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National Airspace System
Operational Concept-
AATT Products
Mapping Analysis

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Preface

This reports documents research undertaken by the National Center of Excellence for Aviation Operations Research, under Federal Aviation Administration Contract Number DTFA03-97-00004. This document has not been reviewed by the Federal Aviation Administration (FAA). Any opinions expressed herein do not necessarily reflect those of the FAA of the U.S. Department of Transportation.

National Airspace System Operational Concept-AATT Products Mapping Analysis

Abstract

A series of programmatic analyses are performed in support of the National Aeronautics and Space Administration (NASA)'s Advanced Air Transportation Technologies (AATT) program. The analyses examine the ability of the latest air transportation technologies planned for development by the AATT program to satisfy the future operating requirements of the National Airspace System (NAS).

The first analysis, a functional mapping analysis, (a) combines and summarizes the free flight operational concepts, as taken from NASA, RTCA Joint Industry/Government, and Federal Aviation Administration (FAA) 2005 reports; (b) derives the required capabilities of the air traffic management (ATM) decision support systems, the integrated flight deck, the flight dispatch operation tools, and certain auxiliary components, such as data link, to enable these concepts; and (c) maps these required capabilities to specific AATT research projects. AATT products are in the form of ATM decision support system and integrated flight deck components. Two time periods are analyzed: 2005 and the Mature State, assumed to be 2015.

In addition to the analysis describing the functional coverage of the AATT products, a transition analysis is performed to determine any existing temporal relationships between the AATT plans and existing government NAS operational concept and system architecture documents.

Finally, the existing AATT top-level product descriptions are enhanced with documentation for four emerging AATT surface operations research products and the format of the existing AATT top-level product descriptions are reviewed to identify content-enhancing changes.

Acknowledgment

These analyses were performed for the National Aeronautics and Space Administration (NASA)’s Advanced Air Transportation Technologies program (AATT). This report could not have been created without the time and effort of many NASA AATT staff and the supervision of Robert Jacobsen, the AATT Program Manager. The authors would like especially to thank George Tucker for his critical guidance and his steadfast support throughout the project. His assistance included an excellent graphical design for the mapping matrices resulting from his collaboration with the NASA-Ames Publications department. Also, the functional mapping analysis would not have been possible without the inputs from the following AATT research project leads: Len Tobias, Harry Swenson, Tom Davis, Rick Zelenka, Banavar Sridhar, Dave McNally, Brian Glass, and Sally Johnson. The report’s transition analysis was strengthened by Del Weathers’ editorial comments, and the AATT surface research product descriptions could not have been written without the generous support of Yuri Gawdiak, Stan Harke, Lilly Spirkovska, Ron Reisman, and Bill McDermott of the SMA Project Office. We appreciate all of everyone’s help that we received during the generation of this report.

The work was performed under contract to the University of California, Berkeley as part of the National Center of Excellence for Aviation Operations Research.

The study was conducted by Seagull Technology, Inc., of Los Gatos, California. Dr. George Couluris managed and coordinated project team work activities and wrote the sections dealing with the Terminal mapping analysis. Mr. David Schleicher wrote up the Surface mapping analysis, the transition analysis, the four surface product descriptions, and acted as the technical editor of the document. Dr. John Sorensen wrote the sections dealing with the Flight Planning and En Route mapping analysis, as well as, the AATT product description review. Ms. Tara Weidner and Dr. Frank McLoughlin supported the mapping analysis and documentation, and Ms. Melinda Byram assisted with the final report’s preparation.

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Executive Summary

Introduction

Operational concepts for the future advanced air traffic management (ATM) system have been developed by the National Aeronautics and Space Administration (NASA), Federal Aviation Administration (FAA) and RTCA. These concepts are based in part on RTCA's Taskforce on Free Flight Implementation and the FAA's National Airspace System (NAS) Architecture documents, and describe time-phased future air traffic services that require advanced ATM technologies and procedures. In general, there are certain themes that set the context for the concepts that are presented in the RTCA, FAA, and NASA operational concept documents. They are:

1. Separation assurance will shift from being only a ground based ATM responsibility to one that is shared with the flight deck (FD). This is facilitated by automatic dependent surveillance (ADS)-based surveillance, navigation and landing guidance using differential global positioning system (GPS), communications by data link, use of cockpit display of traffic information (CDTI), and an oceanic structure that will evolve to resemble that of domestic en route operations.
2 Terminal area operations will be more efficient than today. This will include expanded route options with transition to user preferred trajectories (UPT), and the disappearance of most static route structures.
3. Delay absorption will be implemented by allocating arrival intervals and arrival flow rather than departure control, ground holds, and en route constraints.
4. The NAS-wide information system and data link will be used for information exchange, and collaboration among ATM, airline operational control (AOC), and the flight deck will increase.
5. The timing of procedure changes will match the advent of new technology.

NASA has recently initiated a research and development program to develop new technologies to support modernization of the NAS. This Advanced Air Transportation Technologies (AATT) program will develop prototype research products that support the emerging NAS operational concepts. Assisting the AATT program, Seagull has conducted an examination of the abilities of the currently proposed AATT products to support the requirements of the future ATM system. This examination includes:

- A functional mapping analysis which describes the relationship between the proposed AATT products and the emerging NAS operational concepts.

- A transition analysis of the temporal validity of the proposed AATT product development schedule with respect to both the evolving NAS operational concepts and the current implementation phasing plans for the future NAS infrastructure.

- A documentation of four additional AATT products and a review of the current AATT product documentation format.

These three efforts are described in the following paragraphs.

Functional Mapping Analysis

The AATT products used for the functional mapping analysis are:

- Active Final Approach Spacing Tool (A-FAST)
- Advanced En Route Ground Automation (AERGA)
- Airborne Planner for Avoiding Traffic and Hazards (APATH)
- Airspace and Sector Tool (AT/ST)
- Collaborative Arrival Planning (CAP)
- Conflict Prediction and Trial Planner (CPTP)
- Enhanced Cockpit Display of Traffic Information (E-CDTI)
- Enhanced Surface Movement Advisor (SMA-2)
- Expedite Departure Path (EDP)
- Passive Final Approach Spacing Tool (P-FAST)
- Passive Surface Movement Advisor (SMA-1)
- Traffic Management Advisor (TMA)

The functional mapping analysis consisted of a distillation of future NAS operational requirements from the existing government and industry NAS operational concept documents and a mapping of the expected AATT research products to these requirements.

The AATT products are summarized in the following paragraphs relative to their general mapping onto flight planning, surface, terminal, and en route domains of flight.

Flight Planning

Only the AATT APATH product addresses some of the future flight planning operational requirements at this time, and this is solely from the flight deck perspective. Ground requirements, both AOC and ATM, are not addressed by AATT products at this time.

Surface

AATT products address many of the future surface operations concept requirements.

SMA-1 and SMA-2, in coordination with EDP, A-FAST, and CAP; will integrate ground traffic movement with arrival and departure sequencing and scheduling, and support ground traffic situation monitoring. APATH will support situation visualization in the cockpit and facilitate interaction between the pilot and ATM.

Terminal

AATT products address many of the future extended terminal operational concept requirements.

TMA, P-FAST, and A-FAST provide sequencing and scheduling of arrivals in the extended terminal airspace to improve runway utilization and trajectory assignments. EDP provides for efficient, conflict free departures extending into the extended terminal airspace. CAP enables collaboration between the AOC and CTAS-equipped ATM on arrival sequencing and scheduling. AT/ST and AERGA enhance ATM sequencing and scheduling capabilities by expanding options for terminal trajectory selection and assignment of user preferred routings (UPR) and profiles. APATH supports an advanced integrated flight deck which will enable the pilot to interact with dispatcher and controller in planning and implementing user preferred trajectories.

En Route

AATT products address many of the future en route operational concept requirements.

CPTP, AT/ST, AERGA, and APATH provide general ATM decision support system (DSS) functionality over the en route domain. CPTP, AT/ST, and AERGA provide the means of advanced conflict probing, provision of efficient aircraft flight and traffic flow around conflicts, and the negotiation of trajectories among the flight deck, ATM and AOC. As is the case for terminal airspace, APATH supports an advanced integrated flight deck which will enable the pilot to interact with dispatcher and controller in planning and implementing user preferred trajectories.

Transition Analysis

After the functional mapping analysis was complete, a transition analysis was conducted to investigate the temporal validity of the current AATT product development schedules when compared to the timelines of the existing NAS operational concept and system architecture documents.

In general, the results from the previous product-by-product, temporal analysis section can be summarized by stating that the AATT products seem to be timed rather well to support current FAA/RTCA ATM evolution plans. In fact, the majority of the AATT products are planned for NAS implementation sooner than their respective operational concept functional requirement dates require. Specifically, the following AATT products make up a list of earlier-than-expected ATM decision support systems:

- Traffic Management Advisor
- Passive Final Approach Spacing Tool
- Passive Surface Movement Advisor
- Conflict Prediction and Trial Planning
- Enhanced Surface Movement Advisor
- Airspace and Sector Tool
- Advanced En Route Ground Automation.

The only AATT product that tends to stand out as providing capabilities significantly later than the aviation community might desire is APATH. Specifically, APATH’s development and implementation of enhanced CDTI capabilities will be too late to satisfy near-term operational concept-derived CDTI requirements for self-spacing in terminal airspace.

The relative timeliness of the AATT products aside, the explicit statement of requirements for future AATT product functionalities in the FAA/RTCA plans tend to be rather weak. First of all, the NAS Architecture 2.0 documents ignore most of the proposed AATT product functionalities. In fact, the only functionalities that the NAS Architecture 2.0 alludes to are those found with:

- Traffic Management Advisor
- Passive Final Approach Spacing Tool

- Passive Surface Movement Advisor
- Conflict Prediction and Trial Planning
- Enhanced Surface Movement Advisor.

Furthermore, even the FAA and RTCA operational concepts tend to be vague about the requirements and timing for specific AATT product functionalities.

AATT Product Additions and Review

The last programmatic analysis performed involved the strengthening of the existing portfolio of AATT product descriptions. In order to improve the state of the existing documentation on AATT products, Seagull Technology performed two tasks. The first task involved the documentation of a number of additional AATT products that are mentioned on the AATT Product Schedule, Appendix B from Volume 2 of Reference 5, but for which no detailed description existed. These products are:

- Collaborative Departure Scheduling
- Low/Zero Visibility Tower Tools
- Surface Data Warehouse and Analysis Tools, and
- National Surface Advisor Tool.

The second task involved a review of the format and content of the existing AATT product descriptions from Appendix A from Volume 2 of Reference 5.

As a result of these two tasks, Seagull identified significant room for improvement in the existing AATT product descriptions and their format. During the completion of the AATT product description writeups, it became apparent that there were more AATT-funded efforts that were not covered by an existing product description. These ongoing or future efforts included the Complex Airspace Adaptation Planner, the Active Surface Movement Advisor, the Surface Development Test Facility, the Atlanta Surface Testbed, and Distributed Air/Ground Traffic Separation, and it is recommended that AATT product descriptions should be written to cover these efforts. The AATT product description review, which offered both general and product-specific description suggestions, resulted in a number of recommendations including:

1) The document needs to explain better the interrelationships of the AATT products and how their combined efforts support the objectives of “free flight”. For example, there is not a strong connection reflected in the product writeups between the research being planned and conducted to develop the ground decision support tools (DSTs) and the flight deck research (E-CDTI and APATH). For free flight to work, this integration is vital and needs to be reflected in the overall plan and the part each product plays in following this plan.

2) Any disconnects that still exist between ongoing research efforts and the product descriptions need to be resolved and the product description text needs to be reflect this fact.

3) A new section to the Appendix A introduction that explains the purpose of each of the subsections in the product descriptions should be added.

4) There does not appear to be a good reason to list the AATT products separately if they represent a continuum of effort with several deliverable builds of the same product family, so the extended product families such as SMA-1 and SMA-2; P-FAST and A-FAST; CPTP, AT/ST, and AERGA; E-CDTI and APATH, etc., should be combined.

5) A new subsection structure is recommended that consists of: Problem statement, Product description, Perceived benefit, Operational scenario, Information flow, and Development status, and all of the product descriptions should be rewritten to conform to this format.

6) The descriptive material for each product should be consistent with current AATT Level 3 program plans. The Appendix material should be revised yearly as the product content evolves.

National Airspace System Operational Concept-AATT Product Mapping Analysis

1. Introduction

The National Aeronautics and Space Administration (NASA), Federal Aviation Administration (FAA) and RTCA have been developing operational concepts for the future advanced air traffic management (ATM) system. These concepts, based in part on RTCA's Taskforce 3[1] and the FAA's National Airspace System (NAS) Architecture documents[2], consist mostly of time-phased future air traffic services that require advanced ATM technologies and procedures. The latest operational concept results can be found in two recently-distributed documents[3,4] by the FAA and RTCA and documentation by NASA[5].

NASA has recently initiated a research and development program to develop new technologies to support modernization of the NAS. This Advanced Air Transportation Technologies (AATT) program will develop prototype research products in support of the ATM system concepts.[6]

An important initial effort of the AATT program is to establish an understanding of how well the currently proposed AATT products[6] address the requirements of the future ATM system. In order to understand this better, three tasks have been undertaken by Seagull Technology. The first task, a functional mapping analysis, describes the relationship between the proposed AATT products and the operational concepts. This task consists of a distillation of future NAS operational requirements from existing operational concept documents and a mapping of expected AATT research products to these requirements. This task is described and documented in Section 2 of this report. The second task is a transition analysis of the temporal validity of the proposed AATT product development schedule with respect to the current implementation phasing plans for the future NAS infrastructure. This transition analysis is documented in the third section of this report. Finally, a third task to help strengthen the existing documentation of AATT products was carried out. This task, consisting of the documentation of four additional AATT products and a review of the current AATT product documentation format, is the subject of the fourth and final section of this report.

2. Functional Mapping Analysis

2.1 Introduction

NASA's AATT program will address many of the capabilities required to enable planned future aviation industry operational concepts. To understand the AATT program coverage of these needs, a detailed review of industry operational concepts and the planned AATT program product development activities was initiated. The result is a tracing of future NAS concepts and required enabling capabilities and their mapping to the various AATT products.

2.2 Methodology

Initially, a detailed review of three operational concept documents was made to distill the primary characteristics of the future NAS concepts as well as the specific capabilities required to enable these concepts. The three documents that served as a baseline description of the future NAS evolution are the following:

- RTCA Select Committee on Free Flight Implementation, "A Joint Government/Industry Operational Concept for the Evolution of Free Flight," August, 1997.[3]
- Department of Transportation, Federal Aviation Administration, "A Concept of Operations for the National Airspace System in 2005", Revision 1.3, June 27, 1997.[4]
- National Aeronautics and Space Administration, Ames Research Center, "Advanced Air Transportation Technologies ATM Concept Definition - Volume 1: Current and Future Operational Concepts for the National Airspace System," October 21, 1997.[5]

These documents encompass the future NAS state as perceived by both NAS airspace users (RTCA) and the air traffic management service provider (FAA ATS). In the RTCA document, the future states of the NAS examined included that for the years 2000, 2005, and a "Mature State", while the FAA document looks strictly at the year 2005, and the NASA document focuses on a current ops concept time period defined by the years 1997-2000, and two future ops concept time periods - the years 2000-2005 and 2005-Mature State . For the purposes of this study, two future time periods are addressed; one corresponding to a combination of the 2000 and 2005 states, and one corresponding to the "Mature State". The 2000/2005 period serves as a timeframe to address near-term system evolution with free flight. The mature state period incorporates future free flight capabilities, assumed to be realized in approximately 2015.

As part of the document review, high-level concepts were distilled for both 2000/2005 and the mature state across four domains of interest. These domains are flight planning, surface, terminal, and en route. For the purposes of analysis, the terminal domain was defined as extending approximately 200 nmi from the airport, coincident with the planning horizon of the Center-TRACON Automation System (CTAS). Then, the specific technical and procedural capabilities required to enable these operational concepts were derived. The result is a tracing of high-level operational concepts to specific future required capabilities (for details, see Figures 2.3.1-4).

Secondly, a review was made of the AATT Program's currently planned development activities.[6] This review highlighted the future capabilities addressed by the AATT products as well as the necessary supporting technologies and the anticipated end of the product's concept development. Additional information on the specific AATT products was found through interviews with each product developer.[7]

The AATT products and tools were then mapped against the required capabilities found in the NAS operational concept review. The mapping occurred across the four domains and two timeframes. For each NAS required capability, the mapping identified the level at which each subject AATT product addresses the need. Four degrees of coverage were identified; The required capability is (1) addressed (2) is supported (3) could be addressed, or (4) is not applicable, by the subject AATT product (for details, see Figures 2.4.1-4).

2.3 Future NAS Operational Requirements Analysis

This section presents the operational concepts and required capabilities (enabling technologies) for the four domains – flight planning, surface, terminal, and en route – for 2000/2005 and the mature state (approximately 2015). For each domain, the concepts for 2000/2005 first are summarized. The required capabilities for these concepts then are presented in terms of ATM decision support system, integrated flight deck (FD), AOC (for airline operations) or flight information service (FIS)/fixed-base operator (FBO) (for general aviation (GA)), and auxiliary systems. This sequence is repeated for the mature state.

In the “Concept-Requirements” matrices which follow at the end of this section, the operational concepts of the 2000/2005 and mature state (2015) timeframes are listed in the left column, and the required capabilities for corresponding timeframe are listed in the two far right columns. An intermediate column identifies the high-level concept(s), by number, supported by each capability. As such, the matrix summarizes the capabilities necessary to support each NAS concept. The “Concept-Requirements” matrices cover each of the studied NAS domains and follow in the order of: flight planning, surface, terminal, and en route.

2.3.1 Flight Planning

See Figure 2.3.1 at the end of Section 2.3 for the Flight Planning Concept-Requirements Matrix.

2.3.1.1 Flight Planning Concepts

By year 2005, flight planning processes will provide plans that range from Standard Instrument departure (SID)-to-standard terminal arrival route (STAR) user preferred routes to airport-to-airport user preferred trajectories. The NAS user (dispatcher or pilot) will be able to prove the flight plan against forecast constraints such as hazardous weather, active special use airspace (SUA) boundaries, dense traffic conditions and terrain. These constraints will be checked to determine the validity and feasibility of the flight plan (FP) before it is filed. After the FP is filed, it will be used to automatically update the NAS traffic demand profile for all affected regions. After takeoff, the FP record will automatically be updated as flight conditions change; this will continue until landing.

Concepts specific to the AOC will include generation of flight plans that conform to International Civil Aviation Organization (ICAO) standards for four-dimensional (4D) profiles, use of a NAS-wide Information System (NASWIS) to obtain weather forecast and other data necessary to generate the flight plan, and collaborative flight planning with ATM personnel to remove most conflicts before takeoff. The flight plan will be automatically data linked to the flight management system (FMS). The filed FP will contain more data than today to communicate such items as preferred runway and gate, aircraft performance data, and expected landing speed. The FP will be updated automatically during flight as conditions change for pilot, AOC or ATM.

For the general aviation pilot, the flight planning process will include access to the NASWIS for input information and NAS status updates. Terrain and navigation data will be provided to check the FP as well as uplink to the cockpit. The pilot will be able to communicate with ATM for clarification on restrictions or flight information within the NASWIS. Visual Flight Rule (VFR) flight plans will be automatically provided to ATM for enhanced VFR flight following, search and rescue.

By 2015, flight plans will generally describe full user preferred trajectories from airport to airport. Interactive flight planning will be made directly available to the flight crew.

2.3.1.2 Flight Planning Required Capabilities

To enable use of the user preferred flight plans, the ATM DSS will need to be able to handle flight plans that initially range from SID to STAR. Later, these will extend from airport to airport and be 4D. The DSS conflict probe must be able to take the FP and probe it against hazardous weather, dense traffic, and other flow constraints that are being predicted. The DSS will then collaborate with AOC or pilot to remove problems or detected constraint violations. The ATM system will provide airspace and flow restriction information to the NASWIS so that it can be accessed by the flight planning process. Special services to general aviation include enhanced flight following, in-flight FP changes in response to changing conditions, and personal computer (PC) access to NASWIS.

The integrated flight deck will be equipped to use the expanded flight plans, uplinked data concerning associated navigation, weather, and terrain data, and the uplinked FP itself.

Auxiliary systems needed to facilitate the enhanced flight planning/re-planning process include the NASWIS, two-way data link (TWDL), ground-ground data exchange, and the global weather forecast system.

The AOC of the future must be equipped to generate the UPR and UPT. These will be waypoint based rather than tied to today’s navaids. The dispatcher must have the DSS tools to enable probing the proposed FP against various flight constraints listed earlier. AOC DSS tools are also needed to collaborate/iterate the flight plans with ATM after filing or during flight to respond to changing NAS conditions and constraints. Finally, the AOC will provide comprehensive flight following and in-flight re-planning capabilities as the flight progresses and flight conditions change from those predicted when the original FP was computed and filed.

2.3.2 Surface

See Figure 2.3.2 at the end of Section 2.3 for the Surface Concept-Requirements Matrix.

2.3.2.1 Surface Concepts - Year 2000/2005

By the year 2005, surface operations will benefit from improved communication, navigation, and surveillance infrastructure and products. Aircraft Communications Addressing and Reporting System (ACARS) and voice communications will have evolved toward more robust and data-efficient digital data link communications. Digital communications capability at the time will enable richer information exchange including surface activity and weather.

Aids to navigation, such as VHF Omni-directional Ranges (VORs), Distance Measuring Equipment (DMEs), Non-Directional Beacons (NDBs), and Instrument Landing Systems (ILSs), which have had limited or no value to surface operations, will be superseded by satellite-based navigation systems such as Global Positioning System (GPS), Differential Global Positioning System (D-GPS), Wide Area Augmentation System (WAAS), Local Area Augmentation System (LAAS) and Global Navigation Satellite System (GLONASS). In addition to being available for surface operations, such capabilities provide sufficient accuracy for foul weather operations.

Surveillance of surface and airborne aircraft will include Automatic Dependent Surveillance System (ADS)-A/B. Position and identification (ID) information will be exchanged among vehicles directly and with ground control. Weather data will also be available.

By 2005, a surface management information system will be operational. The system will include military and civilian vehicles. The system will be networked with a NAS-wide information management system (NASWIS) for national air and surface monitoring and planning.

Air Traffic Control of surface activity will be enhanced and integrated with departure and arrival requests and activities. The integration will be characterized by more shared information. Situational awareness will be improved with richer and more timely information. Decision support systems will allow controllers to more readily assure separation and enhance flight efficiency by:

1. Including Cockpit Display of Traffic Information (CDTI) and other relevant flight information. This will provide low-visibility surface accident avoidance and taxi efficiency.
2. Providing more efficient clearances with increased terminal area throughput. Such tools will enable better coordination among gate-out/in, ramp entry/exit, taxi, departure, and descent movements.

In addition, the decision support tools will enhance traffic flow management, by the ability to assist in setting airport acceptance rates, expected taxi times, and airport configuration.

2.3.2.2 Surface Required Capabilities - Year 2000/2005

By 2005, the flight deck will require a satellite navigation capability to support ADS-A/B surveillance. Flight decks will also require low-cost, multi-function displays equipped with navigation mapping capability augmented by layered, geo-referenced information relative to “own” position, including applicable: other traffic; airport status, including runway, taxiway, ramp, and gate information; weather, including surface observations, Pilot Weather Reports (PIREPs), AIRMETs, SIGMETS, precipitation, and icing; Notices to Airmen (NOTAMS); terrain and obstacle information; data and voice communications frequencies (Automated Terminal Information System (ATIS), clearances, etc.); and data link (DL) interface.

As conditions warrant, General Aviation must be equipped with portable or panel-mounted GPS-based moving-map multi-function display (MFD) equipment.

Limited cockpit-based collision avoidance can be exercised among aircraft equipped with Traffic Alert and Collision Avoidance System (TCAS)/CDTI for airborne conflict detection and CDTI for ground-based conflict detection and alerting.

Air carriers will require TWDL for nominal communications with ATM and AOC. This digital capability will be coupled with a digital voice communication link. Communications from ATC and AOC to surface operations will include the following uplink content: ADS-A/B traffic information; updates of terminal weather nowcast and forecast; airport status; negotiation with ATC and AOC about pre-departure clearances or operationally-significant plans and data; routine communications and reporting, including database updates; 4D flight plan with re-plan updates; and Automated Terminal Information System (ATIS). Communications from surface vehicle operators to ATC and AOC will include ADS-A/B messages with position, velocity, and intent; user preferred 4D trajectories, gate, runway, and metering fix assignments; and aircraft performance data, as applicable.

The integration of TWDL information among the flight deck, ramp, AOC, and ATM will be required to collaboratively plan gate push-backs.

For general aviation, a TWDL will be required for operators desiring an FBO-GA interface.

By 2005, surface operations will be covered by ATC Decision Support Systems. Surface activity, arrival clearance, and departure clearance planning will reflect the integration of (1) current and predicted 4D surface, arrival, and departure information, and (2) planners for departure and arrival clearances.

The current and predicted 4D surface, arrival, and departure information will include: aircraft schedules; aircraft position and intent; aircraft type; wake turbulence rules; user preferences, including runway, gate assignment, and scheduled departure/arrival times; noise abatement constraints and noise impact information; airport configuration information; and traffic flow management initiatives.

Planners for departure and arrival clearances will include: AOC-ATC collaboration; pushback clearances that include aircraft location, type and departure sequence number; arrival clearances include scheduling, runway assignments, taxi routing and predicted surface congestion and minimizing time-to-gate; taxi clearances based upon predicted 4D aircraft movements, and taxi sequence and routing for maximum terminal area efficiency; departure clearances based upon predicted surface, arrival, and departure trajectories (these will include, as applicable, ascent and descent profiles, cruise speed, and altitude).

The ATM decision support system will have (a) surface ATC decision support and (b) traffic flow management decision support components. The surface ATC decision support system will have ground situation monitoring that will include: ground situation display; conflict detection and alerting, with the conflict detection including aircraft-to-aircraft, aircraft-to-ground vehicles, and runway incursion capability; and clearance conformance monitoring and alerting. The traffic flow management decision support system will have advisories for: airport acceptance rates; nominal taxi times, including de-icing taxi times; and airport reconfiguration.

These decision support systems will be integrated using an ATC-traffic flow management (TFM) display system. The display will simultaneously display surface, departure, and arrival information. The information displayed will include: surface management information system information for busy airports; NAS-wide information for non-busy airports; and airport and nearby air-spaces with data tags for all vehicles. The integrated display system will have robust connections to surface management information systems, NASWIS, Terminal Radar Approach Control (TRACON), and Air Route Traffic Control Center (ARTCC) decision support systems.

The ATM decision support system will have two-way data links for: (a) ATM/FD, (b) ATM/AOC, and (c) ATM/ATM communications. The data links will accommodate routine communications and uplink ATIS updates. They will also accommodate uplink clearances, including departure clearances that specify ascent and descent profiles, cruise speed, and altitude. This clearance uplink will have the capability to consider and incorporate user preferences. The downlinks will include: user preferences; 4D flight plans; and ADS-A/B information. Other uses of the two-way data link will include the communication of standardized taxi routes and “cohesive taxi plans” for Department of Defense (DOD) users.

For operation in 2005, there will be a need to monitor the status of the national surface operational information infrastructure and provide continual reporting. The information monitored will include: airports, runways, taxiways, and gates; navaids; acceptance rates; communications frequencies; standardized taxi routes; NOTAMs; and other information. A synthetic voice recording of ATIS is expected.

There will be a need to monitor the status of national terminal-area weather and provide continual reporting. The monitoring and reporting will include: terminal weather radar; wind shear prediction and alerting systems; Automated Weather & Surface Observation Systems (AWOS/ASOS); and the Integrated Terminal Weather System (ITWS).

Two-way data link communications will be required among (a) FD/ATM, (b) FD/AOC, (c) ATM/AOC, and (d) ATM/ATM. These links will: facilitate decision support system-to-flight management system information exchange and negotiation; accommodate routine communications; enable uplinked updates of weather, ATIS, and expected clearances; and provide a secure link for communications with DOD users. Voice communications will include some synthetic voice capability and secure communications for DOD.

Enhanced GPS navigation will include WAAS, LAAS, and future GPS innovations.

An integrated ground surveillance system will be required. This system will include improved surface detection equipment and will fuse radar, ADS-A/B position reports, intent, obstruction transmissions, runway/taxiway position and status, and weather information.

There will be tower automation enhancements that will include: ATCT local area networks (LAN); inter-facility wide area networks (WAN); and surveillance displays.

A surface management information system will be required to manage information about: airport environmental information; noise abatement procedures, curfews, and NOTAMs; current taxi, departure, and arrival schedules; aircraft and ground vehicle position and intent information; flight information; ATIS; terminal area weather (current and forecast), including current observations, Runway Visual Range (RVR), surface condition reports, precipitation, wake turbulence, windshear advisories, winds aloft, [E-]PIREPs, etc.; traffic flow management initiatives; airport acceptance rates; taxi times (including de-icing taxi times); airport configuration; any GA-specific information; NAS-wide information system (connection required); airbase surface management information system for DOD users (interface required), including DOD ATC, local base operations, coordinated base operations, flight deck, command post, and ground service providers; and ad-hoc surface management information about less-busy airports. Interfaces will be required for appropriate civilian users including ATC, TFM, the Flight Deck, AOCs, Ramp Operators, Airport Operators, and Airport Emergency Centers.

A NAS-wide information management system will be required. This system will provide status about facilities infrastructure, including ATIS; NOTAMs; and runway, taxiway, and gate availability and status. The status of the NAS infrastructure will be monitored and reported. The information management system will also monitor: ADS-A/B aircraft position reports; active and proposed Aircraft 4-dimensional flight plans; real-time aircraft 4D trajectory updates at push-back and wheels-up; aircraft performance data (e.g., descent speed profile, weight); and wind and weather nowcast/forecast from common sources. The NAS-wide information management system will be connected to surface management information systems, AOC, and ATM decision support systems.

Airline Operation Control centers decision support systems will include weather information for uplink to an FMS. The uplink capability will include flight plan/re-plan generation that will consider weather and traffic. User preferences will be generated and uplinked to the flight deck. AOCs will have an interactive multi-flight route, schedule, and sequence change probe that will output estimated cost-differences among options. The AOCs, or FBOs in the case of general aviation, will also have access to surface management and NAS-wide information systems.

By 2005, substantial information will be shared between AOCs and ATM. The information shared will include: user runway preference and gate assignment; updated estimates of gate pushback, taxi, and departure time; NAS infrastructure status; ATIS; weather information; pre-departure clearances; and push-back clearances, including aircraft position, aircraft type, and sequence number.

There will also be a decision support system for ramp operators. It will include displays of airborne and surface traffic schedules and positions. Advisories will be available for ramp operators for scheduling and sequencing of gate-out/gate-in maneuvers and ramp movements. Operators will have access to the surface management information system, and be connected to AOC and ATM DSSs.

The activities of ramp operators, AOC, and ATC will be coordinated to include information sharing about preferred and estimated gate-out/gate-in times, ramp entry/exit times, taxi-out/taxi-in times, and departure/arrival times. This will enable coordinated surface movement clearances.

2.3.2.3 Surface Concepts - Mature State

By 2015, surface safety and traffic throughput will be independent of VFR/instrument flight rule (IFR) conditions. Safe surface movements will occur in zero-visibility. Properly equipped aircraft and trained flight crews will be able to self-separate. Separation assurance responsibility will be shared between the flight deck and ATM.

Precision satellite navigation and surveillance will be widely used. Commercial aircraft will broadcast accurate aircraft position, velocity, and attitude information. General aviation will have wide use of panel-mounted multi-function and primary flight displays (MFDs, PFDs) with traffic, weather, and terrain/obstacles.

There will be full use of two-way digital data link for all routine communications, aircraft and NAS status updates, and hazard alerts.

Advanced surface communication, navigation, surveillance, and air traffic management (CNS/ATM) equipment will be expanded to more airports.

2.3.2.4 Surface Required Capabilities - Mature State

By 2015, the flight deck will have enhanced attitude determination and navigation with D-GPS, WAAS, LAAS, and/or subsequent innovations. Panel-mounted MFDs and PFDs will be highly integrated and will include information about: traffic; weather (various types: icing, precipitation, lightning, convective activity, METARS, etc.); terrain and obstacles; navigation and associated flight assistants (e.g., tunnel-in-the-sky); airport environment data link overlays; and conflict avoidance guidance.

There will be extensive conflict detection and alerting. Cockpit display of traffic information will be enhanced and will benefit from sophisticated aircraft-aircraft and aircraft-ground data link. Traffic information communicated will include aircraft and surface vehicle ID, vehicle type, precision position and velocity (3D), size, heading information, and 4D trajectory intent information. Conflict detection and alerting will include operations in the “traffic pattern” and will exploit enhanced airborne and surface traffic and terrain information. Airfield conflict detection and alerting will exploit CDTI to avoid other equipped aircraft, ground vehicles, ground obstructions, hazards, runway/taxiway incursions and ramp activity.

On the surface, the flight deck will automatically exchange information via two-way digital communications with ATM and AOC. The flight deck computer will be tied directly to the AOC and ATM computers for routine surface operations. Ground operations will automatically uplink updates of hazardous weather alerts, taxi clearances, and ATIS. The flight deck will downlink position, velocity, status, and intent information.

By 2015, there will be increased implementation of ATM DSSs. There will be zero-visibility, self-separation ground movements. To realize this capability, there will be shared user-service provider separation roles, responsibilities, and associated procedures. A graceful transition of pilot separation responsibility to ATM-based separation responsibility will be required. Graphical user interfaces will be designed to allow rapid strategic and tactical monitoring of user adherence to ATM clearances, aircraft conflicts and their solutions.

There will be full use of ATM-FD, ATM-AOC, ATM-ATM digital data link. All routine ATM, AOC and FIS communications will be handled by digital data link. Communication frequency changes will occur automatically between controllers, but with control monitoring and oversight. The data links will provide real-time updates of NAS demand, NAS capacity, and weather changes.

By 2015, there will be increased collection of airport status information, including runway and taxiway availability, passenger loading gate movements. An increased implementation of weather status monitoring and reporting systems will exist.

Two-way digital data link among FD-ATM, FD-AOC, ATM-AOC, and ATM-ATM will accommodate all routine communications, including ATIS information. ATIS will be enhanced to include runway visual range, braking action and surface condition reports, current precipitation, runway availability, and wake turbulence and wind shear advisories. ATC will have access to a NAS-wide information system. Real-time broadcast of NAS demand, NAS capacity, and weather change updates will be possible, including automatic simultaneous broadcast of hazardous weather alerts and ATIS. Voice will be used for emergencies and as a back-up for automated equipment.

There will be greater implementation of synthetic voice communication systems.

Precision surface navigation systems will be required, including the capability for precise heading and position information derived from reliable GPS, D-GPS, WAAS, LAAS, and possible future innovations.

The surface surveillance system will have a greater integration among information sources. ADS-B will serve as the primary surveillance technology, with radar providing limited area backup. Innovations to GPS technology will enhance ADS-B surveillance accuracy.

There will be greater implementation of ATCT Automation enhancements, and greater implementation of surface management and NAS-wide information systems.

Low-visibility ground vehicle movement systems will exist and have associated airfield situation displays. These capabilities will be enabled by ADS-B with position, velocity, and intent broadcasts.

By 2015, there will be greater implementation of AOC and ramp decision support systems.

2.3.3 Terminal

See Figure 2.3.3 at the end of Section 2.3 for the Terminal Concept-Requirements Matrix.

2.3.3.1 Terminal Concepts - Year 2000/2005

More arrival and departure routes will become available in the year 2000 based on area navigation (RNAV) and new procedures for distributing waypoint data. Precision instrument approaches to more runways will be possible with RNAV accuracy augmentation. The removal of 250 kt restriction below 10,000 ft in Class B will increase the use of user preferred climb profiles.

Increased pilot situational awareness will be enabled with ADS-B/CDTI and conflict detection and resolution assistance. Data link transmission of airport/ATIS data for cockpit display will reduced verbal miscommunication. Enhanced ground proximity warning information and cockpit display will reduce the instances of controlled flight into terrain (CFIT).

Better cockpit display of weather, navigation, obstruction, moving map and traffic situation will enable more accurate aircraft visual separation by pilots during approach or departure, and will enable continual application of this self-separation capability in intermittent visual meteorological conditions/instrument meteorological conditions (VMC/IMC). Pilots will begin using approaches with independent navigation (GPS/RNAV/inertial navigation system(INS)/FMS) and improved cockpit display. Reduced visual minima will be implemented with FMS approach and departure offsets, horizontal/vertical procedural separation, and speed control or CDTI station keeping.

GA safety will be improved with the enhanced terrain and obstruction data display. Some DOD aircraft will be equipped with collision avoidance and cockpit display of weather data; most will use ILS/microwave landing system (MLS).

By the year 2005, a common situational awareness will be shared by ATM user and provider, which will enhance safety and flexibility and support collaborative decision making. Common situational awareness will be based on improved satellite-based RNAV, ADS-B capabilities, common data link, and more aircraft equipage with and better quality of cockpit displays of traffic, current weather information, hazardous weather alerts, terrain, obstructions, and routine messages.

Reduced or time-based separation standards and more direct routes will be implemented also by 2005. Precision instrument approaches to any airport or runway will be possible with ground-based RNAV accuracy augmentation. The 250 kt restriction below 10,000 ft will be removed from more Class B airspace for arrivals and departures.

More flexible approach and departure procedures and better merging, sequencing and runway assignment will be implemented with: enhanced ATM decision support systems for terminal operations; ATM/FMS/AOC data link exchange of information; improved trajectory prediction and control accuracy; improved trajectory adherence by aircraft/FMS; pre-defined data link messages such as altitude clearance and radio frequency change instructions; and reduced air-ground communications, which will provide more time for ATM planning functions to accommodate increased traffic.

Enhanced collaborative decision making between ATM and AOC will improve the traffic flow management process. As part of this improved process: flight status and NAS infrastructure data will be available to users and providers; daily traffic flow, runway configuration changes will be anticipated; arrival flows, departure queues and configuration transitions will be planned to minimize traffic disruption; ATM and AOC will consult to resolve congestion through schedule adjustments or flow constraints; and TFM initiatives will be data linked to pilots and controllers.

IFR and VFR transition routes/corridors for GA traffic will be incorporated into some terminal areas. Most DOD aircraft will be equipped with multi-mode receivers (ILS/MLS/GPS approach), and secure data link operations will be introduced.

2.3.3.2 Terminal Required Capabilities - Year 2000/2005

Functional capabilities required to support the terminal operational concepts for the 2000/2005 time frame address the ATM decision support system, integrated flight deck, auxiliary system, and AOC system.

The ATM decision support system will require adjustment or establishment of ATC procedures for: reduced separation standards; time-based separation; pre-defined routes, profiles and precision landings for RNAV, Vertical Navigation (VNAV), FMS, and GA operations; and the delegation and management of airborne self-separation. High-fidelity data link capabilities will be the primary service for communication among ATM, FMS/pilot, and AOC. This service will provide for the: uplink of ATC instructions, arrival and departure route and profile navigation data, and meteorological nowcasts and forecasts; downlink of aircraft status and intent, meteorological measurements; and ATM-AOC coordination and negotiation for management of congestion, severe weather, and other irregularities.

The ATM decision support system also will require enhancements to the ground-based automation basic functions and decision aid services. Enhanced capabilities for ground-based ATM automation basic functions will include: ADS-B augmentation of ATC traffic situation and trajectory data; use of improved nowcast and forecast wind and temp field estimates; higher-fidelity trajectory tracking; higher-fidelity clearance conformance monitoring; higher-fidelity trajectory prediction; higher-fidelity aircraft performance modeling; higher-fidelity automated conflict detection probe; and higher-fidelity automated restricted airspace and terrain probe. Enhanced ground-based automated decision aid services will be required to support improved runway and airspace utilization, user flight trajectories, and controller traffic handling capabilities, and will include: optimized arrival and departure scheduling; improved sequencing and spacing; runway, arrival and departure gate traffic flow balancing; more efficient profiles assignments; more direct routing assignments; improved response to configuration and other weather-related operational changes; severe weather avoidance trajectory generation with scheduling, sequencing and spacing; improved controller situation visualization and decision-making support tools; controller advisories generation; controller staffing and traffic workload balancing; and ATM alert and avoidance or escape capabilities for imminent traffic conflicts, controlled flight into terrain and obstacles, hazardous weather (i.e., severe convective weather, turbulence, wake vortex, wind shear, and lightning), and restricted airspace.

Advanced computer human interface (CHI) capabilities for controllers will be required to enable effective ATM decision support system operations with data link and new procedures.

The integrated flight deck in the 2000/2005 time frame will require enhanced navigation and guidance capabilities, which employ differential GPS with ground-based augmentation as the primary navigation source (using LAAS and WAAS for precision landing and flexible routing, and integrity beacon landing system (IBLS) for all weather landing), and FMS (using optimal RNAV and VNAV profiles and FMS-coupled autopilot/autothrottle). High-fidelity data link among ATM, FMS/pilot, and AOC will provide for the: uplink of predefined altitude clearance, radio frequency change, modified communications frequencies, ATIS, wind and temperature nowcasts and forecasts, active waypoints, and RNAV/VNAV routes; downlink of aircraft position, velocity vector, weight, wind and temperature data; and exchange of flight plan, aircraft performance, and gate-Out/wheels-Off/wheels-On/gate-In (OOOI) data.

The integrated flight deck also will require development of an enhanced multifunction display capability for the cockpit, which will provide the pilot with layered information visualization and guidance for airborne spacing or station keeping and merging and maneuvering. Layered information visualization will display moving map, traffic, navigation, routine and hazardous weather, terrain, obstacle, and restricted airspace data. Airborne spacing or station keeping and merging and maneuver guidance will include: TCAS/CDTI/ADS-B integration; potential traffic conflict detection and resolution; self-spacing merging guidance; sector density and airport delay probing; and alert and avoidance or escape guidance for traffic conflicts, controlled flight into terrain and obstacles, hazardous weather, and restricted airspace.

Advanced computer human interface capabilities for pilots will be required to support multifunction display operations with data link and enhanced avionics.

The auxiliary system will require enhanced infrastructure status monitoring and reporting, including status updates of airport, runway, navaid, acceptance rate, and other operational factors. An integrated surveillance system will be required to fuse radar, ADS-A/B reports and intent information. The two-way data link will: facilitate decision support system-to-FMS information exchange and negotiation; accommodate routine communications; uplink weather updates and expected clearances; downlink weather measurements and flight performance data; and provide data link security encryption. A NAS-wide information system will be required which provides: wind and weather nowcast and forecast data from common sources; SUA status and schedule plans; aircraft 4-dimensional flight plans; aircraft ADS-A/B reports of position, velocity, and intent data; aircraft performance data (e.g., descent speed profile, weight); airspace and route structure on global grid system; facilities infrastructure status; and runway status and other ATIS airport data. Integrated global weather nowcasts and forecasts will: incorporate viable weather information including aircraft downlinked measurements; regularly update projections to facilitate accurate trajectory prediction; and parse meteorological data into user blocks for the ATM decision support system, AOCs, and weather service providers.

The integrated AOC system will require enhanced support services and display capabilities, including: access to NAS-wide information system; user preferred trajectory flight plan and re-plan generation for changes due to weather, traffic, and other factors, with data linking of the results to flight deck; an interactive route change probe for more point-to-point routing (which will allow desired schedule and sequence generation, desired conflict resolution strategy, collaborative route modification, assist coordination of TFM initiatives to relieve airspace congestion); and parsing of weather for uplink to FMSs. AOC-ATM information sharing capabilities will exchange data describing schedule revisions, active and proposed routes, and NAS infrastructure status, and will facilitate collaborative decision making (CDM) operations and routine approval of user preferred trajectories with minimum re-routing and en route holding.

2.3.3.3 Terminal Concepts - Mature State

By 2015, ADS-B will be fundamentally complete, and all aircraft will be able to take advantage of the capability to broadcast position to the ATM system and other users. Data link will be available for routine pilot and ATM communications. Safety will be increased with better response to emergencies using automatic data linking of emergency communication (alerts, warnings, resolution and intervention instructions) and elimination of the time required for human relay of messages.

New procedures will be developed to reduce congestion over waypoints using CDTI/ADS-B, data link and ATC decision support systems. ATC will oversee separation assurance, allowing free-maneuvering in low-density areas. ATC will provide sequencing and primary separation assurance in high density areas, with some cockpit self-separation assigned by ATC when operationally advantageous. Improved airport and airspace utilization and increased arrival and departure flexibility with increased sensitivity to user preferences in high-density areas will be achieved. This enhanced service will involve: the dynamic setting of multiple RNAV arrival and departure routes; the option of pilots to select preferences from the set of routes-in-use (that are data linked to equipped aircraft), or to exchange and negotiate route preference, constraints and assignment information by data link with ATM; the establishment of aircraft arrival and departure sequencing plans by ATM decision support systems; and the utilization of the required time of arrival (RTA) capability of aircraft to implement the ATM plan.

IFR and VFR transition routes/corridors for GA traffic will be incorporated into all terminal areas. All DOD aircraft will be equipped with GPS, data link (with secure encryption), ground proximity warning system (GPWS), CDTI and on-board collision avoidance.

2.3.3.4 Terminal Required Capabilities - Mature State

Functional capabilities required to support the terminal operational concepts for the year 2015 extend and expand the 2000/2005 time frame requirements for the ATM decision support system, integrated flight deck, auxiliary system, and AOC system.

The ATM decision support system in the mature state will require adjustment or establishment of ATC procedures for full data link operations which support user preferred trajectory negotiation and data exchange, and delegation and management of airborne self-separation (which allows self-separation in high-density areas when operationally advantageous and free-maneuvering in low density areas). The capabilities of the high-fidelity data link among ATM, flight deck, and AOC will be enhanced to provide for the uplink of all ATC clearances, advisories, and alerts, and the downlink of aircraft user preferences, priorities, and requests.

Enhanced ground-based automated decision aid services will be extended to provide: improved integration of user preferences with ATM scheduling, sequencing and spacing, and route/profile/runway and required time of arrival assignments; and ATM automatic generation of emergency communications, such as wind shear alerts, collision alert/resolution advisories, and incursion alert/resolution instructions

The integrated flight deck in the 2015 will require enhancement of the high-fidelity data link among ATM, flight deck, and AOC to provide for the: uplink of maneuver instructions, other ATC messages, trajectory constraints or route options, required time of arrival, and emergency messages; and downlink of preferred trajectory or route selection, separation coordination and emergency messages.

The multifunction display capability for the cockpit will require expansion of airborne spacing or station keeping and merging and maneuver guidance to support automatic generation of emergency communications, including wind shear alerts collision alert/resolution advisories, and incursion alert/resolution instructions.

The auxiliary system will require expansion of the integrated surveillance system to establish ADS as the primary surveillance source with radar as limited area backup. The two-way data link will be extended to: accommodate all routine communications digitally; provide voice communication for emergency and automation equipment backup; and provide full data link security encryption.

The integrated AOC system will require expansion of support services and display capabilities to enable full partnership between ATM and the flight deck by supporting the generation of user preferred trajectories and routes, and coordinating strategies for flight diversions, conflict avoidance, traffic avoidance; and emergencies and contingencies.

2.3.4 En Route

See Figure 2.3.4 at the end of Section 2.3 for the En Route Concept-Requirements Matrix.

2.3.4.1 En Route Concepts - Year 2000/2005

By year 2000, improved navigation and guidance on the aircraft will begin to enable the evolution to User Preferred Trajectories (UPT). Improved altimetry, aided by use of GPS, WAAS, and the RNP concept will allow reduction of vertical separation requirements above FL290 to 1000 ft. This will allow smaller step climbs in the flight plan creating more efficient flight profile.

In the horizontal plane, lateral separations can begin to be reduced between aircraft having reduced RNP capabilities enabled by GPS and RNAV. In the longitudinal direction reduced spacing can also occur with RNAV/VNAV equipped aircraft. Controllers and pilots can make use of FMS with 4D capabilities and required time of arrival (RTA) to control the crossing of waypoints to meet certain ATM derived schedules.

The evolution of the cockpit display of traffic information will be used in some en route airspace for basic longitudinal spacing and merging control. (This will first be used in oceanic airspace for in trail climb and descent, and offset climb, descent, and passing maneuvers.)

More aircraft will be equipped with the multi-function display and data link to provide ground derived data to the pilot. The MFD will have layered information on top of the moving navigation map; it will include graphical depictions of hazardous weather regions as well as terrain and special use airspace (SUA) boundaries. In addition, a traffic layer will show adjacent traffic as an extension to today's TCAS II system. Both traffic and weather information will be provided from the ground via data link. Traffic information will also be provided by ADS-B means directly between the equipped aircraft.

Data link will also be used to provide non-time critical information to the aircraft. This will include special routes, changes to the normal communications frequencies, and AOC-derived NAS performance information. ICAO flight plans will be exchanged from aircraft crossing boundaries with Canada and Mexico.

By 2005, ATM decision support systems will be used to enhance separation assurance within the en route airspace. Concepts include improved guidance through hazardous weather regions and enhanced conflict detection and resolution by use of a ground conflict probe. This probe will be used to separate aircraft from active SUAs, terrain, and man made obstacles. General aviation will be given direct routes through Class B and C airspace, ADS-B surveillance protection, and improved VFR flight following as enhanced by ADS-B. The use of the NAS-wide information system will be implemented which will allow sharing of aircraft ADS reports and locations of uncontrolled aircraft. Separation assurance decision support tools will be complemented by the enhanced flight deck which will include GPS navigation, ADS-B, CDTI, and FMS coupling.

2005 will also bring about the coordination of dynamic airspace structuring, flow and traffic management, and the en route re-planning of trajectories. Dynamic routes will be used by ATM to provide temporary solutions to hazardous weather, excessive traffic density, and other airspace problems. Major flow management will be upgraded to include coordination between all phases of the flight operation; the AOC will be enabled to work with ATM to specify arrival sequences. Strategic traffic management will include using the conflict probe as a tool for predicting future traffic densities; this will enable mitigating density problems upstream of where they would occur. ATM will work collaboratively with AOCs and pilots in the process of en route re-planning.

By 2005, the use of static airspace boundaries will be greatly reduced or eliminated. Dynamic airspace boundaries will be regularly adjusted to accommodate traffic, weather and infrastructure changes, as are required.

Data link will enable the integration of flight deck and ground automation processes. Routine manual communications will be automated. Information uplinked will include weather, navigation fix, changes to stored charts, and flight plan modifications from either AOC or ATM. Data downlinked will include aircraft intent, real-time weather measurements, equipment status, and aircraft performance data to assist the ATM processes.

2.3.4.2 En Route Required Capabilities - Year 2000/2005

By year 2000, the ATM decision support system will require incorporation of the automated conflict probe, the use of RNP and a collision risk model to govern reduced separations, the redefinition of required vertical separations above FL290, use of CDTI for merging, spacing and maneuver control, data link and associated controller interface, and a means of measuring NAS performance and reporting to the NASWIS.

The flight deck will require navigation and guidance upgrades provided by GPS, the establishment of RNP, and use of FMS for RNAV, VNAV and RTA capabilities. The MFD will be used to provide layered display of traffic, terrain , hazardous weather, and SUA boundaries. Data link and its pilot interface on the MFD will provide for uplink of routes, communication frequencies, flight plan changes, weather, SUA status and other information. The use of ADS-B will complement the traffic display as well as provide means of surveillance in regions of non-radar coverage.

By year 2005, the ATM DSS conflict probe will be extended to include use of RNP, ADS-B, intent, aircraft performance data, and FMS-derived climb/descent profiles. The probe will be extended out to strategic distances to facilitate strategic conflict resolution. Aircraft status tracking will eliminate the need for paper flight strips. Dynamic routes will be used to navigate through storm cells. Seamless coordination and communications will take place between facilities and aircraft via DATA LINK and use of the NASWIS.

The DSS will support traffic flow management by means of predicting the demand profile (dynamic density), identifying capacity problems, formulating potential solutions, negotiating solution changes to the flight plan with the AOC, and distributing these changes via NASWIS and data link. AOC preferences in schedules and sequences will be accommodated.

The DSS will adjust sector and TRACON boundaries to accommodate traffic flow management objectives.

The traffic controller/manager will use advanced graphics display systems to provide interface to DSS tools, data link, dynamic boundaries, and other computer-human interface requirements.

Auxiliary systems required include means to monitor the NAS infrastructure; the ability to integrate both ADS-B and radar data with intent information; the full use of two-way data link between DSS and flight deck; full use of NAS-wide information system; and an integrated global weather forecast system with means of updating using regular downlinked measurements. The AOC system includes the computation and display means to allow the airline dispatcher to collaborate with the controller on UPT flight planning and re-planning, and use of an interactive route change probe. AOC-ATM information sharing will facilitate exchange of routes, infrastructure status, and other CDM functions.

The 2005 integrated flight deck will include full use of satellite navigation for ADS-B applications and full use of the FMS for precision guidance. The MFD will be used for CDTI applications, dynamic routing for avoidance of hazardous weather, full use of a terrain and obstacle data base, and the data link interface. The primary flight display (PFD) will include provision for communicating 3D conflict avoidance guidance to the pilot. This technology will be available to general aviation and helicopter pilots as well as air carriers.

For air carriers, means will be provided for two-way data link between the flight crew and the dispatcher and flight crew and traffic manager. Important information will be both uplinked and downlinked to enable provision for user preferred trajectories. The three-way flight deck-AOC-ATM trajectory negotiation and information exchange will be facilitated by TWDL.

2.3.4.3 En Route Concepts - Mature State

By 2015, free maneuvering operations will be fully enabled in low to medium density en route airspace. Means will be provided to facilitate air-to-air self separation. The aircraft will use the FMS to fine tune the flight plan in 4D space.

Data link will be used to facilitate dynamic resectorization and the automation of communications required for frequency change between sectors.

En route restrictions and ground delay program will be mostly eliminated.

For general aviation, low altitude direct routes will be allowed whenever traffic conditions permit. The GA pilot will use the MFD for full situational awareness regarding traffic, weather, and terrain conditions.

2.3.4.4 En Route Required Capabilities - Mature State

By 2015, free maneuvering operations will be enabled by a DSS which will feature the ATM system ability to monitor self separation; graceful transition of responsibility to ATM control in high density areas; shared user-service provider separation roles, responsibilities, and procedures; and a graphical user interface designed to allow rapid monitoring of traffic conflicts and provision of their solutions.

Data link will be used to meet total information transfer bandwidth requirements. Voice communications will be used only as a backup.

Traffic flow management will consist of assigning arrival slots as dictated by forecast arrival flow rates. Dynamic resectorization will be done automatically in anticipation of changing dynamic airspace density.

General aviation will be provided access to low altitude direct routes within all airspace, in accordance with actual traffic conditions. This will be facilitated by use of the traffic probe.

Auxiliary systems will include full use of TWDL and an integrated radar-ADS-B surveillance system.

The AOC system will be designed to enable the dispatcher to be a full partner with the traffic manager and the flight crew in generation of UPTs, conflict avoidance, traffic avoidance, and strategies for response to emergencies, contingencies and situations that require flight diversions.

The integrated flight deck will include provisions for implementing the means to air-air conflict detection and avoidance out to strategic ranges. The FMS will fine tune and optimize the AOC flight plan in response to meteorological, traffic and SUA changes. Useful and essential data will automatically be exchanged between the FMS and the ATM and AOC computers.

The general aviation pilot will have full access to low-cost, easy-to-use glass cockpit technology including panel mounted MFD/PFD, conflict avoidance guidance, and uplink of ATM routes for strategic solutions.

2.4 Mapping of AATT Products

Given the future ATM operational requirements just derived, the next step is to map the expected capabilities of the planned AATT products to them. This mapping step was graphically accomplished by generating matrices that cross-correlated the operational requirements to the relevant AATT products. The sources of information that were used to produce the matrices included References 6 and 7.

In the “Requirements-AATT Product” matrices which follow, the required capabilities for the 2000/2005 and mature state (2015) timeframes are listed in the two left columns, while the required capability coverage of the AATT products are listed in the remaining columns. The symbols in the AATT product coverage columns indicate the extent to which AATT product supports the development of the required capability. The four levels of coverage are identified below:

- Filled Square -- Required capability *is addressed* by this AATT product. The research and development of this NASA AATT product intends to address this future ATM system requirement.

- Filled Triangle -- Required capability *is supported* by this AATT product. The research and development of this NASA AATT product does not directly address, but supports, this future ATM system requirement.

- Filled Circle -- Required capability *could be addressed* by this AATT product. The research and development of this NASA AATT product does not currently address this future ATM system requirement, but it could, given the appropriate re-definition of program objectives.

- Open Square -- Required capability *is not applicable* to the specific development of this particular AATT product; i.e., the required capability *is not addressed* by the intent of NASA's AATT program to focus on human-centered decision support systems and procedures for short-to-intermediate term ATM decision-making.

A heading row in the matrices identifies the estimated calendar year of initial operating capability (IOC) calculated as 3.5 years after the expected date of the end of concept development for each product. This 3.5 year assumption was chosen from an analysis of corresponding expected development time periods for en route decision support systems found in Reference 10. One should note, however, that the actual time required will be a function of an individual product’s technical and operational sophistication, and future FAA and airspace user priorities and budgetary levels.

2.4.1 Flight Planning

The mapping of these requirements to APATH is shown in Figure 2.4.1 at the end of Section 2.4. Only the APATH (Airborne Planner for Avoiding Traffic and Hazards) AATT product relates to the flight planning requirements.

APATH addresses many of the future airborne flight planning operational concept requirements. However, ground requirements, both AOC and ATM, are not addressed by AATT products at this time.

2.4.2 Surface

The surface required capabilities are mapped to the associated AATT products in Figure 2.4.2 at the end of Section 2.4. These products are SMA-1 (Passive Surface Movement Advisor), SMA-2 (Enhanced Surface Movement Advisor), A-FAST (Active Final Approach Spacing Tool), EDP (Expedite Departure Path), CAP (Collaborative Arrival Planning), and APATH (Airborne Planner for Avoiding Traffic and Hazards).

AATT products address many of the future surface operational concept requirements.

SMA-1 and SMA-2, in coordination with EDP, A-FAST, and CAP; will integrate ground traffic movement with arrival and departure sequencing and scheduling, and support ground traffic situation monitoring. APATH will support situation visualization in the cockpit and facilitate interaction between the flight deck and ATM.

2.4.3 Terminal

The terminal required capabilities are mapped to the associated AATT terminal products in Figure 2.4.3.1 and to the associated AATT en route products (since a number of AATT products are designed for use in en route airspace, but provide “extended” terminal ATM capabilities) in Figure 2.4.3.2 at the end of Section 2.4. These products are TMA (Traffic Management Advisor), P-FAST (Passive Final Approach Spacing Tool), A-FAST (Active Final Approach Spacing Tool), EDP (Expedite Departure Path), CAP (Collaborative Arrival Planning), CPTP (Conflict Prediction and Trial Planner), AT/ST (Airspace and Sector Tool), AERGA (Advanced En Route Ground Automation), and APATH (Airborne Planner for Avoiding Traffic and Hazards).

AATT products address many of the future extended terminal operational concept requirements.

TMA, P-FAST, and A-FAST provide sequencing and scheduling of arrivals in the extended terminal airspace to improve runway utilization and trajectory assignments. EDP provides for efficient, conflict free departures extending into the extended terminal airspace. CAP enables initial collaboration by an AOC with CTAS on arrival sequencing and scheduling. AT/ST and AERGA enhance sequencing and scheduling capabilities by expanding options for trajectory selection and assignment of user preferred routings and profiles. APATH, as in the case of the en route domain, provides for the advanced integrated flight deck which will enable the pilot to interact with dispatcher and controller in planning and implementing user preferred trajectories.

2.4.4 En Route

The en route required capabilities are mapped to the associated AATT products in Figure 2.4.4 at the end of Section 2.4. These products are CPTP (Conflict Prediction and Trial Planner), AT/ST (Airspace and Sector Tool), AERGA (Advanced En Route Ground Automation), and APATH (Airborne Planner for Avoiding Traffic and Hazards).

AATT products address many of the future en route operational concept requirements.

CPTP, AT/ST, AERGA, and APATH provide general ATM DSS tool functionality over the en route domain. CPTP, AT/ST, and AERGA provide the means of conflict probe, provision of efficient aircraft flight and traffic flow around conflicts, and the negotiation of trajectories between the flight deck, ATM and AOC. APATH provides for the advanced integrated flight deck which will enable the pilot to interact with dispatcher and controller in planning and implementing user preferred trajectories.

3. Transition Analysis

3.1 Introduction

Having completed the NAS Operational Concept-AATT Product functional mapping analysis of section 2, the next logical step was to perform a temporal mapping analysis of AATT products to the high-level NAS operational concepts. This second task involved a transition analysis of the temporal integrity of the proposed AATT product development schedule with respect to the current implementation phasing plans for the future NAS infrastructure. This task is the subject of this section.

The objective of the transition analysis task is to identify any temporal disconnects between the AATT product schedules and the future evolution of the NAS as described through: 1) the FAA 2005 Operations Concept[3], 2) the RTCA Joint Industry/Government Operational Concept for the Evolution of Free Flight[4], and 3) the National Airspace System Architecture Version 2.0[2]. The expected results of the transition analysis was the identification of the implementation of AATT products as either early, timely, or late, as well as, the additional identification of source document or NASA/FAA ATM research synthesis issues that arose during the analysis.

This report details the transition analysis performed in five sections. The first section introduces the background of the analysis. The second section describes the methodology that was used. The third section identifies the results of the AATT product-by-product transition analysis. Next, the fourth section summarizes the analysis findings and identifies important additional functional or temporal issues that were noticed during the analysis. Finally, the fifth section makes recommendations for logical follow-on efforts that would improve the fidelity of this transition analysis.

3.2 Methodology

In order to identify any temporal disconnects between AATT product functionality and both the time-phased operational concept requirements and the NAS infrastructure implementation schedules, an analysis methodology was developed. The details of the analysis method, major assumptions that were made, and an example of the method are described in this section.

3.2.1 Analysis Method

The transition analysis employed the following method. First, the relevant, important documents were collected and read. These documents are:

1) two documents charting the future operational needs of the NAS: the FAA 2005 Operational Concept[3] and the RTCA Joint Government/Industry Operational Concept[4] (Note: In order to assist in determining the operational concept required capabilities that come from the FAA 2005 and the RTCA Joint Government/ Industry Operational Concepts, the previous mapping analysis, the second section of this document, was also used.),

2) one document charting the future NAS infrastructure evolution: the NAS Architecture 2.0[2],

3) one document describing details about the current AATT products: "Summary Overview and Status of AATT Program Development Activities"[6], and

4) one chart describing the current schedule for the AATT products[8] with the latest updates[9].

The second step was to extract from these documents the time-phasing of operational concept required capabilities, the evolution of the NAS infrastructure, and the AATT product functional developments. The resulting temporal and functional mapping was done graphically in a style that mimicked Figure 3-1.

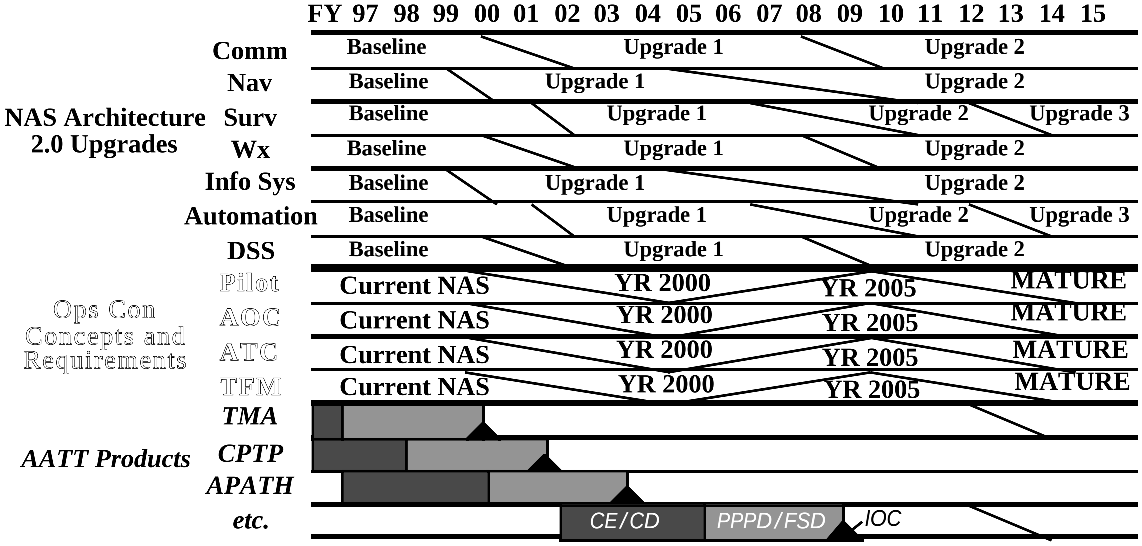

Figure 3-1 Notional Graphical Transition Analysis

Figure 3-1 illustrates how the Operational Concept, the NAS infrastructure, and the AATT products were compared to one another.

The very top of the figure sets the temporal backdrop for the comparison in terms of the Fiscal Year evolution from the current fiscal year 1997 to 2015. 2015 was chosen as an end-point because of two main reasons: 1) NASA typically uses the year 2015 as a synonym for the NAS "Mature State", and 2) most all of the new NAS infrastructure identified in the NAS Architecture 2.0 documents has been phased in by this future year.

The first seven rows in the figure are a representation of eight major categories of NAS infrastructure mentioned in the NAS Architecture 2.0 document. These eight categories are:

- Communication
- Navigation
- Surveillance
- Weather
- Information System
- Cockpit Displays
- Automation
- ATM Decision Support Systems.

For each of these categories, the NAS Architecture 2.0 delineates the evolution from the currently fielded NAS infrastructure through future upgrades of this infrastructure. In Figure 5-1, this evolution is depicted with the "Baseline" systems in place starting in fiscal year 1997 and the future transition to upgrades of the "Baseline" systems, denoted as "Upgrade 1", "Upgrade 2", and "Upgrade 3". The slanted lines in-between the system labels symbolize the gradual implementation of the given new system and its replacement of the older system infrastructure. Steep transition lines represent speedy system implementation and a short transition period, while flatter transition lines represent slower implementation and longer transition periods. During this effort, based on the NAS Architecture 2.0, a graphical depiction of the actual evolution of the NAS en route and terminal architectures were developed and is included in Appendix A.

The next four rows in Figure 3-1 depict the functional transitions in the NAS, as found in the FAA 2005 and the RTCA Joint Government/Industry operational concepts. The transition involves the changing NAS concepts and required capabilities from the current NAS to those in the Year 2000, Year 2005, and the Mature State operational concepts. The depiction of these changing concepts and required capabilities relied significantly upon the analysis of the operational concepts found in Section 2 of this report. The changing concepts and required capabilities were mapped to the four major decision-making personnel involved with air traffic management: the pilot, airline operational control (AOC) dispatchers, air traffic controllers (ATC), and traffic flow managers (TFM).

Finally, the last rows in the figure represent the phased development of specific AATT products. For each AATT product, the product will go through the following stages of development, as described in Reference 10: Concept Exploration (CE), Concept Development (CD), Pre-Production Prototype Development (PPPD), and Full-Scale Development (FSD). The NASA AATT products development in Concept Exploration and Concept Development are funded and managed by NASA, with a technology transfer period during Pre-Production Prototype Development. Starting with the Pre-Production Prototype Development stage, product development will be funded and managed by the FAA or the airspace users (depending on whether the systems are ATM or cockpit decision support systems) through Full-Scale Development and beyond into deployment and operational use. At the end of the Full-Scale Development phase, the first full-scale operational unit of the AATT product is implemented in the NAS and, at this point, the product is said to have reached its Initial Operating Capability (IOC). This is a very important point in time, since this is when the airspace users and the air traffic management service providers will begin to see operational use of the new product with its associated benefits. The current scheduling of the AATT products was obtained from References 8 and 9, and is summarized in Appendix B.

The actual transition process involved comparing the timing of the NAS infrastructure, new operational concept-derived concepts and requirements, and the development of the AATT products. The result of this AATT product-by-product comparison was the identification of specific product timeliness and the identification of key product-specific functional and temporal issues, as well as, other important issues that came up during the above analysis.

3.2.2 Assumptions

During the performance of the above analysis method, a number of assumptions had to be made. The major assumptions that were made include:

1) The RTCA Joint Operational Concept Caveat

As described in Reference 4, the RTCA Joint Government/Industry operational concept made an important caveat in its use of the temporal “Year 2000”, “Year 2005”, and “Mature State” designations. With regards to the “Year 2000” descriptions, the RTCA operational concept states that: “...the discussion of operational capabilities available in 2000 does not imply that such capabilities exist across the NAS at that time. The discussion of these ‘year 2000’ capabilities serves only to introduce the capabilities for users at certain locations.”

Taking this caveat into the account, the concepts and required capabilities described in the FAA 2005 and RTCA operational concepts must be implemented across the NAS over a finite implementation period. This idea, combined with the notions of long NAS infrastructure implementation periods (as evidenced in Reference 2) and the operational concept use of a five-year difference between two out of the three NAS future states, was used in determining an assumed operational concept implementation schedule shown in Figure 5-2.

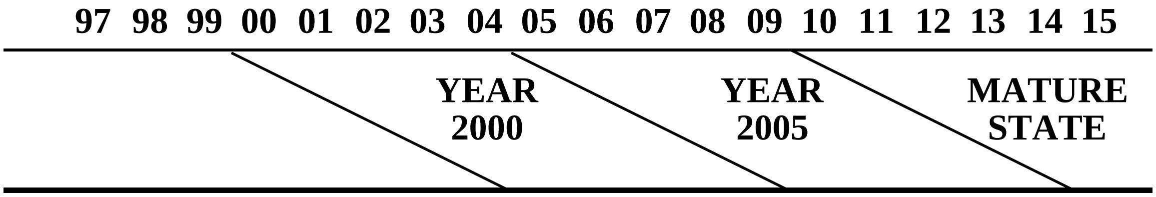

Figure 3-2 Assumed Operational Concept Implementation Schedule

As shown in Figure 3-2, this report assumes a five-year phase-in and phase-out schedule of each of the operational concept periods.

This assumption leads to two important results. The first result, a somewhat paradoxical one, is that "Year 2000" capabilities will only be fully implemented across the NAS in fiscal year 2005 and "Year 2005" capabilities fully implemented only in fiscal year 2010. This result is especially important for those airspace users wanting to see the implementation of a new capability in their part of the NAS as soon as possible, and, as one may imagine, this result easily lends itself to potential temporal misunderstandings.

The second result is that the previously-undefined "Mature State" becomes, in essence, "Year 2010". This result tends to be rather well supported by the NAS Architecture 2.0 documents that show almost all of the two-generations-in-the-future NAS infrastructure in place before the end of the fully-implemented Mature State: 2015.

2) Fiscal Year Designation

A second assumption is that all the years used in the NAS Architecture 2.0 documents were fiscal years. It is difficult in the NAS Architecture documents to distinguish whether years are in the units of calendar years or fiscal years. The use of this assumption will potentially cause a 0.25 year discrepancy with any calendar year schedules (such as those specified in the air traffic control decision support system schedules in Reference 2), but this discrepancy is significantly less than the uncertainties found in system/products definition and current schedules.

3) Initial Operating Capability Dates

Another major assumption was one required to produce the AATT Product Initial Operating Capability dates. The assumption made was that there is a 3.5 year period from the beginning of the Pre-Production Prototype Development phase to the end of Full-Scale Development. This meant that for all AATT products, it would take 3.5 years between the end of NASA's Concept Development and the Initial Operating Capability of a full-scale, operational version of the given product in the NAS. This assumption was made by taking the typical corresponding period for en route decision support systems found in Reference 10. It is difficult to predict the actual time required between the end of Concept Development and the IOC because of a number of factors that include differing levels of product technical and operational sophistication, a lack of previous implementation data (especially in the case of ATC DSSs), and uncertain future FAA and airspace user budgetary levels.

3.2.3 Example: Passive Final Approach Spacing Tool

Finally, in order to illustrate the analysis method, a simplified example is shown in Figure 3-3. Figure 3-3 illustrates a typical analysis done for AATT's Passive Final Approach Spacing Tool.

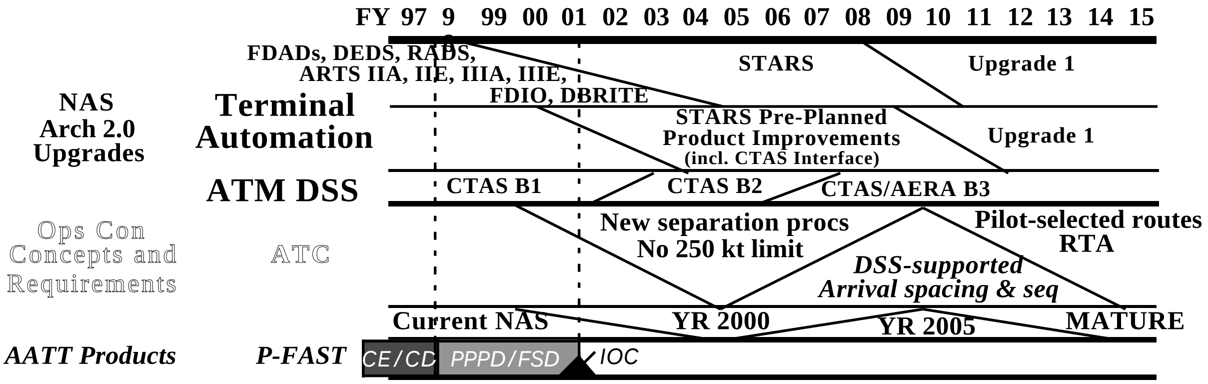

Figure 3-3 Transition Analysis Example: Passive Final Approach Spacing Tool

3.2.3.1 P-FAST Data Collection

A planned AATT product, Passive Final Approach Spacing Tool (P-FAST) is a proposed air traffic controller decision support system for TRACON approach controllers to assist them with the efficient sequencing and scheduling of arrival aircraft into major airports. P-FAST uses its ability to accurately predict the future trajectories of current air traffic to determine optimum aircraft schedules, sequences and runway allocation and to display time-shared sequence and runway allocation data on the air traffic controller’s Full Digital ARTS Displays (FDADs).

First of all, the appropriate terminal automation equipment upgrades, obtained from Reference 2, are shown. These planned terminal automation equipment improvements include the replacement of the currently-implemented ARTS computers, FDAD display units, etc. with the fielding of the new STARS computer terminals and associated displays, as well as STARTS Pre-Planned Product Improvements (that include new terminal automation-CTAS interfaces) and future upgrades (designated as “Upgrade 1”).

Next, also mentioned in Reference 2 is the planned implementation schedule for the air traffic control decision support systems; CTAS builds 1, 2, and 3. Although not explicitly mentioned in Reference 2, P-FAST functionality is referred to in Reference 2’s CTAS Build 2 description of “arrival aircraft sequence number on TRACON displays”.

The FAA 2005 and RTCA operational concepts address P-FAST’s functionality in a somewhat straightforward manner. The most specific references to a capability such as P-FAST are described in the FAA 2005 operational concept document’s proposed “Year 2005” concept, “In 2005, decision support systems assist the service provider to assign runways and merge/sequence traffic, based on accurate traffic projections and user preferences,” and in the RTCA Joint Government/Industry operational concept’s “Year 2005” concept, “Such automation assists the service provider in assigning runways and merging and sequencing aircraft according to user preferences”.

The current AATT P-FAST schedule stipulates the end of Concept Development at the end of fiscal year 1997. With an assumed 3.5 year PPPD/FSD period, the Initial Operating Capability of a full-scale, operational P-FAST is in the middle of fiscal year 2001.

3.2.3.2 P-FAST Transition Analysis

The IOC of P-FAST is well timed to be installed on ARTS/FDAD automation platforms, although they should be in the middle of their phase out of the NAS. The STARS automation platform replacements should be relatively common in the NAS by P-FAST’s introduction, but with the, hopefully, early introduction of the STARS-CTAS interface Pre-Planned Product Improvement, P-FAST’s continued implementation into the NAS, on STARS platforms, should not be adversely impacted.

P-FAST's IOC is a half-year earlier than the NAS Architecture 2.0's assumed introduction of P-FAST in CTAS Build 2, but this is most likely a lack of NASA/FAA coordination of recent DSS development schedules.

In terms of supporting the Year 2005 operational concept requirements, P-FAST rather directly supports this future evolution of the capability of the NAS and, from a temporal standpoint, will be implemented roughly *four years ahead* of the timing inherent in the FAA 2005 operational concept (making the assumptions explained in Section 3.2.2). The apparent "early" timing of the P-FAST capabilities maybe due, at least in part, to the lack of detailed functional transition information in the FAA and RTCA operational concepts. Splitting the functional evolution into three large stages (Year 2000, Year 2005, and Mature State), will not provide the basis for a fine-grained analysis of customer(airspace user, air traffic controller)-expected versus supplier(NASA/FAA)-provided product implementation dates.

3.3 Results

The transition analysis method described in the previous section was performed for each of the AATT products and the results are described for the rest of this section. Each of the AATT products is analyzed in turn by describing the product in brief, discussing its currently planned IOC date, and comparing the product functionality and timing with the both the NAS Architecture 2.0[2] and the FAA and RTCA operational concept documents.[3, 4]

3.3.1 Traffic Management Advisor (TMA)

The AATT product with the earliest implementation is the Traffic Management Advisor. Using accurate air traffic trajectory prediction capabilities, the Traffic Management Advisor is a decision support system that assists both ARTCC TMCs and ARTCC arrival sector controllers in the efficient sequencing and spacing of en route, arriving air traffic over meter fixes, as well as, TRACON TMCs in sector staffing planning and setting efficient traffic flow management parameters such as runway and airport acceptance rates. Based on current AATT product schedules [8, 9], TMA's Initial Operating Capability is estimated to occur in the 3rd quarter of fiscal year 2000.

From a functional standpoint, TMA's capabilities are explicitly spelled out in the NAS Architecture 2.0 document, including references to CTAS Build 1's "meter-fix crossing times" and "interfacility coordination (ARTCC-TRACON)" and CTAS Build 2's "meter list with crossing times". The FAA and RTCA operational concept documents do not clearly spell out a requirement for TMA's functionality, but rather indirectly describes a Year 2000 need for "time-based separation" and a Year 2005 need for "decision support systems...to maintain situation awareness...and sequence and space arrival traffic".

From a temporal standpoint, TMA's IOC occurs after NAS Architecture 2.0's full implementation of CTAS Build 1 and earlier than the initial implementation of CTAS Build 2, at the beginning of fiscal year 2002.

In summary, the analysis leads one to deduce that NASA-planned TMA implementation is earlier than in the FAA and RTCA requirements, but the functional requirement is not very strong.

3.3.2 Passive Final Approach Spacing Tool (P-FAST)

After TMA, the next AATT product to be implemented is the Passive Final Approach Spacing Tool. Like TMA, P-FAST also uses accurate air traffic trajectory prediction capabilities, and P-FAST is a decision support system that assists TRACON approach controllers in the "feeder", "final", and TMU positions in providing efficient terminal arrival aircraft schedules, sequences and runway assignments. Based on current AATT product schedules [8, 9], P-FAST's Initial Operating Capability is estimated to occur in the 3rd quarter of fiscal year 2001.

From a functional standpoint, P-FAST's capabilities are described in the NAS Architecture 2.0 document's reference to CTAS Build 2's "arrival aircraft sequence number on TRACON displays". FAA and RTCA operational concept documents refer to P-FAST's functionality a few times. For example, the FAA 2005 document specifies that in the Year 2005, "decision support systems assist the service provider to assign runways and merge/sequence traffic".

From a temporal standpoint, P-FAST's IOC lines up well with the NAS Architecture 2.0's initial implementation of CTAS Build 2, at the beginning of fiscal year 2002, but is a significant four years earlier than the Year 2005 requirement for P-FAST's terminal ATM decision support capabilities.

In summary, one may conclude that P-FAST is strongly supported as an operational requirement of the future NAS and the current plan for P-FAST's implementation seems to be earlier than anticipated by the airspace users and the air traffic management service provider. However, much of this "earliness" might be an artifact of the limited temporal resolution of the FAA and RTCA operational concepts. Nonetheless, the operational concepts could be corrected to describe the P-FAST capability as a Year 2000 requirement.

3.3.3 Passive Surface Movement Advisor (SMA-1)

The first AATT product to be implemented as a decision support system designed to improve surface operations is the Passive Surface Movement Advisor. Distributing terminal radar data, airline schedule and gate data, aircraft flight plans, aircraft status updates and runway configuration, SMA-1 assists ATCT controllers and supervisors, AOC dispatchers, and airport ramp operators in monitoring and predicting future air traffic surface movements to enable more efficient surface operations. Based on current AATT product schedules [8, 9], SMA-1's Initial Operating Capability is estimated to occur in the 3rd quarter of fiscal year 2001.

From a functional standpoint, SMA-1's capabilities are referred to in the NAS Architecture 2.0 document's very general reference to SMA as "an automation system which facilitates the sharing of information among the air traffic, airline and airport operations community to assist in the decision-making regarding the surface movement of aircraft". FAA and RTCA operational concept documents refer to a Year 2005 required "surface movement information system" capability that includes the functionality of SMA-1.

From a temporal standpoint, SMA-1's IOC occurs significantly later than the NAS Architecture 2.0's initial implementation of SMA Build 1, at the beginning of fiscal year 1998, but is a significant four years earlier than the Year 2005 requirement for SMA's surface information system capabilities.

In summary, one may conclude that the capabilities of SMA-1 are strongly supported as an operational requirement of the future NAS, but there seem to be disconnects in the temporal expectations of SMA-1's development among NASA and both the FAA's System Architecture planners (much earlier) and the FAA and RTCA operational concept planners (much later). Like P-FAST, in the case of the operational concept planners, much of this "earliness" might again be an artifact of the limited temporal resolution of the FAA and RTCA operational concepts. In addition, it would seem appropriate for the operational concept planners to describe the functionality of SMA-1 as a Year 2000 requirement.

3.3.4 Conflict Prediction and Trial Planner (CPTP)

The next AATT product to be implemented after SMA-1 is the Conflict Prediction and Trial Planner. Building on the trajectory prediction capabilities used by TMA and P-FAST, CPTP uses its prediction of en route air traffic trajectories to assist ARTCC controllers in detecting future aircraft conflicts, in developing conflict-free resolution advisories, and in generating advisories to enable efficient air traffic descents into terminal airspace and compliance with miles-in-trail traffic flow management constraints. Based on current AATT product schedules [8, 9], CPTP's Initial Operating Capability is estimated to occur in the 2nd quarter of fiscal year 2002.

From a functional standpoint, some of CPTP's capabilities are referred to in the NAS Architecture 2.0 document's description of CTAS/AERA Build 3's "trial planning, conflict probe" functions. In the RTCA and FAA operational concepts, CPTP's conflict probing capabilities are mentioned as definite, but somewhat generic requirements. The RTCA operational concept document refers to a Year 2000 requirement for a "ground-based conflict probe" with 2005 "enhanced conflict probe and alerting" capabilities. The FAA 2005 operational concept mentions a requirement for a "conflict probe [to] assist the provider in developing safe and effective traffic solutions".

From a temporal standpoint, CPTP's IOC occurs significantly earlier than the NAS Architecture 2.0's planned implementation of CTAS/AERA Build 3 at the beginning of 2006, but seems to be well timed for the RTCA Year 2000 requirement for the ground-based conflict probe.

In summary, one may conclude that the capabilities of CPTP are generally supported as an operational requirement of the future NAS (with the specific conflict probing functionality still "in-the-air") with implementation timing that is a little late for the FAA and RTCA planners. However, one correction should probably be made to NAS Architecture 2.0 document: CPTP functionality should be mentioned as a CTAS Build 2 function, not that of CTAS Build 3.

3.3.5 Enhanced Surface Movement Advisor (SMA-2)

The second AATT surface product to be implemented after the Passive Surface Movement Advisor is the Enhanced Surface Movement Advisor. Building upon SMA-1's capabilities and "enhancing" them with additional arrival and departure aircraft status and prediction information from terminal ATC automation (e.g., CTAS-derived data), as well as, mobile SMA interfaces, access to ETMS and ACARS data, and a number of additional capabilities, SMA-2 improves the situational awareness of the flight deck, ATCT controllers and supervisors, AOC dispatchers, and airport ramp operators in monitoring and predicting air traffic surface movements to enable more efficient surface operations. Based on current AATT product schedules[8, 9], SMA-2's Initial Operating Capability is estimated to occur in the 2nd quarter of fiscal year 2003.

From a functional standpoint, like SMA-1, SMA-2's capabilities are referred to in the NAS Architecture 2.0 document's under the very general reference to the overall SMA program previously mentioned in Section 3.3.3. FAA and RTCA operational concept documents refer to the Year 2005 "surface movement information system" capability that includes functionalities found in SMA-2 such as the "integration of surface automation with departure and arrival automation" .

From a temporal standpoint, SMA-2's IOC occurs slightly later than the NAS Architecture 2.0's implementation of SMA Build 2, at the beginning of fiscal year 2002, although the NAS Architecture 2.0 expected "useful" life of SMA-2 seems to be a curious one year! In comparison to the FAA and RTCA operational concept Year 2005 requirement for its functionalities, SMA-2 is two years early.

In summary, one may conclude that the capabilities of SMA-2 are significantly supported as an operational requirement of the future NAS and are currently scheduled for an early implementation. In general, the NAS Architecture 2.0 treatment of SMA-2's insertion into the NAS seems to be both fuzzy and, most probably, in error.

One functional timing problem that may affect SMA-2's successful development and implementation is the current mismatch in SMA-2's assumption of including EDP-derived departing aircraft information and EDP's estimated IOC date, which is almost three years later (see Section 3.3.7).

3.3.6 Airspace and Sector Tool (AT/ST)

The next AATT product to be implemented after SMA-2 is the Airspace and Sector Tool. Building off of the foundation of CPTP development, AT/ST uses its prediction of en route air traffic trajectories to assist ARTCC controllers in issuing inter-sector, cost-effective conflict resolution advisories, and issuing conflict-free, movement clearances (especially descent advisories) that comply with traffic flow restrictions. Based on current AATT product schedules[8, 9], AT/ST's Initial Operating Capability is estimated to occur in the 3rd quarter of fiscal year 2004.

From a functional standpoint, AT/ST's capabilities are generically referred to in the NAS Architecture 2.0 document's description of CTAS/AERA Build 3's "trial planning, conflict probe" functions. In the RTCA and FAA operational concepts, like CPTP, AT/ST's advanced conflict detection and resolution capabilities are mentioned as somewhat generic requirements. The RTCA operational concept document refers to a Year 2005 requirement for a ground-based "enhanced conflict probe and alerting" capability. The FAA 2005 operational concept mentions a requirement for "improved decision support tools for conflict detection, resolution, and flow management" and "highly accurate conflict detection functions and reliable conflict resolutions that maximize safety while minimizing traffic disruption".

From a temporal standpoint, AT/ST's IOC occurs one year earlier than the NAS Architecture 2.0's planned implementation of CTAS/AERA Build 3 at the beginning of 2006, but seems to be very well timed for the FAA and RTCA Year 2005 requirement for an enhanced, ground-based capability to perform conflict detection, resolution, and flow management.

In summary, one may conclude that AT/ST functionality is generally supported as an operational requirement of the future NAS with implementation timing that is consistent between NASA, FAA, and RTCA planners. A significant problem exists, however, in that current FAA and RTCA plans do not specify their requirements in detail enough to distinguish between the requirements of different advanced conflict probing tools such as CPTP and AT/ST.

3.3.7 Expedite Departure Path (EDP)

After AT/ST, the next AATT product to be implemented is Expedite Departure Path. EDP has accurate air traffic trajectory prediction capabilities like TMA, P-FAST, CPTP, and AT/ST, but uses its ability to predict departing air traffic trajectories to assist TRACON controllers in providing efficient terminal departure aircraft schedules, sequences, departure gate balancing, and en route fix merging. Based on current AATT product schedules[8, 9], EDP's Initial Operating Capability is estimated to occur in the 1st quarter of fiscal year 2006.

From a functional standpoint, EDP's capabilities are very obliquely referred to in the NAS Architecture 2.0 document's description of CTAS/AERA Build 3's "conflict probe...and future aircraft position" functions. In the FAA operational concept, EDP's capabilities are mentioned as a somewhat more definite Year 2005 requirement of "the integration of departures into the airborne traffic environment" and "improved real time assessment of traffic activity in departure...airspace". The RTCA operational concept document supports the need for EDP, but as a rather general reference of a Year 2005 "improved service provider automation and displays...[to] enhance traffic situational awareness and allow for enhanced...departures".

From a temporal standpoint, EDP's IOC coincides with the NAS Architecture 2.0's planned implementation of CTAS/AERA Build 3 at the beginning of 2006, and seems to be well timed for the enhanced departure decision support system requirements for the Year 2005 timeframe from both operational concept documents.

In summary, one may conclude that EDP is generally supported as an operational requirement of the future NAS (with the specific departure functionality not very clear) and its implementation timing is on target across both NASA, FAA, and RTCA planners.

3.3.8 Active Final Approach Spacing Tool (A-FAST)

An AATT product to be implemented at the same time as EDP is the Active Final Approach Spacing Tool. Also using accurate air traffic trajectory prediction capabilities developed for P-FAST, A-FAST is a decision support system that assists TRACON final approach controllers in the “final position in providing efficient terminal arrival aircraft speed and heading advisories that maximize airport arrival throughput. Based on current AATT product schedules[8, 9], A-FAST’s Initial Operating Capability is estimated to occur in the 1st quarter of fiscal year 2006.

From a functional standpoint, A-FAST’s capabilities are ignored in the NAS Architecture 2.0 document. The FAA and RTCA operational concept documents each refer once to an A-FAST-like requirement. The FAA 2005 document discusses that in 2005, “other tools generate advisories to the service provider that aid in maneuvering flights onto the final approach in accordance with the planned traffic sequence.” The RTCA operational concept mentions the 2005 requirement for “service provider automation tools [that] enhance final approach spacing and runway assignment.”

From a temporal standpoint, A-FAST’s IOC lines up rather well, being only one year later than the operational concept’s Year 2005 final approach decision support requirement.

In summary, one may conclude that A-FAST is supported as an operational requirement of the future NAS and its currently planned implementation seems to be rather well-timed with FAA and RTCA operational concept needs. However, the required A-FAST functionality and implementation schedule should be incorporated into updates of the NAS Architecture 2.0 document.

3.3.9 Collaborative Arrival Planning (CAP)

Simultaneously to the implementation of EDP and A-FAST, another AATT product will be implemented with the title, Collaborative Arrival Planning. The Collaborative Arrival Planning is planned as a decision support system to facilitate AOC-ATM information exchange and to provide a collaborative decision-making environment that utilizes the air traffic trajectory prediction capabilities of CTAS for more better fleet management decisions, improved ATC clearances and more efficient aircraft arrival trajectories into congested hub airports. Based on current AATT product schedules[8, 9], TMA’s Initial Operating Capability is estimated to occur in the 1st quarter of fiscal year 2006.

From a functional standpoint, CAP’s capabilities are ignored in the NAS Architecture 2.0 document, except for a quick discussion of “Free Scheduling” AOC-ATM collaborative re-planning. The FAA and RTCA operational concept documents each refer quickly to CAP capability requirements. The FAA 2005 operational concept explains that “increased information exchange...allow for greater accommodation of user requests, including carrier preferences on the sequencing of their arrival aircraft,” and the RTCA operational concept describes that in the Year 2005, “collaboration is extended as AOCs have an expanded role in determining the landing sequence of company flights”.

From a temporal standpoint, CAP’s IOC occurs just one year after the FAA and RTCA’s 2005 requirement for its capability.

In summary, the analysis leads one to deduce that CAP capabilities are required by the FAA and RTCA operational concept plans and the current NASA implementation schedule is relatively well timed with the airspace user and air traffic service provider communities. One problem that needs to be addressed, however, is the inclusion of the CAP functionality and implementation schedule into updates of the NAS Architecture 2.0 document.

3.3.10 Advanced En Route Ground Automation (AERGA)

The next AATT product to be implemented after EDP, A-FAST, and CAP is the Advanced En Route Ground Automation. Building off of the foundation of AT/ST development, AERGA is an

ARTCC controller decision support system which uses its prediction of en route air traffic trajectories and its knowledge of weather, airspace restrictions, and user preferences to reduce ARTCC sector controller workload through automatic conflict resolution advisories, provide traffic flow management plan coordination across adjacent ARTCC facilities, assist ARTCC controllers and airspace users in facilitating collaborative rerouting around hazardous weather and special use airspace, and assist in automated CTAS/FMS trajectory negotiation. Based on current AATT product schedules[8, 9], AERGA's Initial Operating Capability is estimated to occur in the 2nd quarter of fiscal year 2006.

From a functional standpoint, AERGA's capabilities are ignored, for the most part, in the NAS Architecture 2.0 document. One aspect of AERGA's functionality, the collaborative rerouting, actually shows up as being worked on under the "Expanded CDM Capability" with an earlier 1998 IOC date.

In the RTCA and FAA operational concepts, as for CPTP and AT/ST, AERGA's advanced conflict resolution capabilities are mentioned as somewhat generic requirements. The RTCA operational concept document refers to a Year 2005 requirement for a ground-based "enhanced conflict probe and alerting" capability. The FAA 2005 operational concept mentions a requirement for "improved decision support tools for conflict detection, resolution, and flow management" and "highly accurate conflict detection functions and reliable conflict resolutions that maximize safety while minimizing traffic disruption".

Unlike its conflict resolution capabilities, AERGA's automated CTAS/FMS trajectory negotiation, traffic flow management plan coordination, and collaborative rerouting functionality is spelled out as future NAS requirements in the RTCA and FAA operational concepts. The FAA 2005 operational concept specifies an "automatic exchange of information between flight deck and ground-based decision support systems (that) improves the accuracy and coordination of arrival trajectories" "decision support systems...(that) develop the (arrival and departure flow management) plan", and "displays (that) improve the service provider's ability to coordinate with the flight deck and other service providers to ensure the avoidance of hazardous weather." The RTCA operational concept mentions a Year 2005 requirement for "modified routes...developed collaboratively between the AOC and the service provider and then data linked to the cockpit and downstream ATC facilities," and a Mature state requirement for pilot-selected routes that are datalinked to "ATC and used in terminal-area decision support systems to provide appropriate sequencing".

From a temporal standpoint, AERGA's IOC occurs one year later than the FAA and RTCA Year 2005 requirements for ground-based capabilities to perform enhanced conflict resolution and flow management, collaborative rerouting, and automated ATC-flight deck trajectory negotiation (although the RTCA operational concept seems to potentially put this in capability in the Mature state (2010?)).

In summary, one may conclude that the multiple AERGA functionalities are generally supported as operational requirements of the future NAS with implementation timing that is relatively consistent between NASA, FAA, and RTCA planners. However, two potential problems exist. The first is that current FAA and RTCA plans do not specify their requirements in detail enough to distinguish between the requirements of different advanced conflict resolution capabilities such as CPTP, AT/ST, and AERGA. The second is that the FAA's "Expanded CDM Capability" seems to plan to provide collaborative weather rerouting capabilities (similar to AERGA?) starting in 1998, much earlier than that planned for AERGA.

3.3.11 Airborne Planner for Avoiding Traffic and Hazards (APATH)

The only cockpit-based AATT product, the Airborne Planner for Avoiding Traffic and Hazards, is currently planned to be the last AATT products implemented into the NAS. APATH provides strategic flight planning/user preferred trajectory generation, cockpit-based conflict detection and resolution, and display capabilities for pilots (with some potential AOC interfaces) to perform in-flight replanning to avoid traffic, hazardous weather, turbulence, terrain, special use airspace, and congested airspace. Based on current AATT product schedules[8, 9], APATH's Initial Operating Capability is estimated to occur in the 3rd quarter of fiscal year 2007.

From a functional standpoint, APATH's capabilities are ignored in the NAS Architecture 2.0 document, except for the mention of the development of a necessary cockpit display of NEXCOM digital datalink information. The FAA and RTCA operational concept documents each refer to uses of cockpit displays of traffic and weather and associated conflict detection and resolution capabilities. For instance, the FAA 2005 operational concept specifies the existence of traffic displays on the flight deck for use to enhance flight deck situational awareness and to enable pilot-based separation, the uplink and display of weather data and alerts to the flight deck, and the datalinking of user preferences (assumed to be generated on the flight deck?) to ATC. The RTCA operational concept goes into even more detail of how the flight deck can use cockpit displays of traffic and weather information for: Year 2000 enhanced situational awareness and CDTI-based aircraft station-keeping or merging, Year 2005 enhanced collision avoidance logic, improved cockpit weather data and hazardous weather alerts, "decision support systems to assist in conflict detection and the development of conflict resolutions", and Mature state cockpit self-separation and pilot-selected routes that are datalinked to "ATC and used in terminal-area decision support systems to provide appropriate sequencing".

From a temporal standpoint, APATH's IOC timing is somewhat mixed. APATH is implemented too late to satisfy the Year 2000 CDTI-based aircraft spacing, just right to use the 2005 initiation of NEXCOM digital datalink information , a little late for the enhanced cockpit conflict detection and resolution capabilities and improved weather data, display, and alerting of Year 2005, and a little early for Mature state free-maneuvering cockpit self-separation assurance.

In summary, the one may conclude that APATH's enhanced cockpit-based capabilities for detecting, displaying, and aiding in the resolution of traffic and weather conflicts are significantly supported by the FAA and RTCA operational concept plans. The current NASA implementation schedule for APATH is relatively well timed with the airspace user and air traffic service provider communities, although it is passing up chances at offering some useful capabilities that might be implemented earlier into the NAS (such as the CDTI-based aircraft spacing). However, two additional issues that may affect future APATH implementation that are ignored by current levels of FAA and NASA documentation are: 1) potential overlap with the evolution of already-fielded TCAS capabilities (which are not spelled out in any detail in NAS Architecture 2.0), and 2) the potentially collaborative (cockpit-with-ATC) nature to cockpit-based flight planning that current descriptions of APATH ignore.[6]

3.4 Analysis Summary and Issues

In this section, the previous analysis is summarized and significant AATT product implementation issues that have arisen during the analysis are discussed.

3.4.1 AATT Product Summary

In general, the results from the previous product-by-product, temporal transition analysis section can be summarized by stating that the AATT Products seem to be timed rather well to support current FAA/RTCA ATM evolution plans. In fact, the majority of the AATT products are planned for NAS implementation sooner than their respective operational concept functional requirement dates require. Specifically, the following AATT products make up a list of earlier-than-expected ATM decision support systems:

- Traffic Management Advisor
- Passive Final Approach Spacing Tool

- Passive Surface Movement Advisor
- Conflict Prediction and Trial Planner
- Enhanced Surface Movement Advisor
- Airspace and Sector Tool
- Advanced En Route Ground Automation.

The only AATT product that tends to stand out as providing capabilities significantly later than the aviation community might desire is APATH. Specifically, APATH's development and implementation of enhanced CDTI capabilities is too late to satisfy near-term operational concept-derived CDTI requirements for self-spacing in terminal airspace.

The relative timeliness of the AATT products aside, the explicit statement of requirements for future AATT product functionalities in the FAA/RTCA plans tend to be rather weak. First of all, the NAS Architecture 2.0 documents ignore most of the proposed AATT product functionalities. In fact, the only functionalities that the NAS Architecture 2.0 alludes to are those found with:

- Traffic Management Advisor
- Passive Final Approach Spacing Tool
- Passive Surface Movement Advisor
- Conflict Prediction and Trial Planner
- Enhanced Surface Movement Advisor.

Furthermore, even the FAA and RTCA operational concepts tend to be vague about the requirements and timing for specific AATT product functionalities. A good example of this is in the case of ATM decision support systems for improved conflict detection and resolution. The future AATT products targeted towards providing improved ATC conflict detection and resolution offer an evolutionary development approach from automated conflict detection and alerting of non-traffic-flow-managed aircraft and some "what-if" conflict resolution trial planning capabilities with CPTP to the conflict detection and alerting of traffic-flow-managed aircraft and cost-effective resolution advisories of AT/ST to the fully automated conflict detection and resolution capabilities of AERGA. On this topic of ATC decision support tool conflict detection and resolution improvements, the FAA and RTCA operational concepts tend to only speak in generalities, evidenced by the Year 2000 "ground-based conflict probe", Year 2005 "enhanced conflict probe and alerting" capabilities, and Mature State "ground-based conflict probe modified to allow for airborne procedures".

3.4.2 Additional Issues

In addition to the analysis of the fundamental temporal integrity of the current AATT product development schedules, a number of issues arose during the generation of this report that were deemed significant enough to bring to the attention of NASA and FAA research and development program managers. Described in the rest of this document, these issues are categorized by ones associated with the source documentation used for this report, and ones associated with potential NASA/FAA ATM research synthesis problems.

3.4.2.1 Source Documentation

During the analysis performed for this report, problems were identified that were related with the source documentation used. Specifically, important issues were identified with the operational concepts and the NAS Architecture 2.0 documents.

First of all, the temporal analysis of the AATT decision support systems tends to be rather difficult since, in the FAA and RTCA operational concepts, most of the functional information resides for a single time-period: that for Year 2005. Future operational concept development that defines the temporal evolution of specific NAS operational requirements with more detail, both functionally and temporally, will increase the fidelity of future NAS decision support system transition analyses.

Secondly, in addition to the apparent lack of FAA expectations for many AATT product functionalities to be implemented into the NAS, the NAS Architecture 2.0 treats two NAS functionalities in a very vague functional and temporal manner that are potentially very important to current NASA AATT technology and procedure development plans. These two future NAS functional components are the Traffic Alert and Collision Avoidance System (TCAS) and the NAS-wide Information System. Both of these components that might interface with future AATT products are not covered in detail in the NAS Architecture 2.0 documents. The intended evolution and implementation of these NAS components should be defined in more detail.

3.4.2.2 NASA/FAA ATM Synthesis

Also identified were three issues relating to inter-agency NASA/FAA ATM research coordination: one dealing with the current effort for NAS equipment modernization, another dealing with potential FAA-NASA ATM functionality overlaps, and the last dealing with future NAS decision support system implementation platforms.

The first ATM synthesis issue identified is the potential impact of the upcoming FAA NAS equipment modernization upgrades. Ignored in current AATT product descriptions is any mention of potential product functional or schedule dependence on specific current or future NAS equipment. During the timeframe of the research and development of AATT program products, there is currently in FAA plans the expectation of many NAS equipment upgrades to be implemented across the NAS. For instance, in the case of ARTCC facilities, over the life of the AATT program itself (through 2004), the FAA expects to begin to field: new controller display systems (DSRs) starting in 1998, new local area ARTCC computer networks (HID LANs) starting in 1999, new backup surveillance systems starting in 2001, new backup flight data processors starting in 2001, new ARTCC main computers (HCS replacements) starting in 2004, and new computer electronic interfaces (PAMRI replacements) starting in 2004. This plethora of new equipment could cause significant technical, budget, resource, and, therefore, schedule impacts on any AATT products that will be affected. Moreover, as the AATT program progresses and its products get more numerous and more widely implemented, the configuration management for such impacts will get progressively more difficult. This is an issue that both NASA AATT program management and FAA research and acquisitions management need to understand and plan accordingly.

A second ATM synthesis issue that was identified during the transition analysis was the potential for a number of ongoing FAA programs to overlap with the currently planned AATT products. These potential overlaps include the studies of:

1) “collaborative routing” hazardous weather avoidance by the FAA’s CDM program and NASA’s AERGA and APATH research efforts,

2) arrival slot swapping by the FAA’s “Free Scheduling” and NASA’s CAP and APATH research efforts,

3) cockpit-based displays of traffic and other information by the FAA’s TCAS and NASA’s APATH research efforts, and

4) advanced conflict probe capabilities by the FAA’s AERA/URET with NASA’s CTAS B3/CPTP.

These potential overlaps are issues that may offer significant opportunities for synergistic NASA and FAA-sponsored research as long as all parties involved are at least aware of the details of one another’s research scope and results.

Finally, the third ATM synthesis issue that was identified was the future "Common ATM Platform" planned by the FAA for both TFM and ATC DSSs. In the NAS Architecture 2.0 document, in section 2.2.11 on air traffic management decision support systems, the FAA states the expected development of "Common ATM Platforms" that transition ATC DSS programs to a common ATM DSS hardware suite that includes common operating systems and networks to begin implementation at the beginning of calendar year 2006[2]. None of the current NASA AATT product documentation mention such a future NAS hardware dependency. In order to avoid any adverse impacts of the development of this common ATM DSS hardware, both the FAA and NASA need to remain aware of the requirements behind the future ATM DSS hardware and ensure that FAA and NASA ATM DSS developers are both aware of its existence and able to provide technical feedback.

3.5 Recommendations for Future Work

In order to both improve the fidelity of the transition analysis performed in this report, and to improve the quality and consistency of NASA and FAA ATM research and development plans, it is recommended that three future efforts be undertaken.

First, the NAS Architecture 2.0 documents need to be upgraded with a closer coordination between NASA and FAA ATM decision support system planners. Unless there is NASA and FAA budget and technical coordination to smoothly continue the future development of NASA AATT products through full-scale development, the potential benefits that NASA products might provide to either the airspace users or the air traffic service provider will be adversely affected.

Second, the FAA and RTCA operational concepts need to be further refined from both a functional and a temporal standpoint. This refinement should occur in a way such that definitive, detailed improvements in NAS system-effectiveness be spelled out further and a finer-grained schedule for the implementation of these improvements be generated that will tie the detailed improvements to an updated NAS architecture schedule.

Finally, NASA should continue to produce their own understanding of the evolving NAS operational concepts and system architecture, especially in those areas that directly impact current and planned NASA ATM research efforts. Also, more details about AATT product dependencies on the evolving NAS infrastructure needs to be highlighted. At the time of the writing of this report, these NAS infrastructure requirements were only dealt with at a very high level in Reference 6, and need to be better understood by ATM program managers in order to reduce AATT programmatic risk.

4. AATT Product Description Additions & Review

4.1 Introduction

The last task in the mapping analysis of planned AATT ATM products to future NAS operational concepts involved the strengthening of the existing portfolio of AATT product descriptions. In order to improve the state of the existing documentation on AATT products, Seagull Technology performed two tasks. The first task involved the documentation of a number of additional AATT products that are mentioned on the AATT Product Schedule, Appendix B from Volume 2 of Reference 5, but for which no detailed description existed. The second task involved a third-party critique of the format of the existing AATT product descriptions from Reference 6. These two tasks are described and their results documented below.

4.2 AATT Product Description Additions

The first part of the strengthening of the AATT product descriptions involved writing up descriptions for four AATT surface products which did not have AATT researcher-approved existing documentation in the format established in Reference 6. These surface products were: Collaborative Departure Scheduling, Low/Zero Visibility Tower Tools, Surface Data Warehouse and Analysis Tools, and the National Surface Advisor Tool. To the best of the knowledge of the authors of this report, the first three surface products had had no previous AATT product description written about them. The last surface product is essentially a modification of the previously-generated description of the Enhanced Surface Movement Advisor.

In order to writeup the new descriptions, interviews of the appropriate NASA AATT product researchers were conducted, a product description following the format in Reference 6 was written, and the draft description was iterated on based on input from the interviewees and AATT surface product managers until a final description that was approved by all those involved was completed. The final resulting product descriptions follow in the next four sections which, for the sake of clarity, are included as appendices C-F of this report.

4.2.1 Collaborative Departure Scheduling

A description of the planned Collaborative Departure Scheduling surface product can be found in Appendix C.

4.2.2 Low/Zero Visibility Tower Tools

A description of the planned Low/Zero Visibility Tower Tools surface product can be found in Appendix D.

4.2.3 Surface Data Warehouse and Analysis Tools

A description of the planned Surface Data Warehouse and Analysis Tools surface product can be found in Appendix E.

4.2.4 National Surface Advisor Tool

A description of the planned National Surface Advisor Tool surface product can be found in Appendix F.

4.2.5 Final Recommendations

During the completion of the AATT product description writeups, it became apparent that there were more AATT-funded efforts that were not covered by an existing product description. These ongoing or future efforts included the Complex Airspace Adaptation Planner, the Active Surface Movement Advisor, the Surface Development Test Facility, the Atlanta Surface Testbed, and Distributed Air/Ground Traffic Separation, and it is recommended that AATT product descriptions should be written to cover these efforts.

4.3 AATT Product Description Review

Following the additional AATT product descriptions documented in the previous section, this section involves the critique of the AATT Product Descriptions, as presented in Appendix A in Volume 2 of Reference 5. The following points that comprise the critique are intended to be suggestions which would provide clarity and deeper content to the overall ATM operational concept definition. It is assumed here that the expression “ATM” is taken in its larger meaning – that of including all elements of the National Aviation System including the integrated functioning of all aircraft, airports, airline operational control facilities, CNS and weather auxiliary systems as well as the traffic management and advisory functions themselves.

In the following, general comments regarding the product descriptions formats and content, and their relationship to the rest of the two-volume document are first presented. This is followed by suggestions regarding specific content presented for each of the AATT products.

4.3.1 General Suggestions

The overall purpose of the product descriptions is to convey a general description of the specific products that the AATT Program will produce and how these products help fill specific needs to achieve the operational concept of free flight. The operational concept of free flight is summarized in Volume 1 of Reference 5. Sections 2 and 3 of Volume 2 present, in turn, the high level functional capabilities required to realize the free flight concepts of Volume 1 and how the AATT products map onto these functional capability requirements. Thus, the product Descriptions are intended to clarify and add depth to the reader’s understanding of the envisioned products, how they fulfill needs within the capability requirements of Section 2, and how they integrate with other components of the envisioned free flight system.

The following are suggestions for general revisions to Appendix A which would improve its presentation and fulfillment of purpose:

1. The introduction is redundant with earlier material and does not read like it is introducing a section to a larger document. It describes “efforts undertaken to date” rather that addressing specific needs of free flight. That is, it comes across as a collection of description of somewhat independent research efforts rather than being part of an integrated whole with an overall “free flight” theme. It mentions supporting R&D objectives of the FAA/NASA IAIPT rather than the earlier Introduction which describes the objectives of free flight.

   The document needs to explain better the interrelationships of the AATT products and how their combined efforts support the objectives of “free flight”.

2. The paragraph which describes how the material was developed based upon interviews with individual product development leads sounds like there is disconnect between the document authors and the product leads. “High level ambiguities, differences of opinion, and unassigned responsibilities” do not give the reader confidence in program management.

   Any disconnects that still exist between ongoing research efforts and the product descriptions need to be resolved and the product description text needs to be reflect this fact.

3. The Acronyms list should be merged with the more general list before Appendix A. Similarly, all the Reference lists should be merged into one.

4. On page 2 of Appendix A, there is a list of AATT Component Concepts that refers to old ideas in the 1996 NAR. This list is not consistent with the current document products and doesn't add clarity. The entire page as it currently is presented should be removed.
5. The products that have been largely completed under other programs - such as CTAS and SMA – should be grouped under a general background section that describes these products as building blocks for new AATT products. This includes the four products presented as TMA, P-FAST, SMA-1, and CPTP. It is clear from the schedule and product status presented in Appendix B, that these products are being wrapped up and handed off to the FAA rather than being new work. It may be useful to present these in a separate appendix.

   An alternative is to combine the extended products such as SMA-1 and SMA-2; P-FAST and A-FAST; CPTP, AT/ST, and AERGA; E-CDTI and APATH, etc. There does not appear to be a good reason to list them separately if they represent a continuum of effort with several deliverable builds of the same product family.
6. The new AATT products should be grouped in the airspace domains that they support so that there is a closer tie to the concepts and required capabilities mappings as presented in Sections 2 and 3. That is,

Flight Planning –	no AATT ground-DST products at this time
Surface –	SMA-2, A-SMA, LZVTT, SDWAT, NSAT
Terminal –	EDP, A-FAST, CAP, CDS
En Route –	AT/ST, AERGA
Integrated Flight Deck –	E-CDTI, APATH

   This arrangement should include the additional surface products Collaborative Departure Scheduling (CDS), Low/Zero Visibility Tower Tool (LZVTT), Surface Data Warehouse and Analysis Tools (SDWAT), and National Surface Advisor Tool (NSAT). These are described further in Appendices C-F.
7. A new section to the Appendix A introduction should be added that explains the purpose of each of the subsections in the product descriptions. The subsections recommended are:

   Problem statement - The capability requirement that the described product is fulfilling should be stated explicitly. Background material should be excluded since that is covered sufficiently in Volume 1 and is redundant here.

   Product description – The proposed solution and functional overview material into one description section for the product should be combined. This includes roles and responsibilities written in a way that describes how the ATM operation fulfilled will change from the baseline system of today. This can then be used to map out how operational viability of the product will be established. The stages of system functioning if several product prototypes are being planned should be included.

   Perceived benefit –Both user and service provider benefits should be described and will initially be qualitative statements. Later, as benefit analyses are completed, the content should become quantitative.

   Operational scenario – This is an anecdotal description of how the product is used in a short story form. It describes a sequence of events which illustrates the product being used and the activities of traffic manager, pilot, dispatcher and system components including that of the product.

   Information flow – The information flow between air and ground (ATC, TFM, AOC, and other service provider) components in an operation that uses the described product should be described in a way that is consistent with the operational scenario. The diagram should be in time line form and illustrate how the product is operationally used, the key decision and control points in the operation, and an overview of information content requirements that help define data link and other communications needs. These diagrams will also identify the related technologies/ATM components that interface to the product and point out required human interfaces.

Development status – The part of the AATT Program Gantt chart that is relevant should be included as well as tasks for (a) quantifying expected benefits and effects on safety; and (b) developing human factors and interface capabilities.

Each of the product descriptions should be rewritten to conform to this format.

8. The descriptive material for each product should be consistent with Level 3 plans. The Appendix material should be revised yearly as the product content evolves.
9. A general mapping of each of the products to the related Joint Research Project Descriptions should be done in a general section; this should not be repeated within each product description. Also, the products should be mapped to the FAA NAS Architecture description.
10. There is not a strong connection reflected in the product writeups between the research being planned and conducted to develop the ground DSTs and the flight deck research (E-CDTI and APATH). For free flight to work, this integration is vital and needs to be reflected in the overall plan and the part each product plays in following this plan.
11. Referring to the AATT Product Schedule in Appendix B, there should be corresponding sections to each line item in the schedule. Therefore, as plans firm up for Distributed Air/Ground Traffic Separation, etc., their products should be defined and written into this product description.
12. A set of objectives/tasks within either Concept Definition or Systems Engineering should be added to integrate each of the various products first within the context of AATT, second within the general NAS architecture, and third within a global CNS/ATM system.
13. The entire document should be checked for spelling errors and inconsistencies. For example, the “Designated Point of Contact” for Airspace and Sector Tools is not identified as the “AT/ST Development Manager”, but as the “CPTP Development Manager”. Also, “standard” product names should be chosen and used consistently within the product descriptions and product schedule. For example, in the product description section, Appendix A, CPTP is the “Conflict Prediction and Trial Planning Tool”, but in the product schedule, Appendix B, it is the “Conflict Prediction and Trial Planner”.

4.3.2 Specific Product Suggestions

The following suggestions are made with respect to each product listed in Appendix A.

4.3.2.1 TMA

1. The proposed solution section begins with history which is not needed.
2. By being used, the TMA changes the responsibility of the traffic manager. The statement “The TMA causes no change to the current responsibilities ...” does not reflect this fact. The traffic manager is responsible for making the best decision he/she can to facilitate expeditious flow of traffic. This includes using the best tools available for the job which implies that if the TMA provides superior information for doing the job, then the traffic manager should be responsible for using it. A similar statement can be made for each of the subsequent products.
3. The System Architecture Requirements section refers to providing optimal landing and meter fix crossing times. It should be added that this is based on an existing first-come, first-served criterion. Later versions will be more optimal, based on airline landing sequence needs and preferences.
4. AOC and TFM interfaces – It should be mentioned that these components need to be integrated with the TMA function in the future.

5. Current Status, Technology Readiness Level, and Expected End of Concept Development– Each section basically says that the project is over. So why is it included here? If it is not over, how is TMA related to the AATT milestones?
6. Overall - It is recommended that this product be removed from the AATT product list and described elsewhere as a building block or be combined with the CAP product.

4.3.2.2 P-FAST

1. The P-FAST description should include the hooks being provided to related technology. This includes an upgrade to A-FAST, use of weather from ITWS, use of the STARS console, and a future integration with SMA products.
2. As with TMA, the description says that the project is essentially over. So why is it included here?
3. Under the second paragraph of the Expected Course of Development section, P-FAST is described as being part of “CTAS-AOC collaborative decision making tool,” and will be integrated with “Arrival Automation-Departure Automation AOC Planner/Negotiator” and “Integrated Arrival-Departure-Surface Management Planner-Negotiator.” Since these are, at the very most, only mentioned once as AATT NAR “component concepts” that are confusingly related to other AATT products, the relationship of P-FAST to these other AATT products is very unclear.
4. Overall - It is recommended that this product be removed from the AATT product list and described elsewhere as a building block or be combined with the A-FAST product.

4.3.2.3 SMA-1

1. The Proposed Solution section is not explicit in terms of describing the solution. It is not readily understandable.
2. The benefits section is long and wordy for a qualitative statement.
3. The function - dynamic balancing of runways due to actual and predicted traffic loads – is redundant with the similar P-FAST function. Are they mutually exclusive, and how are they different?
4. Why is there no interface between SMA and TFM/CDM?
5. The tie of SMA-1 to its Related AATT Milestone is not clear.
6. The relationship between SMA-1 and its follow-on products, SMA-2, SMA-3, and NSAT is unclear and should be explained.
7. Overall - It is recommended that this product be removed from the AATT product list and described elsewhere as a building block or be combined with the SMA-2 product.

4.3.2.4 CPTP

1. Responsibilities - The air traffic controller’s responsibilities do change if the CPTP tool is adopted for regular use.
2. Functional questions - Why is use of data link not included in the functional description? How is uncertainty in aircraft trajectory prediction measured and handled? Why is Required Navigation Performance (RNP) not used as a relevant parameter? Why not use ADS-B instead of “advanced radar tracker?” Why are hooks for down link of weather measurements for better wind/temperature measurement and updates more rapid than 3 hours not included? (i.e., there should be flight deck and AOC interfaces).
3. What is the relationship of this product to the MITRE URET and previous AERA products? The Other Challenges section leaves the reader hanging.

4. The Expected Course of Development section refers to an evolution to AT/ST and other enhanced functionality. It is recommended that this product description be blended with AT/ST and AERGA writeups.
5. The Clearance Advisory Function section includes heading and speed control. What about altitude change control?
6. The last sentence of the Spacing Function section does not make sense.

4.3.2.5 AT/ST

1. The material in the first paragraph is redundant with earlier document material.
2. Second paragraph, third sentence: "For aircraft flying in environments that do not require traffic management..." This does not make sense. AATT is about environments that do require traffic management. Perhaps the document should specify "traffic flow management".
3. The Proposed Solution description of Sector Tool (ST) is vague. What is it?
4. According to the product description, the concept is not dependent upon DSR. Why not design AT/ST to take advantage of what DSR brings?
5. The Responsibilities section does not make sense. With these new tools, everyone using them will have new responsibilities.
6. Design of AT/ST should take advantage of data link, ADS-B, GPS, RNP, and FMS.
7. In the Other Challenges section, there may be a tradeoff of using the airspace coordinator (AC) position with being able to enlarge sector airspace and reduce other controllers needed.
8. It is recommended that the Expected Course of Development section be tied to a Gantt chart to explain the timing and relationship of development phases and associated product builds. The CPTP material should be absorbed into this description.

4.3.2.6 AERGA

1. Unclear functionality - The description is confusing in that it describes absorbing the CTAS Descent Advisor technology and coordinating with adjacent facilities. These were also included as part of the ST description. The Metering Clearance Advisories section seems to be totally redundant with ST functions. The Interfacility Operations section seems to be part of the AT function.
2. Perhaps separate AERGA from AT/ST by focusing AERGA on cooperative air-ground separation, negotiated trajectories, and conflict resolution. It is recommended that there be a strong tie in with E-CDTI and APATH products and the FAA's FMS-ATC Next Generation (FANG) project.
3. The Benefits section is vague in meaning.
4. Again, as in the case of AT/ST, it is recommended that data link, ADS-B, etc., should be used to the fullest extent and AERGA should not be tied to an advanced radar tracker. Also, there should be a direct flight deck interface in this product.

4.3.2.7 A-FAST

1. The Baseline System Function section states that A-FAST results from a number of software functionalities developed for P-FAST and are described. Thus, these functionalities are part of P-FAST. Describe explicitly what is A-FAST?
2. There may be advantages to including the use of data link to send A-FAST advisories to an FMS that drives an autopilot. This should be included in the concepts explored, and a tie to the E-CDTI and APATH work is appropriate.
3. AOC and TFM could use landing sequence and runway assignment information to improve their decision support systems.

4. General – It is recommended that P-FAST material be absorbed into this product so it will be seen as a continuum.

4.3.2.8 EDP

1. There could be a tie in between EDP and the flight deck FMS through data link. This would provide the EDP tool with a more accurate estimate of the aircraft climbout path. This, in turn, would enhance conflict prediction. This lack of being able to predict climb paths was a known shortcoming of the AERA program conflict prediction process.

4.3.2.9 SMA-2

1. The Problem Statement does not state the problem that requires “numerous future improvements and enhancements” to SMA-1.
2. It is recommended that SMA-1, SMA-2, NSAT, and SMA-3 be combined into a continuous program description with several builds.
3. There seems to be redundancy with P-FAST in the System Function description (e.g., “dynamic balancing of runways due to actual and predicted traffic loads”).

4.3.2.10 CAP

This is a good writeup in that it contains all the relevant information to describe the project and its expected products, consistent with the current stage of development.

4.3.2.11 E-CDTI

1. It is recommended that the E-CDTI product description be expanded to include its use by the AOC for more strategic routing changes to avoid conflict; include its capabilities to assist in avoiding severe weather, regions of dense traffic, SUA, terrain, and obstacles; provide a data link, navigation information and flight planning; include its integration into a general multifunction map display.
2. The development of E-CDTI should include research into using the primary flight display (PFD) for CDTI functions.
3. E-CDTI development should introduce the use of ADS-A/B, RNP, strategic conflict detection, and many other uses of CDTI besides situational awareness to enable conflict detection and resolution. Examples include merging, spacing, station keeping, coordinated path crossing and passing maneuvers.
4. The benefits list should be accordingly expanded beyond improved separation assurance.
5. E-CDTI development should also develop a baseline system for non-FMS equipped aircraft including general aviation and helicopters.
6. Mode S should not be assumed to be the ADS-B medium; it is very limited and may not survive as a technical option. At least two other candidates (STDMA using VHF and UAT using UHF/L band) are being tested. Satellite communications may also provide an appropriate communications medium.
7. Certainly controllers and perhaps dispatchers (for strategic decision making) will have roles in interacting with aircraft having enhanced traffic displays. Therefore, the appropriate interfaces between E-CDTI and controller and dispatcher decision support systems should be defined.

4.3.2.12 APATH

1. It is recommended that the proposed solution description be expanded to include the use of AOC, ground flight dispatch centers, or flight service stations in computing the optimum user preferred trajectories.
2. “TCAS” is the Traffic Alert and Collision Avoidance System, not the Traffic Collision Alerting System.

3. The APATH overall concept should include three two-way information exchange processes : pilot-controller, pilot-dispatcher, and dispatcher-controller.
4. The Responsibilities section should be rewritten to include changed responsibilities in collaborative shared decision making process involving pilot, dispatcher, and controller.
5. The role of data link should be brought in to facilitate information sharing to enable this concept. The CNS requirements go beyond the ADS-B transmissions.
6. There is certainly a Controller Interface requirement implied by this product/service.

4.3.2.13 Human Factors Sections

1. The benefits assessments should be expanded beyond that for safety. Safety must be maintained but the larger need of the AATT Program is to increase operational efficiency for the airspace user and to increase productivity for the service provider. The tradeoffs between safety and increased efficiency and productivity should be examined.
2. The Human/System Interface section should be expanded and rewritten to include the role of developing specifications for computer-human interface (CHI) devices for traffic controller/manager, flight crew, and dispatcher. This work should not be constrained to be just "development tools" without the direct role in designing future NAS operations.
3. Throughout the section, the roles of flight crew and dispatcher should be included. As written, this area seems restricted to that of traffic controller/manager.

4.3.2.14 SatComm Study

This is the beginning of a valuable study. However, it should be published as a separate technical report and referenced as appropriate. It has no direct role in this AATT Concept of Operations report. The same can be said for other technology surveys that have been conducted or will be funded and conducted with AATT resources.

4.3.2.15 Appendix B: AATT Project Schedule

1. This schedule needs to be consistent with the product descriptions and the rest of the report. Certain tasks and projects remain to be filled in.
2. As mentioned previously, specific timelines from this master schedule can be used within each of the product descriptions to convey a clearer idea of the milestone status and when deliverables can be expected.

Acronyms/Glossary

3D	Three-dimensional
4D	Four-dimensional
AATT	Advanced Air Transportation Technologies
ACARS	Aircraft Communications Addressing and Reporting System
ADL	Aggregate Demand List, a CDM product
ADS	Automatic Dependent Surveillance System
ADS-A	An Automatic Dependent Surveillance System concept involving airspace user transmission of aircraft position to air traffic control
ADS-B	Automatic Dependent Surveillance System - Broadcast, An ADS concept involving airspace user transmission of aircraft position to air traffic control and other local airspace users
AERA	Automated En Route Air Traffic Control
AERGA	Advanced En Route Ground Automation, an AATT Product
A-FAST	Active Final Approach Spacing Tool, an AATT Product
AIRMET	A weather advisory of meteorological activity that is hazardous to small aircraft.
AOC	Airline Operational Control
APATH	Airborne Planner for to Avoid Traffic and Hazards, an AATT Product
APMS	Aviation Performance Measuring System
ARSR	Area Route Surveillance Radar
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
ASC	FAA’s System Capacity Office
ASOS	Automated Surface Observation System
ASR	Airport Surveillance Radar
ASR-WSP	Airport Surveillance Radar - Windshear Processor
ATC	Air Traffic Control
ATCBI	Air Traffic Control Beacon Interrogator
ATCT	Air Traffic Control Tower
ATIS	Automated Terminal Information System
ATL	Atlanta-Hartsfield International Airport
ATM	Air Traffic Management
AT/ST	Airspace and Sector Tool, an AATT Product
ATS	Air Traffic Services
AvSP	NASA’s Aviation Safety Program
AWOS	Automated Weather Observation System
B1/B2/B3	Build 1/ Build 2/ Build 3
CAP	Collaborative Arrival Planning, an AATT Product
CASA	Controller Automation Spacing Aid
CD	Concept Development
CDC	Computer Display Channel
CDM	Collaborative Decision Making, an FAA program
CDS	Collaborative Departure Scheduling, an AATT product
CDTI	Cockpit Display of Traffic Information
CE	Concept Exploration
CFIT	Controlled Flight Into Terrain
CHI	Computer-Human Interface
CONUS	Contiguous United States
CORBA	Common Object Request Broker Architecture
CNS	Communication, Navigation, and Surveillance
CPTP	Conflict Prediction and Trial Planner, an AATT Product

CTAS	Center-TRACON Automation Tool
CY	Calendar Year
DBRITE	Digital Bright Radar Indicator Tower Equipment
DEDS	Data Entry and Display Subsystem
D-GPS	Differential Global Positioning System
DL	Datalink
DME	Distance Measuring Equipment
DOD	Department of Defense
DSP	Departure Sequencing Program
DSR	Display System Replacement
DSS	Decision Support System
DST	Decision Support Tool
E-CDTI	Enhanced Cockpit Display of Traffic Information, an AATT Product
EDARC	Enhanced Direct Access Radar Channel
EDP	Expedite Departure Path, an AATT Product
EGPWS	Enhanced Ground Proximity Warning System
E-PIREP	Electronic Pilot Weather Report, an electronically-broadcast pilot weather report
ETMS	Enhanced Traffic Management System
FAA	Federal Aviation Administration
FBO	Fixed Base Operator
FD	Flight Deck
FDAD	Full Digital ARTS Display
FDIO	Flight Data Input Output
FDP	Flight Data Processor
FIDS	Flight Information Display System
FIS	Flight Information Service
FIS-ATIS	Flight Information System-Automated Terminal Information System
FL	Flight Level (in 100’s of feet altitude)
FMS	Flight Management System
FP	Flight Plan
FSD	Full-Scale Development
ft	Feet
FY	Fiscal Year
GA	General Aviation
GDP	Ground Delay Program
GLONASS	Global Navigation Satellite System
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
HID LAN	Host Interface Device Local Area Network
IAIPT	Interagency Integrated Product Team, an existing FAA/NASA ATM R&D steering committee
IBLS	Integrity Beacon Landing System
ICAO	International Civil Aviation Organization
ID	Identification
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
IOC	Initial Operating Capability
IPT	Integrated Product Team
ITWS	Integrated Terminal Weather System
JRPD	Joint Research Project Description, a high-level research summary of planned FAA and NASA ATM research
kt	Knot = 1 nautical mile per hour
LAAS	Local Area Augmentation System

LAN	Local Area Network
LZVTT	Low/Zero Visibility Tower Tools, an AATT product
METARS	Aviation Meteorological Forecasts
MFD	Multi-Functional Display
MLS	Microwave Landing System
MSSR	Monopulse Secondary Surveillance Radar
MWP	Meteorologist Weather Processor
NAR	Non-Advocate Review, an official NASA programmatic review
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASWIS	NAS-wide Information System
NDB	Non-Directional Beacon
NEXCOM	Next Generation Air/Ground Communications System
NFIDS	National Flight Information Display System
nmi	Nautical mile
NOTAM	Notice to Airmen
NSAT	National Surface Advisor Tool, an AATT product
OAG	Official Airline Guide
OOOI	gate-Out, wheels-Off, wheels-On, and gate-In flight times
PAMRI	Peripheral Adapter Module Replacement Item
PC	Personal Computer
P-FAST	Passive Final Approach Spacing Tool, an AATT Product
PFD	Primary Flight Display
PIREP	Pilot Weather Report
PPPD	Pre-Production Prototype Development
PVD	Plan View Display
R&D	Research and Development
RADS	Radar and Alphanumeric Display Subsystem
RNAV	Area Navigation
RNP	Required Navigation Performance
RTA	Required Time of Arrival
RVR	Runway Visual Range
SDTF	Surface Development Test Facility, a planned virtual ATCT simulator
SDWAT	Surface Data Warehouse and Analysis Tools
SID	Standard Instrument Departure
SIGMET	A weather advisory of significant meteorological activity
SMA	Surface Movement Advisor
SMA-1	Passive Surface Movement Advisor, an AATT Product
SMA-2	Enhanced Surface Movement Advisor, an AATT Product
STAR	Standard Terminal Arrival Route
STARS	Standard Terminal Automation Replacement System
STDMA	Self-Organizing Time Division Multiple Access
SUA	Special Use Airspace
S/W	Software
TACAN	Tactical Air Navigation
TBD	To Be Determined
TCAS	Traffic Alert and Collision Avoidance System
TCP/IP	Transmission Control Protocol/Internet Protocol
TDWR	Terminal Doppler Weather Radar
TFM	Traffic Flow Management
TMA	Traffic Management Advisor, an AATT Product
TMC	Traffic Management Coordinator
TMS	Traffic Management System
TMU	Traffic Management Unit

TRACON	Terminal Radar Approach Control
TRL	Technology Readiness Level
TRL-6	Technology Readiness Level 6, the assumed end of ATM concept development when NASA technologies are transferred to the FAA
TWDL	Two-Way Datalink
UAT	Universal Access Transceiver
UHF	Ultra High Frequency
UPR	User Preferred Route
UPT	User Preferred Trajectory
URET	User Request Evaluation Tool, a MITRE conflict probe tool
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VNAV	Vertical Navigation
VOR	VHF Omni-directional Range
VORTAC	VOR collocated with TACAN
VRML	Virtual Reality Modeling Language
WAAS	Wide Area Augmentation System
WAN	Wide Area Network
WARP	Weather and Radar Processor

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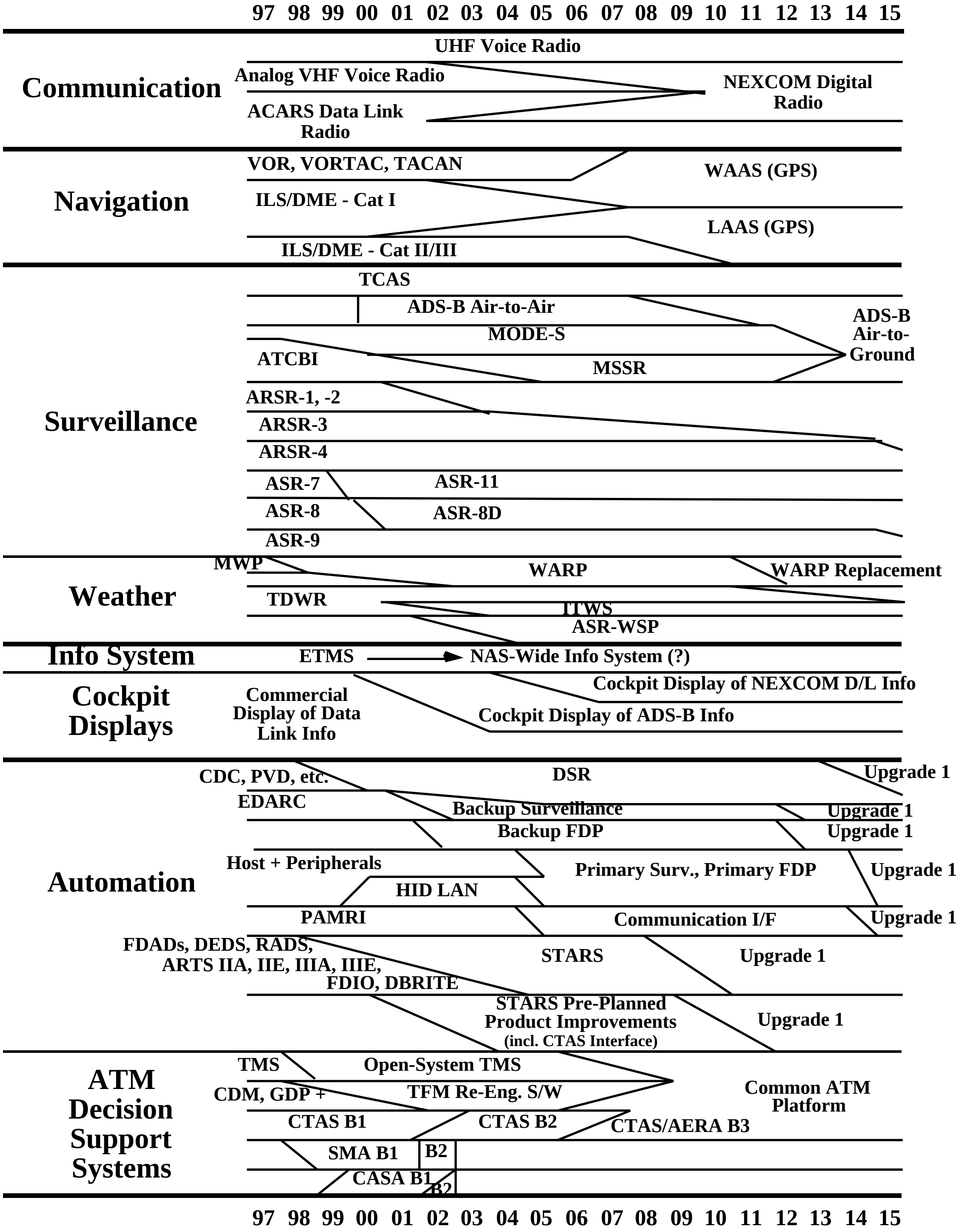
Appendix A: En Route and Terminal National Airspace System Architecture Evolution



*Federal Aviation Administration, *National Airspace System Architecture*, Version 2.0, FAA Office of Systems Architecture and Program Evaluation, Washington DC, October 1996.

Appendix B: AATT Product Development Schedule

(Compiled from References *, ** below)

Acronym	Product Start Date (FY)	End of CE (FY)	End of CD (FY)	End of PPPD (FY)	End of FSD (FY)	IOC Date (CY)
TMA			**1Q97**		**3Q00**	**2000**
P-FAST			**1Q98**		**3Q01**	**2001**
SMA-1			**1Q98**		**3Q01**	**2001**
CPTP			**4Q98**		**2Q02**	**2002**
SMA-2	**3Q97**	**1Q99**	**4Q99**		**2Q03**	**2003**
AT/ST		**1Q98**	**1Q01**		**3Q04**	**2004**
EDP	**2Q97**	**3Q00**	**3Q02**		**1Q06**	**2005**
A-FAST		**3Q00**	**3Q02**		**1Q06**	**2005**
CAP	**1Q97**	**1Q00**	**3Q02**		**1Q06**	**2005**
AERGA		**1Q99**	**4Q02**		**2Q06**	**2006**
APATH	**1Q97**	**1Q01**	**1Q04**		**3Q07**	**2007**

Note: Dates are for 1st day of the corresponding quarter

CE = Concept Exploration
CD = Concept Development
PPPD = Pre-Production Prototype Development
FSD = Full-Scale Development
IOC = Initial Operating Capability
IOC/End of FSD = End of CD + 3.5 years
FY = Fiscal Year
CY = Calendar Year

*NASA-Ames AATT Project Office, “AATT Program Development Schedule & TRL Projections,” June 5, 1997.

**Tucker, George, private communications regarding AATT Product Development Schedule, NASA Ames Research Center, September 20, 1997.

Appendix C: Collaborative Departure Scheduling

C.1 OBJECTIVE

C.1.1 Background/Problem Statement

Recent records of air traffic delays in the National Airspace System (NAS) (see Ref. 1) identify the taxi-out phase of flight as the single phase of flight where most delays are experienced by airspace users. Efforts to shed light on the reasons for these delays (see Ref. 2) identify many causes including: too many flights prepared to depart at the same time; limited controller planning capabilities due to insufficient ground surveillance information, high workload and a lack of planning aids; complex ground movement interactions between departing, arriving, and relocating aircraft; a lack of knowledge shared across the major ground movement control authorities (i.e., pilots, airlines, ramp tower controllers, and air traffic controllers) and TRACON controllers; and limited departure queue sequencing options and control that result from limited airport areas for taxiing.

Additionally, the inability of the airlines to assign prioritizations to individual flights results in these air traffic delays adversely affecting schedule and flight passenger connections, and thus, the economic costs of these delays more than necessary.

With forecasted future air travel demands and limited increases in capacity, these delays and their costs will likely increase with time.

C.1.2 Proposed Solution

In order to research potential solutions to these taxi-out air traffic delay problems, the Federal Aviation Administration (FAA) and the National Air and Space Administration (NASA) are working together to develop new operational concepts, procedures, and technologies under the Collaborative Departure Scheduling program (CDS). This program plans to develop new joint airline/ramp control/air traffic control (ATC) taxi procedures and necessary information technology to increase ground movement efficiency for departing aircraft.

As currently envisioned, these new procedures and technologies will increase ground situation information sharing amongst the airlines, ramp controllers, and air traffic controllers, and they will involve both optimization of departure sequences for maximum airport throughput and integration of departing aircraft movements with those of arriving aircraft and relocating aircraft. Potential CDS concepts are just starting to be formulated and span the spectrum from increased information exchange to automated, expert controller advisory systems.

C.1.3 Expected Benefits

The new procedures and technologies developed by the Collaborative Departure Scheduling program have the potential to benefit the major NAS stakeholders impacted by ground movement efficiency: the airspace users (especially the airlines), the flying public, airport authorities, and the air traffic management service provider (i.e., the FAA air traffic controllers). The major benefits that might accrue to these NAS stakeholders fall into the categories of safety, capacity and delay, flight efficiency, and operational productivity.

If successfully implemented, these new procedures and technologies should benefit all of these stakeholders by enhancing safety. These safety improvements may result from at least two causes: 1) improving ground situational awareness by facilitating airline dispatcher/ramp controller/air traffic controller intent and information sharing, and 2) reducing ATC workload by reducing ground control frequency congestion.

The enhanced information transfer across all authorities that control departure aircraft ground movements and departure sequence optimization that will result from the Collaborative Departure Scheduling program should also result in significant airport capacity increases that will increase aircraft throughput and both reduce aircraft delays and increase flight efficiency.

Also, the more efficient procedures and new technologies produced by the CDS program may increase the operational productivity of the airline dispatchers, ramp controllers, and air traffic controllers. By having a better ability to coordinate control decisions and predict future ground movements, the dispatchers and controllers should be able to reduce the number of clearances that they have to issue, freeing them up to either handle more aircraft movements and/or extending their ability to perform additional tasks, such as more strategic planning.

C.1.3.1 Airspace User Benefits

Specifically, the airspace users should benefit from the CDS program through reduced ground delays which will result in reduced direct operating costs and increased schedule integrity, and reduced airline dispatcher workload that may result in increased flight handling capabilities.

C.1.3.2 Air Traffic Service Benefits

The air traffic service provider should benefit from the CDS program through increased airport capacity that will allow increased aircraft throughput, more efficient management of the surface and queuing of departing aircraft, and the potential for reduced ATC ground controller workload which may increase the air traffic handling capability for ATC ground controllers.

C.1.4 Related Joint Research Project Descriptions (JRPD)

J31 – Airport Surface Management Technologies

C.2 FUNCTIONAL OVERVIEW

C.2.1 Roles

The future operational concepts that result from the CDS program will unlikely alter the current roles of the airline dispatcher, ramp controllers, and ATC ground controllers.

C.2.2 Responsibilities

However, these future operational concepts may likely alter the responsibilities of the airline dispatcher, ramp controllers, and ATC ground controllers. Specifically, airline dispatchers may be allowed to prioritize individual flights for departures and the collaborative nature of future pushback, ramp movement, taxi-out, and departure clearances will require new information transfer and clearance procedure responsibilities for the major control authorities involved.

C.2.3 System Function

The new CDS procedures and technologies that will be developed should enable increased information sharing, ground movement sequencing optimization, and irregular operations departure scheduling improvements.

The increased information sharing will involve dissemination of critical data important to enabling more efficient departure ground movement strategies (e.g., estimated times of arrival, airline flight priorities) amongst the major departure ground movement control authorities.

Ground movement sequencing optimization will involve the consideration of improved air traffic sequences, taxiway and runway allocation, and interactions of arrivals and relocating aircraft in establishing coordinated pushback, ramp movement, taxi-out, taxi-in, and takeoff clearances. Some of the options here include the use of virtual taxi queues, slot-swapping, groupings of similar aircraft wake vortex categories, and priority-based pushback clearances. The integration of

CDS with the Center-TRACON Automation System and the Expedite Departure Path tools that predict air traffic trajectories in the TRACON airspace for arrivals and departures, respectively, would help to generate coordinated ground and airspace air traffic movements.

Irregular operations departure scheduling improvements will involve the coordination of the departure ground movement control authorities to tailor departure schedules to maximize throughput under the irregular conditions of airport configuration changes, runway closures, and hub airport destination closures. Such concepts may also be applied to the sequencing of other airborne air traffic flows towards other constrained resources such as runways and holding fixes. In addition, CDS may develop new functionalities to handle the rescheduling of aircraft impacted by the closure of a destination hub airport. Moreover, CDS may also assist in the optimization of runway split changes by identifying the airport runway split that will maximize airport ground movement throughput and the determination of the proper departure ground movement sequencing to respond to such a runway split change.

C.3 APPLICABILITY

C.3.1 User Classes

Only air carriers and air taxi airspace user classes with airline operational control centers at major airports will be affected by the CDS program. General aviation, military aircraft, and air carriers and air taxi airspace user classes without airline operational control centers will not be affected by planned CDS operational concepts.

C.3.2 Flight Rules

CDS operational concepts will affect flights irrespective of whether they are flown under visual flight rules or instrument flight rules.

C.3.3 NAS Domains

CDS operational concepts will apply to ground movements at major airports.

C.3.4 Worldwide Domains

Applicability of CDS operational concepts beyond CONUS domains is TBD.

C.4 SYSTEM ARCHITECTURE REQUIREMENTS

C.4.1 Aircraft Equipage

No necessary aircraft equipage is currently envisioned for the implementation of CDS.

C.4.2 Communication, Navigation, and Surveillance (CNS)

No communication, navigation, or surveillance systems are currently required for the implementation of CDS.

C.4.3 Air Traffic Facility

Also, the communication infrastructure of SMA Build 2 is desirable for CDS implementation. Integration of SMA Build 2 with CTAS will enhance the effectiveness of CDS through more precise knowledge of future arrival aircraft.

C.4.4 Weather

Weather information such as visibility, ceiling, and surface wind data and forecasts will be required for the runway split change optimization and any CDS functionality that intends to handle the rescheduling of aircraft impacted by the closure of a destination hub airport.

C.5 HUMAN/SYSTEM INTERFACE

C.5.1 Flight-Deck Interface

No flight-deck interface is currently envisioned for CDS, but one may be added in the future.

C.5.2 Controller Interface

The CDS controller interface is TBD and will depend on the development of specific CDS operational concepts.

C.5.3 Airline Operations Center (AOC) Interface

The CDS airline dispatcher interface is TBD and will depend on the development of specific CDS operational concepts.

C.5.4 ATM Flow Control Interface

The CDS ATM flow controller interface is TBD and will depend on the development of specific CDS operational concepts.

C.6 DEVELOPMENT STATUS

C.6.1 Previous Tool Functionality History

Improved airport departure sequencing concepts were investigated and developed previously by the FAA under the Departure Sequencing Program (DSP). This program investigated improved departure control schemes by air traffic controllers, but ignored any collaboration with the airlines and ramp controllers.

Members of NASA's research staff initiated CDS concept exploration activities in June 1997 by interviewing ground air traffic control research experts and they analyzed airport ground delay causes (documented in Ref. 2).

C.6.2 Current Status

Currently, NASA's research staff are interviewing air traffic controllers about potential CDS ground movement delay reducing operational concepts that would be feasible, beneficial, and acceptable. In addition, the research staff is being assisted by Ohio State University staff who are interviewing airlines about such potential CDS operational concepts.

C.6.3 Technology Readiness Level:

1: Basic principles observed and reported

C.6.4 Expected End of Concept Development:

According to Reference 3, concept development of CDS will be complete by June 2000.

C.6.5 Related AATT Milestone(s):

Milestone 6.12.5, "Evaluate user-collaborative taxi queuing tool," 2Q FY01 (Ref. 4)

C.6.6 Expected Course of Development

Once potentially-successful CDS delay reduction strategies are formulated, studies will be designed and conducted to evaluate the potential delay reduction benefit. As long as significant potential benefits are identified, prototype software and hardware development will be designed and implemented to distribute the necessary information. Human factors expertise will be used to assist in designing necessary CDS graphical user interfaces. Then, rapid prototyping of the CDS procedures and technologies will be conducted with the assistance of a System Development Team with airlines and controllers. Simulation of CDS concepts are expected to be performed in air traffic simulations in the Surface Development Test Facility (SDTF). Technology development during CDS is expected to include the development of controller assistant technologies, intelligent agents, and agents with imbedded learning systems.

Once CDS is successfully developed for an initial airport, it will be adapted by the FAA to additional airport sites.

According to Reference 3, CDS concept development is expected to begin in June 1999, pre-production prototype development is expected to begin in June 2000, and the beginning of full-scale deployment is expected for December 2002.

C.7 DEVELOPMENT CHALLENGES

C.7.1 Technical Challenges

- High uncertainty in future ground movements (due to ability for aircraft to halt movement and a myriad of passenger, airline, ATC, and weather causes) will limit predictive capabilities of surface movement tools.
- Because of wide variation in major airport layouts, airspace users, ramp control authorities, and departure control strategies employed, site specification of CDS algorithms will be labor-intensive.

C.7.2 Other Challenges

- Because of the enhanced user flexibility of CDS algorithms, new ground movement procedures will need to be tested for potential system gaming schemes that might be used by the airspace users.
- Proprietary airspace user and sensitive air traffic service provider data will have to be properly handled.

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TOOL DEVELOPMENT RESPONSIBILITIES

Development Site(s)

NASA Ames Research Center
Information Systems Directorate

- SMA Project Office

Points of Contact

- Designated Point of Contact:
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  SMA Project Office
  Collaborative Departure Scheduling POC
  (650) 604-4234

- Alternate Point(s) of Contact:
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  SMA Project Office
  SMA Project Manager
  (650) 604-5012

Appendix D: Low/Zero Visibility Tower Tools

D.1 OBJECTIVE

D.1.1 Background/Problem Statement

At major airports when visibility decreases significantly, situational awareness is hampered, and thus, the ability for air traffic controllers to safely provide aircraft movement clearances and monitor separations decreases. This decreased air traffic handling capability by the air traffic control tower controllers results in significant reductions in vehicle throughput on the ground and in the air which, under the airport condition of high traffic loadings, results in significant aircraft movement delays.

In addition to low visibility conditions, the situational awareness of air traffic control tower controllers can be adversely impacted by a number of other situations including: at night due to a “sea-of-lights” visual acuity problem, at any time for “hidden” parts of the airfield (especially certain ramp areas) due to air traffic control tower positional constraints, and the requirement of too much heads-down time with new safety-related automation systems with interior displays.

D.1.2 Proposed Solution

One potential solution to this reduced situational awareness is the use of 3-D synthetic, moveable-eyepoint displays of the airport and aircraft-related information by air traffic control tower (ATCT) controllers and ramp controllers. These displays are being developed using contemporary software technologies that offer the potential to replace current, high development and maintenance cost air traffic management (ATM) software architectures and technologies. These technologies are currently being researched by NASA Ames researchers under the Low/Zero Visibility Tower Tools (LZVTT) effort in NASA’s Advanced Air Transportation Technologies program.

Preliminary concepts envisioned as part of the LZVTT research program include (as mentioned in Reference 1): Low/Obstructed Visibility Enhancement - a limited synthetic view over a part of the airport surface that functions under many low visibility conditions, and Zero Visibility Tower Environment - a full-scale “virtual tower cab” system that provides synthetic surveillance over the entire airport surface and can be continuously used under both visual and instrument meteorological conditions.

D.1.3 Expected Benefits

The new ATCT display technologies to be provided by LZVTT research should benefit the major National Airspace System (NAS) stakeholders that are impacted by major airport ground movement efficiency. These stakeholders include the air traffic management service provider (i.e., the FAA air traffic controllers), the airspace users, ramp control authorities (often airport authorities), and the flying public. The major benefits that may accrue to these NAS stakeholders fall into the categories of safety, capacity and delay, flight efficiency, operational productivity, and reduced capital and maintenance costs.

All of the NAS stakeholders should benefit from the increased safety (e.g., reduced aircraft-aircraft surface accidents, reduced runway incursions) under low visibility conditions that would result from the enhanced air traffic controller situational awareness.

The enhanced situational awareness may also allow air traffic controllers to handle more aircraft under the low visibility conditions which may lead to increased low visibility airport capacities, with the resulting increases in aircraft throughput and reductions in aircraft delays. Such capacity and delay improvements, like the increased safety, should benefit all of the aforementioned NAS stakeholders.

Improved flight efficiencies, benefiting all the above NAS stakeholders, may also result from more efficient taxiway clearances that could be planned and delivered based on better low visibility surveillance information.

Finally, the air traffic management service provider (and the U.S. taxpayers) and ramp control authorities would benefit from both increased operational productivity that would result from both the enhanced air traffic control handling capability and potential for reduced ATCT and ramp control staffing requirements enabled by the LZVTTs and the reduced capital and maintenance costs that may be required. These capital costs may be reduced by consolidating multiple ATCT or ramp facilities for a single airport and, if LZVTTs are highly successful, the potential removal of airfield-collocated control towers or ramp towers to lower cost facility locations. Air traffic management software maintenance costs may be reduced through the use of Java and World-Wide-Web software technologies that offer platform portability and low software design, upgrade, and maintenance cycle times.

D.1.3.1 Airspace User Benefits

All airspace users (air carrier, air taxi, general aviation, and military) at the major airports where LZVTTs will be fielded will be benefited by the improved ground safety, increased low visibility ground throughput, and improved flight efficiencies enabled by the LZVTTs.

D.1.3.2 Air Traffic Service Benefits

The NAS stakeholder most benefited by the use of the LZVTTs will be the air traffic management service provider. Using the LZVTTs have the potential for providing many different types of benefits for the air traffic management service provider that include:

1) Improved safety through the use of more optimal controller view angles enabled by the LZVTT’s ability to place controller viewpoints anywhere in 3-D space,
2) Increased safety by resolving the nighttime ATCT “sea of lights” problem through LZVTT’s aircraft image enhancement,
3) Increased safety through the reduction of controller workload by reducing the amount of head-down time through the use of LZVTT overlays and heads-up displays,
4) Increased capacity and reduced delay by improving low visibility air traffic controller traffic handling capabilities,
5) Improved controller productivity through increased air traffic handling capabilities enabled by LZVTTs,
6) Potential to reduce the future increase of controller staff costs to handle the forecasted increases in air traffic operations through the increased air traffic handling capabilities enabled by LZVTTs,
7) Lower air traffic management capital costs by reducing the number of separate control towers necessary to handle traffic for the entire airport surface (and potentially to move the ATCT facility to a lower cost non-airport-collocated location) that would be possible given the remote synthetic vision capabilities enabled by LZVTTs,
8) Lower air traffic management software design, upgrade, and maintenance costs through the use of Java and World-Wide-Web technologies that offer faster and less-intensive software engineering efforts.

D.1.4 Related Joint Research Project Descriptions (JRPD)

J33 – Low/Zero Visibility Tower Environment

D.2 FUNCTIONAL OVERVIEW

D.2.1 Roles

The future use of LZVTTs will unlikely alter the current roles of the air traffic control tower ground and local controllers and ramp controllers.

D.2.2 Responsibilities

The future use of LZVTTs will unlikely change the current responsibilities of the air traffic control tower ground and local controllers and ramp controllers.

D.2.3 System Function

LZVTTs will provide user-selectable displays of 3-D airport ground movements under both visual and instrument meteorological conditions. These LZVTTs will consist of prototype automation software and hardware, algorithms, display hardware and controller input devices. The LZVTTs will include new sensor fusion and interface software that will be able to serve multiple client types.

Input data to these displays will be FAA Level-D certified Visual Databases (e.g., 3-D airport maps), aircraft (and ground vehicle?) position information, and vehicle identification information. Useful output display media are currently under research, and include color video display terminals, large flat-panel displays, heads-up displays, and virtual reality goggles and glove units.

Early on, the emphasis of LZVTT research will be on the synthetic display of airport movement information and controller input devices and control functions. Later, if it proves to be feasible and useful, LZVTTs may incorporate playback functions and ground movement conflict detection and alerting capabilities (to possibly include vehicle-vehicle proximity, vehicle-ground surface proximity, ground clearance conformance, and ground clearance conflicts).

D.3 APPLICABILITY

D.3.1 User Classes

All airspace user operations at major airports.

D.3.2 Flight Rules

LZVTTs will operate during VMC and IMC, so both VFR and IFR traffic will be affected.

D.3.3 NAS Domains

Only major airport surfaces will be impacted (not TRACON airspace).

D.3.4 Worldwide Domains

Applicability beyond CONUS domains is TBD.

D.4 SYSTEM ARCHITECTURE REQUIREMENTS

D.4.1 Aircraft Equipage

As currently envisioned, the LZVTTs do not require any flight-deck-related information. However, for LZVTTs to be useful operationally under very low visibility conditions, some enhanced vision capabilities will be necessary for the flight deck.

D.4.2 Communication, Navigation, and Surveillance (CNS)

The LZVTTs will require no communication or navigation information.
However, they will require surveillance information: especially, ground and airborne aircraft position and related aircraft identification data. This surveillance information is expected to be provided in an FAA sensor package that will include: 1) aircraft and ground vehicle position data from ASR-9, ASDE-3, and any other available surveillance sources (such as ADS-B or infra-red sensors and related image processing), and 2) aircraft identification data from systems to be determined, such as the FAA's ATIDS program or another aircraft position-aircraft identification correlation system.

D.4.3 Air Traffic Facility

Since, LZVTTs will serve the needs of air traffic control tower controllers and ramp controllers, they will need to reside in existing or future Air Traffic Control Tower (ATCT) and ramp towers facilities. Versions of LZVTTs that will enhance the visual surveillance of the airport surface will need to be located in ATCT and ramp tower facilities that are collocated with the relevant airport of interest.

D.4.4 Weather

As currently envisioned, the LZVTT information architecture does not require any weather-related information.

D.5 HUMAN/SYSTEM INTERFACE

D.5.1 Flight-Deck Interface

No flight-deck interface is currently envisioned for the Low/Zero Visibility Tower Tools. However, research on potential collaborative and automated LZVTT interfaces with cockpit-based low-visibility decision aids such as those being developed by the Taxiway Navigation and Situational Awareness (T-NASA) element of NASA's Terminal Area Productivity (TAP) program is possible.

D.5.2 Controller Interface

The controller interface for the LZVTTs is currently being researched. Potential display variations include color video display terminals (such as those already developed for the Surface Movement Advisor), heads-up displays, large, full-scale flat panel displays, and virtual reality goggles. Possible input devices to perform operations such as changing the 3D perspective viewpoint include mouse, trackball, and virtual reality gloves.

D.5.3 Airline Operations Center (AOC) Interface

An AOC ramp controller interface is possible for future versions of the Low/Zero Visibility Tower Tools.

D.5.4 ATM Flow Control Interface

No ATM Flow Control interface is currently envisioned for the Low/Zero Visibility Tower Tools.

D.6 DEVELOPMENT STATUS

D.6.1 Previous Tool Functionality History

NASA research staff commenced research on a 3D synthetic display of air traffic data in February 1997. Preliminary LZVTT management and technical meetings have been conducted with FAA personnel that include Denny Lawson from FAA Headquarters and Phil Zinno from the FAA's Technical Center (at Siggraph in August 1997).

D.6.2 Current Status

A white paper has been written by NASA researcher, Ron Reisman, on the scope of the Low/Zero Visibility Tower Tools effort (see Ref. 4).

Currently, a LZVTT research prototype exists in the NASA Ames research labs that displays live Atlanta Hartsfield International Airport ASR-9 surveillance aircraft positional data on a 3D, synthetic computer monitor display.

D.6.3 Technology Readiness Level:

1: Basic principles observed and reported

D.6.4 Expected End of Concept Development:

According to Reference 1, concept exploration of the Low/Zero Visibility Tower Tools will be complete by June 2002. Adding a period of concept development assumed to be 1 year (equal to the concept development period for the Collaborative Departure Scheduling Tool of Reference 2), results in the concept development of the Low/Zero Visibility Tower Tools to be complete by June 2003.

D.6.5 Related AATT Milestone(s):

Milestone 6.12.6, “Complete simulation of IFR tower operations,” 2Q FY02 (Ref. 3)

D.6.6 Expected Course of Development

The expected development of the Low/Zero Visibility Tower Tools technologies will be a joint NASA and FAA effort. NASA Ames will conduct the continued technological and human factors research of input data fusion techniques, different display options, available control functions, and user-friendly computer-human interfaces. Evaluations of the emerging LZVTTs are expected to be conducted in the Surface Development Test Facility (SDTF), a full-scale virtual ATCT, currently under construction at NASA Ames Research Center. The FAA will be involved in functionality requirements analysis, user liaison, and implementation issues (such as integration with other extant air traffic management technologies such as ATIDS). In addition, a joint FAA-NASA System Design Team (SDT) will be used to assist in the focusing of research efforts to develop a user-friendly air traffic management product with well-thought out procedures for its use in the field. A large portion of the research effort is expected to involve collaboration between the LZVTT researchers and the SDT and human factors experts to develop functionalities appropriate to the LZVTT technologies.

Once the LZVTT technology feasibility is proven, the research will be focused on a product to be field-tested as a supplement to conventional “out-the-window” ATCT control. Preliminary plans identify the development of a “Low/Obstructed Visibility Environment” product whose concept exploration phase will be initiated in January 1999 and whose concept development will be initiated in June 2001 (see Reference 1).

Later, LZVTT research emphasis will be on developing displays that will allow the controllers to refer only to a synthetic 3-D scene. Current plans refer to the development of a “Zero Visibility Tower Environment” product whose concept exploration phase will be initiated in January 2000 and whose concept development will be initiated in June 2002 (see Reference 1). In order to provide the future “virtual tower cab” capabilities of this product, the LZVTTs will eventually interface to the Surface Development Test Facility (SDTF).

D.7 DEVELOPMENT CHALLENGES

D.7.1 Technical Challenges

- Aircraft data tag fusion with aircraft position information.
- Robustness of innovative Java/VRML software technologies for Air Traffic Control applications.
- Robust LZVTT software-hardware system failure backup schemes.

D.7.2 Other Challenges

- Availability and reliability of sufficient ground and airborne surveillance sensors.
- Significant capacity increases may require synthetic vision in aircraft cockpits such as that being researched by the Taxiway Navigation and Situational Awareness (T-NASA) element of NASA's Terminal Area Productivity (TAP) program.
- Reduction of controller job satisfaction if visual aspect of control towers are removed.

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3. Denery, Dallas G., et al., "Advanced Air Transportation Technology Program (AATT) NAR Presentation," November 6, 1996.

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Appendix E: Surface Data Warehouse and Analysis Tools

E.1 OBJECTIVE

E.1.1 Background/Problem Statement

Currently, surface air traffic operations in the National Airspace System (NAS) are experiencing their highest level of recorded phase-of-flight delays (Ref. 1) and increasing numbers of safety incidents (Ref. 2). Moreover, these air traffic operational problems will likely increase with the expected continued growth in air traffic operations.

However, attempts to determine the causes of these problems and formulate new strategies to avert them are hampered by the fact that despite the importance of these air traffic operations to the US economy, not much relevant NAS data is accessible from which to draw any conclusions. Airport information systems such as the National Aeronautics and Space Administration (NASA)'s Surface Movement Advisor (SMA) do handle on the order of 50 Mbytes of relevant NAS data every day, but this data is thrown out every 15 days.

The lack of access to convenient archiving and data search capabilities of current and past air traffic operations significantly affect the ability for both NAS operational personnel and analysts of NAS operations to objectively draw any conclusions about current and past air traffic operations that might improve the efficiency and safety of NAS operations.

NAS operational personnel are affected through their inability to access certain data and who rely on data whose precision is unknown. These personnel include airline dispatchers who can only access data about their own operations and may not know when congestion may be building up on the airport surface and air traffic controllers who rely on notoriously imprecise information such as airline schedule and gate data from the Flight Information Display Systems (FIDS or NFIDS) and the Official Airline Guide (OAG). In such an operational setting, both the airspace users and the air traffic managers have little or no access to archival NAS data for similar air traffic demand and airfield capacity scenarios. This resulting limited operational personnel knowledge about the current and near-future NAS operations results in a lack of effective, strategic, proactive decisions by airline dispatchers and air traffic managers.

Analysts of NAS operations are also affected by the dearth of archival NAS information. This lack of information severely limits the ability for the correlation of surface problem cause-and-effect that would assist in determining ways to improve NAS operational efficiency and safety. Without such information, rigorous statistical analysis of surface operations is substituted by the sifting through of limited data collection, cognitive recollections and personal anecdotes. Often, the analysis resulting from the existing data is at too high a level to identify distinct causes of identfied problems or limited to the examination of a specific incident whose general applicability will be in question. Specific problems that result include: the difficulty of NAS operations managers to establish accurate and robust ATM operational performance metrics, the inability of airlines to track down surface problems and causes due to their inability to see data on other air traffic movements that are outside of their control, the complicated operational assessment of new air traffic management procedures and technologies, the lack of existing NAS safety risk information, and the limitation of NAS safety officials in using objective data to determine incident/accident causal factors.

E.1.2 Proposed Solution

In order to extend the current surface operations data collection and analysis capabilities of the NAS, NASA's Advanced Air Transportation Technologies (AATT) program is embarking on a research and development program to produce a Surface Data Warehouse and Analysis Tools (SDWAT). The SDWAT program, currently in its early concept exploration phase, aims to develop a comprehensive archival database to assist in the ability for NAS operational personnel and analysts to conduct strategic analysis of surface operational problems that identify problem causes and suggest new procedural and technological improvements. The development of SDWAT capabilities will begin with the creation of a fast-time, off-line, multi-user database management system with advanced data search, data analysis, optimization and display capabilities of archived Surface Movement Advisor (SMA) data feed information. Further developments will focus on the creation of NAS surface air traffic operations performance baselines and the use of such a database system for advanced real-time or near-real time surface operational personnel NAS status and NAS data quality alerting. Use of advanced SDWAT capabilities are also expected to be integrated with NASA's Surface Development Test Facility for the purposes of real-time testing of new airport surface operational strategies, and with NASA's National Surface Advisor Tool, to enhance the effectiveness of real-time, airport operations.

E.1.3 Expected Benefits

Through the enhancement of current surface operations data collection and analysis quantity and quality, the development of SDWAT has the potential to provide increased efficiency, capacity, flexibility, and safety for all primary airfield users and operators. SDWAT may lead to greater NAS efficiency through increased Airline Operational Control (AOC) and ATM awareness of operational problems, their causes and their formulation of new solutions to mitigate the operational problems. Improved NAS safety may result from the more thorough investigation of surface incidents and accidents through a safety official's use of SDWAT.

E.1.3.1 Airspace User Benefits

Airspace users (especially those with complex surface operation strategies such as airlines that use hubbing) may reduce their direct operating costs through the increased efficiency, capacity, and flexibility provided by improved surface operation practices (such as more efficient schedules, improved pushback strategies) enabled by airspace user use of SDWAT. Specifically, the ability for airlines to have access to general airport operational data, as opposed to those just on their aircraft movements, will assist in identifying improved airline control strategies, improved flight schedule adherence and decreasing operational costs. In addition, any safety improvements enabled by SDWAT will likely decrease operational costs due to reduced airframe losses and personnel liability costs and increase revenues due to improved passenger satisfaction.

E.1.3.2 Air Traffic Service Benefits

With the implementation of SDWAT, the air traffic service providers should be able to better identify operational and safety problems and possible solutions that will improve the efficient use of NAS airfield and airspace resources and increase the safety of the NAS. Better predictions of future air traffic behavior and enhanced situational awareness based on SDWAT capabilities should enable improved and more strategic air traffic management decisions. In specific, improvements in the notification of airline-provided data quality and, thus, better predictions in expected air traffic demand, will allow air traffic control tower controllers and traffic flow managers to better balance the expected demand with given ATC resources. Also, the quantification of air traffic management system performance and the ability to evaluate new ATM control strategies will not only improve the efficiency of operations, but will improve air traffic management service provider research and development investment decisions and reduce R&D costs.

E.1.4 Related Joint Research Project Descriptions (JRPD)

J31 – Airport Surface Management Technologies

E.2 FUNCTIONAL OVERVIEW

E.2.1 Roles

The creation of the SDWAT archival database may enhance the strategic nature of ramp controllers', AOC dispatchers', and traffic flow managers' decisions, and enable a greater tactical role in supervising NAS operations by ATM supervisors and FAA safety officials (e.g., the FAA Office of System Safety) to be able to better investigate NAS safety problems.

E.2.2 Responsibilities

The development of SDWAT database capabilities may increase the amount of effort from airspace users and air traffic management providers on performing operational analysis.

E.2.3 System Function

The SDWAT will consist of a comprehensive, archival, multi-user database with advanced data processing, search, and display capabilities that will aid in the analysis of surface operation problems and solutions, provide an enhancement of NAS prediction capabilities, and improve real-time operational situational awareness.

The SDWAT will provide a state-of-the-art database management system for all accessible data relevant to air traffic surface operations. The SDWAT will include both past and current ATM information and will nominally consist of all data that is received from SMA. This data will include:

1) Real-time Automated Radar Terminal System (ARTS) arrival and departure data
2) Airline schedule and gate data from Flight Information Display Systems (FIDS or NFIDS) and the Official Airline Guide (OAG)
3) Airline flight plans
4) Real-time individual aircraft status updates from the AOC dispatchers
5) Runway and taxiway status and configuration (including departure splits, landing directions, runway and taxiway closures, etc.)
6) Aircraft Communication Addressing and Reporting System (ACARS) and ground-unit information on the block status and movement of aircraft
7) Weather information
8) Aircraft Performance Management System (APMS) data
9) Enhanced Traffic Management System (ETMS) data

As SMA incorporates other data feeds such as:

1) Center-TRACON Automation System (CTAS) arrival information
2) Expedite Departure Path (EDP) departure information
3) Collaborative Decision-Making (CDM) Aggregate Demand List (ADL) information,

it is anticipated that these data will also be stored by the SDWAT.

The SDWAT database will incorporate advanced data processing, search, and display capabilities that will include new data and database fusion techniques, data deidentification (in order to aggregate data to sidestep any data security or proprietary issues), new optimization algorithms, data mining, neural networks, and improved software data visualization schemes.

The SDWAT will provide the database management system analysis functionalities that will provide new algorithms that identify and quantify conditions and events that impact surface operational efficiency and safety. These capabilities will improve the ability for users to better identify surface operational problems, their causes, and to suggest new procedural and/or technological solutions. In addition, the SDWAT will provide the information and analysis capabilities to both quantify nominal ATM performance and to evaluate the impact of potential operational improvement schemes (such as new scheduling strategies). The former capability to quantify ATM performance will improve the ability to do benefits analysis of new surface decision support tools. The latter capability to evaluate improvements will likely take the form of both fast-time simulation and real-time simulation (involving the synergy of NASA's SDTF). In the case of the real-time simulations using the SDTF, the functionality will be designed to allow airlines to test many different scheduling strategies in a short turn-around time (on the matter of days).

In addition to analysis functionalities, the SDWAT will provide improvements to real-time NAS operational information that will enhance operational situational awareness. These improvements will include algorithms to identify surface data quality (i.e., Data Quality Tools), algorithms to enhance the predictive capabilities (and, thus, strategic planning) of the AOC and ATM, and automated notification capabilities. The Data Quality Tools will include capabilities that will provide real-time filtering to advise tower controllers on usefulness of information (i.e., when airline updates are poor and when their systems go down). The advanced predictive capabilities will include better predictions of taxi times, traffic demands, and airport configuration and be based on airport standard operational procedures, statistical analysis, and artificial intelligence techniques. Finally, the automated notification capabilities of the SDWAT will include internet applet-based remote displays and will be based on user-specified triggers and automated event-identification algorithms such as email and web-pushed updates.

E.3 APPLICABILITY

E.3.1 User Classes

The SDWAT is intended to benefit major airline dispatch operations with AOC centers connected to the SDWAT.

E.3.2 Flight Rules

All aircraft operating on the airport surface, both VFR and IFR flights, will have their flight movements recorded into the SDWAT.

E.3.3 NAS Domains

The information incorporated into SDWAT will include all air traffic operations that impact airport surface operations including those within airport surface ramp and movement areas, tower-controlled terminal airspace, and TRACON airspace, as well as, pertinent national airport traffic flow information.

Initial versions of the SDWAT will be focused on air traffic operational data associated with Atlanta-Hartsfield International Airport, but later versions will be tailored to operations at other heavily-trafficked US airports.

E.3.4 Worldwide Domains

Applicability beyond CONUS domains is TBD.

E.4 SYSTEM ARCHITECTURE REQUIREMENTS

E.4.1 Aircraft Equipage

No special/additional aircraft equipment will be required to function with SDWAT.

E.4.2 Communication, Navigation, and Surveillance (CNS)

The SDWAT system will be based upon a communications infrastructure that includes:

1) Computer network equipment
2) SDWAT servers
3) Interface equipment for accessing data from external data sources (ARTS, Weather, FIDS, OAG, APMS, ETMS, etc.)

4) Human-system interface monitors and display systems for both analysts and operational personnel.

E.4.3 Air Traffic Facility

Use of SDWAT will require an interface with an operational SMA or National Surface Advisor Tool (NSAT) system. Later incorporation of real-time operational information will require the addition of two-way communications infrastructure with operational users.

E.4.4 Weather

Local weather information will be required as an input to SDWAT in order to assist in the prediction of the weather-related impact on air traffic flows.

E.5 HUMAN/SYSTEM INTERFACE

E.5.1 Flight-Deck Interface

None.

E.5.2 Controller Interface

The SDWAT interface for controllers is to be determined. A future two-way communication interface is expected during the development of the Data Quality Tools and other real-time operational air traffic control tower (ATCT) alert notifications.

E.5.3 Airline Operations Center (AOC) Interface

The SDWAT interface for AOC dispatchers is to be determined. A future two-way communication interface is expected during the development of real-time operational air AOC alert notifications.

E.5.4 ATM Flow Control Interface

The SDWAT interface for traffic flow managers is to be determined.

E.6 DEVELOPMENT STATUS

E.6.1 Previous Tool Functionality History

NASA concept exploration work on SDWAT began in FY98. So far, these concept exploration activities have focused on: 1) discussions with potential SDWAT users about their functional requirements, 2) work on a high-level specification of the data warehouse, 3) investigations into the SDWAT data storage needs (currently these needs are on the order of 50 Mbytes of information per day), and 4) some experimenting with data filtering and output formats using stored SMA Build 1 data.

E.6.2 Current Status

Currently, SDWAT researchers are performing more concept exploration activities including studying principles of data warehousing and looking at SDWAT hardware options (including potential use of the NASA-Ames Mass Storage Facility).

E.6.3 Technology Readiness Level:

1: Basic principles observed and reported

E.6.4 Expected End of Concept Development:

At this point in time, the expected end of SDWAT concept development is unknown.

E.6.5 Related AATT Milestone(s):

None (or possibly, Milestone 4.0.4, “Complete surface active DSTs,” 2Q FY99 (Ref. 3))

E.6.6 Expected Course of Development

The development of the SDWAT will begin with the development of an off-line, database management system consisting of data stored by the SMA at Atlanta-Hartsfield International Airport (ATL) and using COTS visualization and simulation capabilities. Later, SDWAT development will work towards a database management system that supports both real-time air traffic operations and real-time simulations involving the SDTF.

FY98 system development activities will focus on the creation of a prototype Surface Data Warehouse and the generation of initial on-line analysis tools to include an automated notification prototype and a live performance baseline monitor. FY98 analysis activities include the preliminary analysis of ATL SMA Build 1 data quality and a SMA Build 1 performance report.

Over the life of the SDWAT research, NASA will be testing the feasibility and prototyping a number of different concepts. Eventual commercialization of many of these concepts is expected.

E.7 DEVELOPMENT CHALLENGES

E.7.1 Technical Challenges

Potential technical challenges for successful SDWAT development include:

- Accuracy and validity of statistical data sources used for traffic prediction
- Speed of useful data retrieval
- Scaleability and flexibility of data architectures.

E.7.2 Other Challenges

Additional potential challenges include:

- FAA and airline data access, security and proprietary concerns
- Ability for development effort to manage the wide spectrum of different user requirements for data
- Ability for operational personnel to have enough time to conduct database searches
- Funding for data warehouse maintenance
- Commercialization of SDWAT concepts.

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TOOL DEVELOPMENT RESPONSIBILITIES

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Appendix F: National Surface Advisor Tool

F.1 OBJECTIVE

F.1.1 Background/Problem Statement

Expediting airport surface traffic is of extreme importance to realizing near-term and long-term goals of increasing National Airspace System (NAS) capacity and throughput. Today, the majority of delays affecting airline operations are experienced on the airport surface during taxi-in and taxi-out. Given the hub-and-spoke nature of today's major airlines operations strategic surface management of the airport resources will have a critical impact on providing efficient gate-to-gate planning and operations. Without improved ground traffic flow and resource management, the surface environment will become an even greater bottleneck to NAS system throughput as future traffic demand increases, despite increased throughput enabled by advanced airborne traffic management tools such as the Center-TRACON Automation System (CTAS). Moreover, in addition to meeting the challenge of increased capacity (Note: commercial aircraft in operation are projected to grow from 11,000 aircraft today to 20,000 aircraft by 2010 according to Reference 1), improved coordination of surface activities between FAA controllers, airline operators, and airport facility operators is required to achieve greater safety and flexibility of surface traffic operations.

At many large airports, it is anticipated that immediate benefits would be achieved by increased information sharing and interaction among the various airport operational users, independent of supporting airborne automation aides that may not become available until a later date.

In order to test the feasibility and potential payoff of a near-term surface information exchange, a proof-of-concept prototype system, referred to as the Surface Movement Advisor Build One (SMA B1), has been developed by a joint NASA/FAA partnership to understand the nature of airport surface operations, test user requirements, evaluate potential data sources, and rapid-prototype various human factors display studies and advisory capabilities. The SMA B1 prototype system is deployed at the Atlanta-Hartsfield International Airport. The current system is providing 7-day, 24-hour support to daily operations at all three ramp towers, the city of Atlanta and at various Airline Operations Centers at ATL. The tactical success of the SMA concept has been investigated independently by the FAA and their assessment has documented a cost savings by the SMA system for Atlanta at about $50,000 a day.

F.1.2 Proposed Solution

Given the savings already achieved with the SMA B1 system, the logical next development steps are to capitalize on the existing SMA B1 capabilities by developing and testing national data feeds to evaluate tactical national deployments as well as to prototype strategic surface capacity planning tools that can be incorporated into programs such as Collaborative Decision Making (CDM) to provide true gate-to-gate planning and operations. This prototype, referred to as the National Surface Advisor Tool (NSAT), will provide researchers and end users the necessary functions and displays in order to rigorously test emerging new concepts and develop the requirements for the national implementation of advanced surface information exchanges. The establishment and enhancement of a fielded NSAT prototype should provide significant benefits at a low cost and for a short time from concept to implementation.

Proposed national data source feeds to be used by NSAT include:

1) the Aircraft Communications Addressing and Reporting System (ACARS) which handles Pilot-AOC communications,
2) the Enhanced Traffic Management System (ETMS) which contains strategic air traffic management-relevant data such as weather data, Host computer flight data, Official Airline Guide (OAG), and Dynamic Ocean Tracking System (DOTS),

3) the National Flight Information Display System (NFIDS) data that integrates up-to-date airline scheduling and flight information (e.g., FIDS) data into a single nationwide source, and,
4) wireless portable data entry and display systems to extend the information distribution down to ground crews to enhance ramp and gate operations for baggage handlers, fuel trucks, maintenance, and other ground support personnel.

NSAT will be based on an enhanced data architecture geared for national deployment. Advanced information technology components such as middleware, intelligent agents and meta-databases will be evaluated and tested for performance, scalability support, and auto-maintenance features. Network backbone infrastructures based on NASA's AeroNet, SITA International Aviation Network, CDM's Airline Operations Center Network (AOCNet), and security and agent technologies from the Aviation ExtraNet Joint Sponsored Research Agreement will be used in the development of NSAT.

NSAT data architecture integration is expected to be integrated with other ongoing airline (e.g., the Aviation Performance Measuring System (APMS) interface to allow the rapid extraction of aircraft performance data for use in fleet management, maintenance, and simulation modeling), NASA (e.g., the full-scale air traffic control tower simulator, the Surface Development and Test Facility (SDTF)), and FAA (e.g., the Collaborative Decision Making program) research and development programs.

Also, NSAT will serve as the platform to operationally test and integrate emerging AATT surface concepts such as Collaborative Departure Scheduling (Ref. 2), Low/Zero Visibility Tower Tools (Ref. 3), and Surface Data Warehouse and Analysis Tools (Ref. 4) that are currently being explored by NASA surface air traffic management (ATM) researchers.

F.1.3 Expected Benefits

Through coordination and sharing of airport information, NSAT has the potential to provide increased efficiency, safety, capacity, and flexibility benefits for all primary airfield users and operators. By prototyping a national system, NSAT can extend the benefits observed for SMA B1 from local tactical improvements to national strategic enhancements.

F.1.3.1 Airspace User Benefits

The enhanced airspace user situational awareness produced by the use of NSAT is expected to increase the efficiency of airline operations through improved airspace user fleet control strategies that expedite the movement and coordination of surface fleet aircraft. These increased efficiencies may result in lower direct operating costs through decreased taxi and surface congestion-caused airborne delay times as well as associated lower fuel costs.

Additionally, airline schedule adherence and flexibility will also likely be improved by the capabilities provided by NSAT. Timely and accurate national updates of actual and predicted surface traffic demands and airport configuration status, such as runway and taxiway closures and runway split changes, will allow the AOC to improve their push back decisions and better coordinate arriving and departing aircraft with associated ground equipment and resources especially for hub operations. Push-back and ground resource management decisions will be further aided by improved arrival time estimates provided by the integration of NSAT with other ATM systems such as CTAS and through new NSAT capabilities via wireless handheld portable data entry and display systems. Also, the strategic national data access will not only improve local airport coordination, but entire fleet planning during major ground delays caused by airport closures and/or major weather induced delays.

F.1.3.2 Air Traffic Service Benefits

Air traffic control tower (ATCT) controllers will be aided by NSAT to more safely and efficiently manage the movement of airport surface traffic and improve departure and arrival related decisions based not only on local, but by national impacts.

New NSAT data feeds will also provide the tower coordinators and supervisors with timely updates and feedback of airport restrictions, configuration changes, and traffic-flow management constraints to aid them in improved flow control and configuration management decisions that should increase airfield capacity.

Status updates and predictions provided by NSAT will also assist airport ramp controllers in more efficiently managing ramp operations and gate resources.

Also, since NSAT will be using advanced information technologies such as CORBA (common object request broker architecture), intelligent agents and meta-databases, the resulting NSAT system should offer the information exchange benefits with low development and maintenance costs.

F.1.4 Related Joint Research Project Descriptions (JRPD)

J31 – Airport Surface Management Technologies

F.2 FUNCTIONAL OVERVIEW

F.2.1 Roles

The NSAT is intended for use by four primary airport operational groups - air traffic tower controllers and tower supervisors, AOC dispatchers, traffic flow managers at the FAA's Air Traffic Control System Command Center, and airport ramp operators. Secondary users of the tool and its information may include pilots, National Airspace Logistics Support (NAILS) personnel, and municipal workers involved with construction and maintenance activities for which airfield operational information would be of benefit. The roles of each user of the system is expected to change as they interact with the NSAT system and incorporate information provided by NSAT into their decision-making process.

F.2.2 Responsibilities

The NSAT will cause no change to the current responsibilities of the airspace users and air traffic service providers.

F.2.3 System Function

Evolving from the existing SMA Build 1 proof-of-concept prototype system that is currently operational at the Atlanta-Hartsfield International Airport, NSAT will be an extranet-based system integrating remote database systems and using advanced information technologies such as CORBA (common object request broker architecture), intelligent agents and meta-databases to minimize development cost and maintainability while maximizing portability and performance.

A primary purpose of the prototype system is to gather data from disparate sources and coordinate, interpret, and distribute the information to the relevant airport user groups. Potential data sources include:

1) Real-time Automated Radar Terminal System (ARTS) arrival and departure data,
2) Airline schedule and gate data from Flight Information Display Systems (FIDS or N(ational)FIDS) and the Official Airline Guide (OAG),
3) Airline flight plans,
4) Real-time individual aircraft status updates from the AOC dispatchers,

5) Runway and taxiway status and configuration (including departure splits, landing directions, runway and taxiway closures etc.),
6) Aircraft Communications Addressing and Reporting System (ACARS) and ground-unit information on the block status and movement of aircraft
7) Weather information
8) Aviation Performance Measuring System (APMS) data
9) Enhanced Traffic Management System (ETMS) data
10) Center-TRACON Automation System (CTAS) arrival information
11) Expedite Departure Path (EDP) departure information
12) Collaborative Decision-Making (CDM) Aggregate Demand List (ADL) information

The NSAT system will perform data processing, display, monitoring, and prediction functions to aid in such tasks as:

1) Identification and book-keeping of aircraft entering and leaving TRACON airspace
2) Displaying departure and arrival rates per runway and airport
3) Displaying assigned airport gates and ramps for arriving aircraft
4) Providing information on national departure flow restrictions (e.g. miles-in-trail)
5) Monitoring national surface capacity and demand against current and future operations
6) Monitoring and adjusting of airport configuration data (e.g. departure splits, airport acceptance rates, landing directions, taxi-way closures, and gate utilization)
7) Dynamic balancing of runways due to actual and predicted traffic loads
8) Prediction of taxi times to runways on departure or airport gates on arrival
9) Prediction of the number of aircraft in future departure queues
10) Prediction of changes in traffic demands and airport configuration due to weather conditions

The predictive functions of NSAT will be based upon airport standard operational procedures, statistical analysis, artificial intelligence techniques such as neural nets, and prediction algorithms.

F.3 APPLICABILITY

F.3.1 User Classes

The NSAT is intended to benefit major airline dispatch operations with AOC centers connected to the NSAT network.

F.3.2 Flight Rules

All aircraft with data entered into the NSAT system are assumed to be operating with Instrument Flight Rule (IFR) flight plans.

F.3.3 NAS Domains

The NSAT is designed to aid in the monitoring and prediction of traffic operating within airport surface ramp and movement areas, tower-controlled terminal airspace, TRACON airspace and national airport capacity and demand flows. Traffic flow management information regarding aircraft in en route airspace may be entered into NSAT if it is predicted to impact terminal airspace and surface operations.

The NSAT will be designed to be portable to other airfields beyond Atlanta-Hartsfield International Airport (for which SMA Build 1 is highly customized) by using internet technologies and relying on national data feeds.

F.3.4 Worldwide Domains

NSAT applicability beyond CONUS domains is to be determined.

F.4 SYSTEM ARCHITECTURE REQUIREMENTS

F.4.1 Aircraft Equipage

No special/additional aircraft equipment will be required to function with NSAT.

F.4.2 Communication, Navigation, and Surveillance (CNS)

The NSAT system will be based upon a communications infrastructure that includes:

1) Computer network equipment
2) NSAT servers
3) Interface equipment for accessing data from external data sources (ARTS, Weather, FIDS, OAG, APMS, ETMS, etc.)
4) Human-system interface monitors and display systems for towers, ramps, AOC's, the Air Traffic Control System Command Center, and airport/airline ground crews.

The Aviation ExtraNet will be used to communicate between NSAT servers and the AOC's, ramps, towers, TRACON, and Air Traffic Control System Command Center facilities (based on the internet model of applets, browsers and servers). Current plans also involve evaluating a wireless local area network (LAN) communications interface to NSAT for use by airline and airport ground crews responsible for aircraft block-in/out, baggage handling, aircraft provisions, aircraft maintenance, and airport infrastructure management and repair.

F.4.3 Air Traffic Facility

Two-way communications infrastructure and graphical user interface (GUI) hardware will be required in the air traffic control tower and Air Traffic Control System Command Center facilities for interaction with NSAT. A similar NSAT interface and communications network may also be desired in the TRACON facilities that control arrival and departure air traffic into and out-of the airport where the NSAT system is deployed. In addition, service provider ground crews may also require a wireless LAN communications interface to NSAT.

F.4.4 Weather

Local weather information will be required as input to NSAT in order to aid the tower supervisor in predicting the weather-related impact on airport configuration and capacity decisions. National weather information derived from ETMS data may also be made available by NSAT for use by AOC dispatchers and airport/tower managers.

F.5 HUMAN/SYSTEM INTERFACE

F.5.1 Flight-Deck Interface

Although no additional equipage will be required for NSAT interaction from the flight-deck, a capability will exist for the flight crew to enter and receive NSAT information over the existing ACARS datalink equipment in the cockpit.

F.5.2 Controller Interface

The NSAT is intended for use by tower controllers and tower supervisors. Tower controllers will receive aircraft monitoring and prediction information through a web-based graphical user interface (GUI) display. Various display options will be available to the controller and configurable on an individual basis. Human-factors principles will be applied to the manipulation of windows and data items by the controller using standard input devices (i.e. keyboard, mouse/trackball). The human/system interface will be two-way allowing for controllers and supervisors to enter information back into NSAT such as airport configuration changes and standard operational procedure updates.

F.5.3 Airline Operations Center (AOC) Interface

The NSAT will provide AOC dispatch personnel with information relating to individual flights that belong to their airline. The AOC can then provide simultaneous access to NSAT information within their own network system. Information regarding other airlines will not be available unless otherwise agreed upon. The AOC will interface with NSAT through a TCP/IP protocol incorporating a standard input device and monitor. Communication will be two-way allowing for AOC dispatch personnel to enter information such as flight schedules, gates, and aircraft status updates back into the NSAT system. Status information will be presented to the AOC dispatchers and ground personnel through a combination of either graphical or textual displays.

F.5.4 ATM Flow Control Interface

The NSAT interface to traffic flow managers at the Air Traffic Control System Command Center has yet to be determined.

F.5.5 Airport Ramp Controller Interface

The airport ramp controller will interface with NSAT through a TCP/IP protocol incorporating a standard input device and monitor. Communication will be two-way allowing for ramp control personnel to enter information such as ramp movement clearances. Status information will be presented to the airport ramp controllers through a combination of either graphical or textual displays.

F.6 DEVELOPMENT STATUS

F.6.1 Previous Tool Functionality History

NSAT is the surface information exchange prototype follow-on to SMA Build 1. SMA Build 1 baseline user and technical requirements were established beginning in late 1994 and installation of the SMA Build 1 proof-of-concept prototype system began at Atlanta-Hartsfield in September 1995.

F.6.2 Current Status

The SMA Build 1 proof-of-concept prototype is currently deployed and operating on a continuous basis at the Atlanta-Hartsfield airport. Data is being collected to assess operational usage of the system in cooperation with FAA-established System Design Teams. Human factors expertise from NASA-Ames Research Center and the FAA is being applied to assess the communication and interaction between the SMA B1 system and the various user groups.

A series of SMA Build 1 enhancements have been developed to improve the reliability and the performance of the prototype system to minimize developer and site maintenance and their expected deployment is February 1998.

F.6.3 Technology Readiness Level:

2: Technology concept and/or application formulated

F.6.4 Expected End of Concept Development:

Concept development of the NSAT is expected to continue through fiscal year (FY) 1999.

F.6.5 Related AATT Milestone(s):

4.0.4: "Complete surface active DSTs"

F.6.6 Expected Course of Development

The NSAT concept development is expected to continue through FY 99 with prototype deployment at multiple sites continuing beyond that date, terminating prior to FY 04. These multiple future domestic airport sites are currently being considered and will be studied for feasibility in the NASA Ames Surface Development and Test Facility (SDTF). Future operational testing of NSAT is currently envisioned to continue at the Atlanta-Hartsfield International Airport.

Close collaboration with other ATM systems, NASA's Information Technology Base program and NASA's Aviation Safety Program (AvSP) will be undertaken in areas of data standardization, data security, and network access in order to minimize development costs.

Also, as the products of the Collaborative Departure Scheduling, Low/Zero Visibility Tower Tools, and Surface Data Warehouse and Analysis Tools programs complete concept development, they will be integrated into the NSAT operational prototype.

A next-generation NSAT build is currently anticipated that will aim to improve the monitoring and safety of surface operations by tracking individual aircraft on the ground by interfacing with surface surveillance technologies.

F.7 DEVELOPMENT CHALLENGES

F.7.1 Technical Challenges

Potential technical challenges include:

- Integration with national data feeds in order to test the feasibility of a national deployment,
- Developing sufficiently useful and reliable advanced information technologies such as middleware, meta-databases and intelligent agents in order to integrate national, remote data sources and to minimize maintenance costs,
- Design of a portable interface that allows rapid adaptation of NSAT to different airport sites that may have significantly different operational environments,
- Accuracy and validity of statistical data sources used for traffic prediction,
- Successful application of human factors expertise to achieve maximum benefits from deployed system concepts,
- Verification and validation of system concepts through analysis and simulation prior to prototype deployment.

F.7.2 Other Challenges

Additional potential challenges include:

- Adequate security and performance for a national system deployment,
- Funding of infrastructure and data integration costs associated with future development of the NSAT prototype,
- Depletion of future NSAT development resources in order to maintain and/or expand currently deployed systems.

REFERENCES

1. Boeing Company estimate at NASA ASSIST Workshop '97.
2. Collaborative Departure Scheduling product description, Appendix C, "National Airspace System Operational Concept-AATT Product Mapping Analysis," Technical Report 98163-01, Seagull Technology Inc., Los Gatos, CA, February 1998.
3. Low/Zero Visibility Tower Tools product description, Appendix D, "National Airspace System Operational Concept-AATT Product Mapping Analysis," Technical Report 98163-01, Seagull Technology Inc., Los Gatos, CA, February 1998.

4. Surface Data Warehouse and Analysis Tools product description, Appendix E, “National Airspace System Operational Concept-AATT Product Mapping Analysis,” Technical Report 98163-01, Seagull Technology Inc., Los Gatos, CA, February 1998.

TOOL DEVELOPMENT RESPONSIBILITIES

Development Site(s)

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