualifications include a BS degree in engineering and an MBA in marketing from India, as well as an MS in accounting from the Kogod College of Business at The American University, in Washington DC. He lives with his wife, son and daughter in Northern Virginia.

Appendix IV – Glossary

ADS-B	Automatic Dependent Surveillance - Broadcast
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATM	Asynchronous Transfer Mode
ATO	Air Traffic Organization
AVS	Aviation Safety
BGP	Border Gateway Protocol
CIO	Chief Information Officer
CTAS	Center TRACON Automation System
DHS	Department of Homeland Security
DoD	Department of Defense
ERAM	En Route Automation Modernization
FAA	Federal Aviation Administration
FIAT	Federal Aviation Administration Infrastructure Analysis Team
FTI	FAA Telecommunications Infrastructure
IP	Internet Protocol
LAN	Local Area Network
NAS	National Airspace System
NextGen	Next Generation Air Transportation System
NOCC	Network Operations Control Center
OMT	Operations Management Tool
OSPF	Open Shortest Path First
PNOCC	Primary Network Operations Command Center
RMA	Reliability, Maintainability, Availability
SDP	Service Delivery Point
URET	User Request Evaluation Tool
ZLA	Los Angeles ARTCC
ZLC	Salt Lake City ARTCC