Communications System Architecture Development For Air Traffic Management & Aviation Weather Information Dissemination

Research Task Order 24

Subtask 4.5, Development of Preliminary/Candidate System Architectural Concepts

(Task 4.0)

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1 Executive Summary

This report provides a discussion of needed communication capabilities in 2015, outlines assessment criteria to apply to candidate architectures, and presents alternative concepts for an overall 2015 communication architecture. It serves as the foundation for continued work under NASA AATT RTO 24 to develop engineering-level detail for the architecture and transition plans from the current NAS architecture to a new architecture for 2015. It is based on the needs identified in Task 1, knowledge of communications and information technology advances, and projected changes in the FAA's NAS architecture.

Although the focus of these efforts is on documented user needs, these concepts recognize that user demands often derive from "wants" rather than needs. Awareness of what emerging technology can provide often stimulates a perception of needs. Assessing the quantitative benefits of satisfying specific needs will be left to Task 5. Similarly ranking and selection of specific architectural concepts is deferred to tasks 5 and 6. It is expected that 5 and 6 will serve as a synthesis of the work performed in tasks 1 through 4.

There are eleven fundamental services that any communication architecture for 2015 must support:

- Flight Planning Service
- ATC Separation Assurance Service
- ATC Advisory Service
- Traffic Management Synchronization Service
- Traffic Management Strategic Flow Service
- Emergency and Alerting Service
- Navigation Service
- Airspace Management Service
- Infrastructure/Information Management Service
- Aeronautical Operational Control
- Onboard Services

Each of these services is described by the drivers creating the need for the service and the constraints that limit the service. Candidate Communications System Architectures (CSAs) must address both the drivers and constraints to be viable. This report presents the opposing forces for each service and then derives a series of possible concepts for creating CSAs. These concepts are focused on the tradeoffs between a distributed functional allocation versus a centralized allocation and take into account the ideas of Free Flight, Distributed Air-Ground (DAG) communications, and Collaborative Decision Making (CDM). In addition, each concept must be viewed from the perspective of three separate user classes: air transport, high-end General Aviation (GA)/Business Aviation (BA), and low-end GA, as well as the service providers (e.g. AOC) and air traffic control (ATC). Finally, in keeping with the need to accelerate the introduction of weather information services, the candidate CSAs are characterized by both an AWIN and an ATM focus. It should be noted that ultimately a hybrid of these concepts would be needed based on industry-projected equipage rates and costs as well as the availability and advantages of various communication technologies.

Instead of presenting the CSAs in the form of block diagrams, focusing on an engineering view of the architecture, this report focuses on the users' perspective by presenting scenarios against which each of these concepts could be evaluated. The scenarios will depict how services are provided to users today, and how they could be provided to users in 2015.

Throughout the report, the eleven services are used to anchor the CSAs together and to provide a common thread throughout all TO24 subtasks. A network-centric focus has been maintained in keeping with the overall worldwide evolution of communication systems. Care has been taken to facilitate the combination and extraction of elements from the multiple CSAs. It is hoped that this approach will provide a solid foundation as well as maximum flexibility for follow-on work.

2 Introduction

2.1 Overview of Task Four

Task 4 is intended to develop a series of high-level Communications System Architecture (CSA) concepts to support the delivery of various services to all classes of users of the National Airspace System (NAS). These services are:

- Flight Planning Service
- ATC Separation Assurance Service
- ATC Advisory Service
- Traffic Management Synchronization Service
- Traffic Management Strategic Flow Service
- Emergency and Alerting Service
- Navigation Service
- Airspace Management Service
- Infrastructure/Information Management Service
- Aeronautical Operational Control
- Onboard Services

Each of these services can be viewed from the perspective of the different classes of users as well as from the point of view of the service providers. Communication between the users and service providers can be characterized by the type of traffic, direction of traffic, and the drivers and constraints affecting the service. In task four, a series of candidate Communication System Architectures (CSAs) are developed using these views. Subsequent tasks are defined to develop one of these architectures for both AWIN and ATM. Ultimately, the selected architecture will be defined “end-to-end” and will include ground systems, avionics, and the connecting networks.

The fundamental modes of communications that are likely to be available in 2015 are similar to those available today and include basic VHF or HF radio communications (voice or data), Satellite Communications (SATCOM), or data exchange via Mode-S. For the purposes of task four, very little attention has been paid to the specific mode of communication to be used in delivering a particular type of service. Rather, emphasis has been placed on who needs the data and how the data are employed in using the NAS. The key to answering these questions requires a review of the underlying drivers and constraints for each service.

Because of the concurrency of task one (identification of user needs) and the fact that task two (functional requirements) extends beyond task four, the findings of these two tasks do not feed directly into task four. For defining architectural concepts, though, it was necessary to gain a sense of the needs. This was done by collaboration between people working on the different tasks, rather than acquiring all the details.

Finally, task 4 identifies the criteria for the quantitative and qualitative assessments of candidate CSAs. The assessments, when completed as part of tasks five and six will concentrate on engineering requirements and will address the benefits to specific types of users, thereby driving user equipage decisions.

2.2 Overview of the Document:

Section one provides an executive summary of the overall report.

Section two provides an introduction to task four, the layout of the task four report, and a short description on the approach taken to develop the candidate CSAs.

Section three of this report provides a description of each service, the types of data and the directional flow of the data within that service offering, and a discussion of the drivers and restraining factors surrounding each service. It also describes which users are consumers and creators of the data.

Section four outlines the various concepts derived from the review of services and then discusses each in the context of overall concepts shaping the evolution of the NAS (e.g., Free Flight, Distributed Air Ground (DAG), Collaborative Decision Making (CDM), and the Small Aircraft Transportation System (SATS). Both present and future services are discussed.

Section five provides a discussion of the assessment criteria by which each CSA would need to be evaluated.

Appendix A provides service definitions according to NAS documentation, and appendix B further discusses trends and forecasting in technology.

2.3 Summary of Approach

Task one and task four were executed concurrently to allow for the development of a common set of services around which both the user needs identification process and the candidate CSA development could take place. Once the services were defined, the focus turned to identifying the various users and service providers that would need to use the candidate architecture. In parallel, work began on identifying the types of criteria that would be used to evaluate the architecture. Throughout these efforts, the team worked to separate those considerations that were technology or media based from those that were procedural in nature.

Brainstorming sessions were held with the overall team to postulate the various architectural concepts that appear in this report. Drawing on the extensive literature base collected for tasks one through three and the collective experience of the team, concepts were identified that married aspects of major initiatives such as Free flight, DAG, CDM, and SATS together with the current state of the art in communication technologies and capabilities. These capabilities were then extended and evolved based on various predictive factors such as rate of processor speed growth, the expected launch of data link capabilities, and the rate at which new equipment could be developed and fielded.

Care was taken throughout the development of the candidate CSAs to maintain flexibility for the follow-on tasks. The use of the categories the FAA utilized to structure the NAS technical architecture (i.e., user needs categorized by services and capabilities) will facilitate tasks five through seven and the consideration of transition plans in task eight.

3 Description of Needed Capabilities for 2015

All of the user needs identified in section one can be grouped around the eleven services used to provide ATM and AWIN capability. The figure below illustrates these services and provides example capabilities for each. The rest of this section outlines each service including the types and flow of data that will be used in any new communications architecture. The forces driving the need for a particular service in today's environment as well as the future are identified. Opposing or restraining factors are also noted that will impede the delivery of each service.

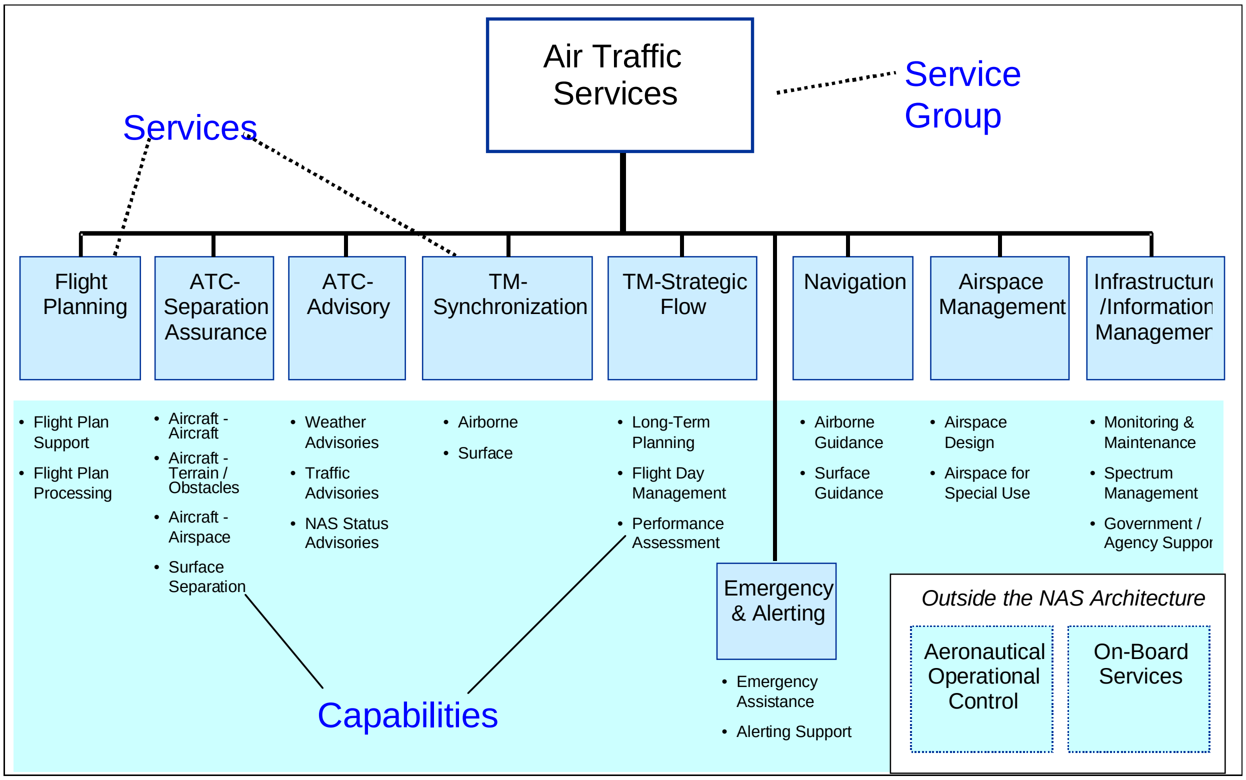


Figure 3-1. Air Traffic Services for ATM and AWIN

3.1 Flight Planning Service

Flight Planning Service includes both Flight Plan Support and Flight Plan Data Processing to support the safe and efficient use of the nation's airspace through the development and use of coordinated flight plans.

The capabilities described below comprise the Flight Planning Service. The first five of these capabilities support today's environment and are considered legacy capabilities. The remaining capabilities are necessary to support the CONOPS for the year 2005 and beyond. These capabilities are as follows:

Provide Aeronautical Information

Aeronautical information (e.g., information regarding special use airspace, preferred or fuel-efficient routes, traffic management, or the condition of selected NAS components) is required in support of flight planning. Such information is required to be easily and conveniently available to users for the total geographic area of NAS responsibility. Because of the large volume of aeronautical information there is a requirement to tailor the information presented to only that which is important to a specified route and time of flight or to specified locations or areas. Users require such information during all phases of flight.

Provide Weather Information

Weather conditions can significantly affect aircraft operations, performance and safety. Planning of flights requires the availability of timely and accurate weather information such as: upper air winds, upper air temperatures, and hazardous weather data. A capability is required to select and access weather information that could affect flight planning. Specialists and users require weather information.

Provide Pre-Flight Information

Pre-flight information includes the dissemination to users of aviation weather and aeronautical information for airports and proposed routes of flight.

Develop and Process Flight Plans

Developing and processing pre-flight and post-flight plans includes accepting and processing flight plans from all users (GA, airlines, military); validating the flight plans; notifying users of any problems; and processing amendments, cancellations and closures.

Implement Flight Plans

Implementation starts with the activation of a flight plan. It includes issuing of clearances for the flight, distributing flight plans to appropriate ATC facilities along the route, as well as processing in-flight changes.

<u>Future User Services:</u>

Collaborative Decision Making

Provides participating AOC's and the FAA with real-time access to current NAS status information, including infrastructure and operational factors. Increases predictability by allowing flight plan changes in response to NAS status and traffic demands through greater information sharing and automated decision aids. CDM will also provide more robust interactive feedback to NAS users' proposed flight plans based upon current constraints such as special use airspace, equipment and facility status, and weather conditions.

NAS-Wide Data Link

Allows controllers and pilots to directly exchange digital messages, such as FIS and TIS information, throughout the NAS.

Interactive Airborne Refile

Provides in-flight, electronic exchange and automated processing of flight plan change requests between pilots and controllers for entire route clearance.

Flight Plan Evaluation

Provides interactive feedback to NAS users proposed flight plans based upon current constraints such as special use airspace and equipment status.

Flight Plan Support provides NAS users with essential weather and aeronautical information such as available routes, special use airspace (SUA), daily demand conditions, anticipated flight conditions, NAS operational and maintenance status, and FAA facility status. Flight Plan Processing provides acceptance and processing of flight plan data, validation of flight plans; problem notification; processing of amendments, cancellations and flight plan closures.

Automated data link capabilities are needed to enable airspace users to conduct pre-flight and in-flight activities and receive information essential to flight without talking directly to control and/or flight service personnel.

Technical factors and user needs that tend to drive change for flight planning are listed below along with factors that may act as constraints.

Table 3.1-1. Flight Planning Service

Driving Forces →	← Constraints	Comments
Need for current route and other aeronautical information	• Access to information, DUATS, PATWAS, AFSS/FSS, TIBS, BASOPS and airline dispatch office. • Difficulty of using charts for some people using unfamiliar routes.	Large volume of information, from numerous sources and databases, must be customized for specified route, time and location/area.
Need for weather information	• Reliance on human weather observers • Difficulty understanding voice or data weather description • FAA reliance on meteorologists for weather information as primary source • Delays caused by manual receipt and entry of PIREPs by the Controller for operationally significant weather data • Controller weather data relay to pilots on a workload permitting basis	More efficient operations could be available with: • Complete automated surface observations • Increased use of data communications; reduced need for voice communications • Direct Automation support to pilots and FAA ATC personnel • Automated processing of real-time aircraft sensor data • Automatically generated tailored weather products • Direct dissemination of weather products to the cockpit. Controller provided weather services only on request, and only on a workload-permitting basis • Automated aircraft advisories
Reduction of delays while developing and processing flight plans	Rejection of flight plan by Host requires time-consuming resubmission	If Flight Service or the Host Computer rejects the flight plan, the flight plan must be amended or refiled. Improvement of the filing process to avoid rejection should be considered.

Driving Forces →	← Constraints	Comments
Ability to interactively refile or amend while airborne	• Insufficient interconnection of systems • Integrity and security of links • Bandwidth needed for interactive feedback • Limited "real estate" on cockpit screens	Constraints may require amending or filing another flight plan There is a need for better validation and automated transmission of flight plans, perhaps with some form of automated correction. More importantly, there a need to support upload of the approved flight plan to the FMS because manual uploads is time consuming and error prone.

3.2 ATC Separation Assurance Service

Separation Assurance Service ensures that aircraft maintain a safe distance from other aircraft, terrain, obstacles, and certain airspace not designated for routine air travel. Separation assurance involves the application of separation standards to ensure safety. Standards are defined for aircraft operating in different environments. These standards are based on both aircraft performance (the ability to know and maintain location) and surveillance equipment performance (the ability to receive and display aircraft position).

Aircraft-to-Aircraft Separation

Aircraft to aircraft separation prevents collision between airborne aircraft. Advancements in conflict detection and resolution systems may make it possible for aircraft to maintain separation without ATC intervention. Avionics will provide dependent surveillance reports to proximate aircraft and will be able to receive data link messages directly from the ATC automation system regarding other aircraft positions.

Both pilots and controllers will have an increasing need for situational awareness. Adequate communications coverage, including (up-link/down link) data link capability with the users, will reduce controller workload in locations where separation standards are currently procedural due to inadequate surveillance. Equipment limitations will be reduced in the future with the availability of Traffic Information Service, TIS, which will allow pilots to perceive other aircraft.

Aircraft-to-Terrain/Obstacles Separation

NAS employs separation standards to prevent collision between aircraft, terrain, and obstacles. Methods used include published safety zones and processing of position and intent information. Automated aural and visual indications of obstacle dimensions and location, as well as terrain proximity, available to all users, will enhance aviation safety. Pilots need the ability to obtain relevant, current charts with minimal expense and inconvenience. Terrain and Obstacle separation will be part of pilot situational awareness just like aircraft separation.

Aircraft-to-Airspace Separation

Aircraft are separated from Special Use Airspace (SUA) such as prohibited, restricted, and warning areas. Aircraft are either restricted or prohibited from SUAs depending on the type and status of the airspace. Automated aural and visual indications of SUA dimensions and location, available to all users, should reduce violation of SUA.

With the future implementation of commercial space, there may be an increase in SUAs (and more frequent use of those SUAs). The SUA schedule will be more accurate and better integrated with overall planning of ATC operations. Aircraft access to SUAs will be increased by the ability to share schedule information.

Surface Separation

Surface separation applies to vehicle movements on the airport movement area, taxiing aircraft, and protection from designated critical zones. Depending on local practices, tower controllers manage and control the surface of the airport including the taxiways, runways, and movement areas designated as controlled area. In other cases, controllers manage the optimized queues of arrival and departure aircraft. Pilots are responsible for separation of their aircraft from other aircraft, vehicles, obstructions, and designated critical zones while in transit to and from the airport movement areas.

While not yet sharing the responsibility for separation, pilots need on board systems that provide valuable assistance to the Ground Control Manager (GCM). Automation enhancement increases the margin of safety for aircraft, as surveillance and tracking of movement on the surface is much more precise. Airports will also be equipped with tracking radar and data transmitting systems that provide both pilots and the GCM with accurate information regarding the movement of all vehicles on the airport surface, a safety enhancement, especially in low visibility situations. A Surface Management System (SMS) can provide a collaborative decision making capability among ATC, the airlines, and airport operators to reduce delays in surface operations. Read and acknowledge messages will be expanded beyond pre-departure clearances and taxi routes to include best gate, gate time arrival, gate time pushback, etc.

At busy, local general aviation airports, the pilot will have more responsibility for surface separations or be restricted to certain airports. Busy airports are not often suitable for pilots with limited experience or with the minimal mandated equipage. Busy GA airports will need to support moving maps, automated clearance capabilities, automated weather warnings, and surface departure automation.

At the smallest GA airports, the procedural separations – one in/one out – will change when all aircraft operating at the aircraft are equipped to "see" each other. This will be especially helpful in remote areas with minimal low altitude radar coverage.

In 2015, separation will be managed mainly by data communications for airlines and predominantly by voice communications for low-end GA. By 2015, some GA users will choose to equip with a data capability, and some airlines may choose not to equip. Similarly, some users may choose to equip with technology that supports self-separation.

Air traffic controllers separate aircraft in the NAS using either procedural (non-radar) or surveillance (radar) techniques. Surveillance techniques provide more efficient separation of aircraft than procedural techniques. Controllers can also use the surveillance information to provide aircraft identification and location, navigation assistance, instrument approaches, traffic advisories, and unsafe condition alerts.

Surveillance systems such as radar can locate and identify aircraft, whether IFR or VFR. Radar surveillance systems are classified as either primary or secondary. Primary radar surveillance requires no cooperation from the aircraft targets. The aircraft position and velocity are determined by reflecting surveillance (radar) signals off the aircraft skin and using algorithms to process the received signals. Secondary radar surveillance takes advantage of cooperative aircraft equipped with transponders that respond to interrogation. The response signal is processed and displayed at the controller's station. This allows aircraft trajectory (active track) information to be determined. In addition, aircraft may be equipped with dependent equipment that continuously broadcasts trajectory and other information.

For aircraft to aircraft separation using surveillance techniques, controllers analyze the aircraft intent (from flight plans) and the actual and predicted trajectories (surveillance track data) to determine and resolve conflicts. For procedural separation, the pilot's flight plan and reported position, altitude, and estimated time to the next reporting point are used to control aircraft. A combination of time, distance, altitude, routes and visual methods separate aircraft, as appropriate, for departure/arrival and en route flight conditions.

Aircraft-to-SUA Separation

The controller needs to know the aircraft's intent and actual position as well as the location and status of the airspace. Surveillance track and flight plan information provide the actual and intent information needed by the controller to ensure that the aircraft flight trajectory remains an appropriate minimum distance from the SUA boundary. The controller either assigns altitudes to keep aircraft out of airspace or vectors aircraft around the airspace. Procedural separation assigns route and/or altitudes and monitors pilot reports to ensure that the aircraft remains an appropriate minimum distance from the boundary of the SUA.

Aircraft-to-Obstacle Separation

Air traffic controllers use aircraft intent and/or actual trajectory and known obstacle locations to separate aircraft from obstacles. Aircraft can be tracked using surveillance to ensure that the aircraft's trajectory maintains minimum lateral or vertical separation from the obstacle. Procedural techniques rely on aircraft route and/or altitude assignment and pilot reports to ensure the aircraft remain clear of all obstructions in accordance with appropriate separation standards.

Data Link Delivery of Expected Taxi Clearances (DDTC)

Terminal controllers are responsible for maintaining separation between aircraft, airspace and obstructions appropriate to operational conditions and types of aircraft in the system. The trajectories of controlled aircraft in the terminal airspace, SUA location and status, and obstacle locations are analyzed to determine potential conflicts. The controllers provide instructions for pilots to maneuver the aircraft to resolve situations that result in less than approved minimum separation. Separation assurance is provided through procedural and surveillance techniques.

En route controllers at ARTCCs are required to maintain separation between aircraft, SUAs, and obstructions appropriate to the en route airspace, operational conditions and types of aircraft. The en route facility maintains flight trajectory information for all participating aircraft in its airspace, SUA location and status, and the location of any obstacles. The en route controllers determine potential conflicts and provide instructions to pilots to maneuver the aircraft to avoid or remedy any conditions that result in less than approved minimum separation. Separation is provided and maintained through a combination of procedural and surveillance techniques.

Oceanic controllers, responsible for international airspace assigned to the NAS, are required to provide separation between aircraft, SUAs and obstacles appropriate to the oceanic airspace, operational conditions and types of aircraft. The responsible oceanic center maintains predicted aircraft trajectory information for controlled aircraft in its area. The aircraft trajectory information is used to determine when potential conflicts exist. Pilots maneuver the aircraft in response to controller instructions to avoid or remedy situations that result in less than approved minimum separation. Today controllers provide separation mainly using pilot reports with associated flight plans and procedures.

The separation of aircraft by air traffic controllers in the space domain is a future service. Space vehicles will be separated from aircraft, airspace, and obstacles by using corridors, reserving airspace or some other means, similar to the current procedures used for missile and Space Shuttle launches.

Technical factors and user requirements that tend to drive changes for Separation Assurance Service are listed below along with factors that may act as constraints.

Table 3.2-1. Drivers and constraints for Separation Assurance Service

Driving Forces →	← Constraints	Comments
More efficient movement on airport surface	• Position reporting on airport surface • Structures that obstruct line of sight	• DDTC at DTW has already been enhanced to provide positional information for aircraft using ACARS.
Flexibility for oceanic routes if separation standards can be reduced	• Situational aware-ness of pilots regarding nearby traffic • Situational aware-ness of controllers	• ADS-B has the potential for providing pilots with much better situational awareness than they currently have. • Improved communications is needed to show the controller the same picture as the pilot would have
Crowded airspace in East Coast corridor	• Off-shore areas lack radar surveillance • Off-shore areas go beyond VHF range	• Congestion in Atlantic corridor (e.g., DCA-BOS, MIA-JFK) could be diverted from crowded areas if flights could be routed over water. • Savings could also be realized in the Gulf, by using direct routes.
Free Flight	• Current route system	• There is substantial industry focus on this issue.

3.3 ATC Advisory Service

Today's aviation weather system is characterized by inefficient means of delivery to end-users, weather observations that are sparse, weather forecasts that are low resolution temporally and spatially, and products that provide quantities of cryptic data rather than the needed operationally significant decision aids.

Users need advisories including weather information, traffic, and NAS status information. Weather advisories and information need to be available to the user cockpit either automatically or on request through data link communications with ATC and other facilities. Advisories provide hazardous weather or flight conditions at airports, or along the flight route. Traffic advisories are provided to alert aircraft to potential conflicts with others on the surface or in-flight. These advisories are time critical and must be delivered to the aircraft in time to be applied. Information about the NAS status that has changed or was not readily available during flight planning is provided to in-flight aircraft. Availability of this information via data link to the cockpit will reduce voice communications and workload for both the user and ATC personnel.

Weather Advisories.

Of major importance to both pilots and controllers is the continued improvements in the area of weather tracking and forecasting. Improvements in communications and surveillance technologies facilitate a timely sharing of hazardous weather information between controllers and pilots. PIREPS provide a valuable source of "real-time" weather information. This information comes from pilots in the system reporting encounters with hazardous flying conditions such as thunderstorms, turbulence, icing, and wind shear (sudden changes in the direction of the wind relative to the direction of the aircraft). Enhancement in dissemination of PIREPs and easy-to-interpret weather information to the occasional pilot is needed for pre-flight and especially during in-flight. Additionally, pilots need more information about the severity of convective activity and cloud-to-cloud lightning often associated with thunderstorms.

Evolutionary strategy should focus on quickly developing prototypes with key related systems and ensure that interfaces and operations concepts are thoroughly validated by user evaluation teams in an operational environment. A flexible design can accommodate many levels of sophistication in automation capabilities, from simple separate weather displays to the display of integrated presentations of combined Doppler radar, weather satellite and other weather information suitable for the most sophisticated graphical display system.

Human factors considerations of information system design and sensory overload should seriously be examined. Weather information should be provided in standardized formats that can be quickly assimilated by the pilot and accommodate varying levels of meteorological skills. The pilot who flies daily gets proficient at reading textual weather; the pilot who makes an occasional weekend flight in a rented aircraft needs all the help he or she can get.

Pilot situational awareness can be increased through improved cockpit avionics. These avionics should display critical flight safety information such as weather, nearby traffic, terrain features, SUA status, notices to airmen, and significant weather advisories. Display of real-time weather information in the cockpit will help alleviate some of the hazards encountered during en route flight.

Both passenger and cargo Airlines need to have same picture of weather for decisions as ATC/TF in order to achieve collaboration. Businesses using the NAS need more predictive (i.e., accurate) weather, but for different purposes:

- Snow/ice – to adjust ground operations and schedules
- In air ice – to fly around (as is done for a thunderstorm)
- Thunderstorm at airport – to wait it out
- Thunderstorm en route – to work with ATC to fly around. The current communications sector setup is a potential impediment. It is necessary to be able to adjust the boundaries of sectors (with the accompanying change in frequencies) to accommodate an overwhelming number of aircraft flying through a relatively small hole in a storm. Changes in flight need to be accommodated for a specific aircraft rather than between airport pairs. Currently, thunderstorms in Kansas City can cause ATL, ORD, DFA, LGA, and LAX (for example) to shut down. With many major airports shut down, overall traffic in the NAS becomes light and the remaining operating airports to flow very well. The communications system needs to support dynamic reallocation of airspace, and making smaller sectors (to be able to reduce the number of aircraft in the sector to manageable levels). The communications also needs to support the changing of a flight plan for a specific flight.

For most aircraft, weather advisories are provided via voice or digital ATIS. In either case, the information is broadcast (although controllers using voice can ask pilots for confirmation that the message has been received). Airlines often receive additional information using the ACARS link, which today is primarily for AOC data.

For those weather reports that are transmitted via data links, current reports are textual or use primitive graphics. Recent advances in compression algorithms have reduced message sizes, while new communication technologies have increased capacity. Some of the advances in compression techniques have resulted from the aviation industry's efforts to make "weather in the cockpit" more practical, but the tremendous growth in applications using the Internet has spawned more research and standardization in graphical compression techniques. Progress is being made on standards for providing weather in the cockpit.

In the next few years, more constellations of communications satellite in low or medium earth orbits will become operational. Preliminary marketing of downlinked broadcast entertainment services[1] is underway. Satellites could be used to broadcast basic weather data to equipped aircraft, with additional features for premium subscribers. Current CPUs are already powerful enough to selectively display broadcast data based on a pilot's profile. Such systems would need to be improved for ease use.

In the future, weather advisories can be automatically broadcast to pilots and controllers simultaneously. Both controllers and pilots need a system that could relay this time critical information so that alerting time is not delayed as the information is relayed by the controller to the pilot, and does not divert the controller from other important activities.

Pilots and controllers have different needs for information. Pilots need weather information that is tailored to their current course or planned route of flight. Controllers need access to a larger picture, extending to surrounding sectors and even other facilities, because weather conditions in neighboring areas can affect traffic conditions in their areas.

Although the planning styles of pilots vary, pilots should be able to request pre-flight and in-flight geographical weather data for anywhere in the NAS (or in the world, for longer-range aircraft).

With the FAA's policy on FIS, which reduces the role of the FAA for delivery of weather and shifts it to the private sector, there appears to be a viable market for for-profit weather service providers.

Military and civilian aircraft use different sources and transmission mechanisms for weather data.

Traffic Advisories

Traffic advisories need improved accuracy, with minimal human intervention by controllers. In today's environment the controller may be occupied with higher priority duties and unable to issue traffic information. In 2015, on-board computers and interfaces to the ATC surveillance and tracking systems will eliminate the role of the controller as the conduit for traffic advisories. Traffic advisories could be self-broadcast by aircraft, or rebroadcast by the ground system (expanded TIS—B). Accuracy would improve by having everyone on the same reference system. In the future, SUAs may be released more frequently (especially if space launches become more

[1] CD-quality music broadcast to appropriately equipped automobiles or trucks.

frequent). It may be desirable to have a combination traffic/NAS status advisory in the form of a broadcast message.

NAS Status Advisories

NAS status advisories are now available to pilots during pre-flight, on the Automated Terminal Information System (ATIS) via voice, and the D-ATIS system via digital means. With the appropriate avionics, computer software, interface and up-link capability, the pilot could automatically obtain NAS Status Advisories via the FAA's D-ATIS system.

The FAA maintains a National Airspace Performance Reporting System (NAPRS) database containing the status of key NAS systems, which may be available to the cockpit (with the appropriate avionics interface). Although NAPRS is not currently a real-time reporting system, it could be the basis of a database to provide pilots with NAS equipment status.

NAS Status Advisories can be expanded to have the RMM information translated to synthetic voice to handle some equipment outages. If the NAS is using dynamic resectorization, then there may be a desire to have some NAS configuration information broadcast from airports or have it available pre-flight via the Internet.

Technical factors and user requirements that tend to drive change for ATC weather, traffic, and NAS status advisories are listed in the table below, along with factors that tend to act as constraints.

Table 3.3-1. Drivers and Constraints for ATC Adviory Service

Driving Forces ➔	🡐 Constraints	Comments
• Avoidance of hazardous weather • Possible fuel savings by taking winds aloft into consideration	• FIS weather policy • Shift to private sector may preclude some options of packaging FIS with TIS, ADS-B • Volume of data involved for maps	Weather information needs to be provided in a format which can easily be assimilated by the pilot and accommodate varying levels of meteorological skills
• Traffic, especially in congested airspace or airports	• Size of displays • Heads-down time • Latency	Information displayed in the cockpit needs to be easy to interpret

3.4 Traffic Management Synchronization Service

Today's current array of independent systems and varying standards will evolve to a shared environment connecting users and service providers for traffic flow management, flight services, and aviation weather. New decision support tools must be implemented to help users and service providers make collaborative decisions to prioritize and schedule flights and better organize air traffic locally and nationally. These tools will allow users and service providers to more efficiently direct flight paths, sequence departures and arrivals, change routes, and balance capacity and demand throughout the NAS. The objective is to reduce variability in services and optimize use of airspace and available runways.

Traffic synchronization supports expeditious flight for the large number of aircraft using the NAS during any given period of time. Airborne synchronization involves sequencing of aircraft to maximize efficiency and capacity of the NAS through all phases of flight (arrival, departure, and cruise). The surface is managed by formulating taxi sequences and communicating instructions to pilots and vehicle operators for the safe and efficient flow of traffic on the airport surface. Timely coordination between AOC and ATM on NAS projections and user preference, with appropriate data being available via data link, will be beneficial to the user.

Traffic synchronization needs to be able to deal with many types of input to adequately process user preferences – and user status – such as weight, optimal descent profile, optimal departure, and navigation capability. With improved Flight Management Systems, the aircraft should be able to relay data about the aircraft to the controller's Decision Support System (DSS) tools without pilot intervention.

Collaboration needs to be able to begin before the flight, using tools such as electronic whiteboards, AOCnet or bulk flight plan filing and refiling. Collaboration will occur during flights with the AOC acting in conjunction with the pilot to work with Traffic Management and ATC. The interactions need to be automated in such a way that the decisions made during the collaboration between pilots and controllers (and the related AOC and TM) are automatically stored into the various computers, unlike today's situation in which orally communicated agreements must then be inserted manually into computers. By 2015 (or much sooner), software assurance techniques will provide adequate assurance that the decisions endorsed by the pilots and controllers are correctly stored into the ground and airborne computers, but it is not likely that the computers will be trusted to make decisions without a "human in the loop."

Avionics will evolve to take advantage of the benefits found in the new communication, navigation and surveillance related technologies. With the new avionics and supporting ground infrastructure, enhanced services will be available to help users fly safer and more efficiently. The pace of modernization will be benefits-driven and dependent on users equipping with the new avionics.

Technical factors and user requirements that tend to drive change for traffic management synchronization are listed below, along with factors that may act as constraints to change.

Table 3.4-1. Drivers and Constraints for Traffic Management Synchronization Service

Driving Forces →	← Constraints	Comments
Traffic Management Synchronization Service	• Sustain critical NAS infrastructure • Continuity of ATC services	Changes to procedures, training, airspace design, and certification of both ground systems and avionics are will ensure users and service providers realize the new capabilities

3.5 Traffic Flow Management

Air traffic management (ATM) encompasses traffic flow management (TFM) and air traffic control (ATC) capabilities and is designed to minimize air traffic delays and congestion while maximizing overall NAS throughput, flexibility, and predictability.

The description of TFM functionality includes capabilities at the Air Traffic Control System Command Center (ATCSCC) with some functionality distributed to traffic management units (TMUs) at air route traffic control centers (ARTCCs), at high-activity terminal radar approach control (TRACON) facilities, and at the highest-activity airport traffic control towers (ATCTs). To avoid duplication, only TFM functionality is described in this section.

TFM is the strategic planning and management of air traffic demand to ensure smooth and efficient traffic flow through FAA-controlled airspace. To support this mission, traffic management specialists (TMSs) at the ATCSCC and traffic management coordinators (TMCs) at local facilities (ARTCCs, TRACONs, and towers) use a combination of automation systems and procedures known collectively as the TFM decision support systems (DSSs).

Currently, the Traffic Management Strategic Flow Service concentrates on using ground delay programs to ensure that airports and airspace are not overloaded. This is not an efficient solution for allocation of air space.

<u>Summary of Projected 2015 TFM Capabilities:</u>

The NAS-wide information network is designed to facilitate collaboration and information sharing between users and service providers. NAS users will be involved in collaborative decision making by actively participating in flow strategy development, when appropriate, and by modifying their operations to meet air traffic flow initiatives. Collaboration and information exchange will reduce operational uncertainty, improve predictability, and enhance the decision making process by allowing user input into decisions that affect daily operations. Daily system performance data will be recorded to enable quantitative measurements concerning the effectiveness and efficiency of NAS operations from both the FAA and user perspectives. These capacity-related metrics will include delays, predictability, flexibility, and accessibility.

The collaborative process establishes the data exchange capability that will be used to implement ration-by-schedule procedures. The procedures modify the GDP, using the airline schedule, as defined in the OAG as the baseline for allocating actual departures and predicting arrival times, rather than the individual flight estimate. The ATCSCC consolidates the schedule information and transmits it with information on airport arrival capacity constraints.

Control by time of arrival (CTA) provides users with more flexibility in operational planning. CTA uses arrival- rather that departure-based decision making procedures, giving users more control over scheduling their own flights. Users will be assigned arrival times at destination airports and will be able to determine their departure and en route schedules to meet their designated arrival times.

Military scheduling agencies will provide real-time schedules for using SUA that allow sufficient time for service providers and users to incorporate it into their planning. As a SUA's status changes, the NAS is updated in real time, and commercial flights can be routed through it. [1]

Flight plan evaluation provides NAS users with immediate feedback about system constraints and options for their planned routes. This allows users to make timely revisions before submitting a flight plan. When a flight is airborne and operational factors dictate a reroute, the collaborative flight planning process will allow real-time changes, such as reroutes around severe weather or congested airspace. The airport configuration status will include active runway, equipment outages, weather, braking action, and visibility conditions. It will also include operational data, such as arrival and departure rates and types of approaches in use. The CDM process will also

1 Generally, the SUA must be clear of commercial flights 30 minutes prior to being restricted to military operations.

give users the opportunity to take part in deciding when equipment can be shut down for routine maintenance.

Modernized information systems will distribute timely, accurate, and consistent information in electronic format across the NAS, resulting in improved services to users, more efficient use of NAS resources, better flight planning, and more cost-effective systems development and acquisition. The information systems will provide users and service providers with a common view of the NAS for collaborative decision making. Common, standards-based data services will provide data collection, validation, processing, storage, and distribution of data to and from data sources that are both internal (e.g., traffic flow management) and external (e.g., the National Weather Service (NWS), airlines, DOD, and international traffic flow managers) to the FAA.

Data will be dynamically updated as situations change. Data types will include:

Flight Data: Such as the filed flight profile and all amendments, first movement of the aircraft, wheels-off time, in-flight position data, touchdown time, gate or parking assignment, and engine shutdown. The current flight plan will be expanded to become the flight object and will include the added information about the flight. The information will be standardized to be consistent with ICAO standards. The user is one of the main sources of this type of data.

Resource Data: Include static resource data, such as NAS boundaries, configurations, runways, and SUAs; and dynamic resource data, such as airport and airspace capacity constraints, current configuration of runways, system infrastructure status, schedule of SUA activity, and schedule of maintenance activity. The FAA is one of the main sources of this type of data.

Enhanced Weather Data: Include current and forecast weather, hazardous weather alerts for windshear events (microbursts and gust fronts) and other hazards such as icing, turbulence, etc.

Traffic Management Data: Include current and anticipated demand/capacity imbalances and planned strategies for managing them.

NAS Performance Measurement Data: Provide information on NAS performance in a meaningful and readily accessible format for better planning.

Geographic Data: Include terrain maps, obstruction locations, airspace boundaries, etc.

Surveillance Data: Include aircraft-position time and coordinates reports, velocity, and intent information.

The NAS is increasingly dependent on greater information exchange for better and shared planning and decision-making. The NAS will provide users and service providers with consistent, accurate, timely data to allow for future collaboration.

Technical factors and user requirements that tend to drive change for traffic flow management are listed in below along with factors that tend to act as constraints.

Table 3.5-1. Drivers and Constraints for Traffic Management Strategic Flow Service

Driving Forces →	← Constraints	Comments
Cost of delays to airlines and passengers	• Need for confidentiality of airlines information • Connectivity between FAA and AOCs • Less use of voice • Lack of standardized message formats	More precise tools to analyze flow control data, performance, and decision-making

3.6 Emergency and Alerting Services

Emergency assistance services are provided for aircraft in distress situations. ATC services range from assisting an aircraft low on fuel to the nearest airport to aircraft involved in a hijacking. Search and rescue activities include searching for missing aircraft and providing survival aid, rescue, and emergency medical help for occupants after an accident site is located.

Emergency Assistance Services

Emergency assistance services are provided for aircraft in distress situations. NAS ATC facilities provide urgent/distress declarations, aircraft, weather and traffic flow information, and flight plan information to support emergency situations. When emergency situations occur, the responsible ATC facility notifies rescue centers and aircraft operators, in addition to the appropriate foreign, military, federal, state, local and other agencies to help assist in handling the emergency or locating the aircraft.

The ATC facility in communication with the aircraft handles the emergency situation and coordinates the activities of the assisting facilities. The controller may transfer this responsibility to another ATC facility if it is better equipped to handle the emergency. Emergency assistance provided by ATC controllers and other specialists include:

- Providing alternative courses of actions such as distance, time to nearest airport, heading and recommended descent profile.
- Providing current flight information on the aircraft requesting assistance and other relevant information to the appropriate federal, state, local and other agencies.
- Alerting of crash, fire, and rescue services
- Attempting to reestablish aircraft communication using all appropriate means in the event two-way communication is lost with an aircraft under ATC control
- Responding to aircraft requests and notifying appropriate agencies when an aircraft is subject to unlawful interference (hijacking)
- Providing navigation assistance to orient aircraft, avoid or reroute for bad weather conditions, or guiding aircraft to emergency landings at appropriate airports.
- Directing aircraft dumping fuel to suitable dumping areas and notifying appropriate agencies
- Coordinating communications with foreign ATS units as needed

The ARTCCs serve as the central points in the NAS to collect and maintain detailed information for emergency situations. For aircraft operated by a foreign air carrier, the ARTCC responsible for the departure or destination point, when either point is within the United States, relays information to the operator of the aircraft. The ARTCC facilities responsible for the Flight Information Regions (FIR) delegated to the FAA by ICAO provide emergency services to aircraft in oceanic or other airspace outside the NAS.

A terminal ATC facility alerts an ARTCC when an aircraft is considered to be in emergency status that may require Search and Rescue procedures, or an IFR aircraft is overdue. The ARTCC alerts and forwards pertinent information to the RCC whenever an aircraft in its airspace is in an emergency situation or overdue, or when alerted that an emergency situation exists at a terminal ATC facility. The responsible ARTCC or FSS facility coordinates with the RCC, and conducts a communications search to attempt to determine the location of the aircraft. The communication search checks the ATC facilities, airports and other facilities along the route usually from the last reported position to the destination to determine when the aircraft last contacted a facility. The communication search must be initiated before the RCC can began SAR procedures. The assistance of other aircraft known to be operating near the aircraft in distress is also solicited and the results forwarded to the RCC.

The FSSs are the central points for collecting and disseminating information on overdue or missing aircraft that are not on an IFR flight plan.

Terminal ATC facilities, ARTCCs and FSSs are also responsible for receiving and relaying pertinent ELT signal information to the appropriate authorities. When an ELT signal is heard or reported, the responsible ATC facility requests the applicable Direction Finding (DF) Facilities to determine fixes, bearings, and obtain any other pertinent information. Either the ARTCC or FSS collects the ELT information, coordinates with the RCC, and forwards fixes, bearings and other relevant information to the RCC. This information also includes the original and amended flight plan, last recorded or known position, last recorded heading, and the weather conditions for the last known position and projected flight path.

There are any number of circumstances that will result in the emergency service capability being invoked including:

- The pilot, ATC personnel, or officials responsible for the operation of an aircraft declare an emergency situation exists for an aircraft.
- Unexpected loss of radar contact and radio communication with any IFR or VFR aircraft.
- Reports indicate the aircraft either made a forced landing or its operating efficiency is so impaired that a forced landing will be necessary.
- Reports indicate that the crew has abandoned the aircraft or are about to do so.
- Intercept or escort aircraft services are needed
- Need for ground rescue appears likely
- An Emergency Locator Transmitter (ELT) signal is heard or reported.

Alerting Service

ARTCCs and Flight Service Stations (FSSs) alert Search and Rescue (SAR) agencies when information is received from any source that an aircraft is in difficulty, overdue, or missing. SAR is provided through the combined efforts of the federal agencies and the responsible agencies within each state. Operational resources are provided by the U.S. Coast Guard, military components, the Civil Air Patrol, state, county, and local law enforcement and other public safety agencies, and private volunteer organizations.

The SAR activities include searching for missing aircraft and providing survival aid, rescue, and emergency medical help for occupants after an accident site is located.

The U.S. Coast Guard is responsible for the coordination of SAR activities for the Maritime Regions, and the USAF is responsible for the Inland Region. Rescue Coordination Centers

(RCC) established by the Coast Guard and the USAF directs the SAR activities within their regions.

When an aircraft is overdue or missing, a communications search is initiated to determine when the aircraft last contacted an ATC facility. The essential information is gathered for the aircraft (flight plan data, last known position, last recorded heading, search area conditions etc.) and distributed to the RCC prior to initiating the SAR effort. If ATC facilities hear or receive a report of an ELT signal, they attempt to determine the location of the signal. Direction finding facilities obtain fix bearings, and any other pertinent information from the ELT signal. This information is also forwarded to the RCC to support the SAR activities. A combination of Coast Guard, military, Civil Air Patrol, state, county and local law enforcement and other public agencies, and private volunteer organizations perform the actual SAR activities.

Technical factors and user requirements that tend to drive change for the emergency and alerting services are listed in the table below along with factors that may act as constraints to implementing the needed changes.

Table 3.6-1. Drivers and Constraints for Emergency and Alerting Service

Driving Forces ➔	← Constraints	Comments
Poor communication results in unnecessary searches	Communication tends to be poor where infrastructure is expensive to install and maintain (Alaska)	• LEO/MEO could become less expensive making aircraft equipage and ground infrastructure more cost effective. • Pilots would be able to advise ATC of changed plans (e.g. landing to wait out a storm) despite flying out of VHF voice radio coverage.
Lives can be saved if searches are fast	• Pilots may be injured or confused • ELT might be affected by crash	• Luxury automobiles now offer alerting services that report GPS location after an accident or user request; some boats can report location on maritime/aeronautical distress channels • Standalone feature is possibly too expensive, but most components would serve other functions

3.7 Navigation Services

The Navigation Service consists of the navigation guidance for en-route, surface, and approach and landing operations NAVAIDs for en-route enable the use of flight routes; terminal area NAVAIDs support operations near airports; and surface NAVAIDs provide airport surface guidance.

<u>Cruise Navigation Guidance</u>

Cruise NAVAIDs, both ground-based and satellite-based, enable airspace users to determine their position for the purpose of defining and utilizing flight routes.

Ground-base systems accomplish this by enabling position determination by bearing (theta) and range (rho) measurements relative to a predetermined aeronautical fix along established airways.

These airways consist of series of regularly spaced, short-ranged NAVAIDs providing only limited lateral coverage. As a result, traffic is concentrated along these routes.

Space-based systems provide navigation services to properly equipped aircraft over a wide area. Such systems allow more efficient user-preferred routing and do not constrain users to established airways. These NAVAIDs also provide service in oceanic airspace delegated to NAS authority.

Approach and Landing Guidance

Terminal NAVAIDs enable aircraft users to navigate into and out of airports by, first, enabling an incoming pilot to determine the airport location and, second, by helping to correctly orient the aircraft with respect to the runway during approach, landing, and departure. These systems provide vertical, lateral, and distance navigational guidance allowing appropriately equipped aircraft to safely execute non-precision (course guidance only) and precision (course and glide path) landing approaches. Terminal NAVAIDs can be visual or electronic.

Visual NAVAIDs are utilized during approach when the pilot makes the final transition between instrument and visual flying. The NAVAIDs allow the pilot to determine airport locations; his position and orientation with respect to the runway, and provide vertical guidance during non-precision approaches. Different lighting requirements exist for airports rated for each of the three approach categories (I, II, III) with the more stringent requirements applying to Category III airports.

Electronic NAVAIDs are used to support instrument landings in each of the three approach categories. Category I landings are supported by electronic NAVAIDs delivering lateral, altitude (glide path), and distance guidance. Category II runways require another range marker, and Category III require the same guidance features with greater accuracy.

Surface Navigation Guidance

Surface guidance systems are primarily visual, based on lighting and signage. Pilots using these visual aids, with further assistance from detailed maps and tower controllers, maneuver on the airport surface.

Future Navigation Services

The use of GPS, LAAS, and WAAS will result in increased situational awareness in all phases of flight and, therefore, more efficient use of the airspace. The increase in airspace utility, however, will cause spectrum crowding as more users are in the air at the same time.

Areas now governed only by VFR and procedural flying will be opened to instrument flying. The pilot in this environment will use his improved navigational accuracy in conjunction with a land reference database for easier terrain avoidance. Eventually, this database will be available over the Internet and will have filtering capabilities to provide the pilot will all information pertinent to his flight without, at the same time, inundating him.

Surface operations will benefit from the use of LAAS as it will provide the pilot a better awareness of “unmarked” targets (movable and/ or unscheduled objects). LAAS data may flow automatically to the pilot or first through the controller.

The navigation improvements in already congested airspace will allow a further increase in traffic volume as well as the use of more direct routes. This, however, will result in a greater demand for separation services from ATC. Individual controllers may initially take responsibility for more aircraft to alleviate this new demand, but the need will eventually cause the addition of more controllers who will, in turn, further increase spectrum crowding. The use of “pre-made” data messages sent to aircraft when they arrive at certain points in the airspace may be one way of providing separation assurance services to more users while minimizing spectrum congestion.

Oceanic operations will improve as aircraft will be able to fly more precise routes. Better routing will allow more aircraft along each individual route and will allow the overtaking of slower aircraft along the route. In time, some parts of the current oceanic airspace will be treated like extensions of the domestic en-route, and, as a result, better real-time communication capability (both pilot-to-controller and pilot-to-pilot), more frequent position reporting, and pilot response to controller commands, all of which increase spectrum usage, will be needed.

Table 3.7-1. Drivers and Constraints for Navigation Services

Driving Forces →	**← Constraints**	**Comments**
Use of GPS for en route/ terminal navigation	▪ Frequency Spectrum ▪ Cost for users to update aircraft with new Avionics ▪ Concerns whether GPS can provide “sole service” ▪ Availability of voice and data communications for oceanic flights	U.S. Government is committed to provide a second and third signal to improve robustness and reliability of GPS for civilian Users. Also enables real-time determination of highly accurate position location anywhere on earth.
Deployment of WAAS to augment GPS to provide en route/ terminal navigation and CAT I approaches for airports	▪ Frequency Spectrum ▪ Cost Benefits of installing WAAS ▪ Availability of data and voice communications for flights in new en route airspace ▪ Cost for airports to upgrade lighting for new CAT I approaches	GEOSAT uplink stations and communication satellites provide frequency coverage throughout US airspace allowing more user preferred and direct routes. Sufficient accuracy to provide CAT I approaches at most airports.
Deployment of LAAS to augment GPS to provide CAT I/II/III approaches for airports	▪ Frequency Spectrum ▪ Cost Benefits of installing LAAS ▪ Cost for airports to upgrade lighting for new CAT I/II/III approaches	Precisely surveyed ground station, multiple GPS receivers, VHF link and broadcast GPS corrections with integrity messages to 20 to 30 nmi of airport.
Continued need for ground-based navigation as well as SAT navigation	▪ Capability of GPS to provide “sole service” ▪ Frequency Spectrum, availability, and interference concerns ▪ Timeline to transition GA and other Users from old equipment	Use of SAT navigation for “sole service” causes safety concerns about SAT availability, unintentional and intention interference, and other issues. The frequency spectrum will also be even more congested with concurrent use of ground and new SAT navigation systems.

3.8 Airspace Management Service

Airspace management service involves design, allocation, and stewardship of the national airspace resource in order to ensure its safe and efficient use. Effective airspace management is dependent upon the coordination of present and projected stakeholder (aviation and non-aviation) needs, traffic volumes, spectrum availability, effects of airport construction, surface structures, and environmental factors.

<u>Future Airspace Management Services</u>

The future will see shifts in airspace management practices.

- Sector management will become more dynamic in that controllers will have the ability to resize sectors to accommodate continuously changing traffic demands.
- The number of high altitude sectors will be minimized (possibly to only eight for complete national coverage) so that cross-country traffic need change sectors infrequently.
- The re-acquisition process of unused SUA will become more responsive. At present, this process is based on fax-type equipment and, as a result, is slow.
- In large metropolitan areas with multiple airports, low airspace will be managed as if it is serving one large airport with widely dispersed runways changing many communications requirements based on sector size and shape.
- Airspace will be managed as though position information is acquired with radar signal, but, instead, it will stream down from aircraft and their ADS sources.
- Oceanic routes for which demand is to increase, will likely be controlled in a manner consistent with en-route domestic flights instead of present oceanic methods.
- More airspace will be allocated for handling space launches.

Table 3.8-1. Drivers and Constraints for Airspace Management Services

Driving Forces →	← Constraints	Comments
Need to dynamically reconfigure airspace for flexibility and to accommodate increased traffic demands	▪ Automation and decision aids to support dynamically reconfiguring airspace ▪ Controller acceptance of the necessary procedure and paradigm changes • Additional communication requirements to support the different airspace configurations rather than the relatively rigid sectors used today	There is a limited capability to combine sectors of airspace in the ARTCCs today.
User demand for additional low altitude direct routes	▪ Users must be properly equipped with Avionics to fly direct routes ▪ Procedure changes and potential automation support needed to support new direct routes ▪ Increased demand for data and voice communications in highly congested terminal airspace	Many existing low altitude routes cause the aircraft to fly increased distances due to ground navigation aid constraints.

3.9 Infrastructure/Information Management Service

Infrastructure management ensures flight safety and efficiency through the monitoring and maintenance of NAS supporting hardware, spectrum, and information services. Hardware, which includes radar, communication links, navigation aids, and automation, is continuously monitored. Failures are detected and isolated, and corrective and preventive maintenance is performed to ensure the operational readiness of the NAS. Spectrum management secures, protects, and manages the radio spectrum for the FAA and the U.S. aviation community. NAS support provides information and coordination services to the DOD, law enforcement, land grant agencies, state aviation managers, and disaster relief.

The monitoring and maintenance of NAS system performance is done only for systems operated and maintained directly by the FAA. NAS systems are continuously monitored, and anomalies are reported to the operations control center (OCC). The OCC itself also monitors facility key performance parameters and reports its findings to the National Operational Control Center (NOCC). When needed, an OCC may alter facility system controls to maintain facility and/or system optimization. All maintenance and system changes are reported in real-time to allow for expanded collaboration with NAS users.

Future Infrastructure Management

Although infrastructure does not directly support user needs, changes to the communications architecture that address user needs will have a significant effect on the infrastructure. In the current system, the FAA has software to manage the infrastructure it operates. Similarly, airlines manage their own corporate resources (although some have outsourced these activities). With the planned inclusion of network management in the next version of the ATN SARPs, the infrastructure may be able to manage airborne nodes, providing more information, but, at the same time, increasing the amount of network overhead. For both voice and data communications, it is likely that networks will be able to determine the status of other nodes on the network, whether these nodes are service providers (e.g., the CAAs of other States), airlines, or aircraft.

Information and coordination services will be faced with the fact that data sharing will be an issue with the maturation of the NAS network. Well defined methods of information dissemination will reduce costs as the FAA will not need to pay for or generate the same data multiple times; once the data is acquired, it is to remain available to all users. The data sharing will also aid in collaborative flight planning as users will be provided with an accurate picture of which portions of the NAS are functional and how to plan a flight given that certain portions are not.

Spectrum management will also change. At present it aids with the development of national policy governing spectrum allocation, and it provides guidance to all new and existing programs to ensure compliance with spectral standards and existing equipment. Spectral management will become more difficult in the future as new technology will require the use of spectrum previously unused for aeronautical communications. The economic value of spectrum in fields not related to aviation, however, will make it harder to protect for aeronautical mobile system route services [AMS(R)S]. In addition, aeronautical spectrum is currently allocated for specific purposes, such as navigation systems or communications systems. Any architecture that combines capabilities over a single communications pipe (e.g., using ADS-B to provide FIS services) may require changes to spectrum allocation – at both national (FCC, NTIA) and international (WRC, ITU-R) levels.

Table 3.9-1. Drivers and Constraints for Infrastructure Management

Driving Forces →	← Constraints	Comments
SARPs requirements to define and use managed objects, including on airborne nodes	Bandwidth	Requirements for network management
Use of commercial ground-ground networks	Network management tools custom built for FAA	Standardized protocols needed
Use of commercial air-ground networks	Service providers will use their own antenna farms	Changed role for spectrum engineering to protect spectrum, police interference, etc.
Service providers determine technology	ITU-R & FCC/NTIA spectrum allocations	Commercial providers get spectrum allocation. Spectrum is allocated for specific purposes; only aeronautical spectrum is protected.
• Service providers determine technology to satisfy commercial demand • Voice over IP is driving vocoder/ codec development	Clear transmission of voice is necessary	Acceptability criteria are needed for vocoders
Diversity; more types of links	Ability to manage multiple links and to failover when a link becomes unavailable; might require using a different provider	ATN routers are designed to handle multiple links
Security threats	System must accommodate public users, including non-U.S.	Network infrastructure requires protection mechanisms; topology might be affected
User demand for use of most economical, effective communication links	Cost of implementing and supporting multiple links; latency requirements	Current system is like the days of one telephone company; users had no choice as to who provided the service. PETAL II is using dual-stack to support FANS and ATN equipped aircraft.
Use of digital air-ground radios	Co-site interference	New modulation techniques (VDL, inter alia) have different interference characteristics and may require new placements of towers at antenna farms.
Increased use of non-FAA resources	As network management becomes more complicated, skills for problem resolution might be rare	Collaboration tools could make it possible for limited number of highly skilled, extensively trained experts to work on problems non-locally. • Need high-quality, secure links • But experts would not have to travel to job site

3.10 Aeronautical Operational Control (AOC) Service

Aeronautical Operational Control Services are provided by the major air carriers to schedule flight operations, monitor flight progress, and collaborate with FAA Traffic Flow Management on NAS projections and user preferences. AOC messages are those defined as necessary for the safe and orderly operation of an aircraft. While the majority of the messages are related to orderly operation, safety related messages are also significant in number. Typical safety messages include hazardous weather conditions or maintenance issues.

The original set of AOC data messages are the Out, Off, On, In (OOOI) messages. These messages are generated automatically via sensors and radio equipment on board the aircraft. By collecting these messages, airlines developed statistics on flight times and could maintain a rough estimate of aircraft location. Building on the success of the OOOI messages and the infrastructure to distribute them, airlines developed a variety of other messages.

The current AOC messages include the OOOI messages, crew information, fuel verification, delay reports, weight and balance, dispatch release, fuel remaining, gate assignment and coordination, engine parameters and a variety of weather information and maintenance messages. Flight plan information may be exchanged between the flight crew and the dispatch office in order to accommodate delays or rerouting. These planning messages include weather conditions at primary and secondary landing sites, air traffic control conditions and fuel analysis. The cabin crew need for AOC messaging include connecting flight gate information, special services for passengers such as a wheelchair request, and notification of an in-flight medical emergency.

Closely related to AOC messages are Airlines Administrative Communications (AAC). AAC messages have a lower priority than AOC messages but can be expected to increase significantly as data link capacity increases and per message costs decrease. Examples of AAC messages include passenger manifest, reporting crew hours, and in-flight passenger ticketing.

AOC traffic is growing rapidly and has created a commercial business case for an evolutionary bit-oriented system with higher speed, and modern internationally accepted protocols. The future needs for AOC include increasing amounts of engine performance data, flight plan data, and maintenance data. New uses include potential downlink of flight data recorder information and increased negotiations between aircraft crew and controllers for traffic flow management.

International spectrum allocations constrain AOC systems to existing allocations, necessitating greater spectrum efficiency. Future systems will feature common, compatible protocols in order to exchange messages via a variety of media including High Frequency (HF), Very High Frequency (VHF), and satellite. Messages will be routed through the lowest cost path consistent with latency delivery requirements.

Technical factors and user requirements that tend to drive change for aeronautical operational and administrative communications are listed below along with factors that tend to constrain that change.

Table 3.10-1. Drivers and Constraints for AOC and AAC

Driving Forces ➔	← Constraints	Comments
Need for aircraft maintenance data	• Bandwidth	Airlines can improve turnaround time by having right staff and equipment to service problems as soon as aircraft has landed.
Need for engine performance data	• Bandwidth • Confidentiality	Increasing demand for information. Data are provided, but airlines want more.
Flight plan data	• Bandwidth • Use of proprietary protocols	Needed for cost effective use of CDM

Driving Forces →	← Constraints	Comments
Efficient recovery from delays for passengers	• Bandwidth	Need improved gate information, possibly including expediting deplaning of passengers with tightest connections.
Desire for quicker financial and stock reporting	• Bandwidth • Confidentiality	Reports on beverage and duty-free sales for financial information as well as for replenishing stock

3.11 Onboard Services

Passengers have had few communication opportunities in the past. Voice service is available on a large number of aircraft today but has seen limited passenger use due to high cost. Passenger communications can be expected to increase substantially if costs are reduced.

Major increases in cabin services for passengers and cabin crew are envisioned. In the future passengers will have access to voice and data services and will be able to interact with automation systems for a variety of services including voice, in-flight entertainment, shopping, hotel and car reservations, and data exchange services such as electronic mail.

Cabin crewmembers will use the on board services to access their corporate automation to provide passenger services such as flight and travel planning. The same links can provide business functions such as load factor reports, cabin maintenance requirements, and crew availability.

Once connected to ground based automation services, passengers will be able to receive personal business communications.

Passenger communications will be provided by sharing transmission media thereby reducing the cost of all services for ATS, AOC, and the passenger. For shared service, the media must provide the ability to prioritize ATS and AOC messages over passenger messages. For the services that include financial transactions, secure links will be required.

Technical factors and user requirements that tend to drive change for aeronautical operational and administrative communications are listed below along with factors that tend to constrain that change.

Table 3.11-1. Drivers and Constraints for Onboard Services

Driving Forces →	← Constraints	Comments
Sporting events or other entertainment events	• High bandwidth for real-time television • EMI	A commercial firm has announced award of a contract to provide real-time television on A320s
Passengers want to conduct business (telephone, fax, laptop PCs)	• Equipage cost • Size of units • EMI • Interfaces to faxes, PCs • Power outlets • Security (for financial or personal transactions)	Passenger use of communications facilities can justify the installation of satellite or other communication equipment, which might also be useable for ATM, FIS, AOC, or other purposes.
Passengers bring their own equipment	• EMI	

Driving Forces →	← Constraints	Comments
Gambling	• Bandwidth • Latency • Security • U.S. law	• Already in place in flights that do not originate or terminate in the U.S., so some aircraft are equipped • Probably highly profitable

4 Candidate Communication System Architectures (CSAs) for Delivery of User Services

4.1 Communication System Architecture (CSA) Elements

Section 3 defined the user needs for delivery of the services necessary to support safe and efficient operations in the NAS Airspace. In addition, driving and restraining forces were identified, which characterize the differences between each class of service. This section defines candidate CSAs which actually deliver these or subset of these services to the airborne airspace users. Three classes of users are defined as follows:

- Class 1: Operators who are required to conform to FAR Part 91 only, such as low-end General Aviation (GA) operating normally up to 10,000 ft. This class includes operators of rotorcraft, gliders, and experimental craft and any other user desiring to operate in controlled airspace below 10,000 ft. The primary distinguishing factor of this class is that the aircraft are smaller and that the operators tend to make minimal avionics investments.
- Class 2: Operators who are required to conform to FAR Parts 91 and 135, such as air taxis and commuter aircraft. It is likely that high-end GA and business jets and any other users desiring to operate in controlled airspace will invest in the necessary avionics to be able to achieve the additional benefits.
- Class 3: Operators who are required to conform to FAR Parts 91 and 121, such as Commercial Transports. This class includes passenger and cargo aircraft and any other user desiring to operate in controlled airspace. These users will invest in the avionics necessary to achieve the additional benefits.

For purposes of developing candidate CSAs, it is assumed that all three classes of users either desires to or is required to operate under IFR rules. For a 2015 architecture, this will require a certain minimum equipage for aircraft in each class and will be a major cost and benefits (business) factor in assessing candidate CSAs.

The delivery of services traditionally have been provided by service providers; however, the proposed CSAs will address candidates that consider delivery of services by airborne users or delivery by user interaction with other remote data bases. Therefore, the CSAs will address the distribution of certain services to airborne users with the responsibility to deliver services to other users. All candidate CSAs will be developed consistent with the following figure which depicts the airspace users and service providers along with the information exchange paths used to deliver users services between airspace users (A-A) and between airspace users and service providers (A-G).

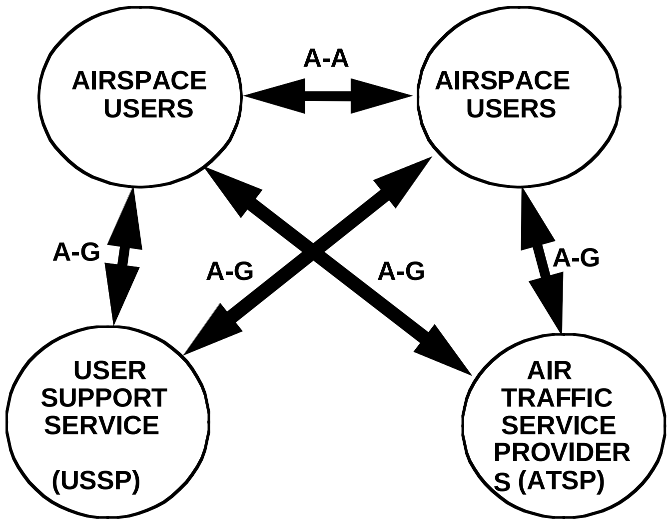


Figure 4.1-1. Baseline Communication System Architecture

The service providers can be categorized as either supporting the users in an advisory or operational fashion (User Support Service Provider) or as part of an air traffic organization (Air Traffic Service Provider). This distinction is critical as certain user services are uniquely provided by only one of the service providers. The following lists the specific organizations/systems that fall under each of the above categories.

User Support Service Providers (USSP)

- Fixed Base Operators
- Military Base Operators
- Airline Operations Centers
- Advisory Systems/organizations
  - ⇒ Flight Information System (FIS) Supplier
  - ⇒ D-ATIS
  - ⇒ National Weather Service; ETC.,

Air Traffic Service Providers (ATSP)

- Automated Flight Service Station (AFSS)
- Traffic Management Units (TMUs)
- Air Traffic Control System Command Center (ATCSCC)
- Surface/Tower ATC
- Terminal ATC
- En Route ATC
- Oceanic ATC

As indicated above, the candidate CSAs for 2015 will address the distribution to airborne users of the responsibility to delivery certain services. Therefore two CSA Service Architectures will be evaluated consisting of:

1. **Centralized Service Provider Service Architecture** – the service providers would provide All services and processed information sent to the users who would utilize the information to maintain safe and efficient operations. The users would provide updates to the service providers and provide information to other users and service providers either mandated for safe operation (TCAS) or derived from observations in the user sphere of operation (PIREPS).
2. **Distributed User and Service Provider Service Architecture** – Certain services would be distributed to the airborne user who would have the responsibility to process information provided by the service providers not only to maintain its own safe and efficient flight but provide processed information to other airborne users and to service providers. Two potential areas of distribution include preparation of flight plans and distributed separation of IFR aircraft.

The distribution of the services or service architectures is a key in defining and selecting candidate CSAs as the distribution impacts the equipage of the airspace users affecting the cost and benefit decisions necessary to actually implement that CSA. The service architecture also affects the type and magnitude of information transferred between airspace users and service providers and the ultimate selection of the communications media.

The following section will evaluate each of the user service categories identified in section 3.0 for each of the two service architectures defined above. It is important to evaluate CSA service architectures at the service level due to the differences in service characteristics. For example, some services have more stringent performance requirements in terms of capacity and latency; or may not apply to either of the distributed or centralized service architectural schemes. The objective is to define a CSA concept that defines the distribution of services across the elements of the CSA as defined in Figure 4.1-1. The evaluation will consider the degree of that the delivery of services are driven by and support the following major Government/Industry/User initiatives such as:

1. AATT/Free Flight Concept
2. AWIN/Aviation Weather Safety Program
3. Distributed Air Ground (DAG) Concept
4. Collaborative Decision Making (CDM) Objectives
5. Small Aircraft Transportation System Concept

The evaluation will also address areas where delivery of services are restrained by:

1. Technology Availability
2. Program Availability
3. Resource Availability

The resulting CSA Concept will be used to define candidate CSAs by identifying different service delivery methods that can be applied to one or more information exchange paths in the CSA Concept. The three methods are defined as follows:

1. **Broadcast Method**- Information will be sent by service provider simultaneously to multiple airborne user subscribers containing the same set of information. Each subscriber must store and extract the information necessary to support their respective flight.
2. **Point-to Point (Addressable) Method** – Information is tailored for each subscriber based on subscriber needs and/or service provider determination and sent only to that specific subscriber. The subscriber must request changes to delivery.
3. **Query/Response Method** – The airborne user determines individual needs and remotely accesses the required information, retrieves the information, and uses the information in executing the particular flight. The databases being accessed could be either on the ground or on other aircraft.

4.2 Communication System Architecture (CSA) Concept Definition

The eleven (11) user service categories will be evaluated against the two (2) service architectures with the objective of identifying applicability of services to functional architectures, determining relative merit relative to supporting major user/industry drivers; i.e., Free Flight and Aviation Weather, and impact of constraining factors, such as, technology, other program dependencies, and resource limitations. The following evaluation will be utilized to (1) define the CSA Concept used for developing candidate CSAs and (20=) used to define critical restraining factors that may play a major part in selecting a CSA from the candidates.

Table 4.2-1. CSA User Service Category Versus Service Architecture

USER SERVICE CATEGORY	CENTRALIZED SERVICE PROVIDER SERVICE ARCHITECTURE	DISTRIBUTED AIRSPACE USER AND SERVICE PROVIDER SERVICE ARCHITECTURE
FLIGHT PLAN SERVICE	• Existing Service implementation • Cannot support full Free Flight or DAG concepts • Flight plan processing and Decision Support Tools relying on flight plans would be impacted as more flights fly direct routes under North American Route Program • CDM would impact processing of flight plans at AOCs and FAA Traffic Flow operations. • No major technology, program, or resource restraints	• Necessary to support AATT/Full Free Flight and DAG • Will improve support to CDM • Requires flight plan processing functions (preparation, modification, etc) to be conducted by onboard airspace user • Requires weather projections along entire route and probably trial planning function • Requires FMS equipage and link to flight plan processing • Significant, additional avionics required for GA users • Changes required for commercial avionics • Restrained by Availability of low cost GA avionics • Requires increases in flight plan data transmitted by airborne user

USER SERVICE CATEGORY	CENTRALIZED SERVICE PROVIDER SERVICE ARCHITECTURE	DISTRIBUTED AIRSPACE USER AND SERVICE PROVIDER SERVICE ARCHITECTURE
ATC SEPARATION ASSURANCE SERVICE	• Current service implementation except for TCAS operations, VFR operations, and Selected Oceanic maneuvers conducted by airborne users • Will support AATT/Free Flight Phase 1 and CDM capabilities but will result in increased processing (conformance checks, etc.) by service providers • Will not support AATT/Full Free Flight and DAG • Requires procedure for integration of pseudo-radar data (ADS, Flight Plans) with radar positional data by ATC Service providers • Requires the GA users have capability to receive and display aircraft positional information to fly IFR • Restrained by Availability of low cost GA avionics • Restrained by availability and capability of FAA ARTCC and TRACON automation systems to incorporate Decision Support Tools.	• Necessary to support AATT/Full Free Flight and DAG • Requires processing and display of traffic and weather information well beyond TCAS radius of operations and perhaps along entire route • Requires some form of conflict probe for airspace users • Requires much greater airspace user interaction with other airborne users • Requires FMS equipage and link to increased positional processing capabilities • Significant, additional avionics required for GA users • Changes required for commercial avionics • Restrained by Availability of low cost GA avionics • Restrained by availability and capability of FAA ARTCC and TRACON automation systems to incorporate Decision Support Tools • Restrained by lack of TCAS equipage on cargo transports and GA aircraft • Will increase amount of aircraft position and state information transmitted by airborne user
ATC ADVISORY SERVICE	• Current service implementation • Will support AATT/Free Flight and DAG concepts with increased quality and transmission capacity • Improved service restrained by FAA, NWS, and Commercial weather /flight information providers • Restrained by Availability of low cost GA avionics	• Same as centralized except that airborne users will have to issue traffic advisories to other users in their area of control beyond TCAS area. • Significant, additional avionics required for GA users • Changes required for commercial avionics • Will increase amount of advisory information transmitted from service providers and from airborne users to other airborne users.

USER SERVICE CATEGORY	CENTRALIZED SERVICE PROVIDER SERVICE ARCHITECTURE	DISTRIBUTED AIRSPACE USER AND SERVICE PROVIDER SERVICE ARCHITECTURE
TRAFFIC MANAGEMENT - SYNCHRONIZATION SERVICE	• Current service implementation • Most impact limited to CDM initiatives • Objectives of AATT/Free Flight are to reduce the occurrences of these Traffic Flow restrictions • No real impact on GA	• No potential impacts except that with distributed flight planning and separation assurance, airborne users will be in position to more efficiently react to restrictions and negotiate possible responses.
TRAFFIC MANAGEMENT - STRATEGIC FLOW SERVICE	• Current service implementation • Most impact limited to CDM initiatives • Objectives of AATT/Free Flight are to reduce the occurrences of these Traffic Flow restrictions • No real impact on GA	• No potential impacts except on preflight planning in conjunction with CDM initiatives.
EMERGENCY AND ALERTING SERVICE	• Current service implementation	• No potential impacts
NAVIGATION SERVICE	• Current service implementation • GA aircraft should have as a minimum the GPS navigational capability • Cost of GA avionics is not a major restraint	• Requires that all aircraft above FL180 have capability to utilize GPS navigational fixes as well as defined alternates • GA aircraft should have as a minimum the GPS navigational capability • Cost of GA avionics is not a major restraint
AIRSPACE MANAGEMENT SERVICE	• Current service implementation	• No major impacts except for increased transfer of information relative to SUA and any other restricted airspace to be used in distributed flight planning.
INFRASTRUCTURE/INFORMATION MANAGEMENT SERVICE	• Current service implementation	• Airborne users would need access to status information on ATC systems and airports to conduct flight planning.
AERONAUTICAL OPERATIONAL CONTROL (AOC) SERVICE	• Current service implementation	• Distributed airborne flight planning and CDM initiatives would increase amount of information exchanges between commercial pilots and dispatchers at AOC
ON-BOARD SERVICE	• Current service implementation	• No potential impacts

Based on the above tables, it is obvious that certain services are prime candidates for distribution to airborne users while others must be utilized by airborne users as a result of the distribution of the prime services. Together, they form the candidate set of distributed services to be used in definition of CSAs. Distributed services, by definition, are those that are utilized not only for the individual airborne user operation but generate information for use by other airborne users and service providers. The following table identifies those services supported by service providers and those distributed to airborne users.

Table 4.2-2. User Services Versus Service Providers and Distributed Airspace Users

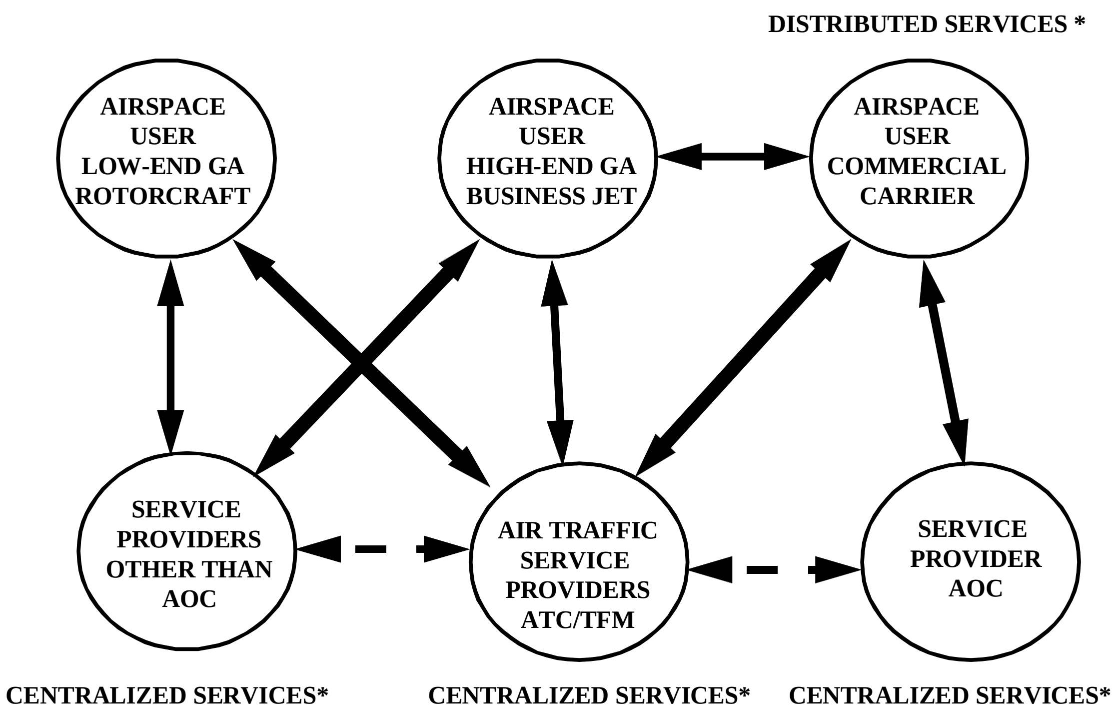
USER SERVICES	USSP (AOC)	USSP (OTHER)	ATSP (ATC)	ATSP (TFM)	DISTRIBUTED (NOTE)
FLIGHT PLAN SERVICE					P
ATC SEPARATION ASSURANCE SERVICE					P
ATC ADVISORY SERVICE					S
TRAFFIC MANAGEMENT - SYNCHRONIZATION SERVICE					S
TRAFFIC MANAGEMENT - STRATEGIC FLOW SERVICE					S
EMERGENCY AND ALERTING SERVICE					
NAVIGATION SERVICE					
AIRSPACE MANAGEMENT SERVICE					S
INFRASTRUCTURE/INFORMATION MANAGEMENT SERVICE					S
AERONAUTICAL OPERATIONAL CONTROL (AOC) SERVICE					S
ON-BOARD SERVICE					

NOTE: P = PRIMARY DISTRIBUTED SERVICE;
S = SECONDARY OR SUPPORTING SERVICE

It is assumed that GA aircraft considered in the development of CSAs are going to fly under IFR rules. As a minimum, all GA aircraft (including Rotorcraft) desiring to gain greater access to airspace under AATT/Free Flight and SATS concepts should be (1) equipped to receive and process weather data in both A/N and annotated (versus raw data) graphic formats, (2) have capability to receive augmented GPS signals for navigation, and (3) have capability to receive and display ADS-B position reports. Those High-end GA aircraft operating above 1000’ should be equipped with the same capability as low-end GA but with added capability to broadcast ADS-B position reports.

In Table 4.2-1, there are several major restraints that must be overcome to achieve the objectives of the AATT/Free Flight, Aviation Weather, and SATS Concepts. The first is related to the above discussion and involves the availability of low cost GA avionics ($500 - $1,000) to include GPS navigation, weather display, ADS-B receive capabilities to under $2,500 to include expanded ADS-B broadcast capability. The benefits to GA airspace users have been documented (relative to gaining greater access to controlled airspace and should justify the above costs. The question is as to whether Industry can meet these cost goals for the avionics. At the other end of the user spectrum, the cost of modifying commercial avionics and equipping cargo transports with TCAS are another set of restraints that must be addressed. Finally, the most difficult restraint deals with revision of ATC orders, standards, and procedures to allow the integration of pseudo-radar position reports from ADS to be integrated with radar position reports and treated equally in separating IFR aircraft. The development of Candidate Communication System Architectures (CSAs) will be conducted assuming that the above restraining factors will be overcome.

The following figure depicts the Communication System Architecture (CSA) Concept derived from the previous tables, which forms the basis for definition of Candidate CSAs in the next section.



***:See Table 4.2-2 for Service Definitions**

Figure 4.2-1. Communication System Architecture (CSA) Concept

4.3 Candidate Communication System Architectures (CSAs) Definition

Candidate Communication System Architectures (CSAs) will be defined in terms of the method of service delivery for each of the air to ground and air to air information exchange path identified in Figure 4.2 -1. The methods of service delivery defined in 4.2 include:

1. **Broadcast Method(B)**
2. **Point-To-Point (Addressable) Method (A)**
3. **Query/Response Method (Q)**

These delivery modes can be applied to individual information exchange paths or groups of information exchange paths. Furthermore, several methods can be applied to a single path. Each method has characteristics which impact a wide range of factors including availability, capacity (bandwidth), avionics, safety, communications media (VHF, SATCOM, etc). therefore a wide range of candidates can be selected and evaluated. The following example represents an initial candidate CSA that will be used as the basis for determining other candidates.

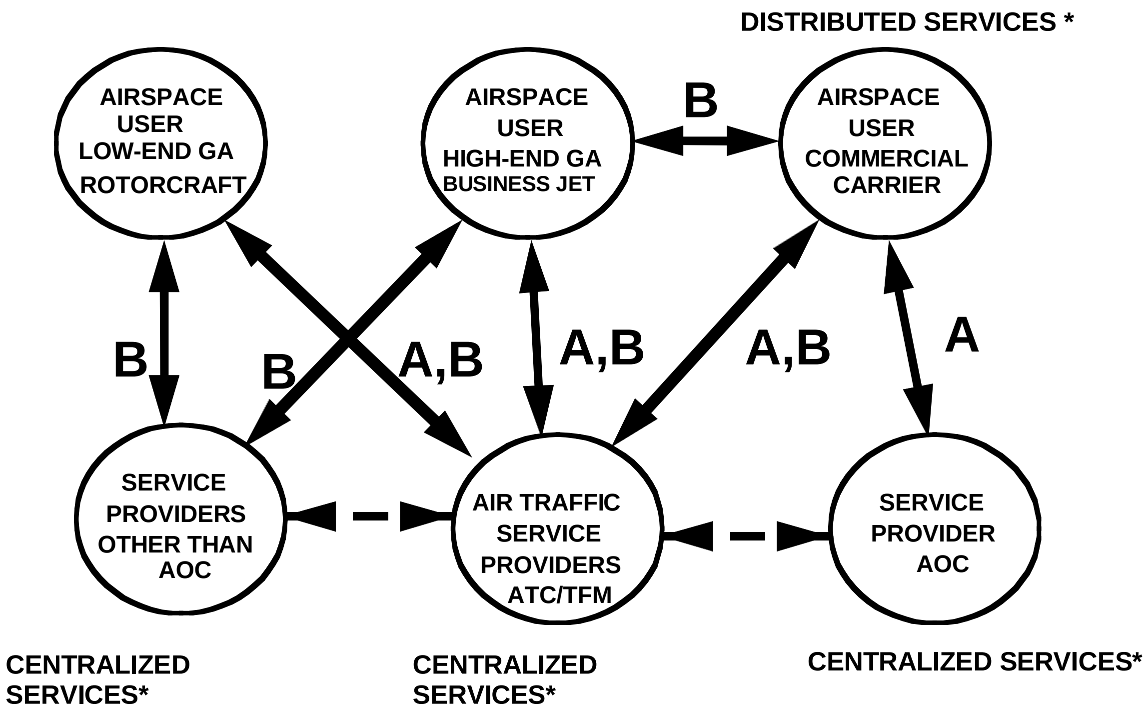


Figure 4.3-1. Baseline Candidate Communication System Architecture

The selection of the above service delivery method is based on the following rationale. For service providers other than the AOC, it makes sense to broadcast the advisories to provide a more cost-effective approach for GA users. The AOC would always use an addressable scheme for not only positive control but also protection of valuable operational information that would be of value to competitors. ATC Service providers would use a hybrid mode with traffic and weather data being broadcast to all aircraft flying in the controlled airspace with addressable mode used to transfer critical ATC and safety messages. It is likely due to cost constraints that Low-End GA would use a simpler and less costly media than either High-end GA or Commercial users. The broadcast air to air link between High-End GA and Commercial users is based on the assumption that both will be flying in the same airspace and will be employing full ADS-B capability.

Additional candidate CSAs can be developed by simply changing the methods of service delivery for individual information exchange paths. It is recommended that the baseline be modified to include the Query/Response Method for (a) GA users interacting with service provider databases and (b) Commercial users interacting with AOC databases. The introduction of this method of service delivery represents a major departure from traditional methods but does present a method that can incorporate both advanced information systems and communications technology. A demonstration of this method of service delivery relative to a wide range of information; including, weather, charting, and traffic is technically feasible at this time. Since the selection of a candidate CSA is linked closely to the selection of the method of service delivery, it is important that the relationship with communications technology be understood. The following discussion presented with that objective in mind.

Comparing candidate architectures – as alternatives – might obscure critical issues that are not easily packaged into a complete architecture but have profound impacts on the architecture.

Perhaps the clearest discriminator between concepts is the degree of linkage between the ATM and weather service providers. The current architecture is based on ATM and weather services being provided by the FAA, using FAA-operated communications links (with some links such as FANS or ACARS operated by commercial aeronautical service providers); airlines and some other users obtain weather from other sources, but the architecture is based on FAA provision of services.

In accordance with FAA policy established in June 1998, flight information services should be provided through commercial service providers. This has significant architectural implications. The current architecture leaves the communications decisions to the FAA. The alternative architecture leaves the decisions to the service providers and users, although the FAA would still have its regulatory role related to certification. In fact, users must pick a non-FAA link if they are to be able to receive these services.

The fact that this link decision might be made by users and weather providers does not take it out of the realm of the NAS architecture. The weather communication link and related avionics could be made totally independent of the links and avionics used for ATM. This, however, would have a profound impact on the economics of the avionics equipage and the amount of space needed for the avionics. If the link, processors, and displays acquired for FIS could also be used for delivery of other services, such as TIS or ADS-B, the level of equipage would change. Thus, the architecture needs to consider whether this non-ATM equipment must be dedicated to non-ATM use, or could also be shared with ATM functions.

This argument leads to a further consideration – whether services developed for commercial, non-aeronautical, applications should be adaptable for aeronautical use – and at what cost? To some extent, there has been a precedent. ACARS was developed to initially support largely administrative functions but has evolved to support AOC capabilities that affect safety and regularity of flight. Pre-departure clearances and ATIS have been delivered over ACARS for several years. In a few years, controller-pilot communications will be able to be conducted over a communications service developed for commercial use.

Aviation, like many other industries, has a critical need for more communications capacity and performance. Ground-based applications, using copper or fiber links, have enjoyed extensive improvements in performance; even without these improvements, capacity can be increased by establishing more circuits. Air-ground applications are not as fortunate; spectrum is a limited resource, although it has benefited from efficiency improvements. Most aeronautical communications, both voice and data, reside in the VHF band. Spectrum managers around the world have faced increasing challenges to manage the sparse capacity in VHF; other bands are needed if growth is to be accommodated.

One of the most effective areas for growth is in the bands suitable for satellite communications. The business case for satellite communications is being made based on general communications use, not just on aeronautical use. Projected high demand for these services has led to designs that provide very high capacity; with the expectation of many users, the satellite infrastructure costs can be spread across many users and types of applications, in order for the satellite communication providers to be able to compete with ground-based communications providers. For most users, ground-ground communications is an alternative and satellites have to be able to have competitive costs and performance in order to have a market. Aeronautical users, who must use radio communication, would be able to take advantage of this technology – probably at lower costs than previous satellite services.

Earlier, several modes of delivering services were described. The following discussion describes alternative ways in which one specific service could be provided, highlighting the characteristics of each of these delivery modes. The overall hierarchy of choices is shown in Figure 4.3-2, which portrays some of the alternative means for providing weather information to the cockpit.

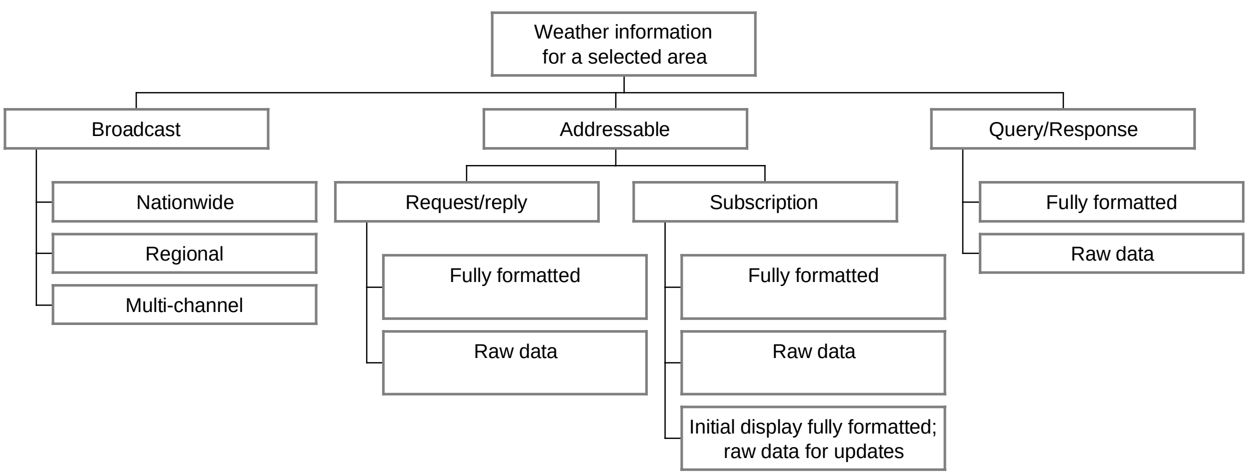


Figure 4.3-2. Service delivery Methods for a Weather Service Provider

When using a broadcast service, the user has no control over what is sent minimal control over what is received, and needs precise control over what is displayed. In terms of equipage, the aircraft needs a means for specifying the data of interest (e.g., via a menu) and a means for processing the request and displaying the results. The aircraft needs a receiver (and antenna suitable for reception), but does not need a transmitter. If the service provider is using broadband communications, it might be possible to have all of the provider's services on a single channel, with the data repeated at fairly frequent intervals to minimize latency to an acceptable range. This could be compared to a scroll of sports scores or stock ticker display on television news; you may have to wait several minutes before the information you want is available. In the case of aviation, it is not possible for the pilot to monitor the display, so automation is needed to select the desired information. It might be possible to subdivide the country into several regions, broadcasting weather of local interest. This could reduce the latency, but would also mean that pilots might have difficulty in obtaining weather for a destination or other portion of the flight. A service provider might also choose to offer multiple channels, in which case a channel selector could provide information for the area of interest, although it would require that the pilot have a simple interface to the channel selector (perhaps a touch screen with an interface that translated the airport symbol or map location into a channel.

This type of broadcast technology is easily achievable for satellites, and will be proven technology within a few years. Some automobiles are being equipped with satellite receivers that can receive multiple channels of CD-quality audio. New models of the Airbus A320 will be able to receive satellite television broadcasts.

Unlike broadcast, addressable point-to-point makes it possible to send user specific information to a single aircraft (or possibly groups of aircraft using a multicast). Point-to-point could be provided as a request/reply service, or on a subscription basis. This method provides many technology choices. Voice is already used for controllers to advise specific flights of weather conditions (although any other pilots on that channel will also hear the advisory). Pilots are able to request information from controllers on weather information, but this can occur only on a time-available basis. Besides the provision of weather information diverting the controller's attention from other tasks, it consumes part of the dedicated voice channel, making it unavailable for other communication.

Point-to-point data communication makes it possible to send considerably more data to the aircraft, including graphical weather displays. Graphical weather, even when compressed, requires a large amount of data. Modern CPUs have enough processing power to transform raw data into a suitable display, assuming that the avionics had appropriate map data. With point-to-point communications, users would be able to request delivery of specific products, possibly with some tailoring. If delivery is on a subscription basis, updates to the weather situation would be provided, either at regular intervals or when there were important changes to the situation. Simple request/reply requires that the service provider be able to remember the requestor's address only for as long as the transaction; subscription service requires that the service provider know the address and communications route to the aircraft for the duration of the subscription. If request/reply were used, it might be possible for a satellite to simply transmit the appropriate response, if the data were able to be stored on the satellite. Subscription service clearly requires that the data originate on the ground and be uplinked to the satellite for transmission to the requestor.

Point-to-point provision of the service requires that the airborne systems have the capability for specifying a request, processing the results (either from graphics ready to display or raw data), and display the data, as well as having a receiver and transmitter, and antenna suitable for transmission. With appropriate automation, the pilot could have a computer that formulated requests based on flight plan or current position, reducing the amount of human intervention to process requests. The service provider's ground systems need to be able to process and respond to requests, as well as having the raw data needed to respond to the requests.

A step beyond the point-to-point delivery mechanism is a query-response capability (although the underlying communication technology would probably be the same as for point-to-point, albeit with different performance requirements). This mode is analogous to some World Wide Web mapping applications, in which a user can query a database or service for information, and then refine the requests. For a weather application, a user might want to zoom in for more detail on potentially hazardous weather, might zoom out to be able to see the big picture to be able to evaluate going around the weather, or might query for information on an alternate airport. Unlike the point-to-point delivery mechanism, in which every user requesting a specific product gets the same product, the query-response mechanism requires tailoring to satisfy each request. Some form of automation is needed for the pilot in order to avoid having the query process be too cumbersome. This method imposes stringent communications requirements. Since the query is for more than a specific canned product, there must be a query language, which would need to be transmitted to the service provider. These queries would consume more bandwidth than the point-to-point service, and would also require shorter latency requirements in order to preserve the interactive nature of the session. Other than performance requirements, the communications equipage for this type of service would be the same as for the point-to-point mode, and could be considered an evolutionary service.

5 Assessment criteria

5.1 Definition of Assessment Criteria

The previous sections presented the set of user services to be supported in any future communications architecture and provided several alternative concepts. This section defines the criteria by which those architectures may be objectively evaluated. Assessment criteria are defined as those characteristics that differentiate among alternatives. In section three, drivers and constraints were introduced. In one sense, each driver or restraining force can be viewed as assessment criteria since they serve to differentiate the various architectures from one another.

The assessment criteria will also be applied during the research activities for Task 5, which develop the 2015 AATT Architecture; Task 6, Develop AATT 2007 Architecture; and Task 7, Develop AWIN 2007 Architecture. In addition, the assessment criteria have general applicability in the development of the transition plan (Task 8); identification of communications systems/technology gaps (Task 10); and the identification of components for future R&D (Task 11).

5.2 Types of Assessment Criteria

The most basic assessment criterion is the degree to which the proposed architecture meets the user's needs. This macro approach is extremely difficult to apply when dealing with multiple users, multiple service providers, and provisions of multiple services. It is also important to note that user's needs are dynamic, and that the derived functional and system requirements provide some flexibility based on the architecture being considered. For example, latency requirements applied to a LEO SATCOM versus a GEO SATCOM may be less and can allow for more flexibility in other parts of the communication path. This type of flexibility may impact decisions being made regarding whether to centralize or distribute a particular function.

A second type of assessment criteria to be considered are those that are non-technical in nature, but that often override the majority of technical considerations. The largest of these is economics. In the low-GA user segment, low-cost is simply a way of life. Requiring a more expensive communications package would have the direct effect of reducing the ranks of GA users. In the commercial air transport segment, the funds could be made available, but now the emphasis shifts to the business case. The adage in the avionics field is that any new equipment has to buy its way onto the airframe. Performing a cost-benefit analysis should be considered one of the most important criteria for any changes proposed in the communications infrastructure.

The next two sections provide a much finer breakout of various criteria that can be applied to differentiate between alternatives. As noted above, many of these items have previously appeared as either drivers or restraining forces in this report.

5.2.1 Quantitative Measures

Criteria can usually be evaluated with the use of an objective numeric metric. In this case, such metrics may still require some level of subjective prediction since the architectures being evaluated will be implemented over an extended period.

Schedule: A timeline for the overall development and fielding of any new communications architecture can be developed for each alternative. Such a schedule would need to consider other criteria listed here including the rate of market take-up for any new equipment, system capacity for production and installation across thousands of airframes and ground sites, and the certification of this new equipment.

Business Case: Business cases would need to be developed for each alternative that provide the cost and benefits to the user. The business case would need to consider opportunity costs, Return On Investment (ROI), and overall life-cycle costs.

System Performance: System performance covers a wide range of system characteristics. Two key concepts for measuring system performance are Required Communication Performance (RCP) and Installed Communications Performance (ICP). In both of these cases, criteria have been defined for system availability, latency, and reliability. Common measures include Bit Error Rate (BER); Mean Opinion Scoring (MOS) for vocoders, and percentages based on system availability (e.g. 99.95%). Another key system performance parameter is facilitation of safety communications through provision of priority message handling, data integrity, and end-to-end pipeline integrity.

Coverage: Coverage looks at overall access to the communications pipeline. That access can be geographic in nature (e.g., polar coverage), political (e.g., certain states opt not to equip their centers with a particular type of radio), or a resource limitation (e.g., insufficient spectrum over a terminal area).

5.2.2 Qualitative Measures

Qualitative measures rely on some degree of subjective evaluation usually based on a ranking scheme.

Technology: In the context of an assessment criterion, it is really the availability of technology that serves to discriminate between alternatives. If an architecture is dependent on "scheduled invention" to provide required throughput or speed, it is somewhat less attractive than one dependent on off the shelf technology. When assessing technology, product development cycles need to be considered as well.

Flexibility or adaptability: Architectures that allow for adaptability in terms of usage across user segments should be preferred over single use approaches. Note that flexibility is inherent in the subset/superset approach to architecture implementation.

Situational Awareness: With the increasing complexity of both ground systems and modern cockpits, special attention must be paid to situational awareness. Although this factor can be viewed as an element of human factors, our preference is to evaluate this criterion separately.

Human Factors: Any new architecture must be evaluated across a wide range of human factors considerations including workload issues and the cognitive limitations of human operators.

Transition: Consideration must be given to factors that will prohibit or delay installation of the new architecture. Phase-out periods, training, co-existence with legacy systems, and the ability of the support infrastructure to accommodate the ramp-up of a new communications infrastructure in the required timeframe must all be considered. Aircraft operators will face new equipment costs as well as additional training. A recent example of how difficult it is to incorporate communications changes can be found in the move to 8.33kHz.

5.3 Assessment as Risk Management

The majority of factors above will become measures of risks for the selected architecture. It is expected that no single architecture will fully address ALL user needs. Design tradeoffs will be needed as the resulting architecture is put together. A risk management plan for the actual development and rollout of the architecture for 2015 should be created early in the development phase and maintained by the FAA in their role as the air traffic manager.

Appendix A

This section provides the Air Traffic service descriptions for the NAS Architecture. A joint team of ASD, AT, and supporting contractors developed the Air Traffic service descriptions. These service descriptions will remain the same as the NAS is modernized unless there is a significant change in the NAS concept of operations or requirements.

A.1 Flight Planning Service

The flight planning service provides both flight plan support and flight plan data processing to support the safe and efficient use of the nation's airspace through the development and use of coordinated flight plans. This includes preparing and conducting pre-flight and in-flight briefings, filing flight plans and amendments, managing flight plan acceptance and evaluation, preparing flight planning broadcast messages, and maintaining flight-planning data archives. This service offers preparation to conduct a flight within the NAS and allows changes to flight profiles while operating within the NAS.

A.1.1 Flight Plan Support

Flight plan support provides NAS users essential weather and aeronautical information. Flight planning requires information such as expected route, altitude, time of flight, available navigation systems, available routes, special use airspace (SUA) restrictions, daily demand conditions and anticipated flight conditions including weather and sky conditions (e.g. volcanic ash, smoke, birds). There is an exchange of a variety of data to support flight planning including NAS operational and maintenance status, weather, FAA facility status, with numerous NAS users to include, fixed base operators, pilots and flight planners, airline operations centers, Department of Defense (DOD) operations offices, and inter alia. Planning and pre-flight briefings contain current and forecast weather including winds and temperatures, surface conditions, and any significant meteorological condition. Aeronautical information includes notices to airmen containing information concerning the establishment, condition, or change in any NAS component (facility, service, or procedure of, or hazard in the NAS) the timely knowledge of which is essential to flight.

A.1.2 Flight Plan Processing

Flight plan processing provides acceptance and processing of flight plan data from all users (e.g., general aviation, commercial, military, customs, law enforcement, etc.); validates the flight plans; notifies users of any problems; and processes amendments, cancellations and flight plan closures. NAS flight plan processing provides evaluation and feedback for both domestic and international flight plans. Flight plan amendments both pre-flight and in-flight are also processed including cancellations, and closures. The NAS disseminates flight plan information as necessary.

A.2 Air Traffic Control Separation Assurance Service

The separation assurance service ensures that aircraft maintain a safe distance from other aircraft, terrain, obstacles, and certain airspace not designated for routine air travel. Separation assurance involves the application of separation standards to ensure safety. Standards are defined for aircraft operating in different environments.

A.2.1 Aircraft to Aircraft Separation.

Aircraft to aircraft separation prevents collision between airborne aircraft. Varieties of methodologies are employed to apply the defined separation standards. These methodologies include the use of visual and automated means.

A.2.2 Aircraft to Terrain/Obstacles Separation.

NAS employs defined separation standards to prevent collision between aircraft, terrain, and obstacles. Methods used include published safety zones and processing of position and intent information.

A.2.3 Aircraft to Airspace Separation.

Aircraft are separated from special use airspace (SUA) such as prohibited, restricted, and warning areas. The SUA is designed to ensure safety for unique aircraft operations or to prohibit flight within a specified area. Separation standards ensure aircraft remain an appropriate minimum distance from the airspace. The standards are applied via methods including regulatory publications and specific control instructions.

A.2.4 Surface Separation

Surface separation accounts for activities such as vehicle movements on the airport movement area, taxiing aircraft, water vehicles, protection from designated critical zones, etc. Standards are employed to ensure safe operation on the surface.

A.3 Air Traffic Control Advisory Service

Air traffic control and other facilities provide advice and information to assist pilots in the safe conduct of flight and aircraft movement. These advisories include providing weather information, traffic, and NAS status information. These advisories and information may be directed to a specific location, broadcast to any user in an area, or provided to a specific user.

A.3.1 Weather Advisories

Weather advisories and information are available either automatically or on request through communication with ATC and other facilities. For example, pilots receive weather advisories from automated weather observing or other systems, ATC facilities, and aircraft operations centers (AOCs). Advisories provide hazardous weather or flight conditions at airports or along the route of flight.

A.3.2 Traffic Advisories

Traffic advisories are provided to alert aircraft to potential conflicts with others on the surface or in-flight. For example, traffic advisories are provided to aircraft or other flight objects that are in the proximity of hot air/gas balloons, missile launches or other potential hazards. Traffic advisories for aircraft on the surface include the number, type, position and intent of the ground traffic.

A.3.3 NAS Status Advisories

Information about NAS status that has changed or was not readily available during flight planning is provided to in-flight aircraft. This includes updates concerning the operational status of airspace, airports, navigational aids (NAVAIDs), in-flight or ground hazards, traffic management directives, and other information that is essential to the safety and efficiency of aircraft.

A.4 Traffic Management-Synchronization Service

Traffic synchronization supports expeditious flight for the large number of aircraft using the NAS during any given period. NAS processes operate to maximize efficiency and capacity in response to weather, NAS infrastructure, runway availability or other conditions. Traffic synchronization is the tactical portion of traffic management providing sequencing, spacing, and routing of aircraft. Traffic synchronization activities are accomplished while maintaining separation assurance and implementing strategic flow management directives. The traffic synchronization service provides tactical instructions to optimize operations while airborne and on the surface.

A.4.1 Airborne

Airborne synchronization involves sequencing of aircraft to maximize efficiency and capacity of the NAS through all phases of flight (arrival, departure, and cruise). Maximum efficiency, predictability and capacity are obtained through the application of processes, which reduce variability in application of the defined separation standards. These activities include prioritization including the input of user preferences.

A.4.2 Surface

The surface is managed by formulating taxi sequences and communicating instructions to pilots and vehicle operators for the safe and efficient flow of traffic on the airport surface. Surface synchronization involves processes intended to maximize surface efficiency, predictability and capacity. It includes activities such as runway assignment, taxi sequence and movement instructions.

A.5 Traffic Management-Strategic Flow Service

The strategic flow service provides for orderly flow of air traffic from a system perspective. NAS demand and capacity is analyzed and balanced to minimize delays, avoid congestion, and maximize overall NAS throughput, flexibility, and predictability. Actual and predicted demand is compared to the current and predicted capacity of the NAS airspace, airports and infrastructure to plan the overall NAS strategy. When necessary, traffic flow management (TFM) plans are developed collaboratively to optimize the flow of traffic while accommodating user requests and schedules, airspace, infrastructure, weather constraints, and other variables. The strategic flow services comprise long-term planning (more than one day in advance) and flight-day traffic management (current 24-hour period) and performance assessment.

A.5.1 Long-term Planning

Long term planning works to maximize efficiency by developing predictions of capacity and demand more than one day in advance. Inputs include capacity and demand models based on airport use data, airspace for special use schedules, airline flight schedules, infrastructure status, and historical flight traffic demand information. It also includes activities designed for continual improvement in the predictive capabilities such as model validation, assessment of specific planned and executed strategies trend analysis and recommended changes.

A.5.2 Flight Day Management

Flight day traffic management optimizes NAS traffic flow for the current 24-hour period. Demand profiles are compared with projections of NAS capacity for the current day and identify periods and locations where predicted demand exceeds predicted capacity. Specific responses to maximize efficiency are developed and implemented through collaboration across the NAS.

A.5.3 Performance Assessment

Performance assessment provides institutional memory by archiving information to support post-flight analyses of NAS traffic flow. The effectiveness of NAS performance is analyzed to propose future improvements. Air traffic trends and activities are analyzed, problems identified and alternatives for improvement developed and evaluated. Long-term improvements to NAS performance include recommended changes to schedules, airspace design, ATC procedures, and the NAS infrastructure.

A.6 Emergency and Alerting Service

The emergency and alerting service monitors the NAS for distress or urgent situations, evaluates the nature of the distress, and provides an appropriate response to the emergency. Applicable situations include those that occur on the ground or in-flight. Emergency services include emergency assistance and alerting support.

A.6.1 Emergency Assistance

Emergency assistance provides direct support in the protection of individuals and property both in the air and on the ground. Examples of the wide variety of circumstances under which direct support is provided include location and navigation assistance for orientation, guidance to emergency airports, and generation of alternative courses of action.

A.6.2 Alerting Support

Alerting support provides indirect assistance for those events/circumstances in which the response is external to the system. For example, when information is received that an aircraft is overdue or missing, ELT signals are received, or search and rescue services may be required, alerting support provides the relevant information and coordinates with the appropriate international, military, federal, state, and local agencies. The appropriate organization(s) then provide direct response(s).

A.7 Navigation Service

The service provides navigational guidance to enable NAS users with suitable avionics to operate their aircraft safely and efficiently under different weather conditions. The service includes both ground and space-based networks of navigational aids for the NAS. These navigational aids broadcast electronic signals or provide guidance in accordance with international standards. The navigation service provides guidance during airborne operations (such as cruise, approach and landing), and during surface operations to appropriately equipped aircraft.

A.7.1 Airborne Guidance

NAS provides mechanisms and aids for point-in-space navigation through a variety of operating environments. These environments include structured routes, random routings and transitions. Guidance is provided for position determination in both vertical and lateral planes in all phases of flight. Additionally, visual aids provide guidance to aircraft transitioning to and from the surface.

A.7.2 Surface Guidance

NAS provides mechanisms and aids for maneuvering on the airport surface safely and efficiently. For example, references are provided to determine present position both electronic and/or visual.

A.8 Airspace Management Service

Airspace management service ensures the safe and efficient use of the national airspace resource. This includes the design, allocation, and stewardship of the airspace. Maximum safety and efficiency in the use of airspace results from coordinating airspace user needs and available capacity. Effective airspace management requires the seamless integration of airspace design and the management of airspace for special use.

A.8.1 Airspace Design

Airspace design provides maximum utilization of the national resource while ensuring safety to the public at large. This includes a cohesive plan for managing airspace changes, establishing and directing a financial plan to meet airspace priorities, establishing standards for modeling and analysis, and developing strategies to ensure environmental compatibility. Airspace planning and analysis considers, among other elements, the existing design, current and projected traffic usage, radio frequency congestion, effects of airport construction, proposed and existing surface structures, and environmental factors such as noise abatement and others. It provides the aviation community with the description, operational composition and status of airspace/airport components of the NAS.

A.8.2 Airspace for Special Use

Airspace for special use provides support to the national defense mission, fosters the development of commercial space enterprises, protects sensitive areas, and ensures the protection of other natural resources. Designation and management of special use airspace ensures optimal access,

A.9 Infrastructure/Information Management Service

Infrastructure management ensures a safe and efficient NAS through management and operation of the infrastructure and optimal use of resources. Infrastructure resources include systems such as radar, communication links, navigation aids and automation, while infrastructure management includes monitoring and maintenance of the NAS.

A.9.1 Monitoring and Maintenance

Monitoring and maintenance includes the activities necessary to monitor the NAS status, detect and isolate failures and outages, and perform corrective and preventive maintenance to ensure the operational readiness of the NAS. Maintaining, operating, and managing the infrastructure requires a variety of planning, engineering, analysis, repair and maintenance functions. It also includes monitoring status, real time assessments and systems implementations in the NAS.

A.9.2 Spectrum Management

Spectrum management secures, protects, and manages the radio spectrum for the FAA and the U.S. aviation community. It is the focal point for management policy and plans, engineering, frequency assignment, radio interference resolution, radiation hazard, obstruction evaluation, electronic counter measures, and other national/international spectrum activities.

A.9.3 Government/Agency Support

Government/agency support provides information and coordination services. Examples of the agencies and organizations supported include, military air defense operations, law enforcement, government land management, drug interdiction, state aviation, Customs, National Transportation Safety Board, and inter alia.

A.10 Aeronautical Operational Control (AOC)

Airlines determine their own requirements for AOC. In those cases where the AOC service shares a communications resource with ATM or FIS applications, the AOC workload must be considered in assessing architectural alternatives.

A.11 On-board services

On-board services potentially include broadcast services for entertainment (e.g., sporting events or other television), information services such as Internet access, business services such as fax or email, and voice or data passenger communications. Some of these services, such as passenger telephony, are likely to use communications links that can also be used for ATM or FIS.

Appendix B – Technology Evolution and Forecasting

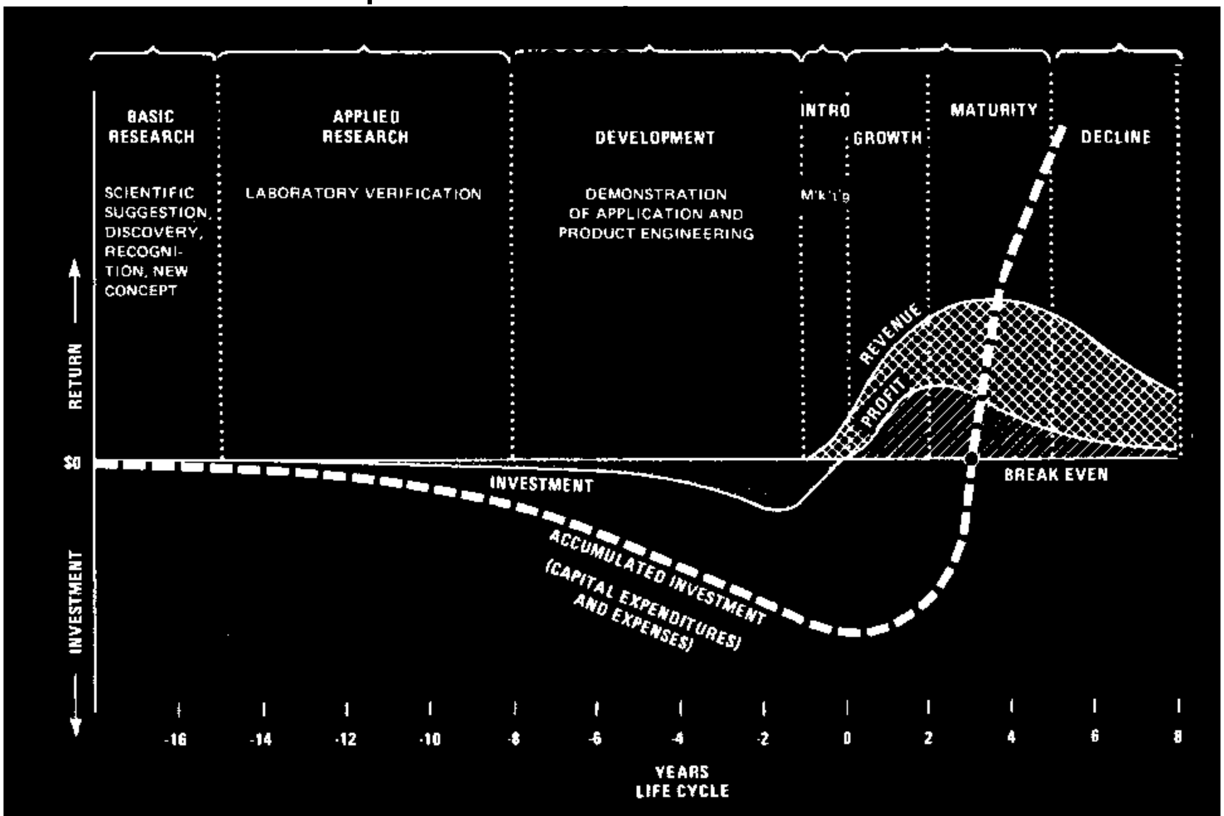
This appendix provides a brief discussion of enabling technology and the rate of its evolution. It identifies and documents the preliminary findings resulting from a brief review of selected forecasts of communication technologies, made approximately fifteen years ago, for their relative accuracy and potential applicability to the candidate communication architecture alternatives identified in section five.

B.1 The Technology Development Timeline

In developing candidate CSA's, we conducted a brief review of the application of technology development and implementation timelines. Technology projections and forecasts that were made approximately 15 years ago were assessed for their relative accuracy and potential applicability to this task. Both the timelines and the technology trend projections have broad applications in not only bounding the description of the range of ATM and AWIN services using a communications architecture, but also in assessing the architecture's flexibility and relative effectiveness and efficiency which result in user profits and benefits.

Figure B-1 shows a generic Product Development Lifecycle Timeline for Command, Control, and Communications (C3) technology. It can be applied to a wide range of aviation defense, and commercial technologies and provides a good view of the investment curve for the introduction of new technology. The elapsed time, or years in the life cycle, vary for each technology, but the approximately 15 – 20 year range was a reasonable estimate of the aggregate amount of time used to develop a "bundle" of technology, and "package" them into a complex product. Examples include a new model commercial passenger aircraft, an air traffic control radar system, a communications satellite system, or a sensor satellite system providing processing and disseminating weather data.

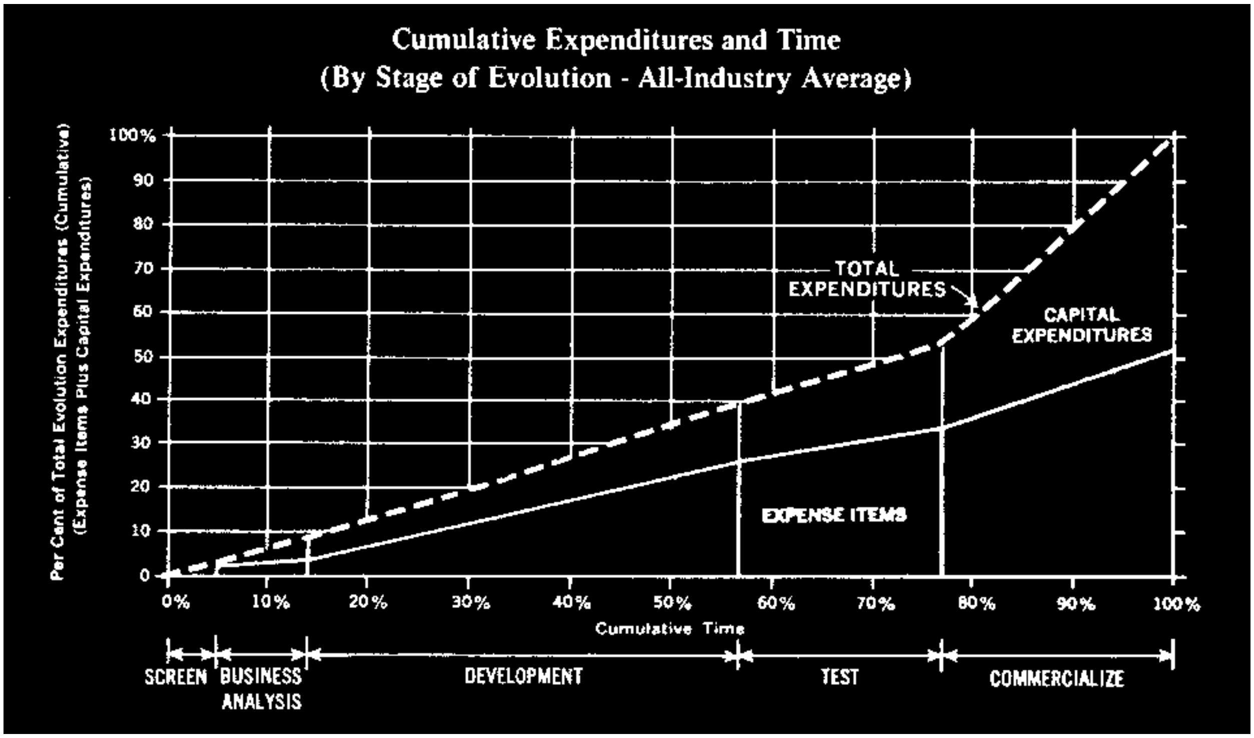
Capital Investment and Return in the



Source: A Methodology for Assessing Trends in the C3 Technology Environment.

Figure B-1. Capital Investment and Return in the Innovation

Figure A-2 provides another view of the cumulative investment expenditures by product development phase for commercial products. Both NASA and DOD have developed similar figures that show the effect of program decision as a percentage of system lifecycle costs, which have been applied by them in an approach similar to a business case analysis. The concepts are used to assess the effects of technology insertion, equipment upgrades, and other broad impacts on new system development decision processes.



Source: A Methodology for Assessing Trends in the C3 Technology Environment

Figure B-2. Product Development Lifecycle and Cumulative Expenditures

Compared to 15 – 20 years ago, significant time compression has occurred throughout the entire technology lifecycle. The development and product introduction timespan has decreased significantly, by at least half, and for many technologies even more. This time compression reduces the industry average from approximately eight years to four years or less. A number of factors seem to have contributed to this decrease. "New ways of doing business" continue to be implemented so that improved "profitability" (e.g., reduced costs) or increased "benefit" can be achieved more quickly in response to pressures from other competitive products and service providers. These 'new ways' have included concurrent engineering, process re-engineering, and outsourcing that allows companies to focus on their core competencies. All of this can be summarized as the mantra that has swept through the aerospace industry as "Faster, Cheaper, Better". It has also given rise to completely new business models that have the effect of creating new markets instead of simply evolving old ones (e.g. the internet and LEO-based global phone service.

The maturity period has similarly been shortened as the next "new thing" comes along to replace the incumbent technology. Much of the reason for this shortened mature phase is that the same technology is rolled back to create the next generation. Faster and more capable computers and manufacturing automation allow for each successive generation to improve on its predecessor. Nowhere is this process more evident than in basic communications infrastructure. Constant improvements in transmission media, switching technology, and spreading "open" standards ensure that communications systems are already obsolete once they reach their peak penetration into the market. Favorable economics has also played a role in the short maturity followed by sharp declines. Start-up companies have had a relatively easy time raising capital to bring new technology to market. Without the overhead and sunk cost of older development efforts to recover, they have been able to steal large pieces of market share. Their presence has forced the larger entrenched companies to cut short their efforts to extract as much profit from previous investments.

B.2 Technology Forecasts – Past History

Having looked at the compression of the development timeline, we then reviewed a number of technology projections and forecasts that were made 15 – 18 years ago. The continuing performance evolution in these technology categories will certainly have an impact on the candidate CSAs. These projections were assessed for their relative “accuracy” of the direction that the technology would evolve, the predicted timeframe, and the projected on products and services. Two of these projections are shown in Figures B-3 and B-4 below.

Sixth Generation...by 1990?
Why is computer technology so important? Because it is virtually the only major commodity on earth that is improving its price-performance ratio in absolute as well as relative terms. The following generalized chart shows computer progress since ENIAC, and anticipates—for the first time in print—the technology/price/performance equation that may be attained in the Sixth Generation

Year	1945	1955	1965	1975	1985	1990–95
Generation	1st	2nd	3rd	4th	5th	6th
Technology	Tubes	Transistors	ICs	VLSI	Parallel processors	Organics? Implants?
Cost factor	1,000	100	10	1	0.1	.01
Performance factor	1	10	100	1,000	10,000	100,000
Installed base	5	5,000	50,000	.5m	10m +	100m +

Source: John Joss/Technology Update

Aviation Week & Space Technology, August 22, 1983

Figure B-3. Projection of Price/Performance Ratios

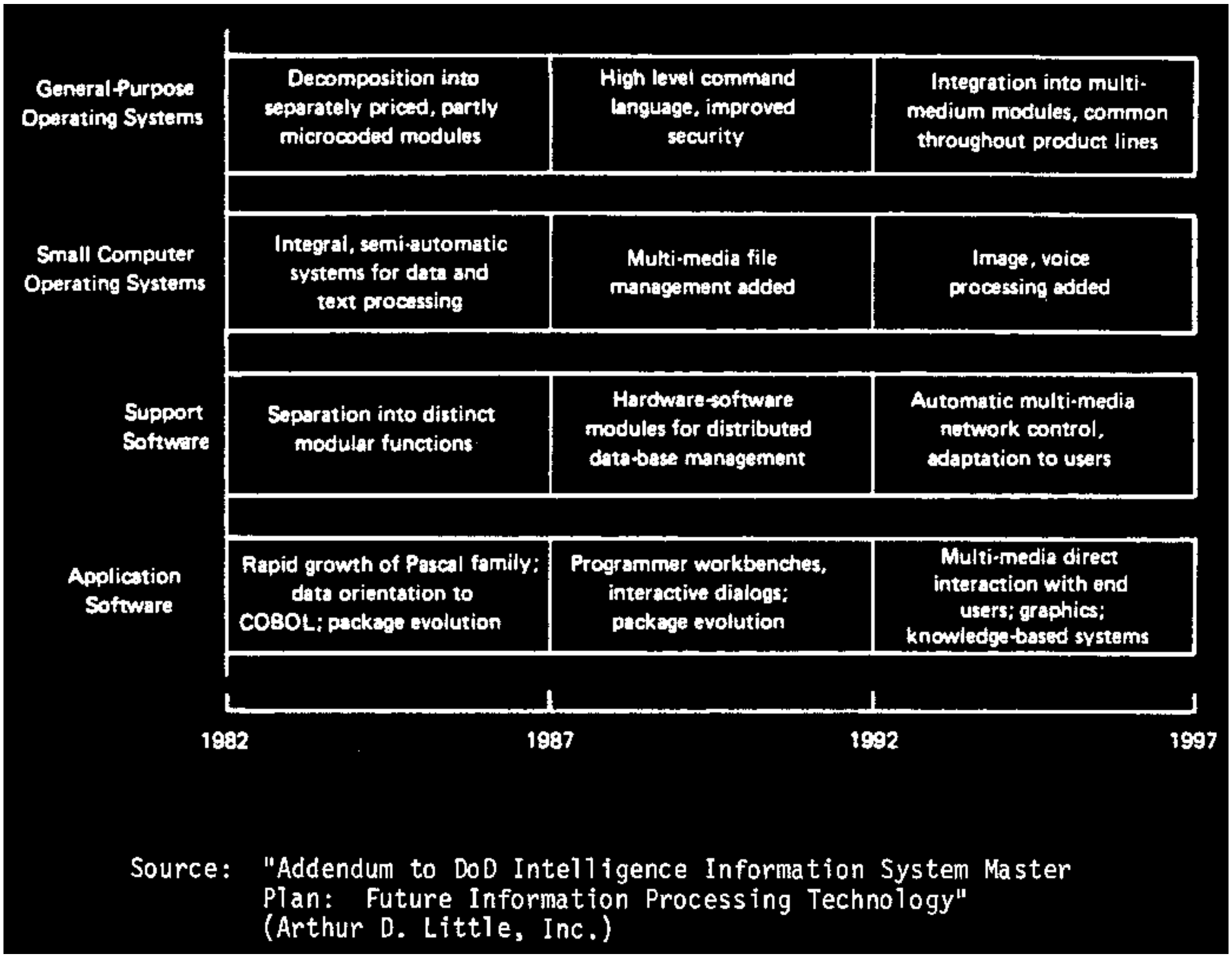


Figure B-4. Projection of Future Information Technology

Figure B-3 shows the projected price performance ratios over time related to key enabling processor technologies. Figure B-4 looks at the broader picture of computing platform and application software. None of the sources reviewed identified the substantial impact of digital signal processors (DSP). As expected, some enabling technologies were identified in the forecasts while others were clearly revolutionary in their appearance during the forecasted period. Few forecasts even hinted at the greatly improved price/performance and size of the processor chips that occurred during the forecasted timeframe. Nor did any of the forecasts project the rapid obsolescence of hardware and software systems and the need to continually upgrade to avoid compatibility problems when interfacing with the rest of an increasingly networked world.

As an aside, in a recent report from Lucent Technologies' Bell Laboratories, scientists projected that at the current rate of chip shrinkage and increased processor speed; silicon processor technologies could reach their limits by 2012. But processor capability and capacity will continue to double approximately every eighteen months. By that point science and industry will have to find new ways to build faster and more capable computers.

B.3 Conclusions – A Quandary

Our brief review of enabling technology and technology forecasting clearly illustrates the rate of technology evolution will continue to accelerate and lifecycles will shorten. It also points out some of the limitations to forecasting since new breakthroughs and new markets are constantly being identified. Unfortunately, the review has illustrated a quandary that will be faced for any new communications architecture. Airplanes and air traffic control systems have historically had very long mature phases. Avionics may be refurbished every five to eight years depending on the type of aircraft, but even this timeframe is long compared to the rate of development in computers and communications. Unlike the commercial world where business cases can be built for upgrading and replacing aging equipment on a regular basis, the cost of overhauling airplanes and control centers is prohibitive. It appears likely that a serious lag will always exist between the latest communication technologies available and those in widespread use in the NAS. This unfortunate reality must be considered in the evaluation of candidate CSAs.