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WORKING NOTE

Adapting Information Engineering for the National Airspace System and Its Application to Flight Planning

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Michael A. Hermes
Sally E. Stalnaker
Dr. Nels A. Broste
Gary L. Smith

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Center for Advanced Aviation System Development
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Abstract

A combined team from the FAA, the aviation community, contractors, and CAASD jointly adapted the information engineering process for the information flows in the National Airspace System. Information engineering was then applied to the information flows necessary for flight planning in a Free Flight environment. The combined team created high level information engineering products and an interactive prototype. CAASD documented an overview of the information engineering approach in this assessment. The application of information engineering to flight planning shows that an enhanced and more dynamic flight planning process is necessary to implement Free Flight advances for improved access, predictability, flexibility, and capacity in the National Airspace System. The study also demonstrates the power of the information engineering process in assessing system needs.

KEYWORDS: Free Flight, Flight plan, information engineering, object-oriented

Table of Contents

List of Figures

Executive Summary

Overview

A combined team from the FAA, the aviation community, contractors, and CAASD jointly conducted activities during FY99 to accomplish the following two goals:

- Adapt an information engineering approach for application to aviation information in the National Airspace System (NAS).
- Assess the information flows in the flight planning aspects of flight information using the information engineering approach.

This document records these activities, the results and conclusions of the approach, an overview of the demonstration prototype developed, and the consequent recommendations. As a result of the approach taken, the team discovered several new avenues of exploration in both the assessment process and in the domain studied. As a result, this study demonstrates the power of the information engineering process in assessing aviation system needs, and it demonstrates that an enhanced and more dynamic flight planning process is necessary to accommodate Free Flight concepts.

Although many of the activities occurred in parallel, this paper follows this sequence:

- An overview of the adaptation of information engineering processes for NAS information flows,
- An evaluation of NAS flight-related data and selection of the flight planning subset for the application of information engineering,
- The application of information engineering to flight planning resulting in an operational concept for dynamic flight planning and an overview of the resulting information architecture,
- A description of the prototype demonstration developed to study and illustrate dynamic flight planning.

Information Engineering Process

Information engineering includes many of the generic processes described for systems engineering, such as:

- Strategic and enterprise planning,
- Analysis and design,
- Synthesis and construction.

Information engineering applies these processes to the identification, development, and implementation of effective data and information flows. Information engineering is particularly effective when applied to decision support systems involving complex processing of information by human and automated components as found throughout the NAS system.

Application to Flight Planning

The application of information engineering to flight planning identified information flows necessary for effective flight planning without being limited by current flight planning procedures and limitations. By focusing on the information needs of the stakeholders and providing information stores and flows to meet those needs, the study took a fresh look at the flight planning process and the automation necessary to support it.

The combined team also developed an interactive demonstration of three flight planning scenarios. These scenarios progress from current processes, through flight plan probing (documented in Free Flight Concepts of Operations), to a more dynamic process of continuously managing flight plans and leveraging NAS user intent.

Recommendations

The recommendations resulting from this information engineering assessment are:

- More broadly apply information engineering processes to other NAS areas: Information synergy across operational domains can be obtained through multi-disciplinary teams of collaborators using information engineering techniques.
- Reassess the entire flight planning process to accommodate the Free Flight concepts and leverage modern distributed systems technologies: To achieve Free Flight, the integration of flight plan processing must be reassessed for:
  - Aeronautical Operations Centers (AOC),
  - Flight Service Stations (FSS),
  - Traffic Flow Management in the national Air Traffic Control System Command Center (ATCSCC) and in the local Traffic Management Units (TMU),
  - Air Route Traffic Control Centers (ARTCC),
  - Terminal Radar Approach Control (TRACON) facilities, and
  - Airport Traffic Control Towers (ATCT).
- Fully share complete four dimensional flight plan information (which is used as control data in flight management systems): Four dimensional flight plan data is necessary to completely leverage user intent data.

- Explore potential impacts of better flight planning on NAS demand assessment: Increased sharing of all user intent data may facilitate improvements in NAS demand assessment.
- Extend the Free Flight Concept of Operations to include dynamic flight planning: Dynamic flight planning based on an improved flight planning process and full user intent data could provide a foundation for free flight decision support.

Acknowledgments

The concepts documented in this paper were the results of the combined effort of the Flight Object Working Group under the aegis of the NAS Information Architecture Committee (NIAC). The Working Group was comprised of FAA, CAASD, SETA, DMR, Ptech, and ILOG staff. The Flight Object Working Group included:

FAA: Josh Hung (project leader), Felix Rausch, Carol Uri

SETA: Dick Sullivan (TRW), Phil Prassee (JTA), Tony Rhodes (TRW)

DMR: Bill Holden

Ptech: Dr. Samer Minkara, Walid Assad

ILOG: Alain Neyroud, Olivier Nicolas

In addition, Long Truong and Ron Schwarz of CAASD provided significant insight and commentary on this work. The following operations experts at CAASD also provided valuable assistance: Jerry Baker, Dusty Rhodes, Don Olvey, and Larry Newman.

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Section 1

Introduction

1.1 Purpose

This document is to record activities to achieve the following goals:

- Adapt an information engineering approach for application to aviation information in the National Airspace System (NAS),
- Assess the information flows in the flight planning aspects of flight information using the information engineering process.

The processes of information engineering as described in this document have been developed over the past several years through teams of FAA, aviation community, contractor, and CAASD staff. The application of information engineering to a particular subset of aviation information was the thrust of the activity that engendered this document.

The purposes of the original project, as identified above, were achieved and the procedures and findings are described in this document.

However, the results and conclusions from this activity extended considerably beyond the original intent. This extrapolation from existing Concepts of Operations to the recommendations for dynamic flight planning demonstrates the power of the information engineering process in assessing system requirements.

1.2 Scope and Intended Audience

The scope this project was to investigate the information aspects necessary for implementing the planning of flights by pilots and Aeronautical Operations Centers (AOC). The flight planning process provided an opportunity to evaluate the information engineering approach and is a foundation for the operational concepts of Free Flight and air traffic management by the year 2005. These flight planning activities are described in Operational Concepts developed through the air traffic services organization of the FAA resulting in the AT Concept of Operations for 2005 [FAA, 1997] and through RTCA activities resulting in an FAA/Industry Concept of Operations for Free Flight [RTCA, 1997a].

However, the results of this information engineering activity extended significantly beyond the original scope. Currently, many potential advances in flight planning are hampered by limitations of current flight planning procedures and automation. The work reported here has identified alternatives. As a consequence, the conclusions of this investigation recommended a significant expansion of the baseline Operational Concepts, flight information exchange, and flight plan probing. These findings not only validated some of the objects and data elements necessary for flight planning, they also validated that an advanced approach to flight planning was necessary to achieve the goals of Free Flight. This concept expansion is referred to in this paper as dynamic flight planning.

This paper is confined to documenting the information engineering activities initiating and leading to the development of a demonstration. The demonstration shows how information is processed in the pre-departure phase of flight planning.

Some additional work was done to begin to describe the crucial aspects of re-planning flights after submission of the original flight plan. The re-planning of a flight occurs either prior to flight departure or while the aircraft is already airborne. The dynamics of these activities include safety related air traffic control and traffic management rerouting components that are beyond the scope of this document.

The audience for this document was originally intended to be the FAA systems engineering and development participants. But based on the recommendations to revisit the Operational Concepts regarding flight planning, the audience now includes the air traffic management and the aviation flight planning communities.

1.3 Organization of Paper

Following the purpose and scope described in Section 1, this document is organized into four logical depictions:

1. An overview of the adaptation of information engineering processes for NAS information flows (Section 2),
2. An evaluation of NAS flight-related data and selection of the flight planning subset for the application of information engineering (Section 3),
3. The application of information engineering to flight planning resulting in an operational concept for dynamic flight planning (Section 4) and an overview of the resulting information architecture (Section 5),
4. A description of the prototype demonstration developed to study and illustrate dynamic flight planning (Section 6).

Section 7 presents the significant results from the adaptation of information engineering and the application to flight planning. Appendix A describes the control cycle in more detail. Appendix B provides use cases developed specifically for the validation demonstration.

Section 2

Information Engineering

2.1 Process of Information Engineering

Systems engineering encompasses a large variety of identification, development, and implementation processes and activities. The processes of systems engineering (as well as software, hardware, and communications engineering) are well documented and often followed. The processes of information engineering, on the other hand, are not well documented.

Information engineering is one element of systems engineering. Information engineering includes many of the generic processes described for systems engineering but are applied to the identification, development, and implementation of effective data and information flows.

2.1.1 Definitions

To avoid complications or confusion about the difference between data and information, the following documented definitions are offered:

- "Data. A representation of facts, concepts, or instructions in a manner suitable for communication, interpretation, or processing by humans or by automatics means." [IEEE, 1990 and IEEE, 1999].
- "Information. The meaning that humans assign to data by means of known conventions that are applied to the data." [IEEE, 1990].

  "Information is the relationship between roles and data. Information is data that is relevant, timely, and actionable. It is relevant if it pertains to the problem at hand. It is timely if it is delivered to an agent in a time frame that makes it useful to the agent for solving a problem. It is actionable if it forms a basis upon which to act." [Hermes, 1998].

Although these definitions clearly distinguish differences between data and information, the terms are often used interchangeably depending upon the perspective of the user. That is, information for one system developer or user may constitute data for another.

For example, raw analog radar signals are transformed into digital signals, compared to known anomalous radar signals, and transformed into usable radar signals indicating aircraft radar returns. These "raw" radar signals (although already significantly processed at the site of the radar equipment) are transferred to and used as information by air traffic controllers in the degraded operational mode in en route centers called Direct Access Radar Channel (DARC). However, these same raw radar signals are used as data by the Host Computer

System (HCS) where they are associated with specific identifiers of planned flights. The combined information is then presented to the appropriate air traffic controller and used in decision making for normal air traffic control operations.

To avoid disparities of meaning between data and information, attempts will be made in this paper to provide context for their meaning when these words are used.

2.1.2 Information Engineering Process

Figure 2-1 is a model of systems technology developed by the Department of Energy and based on a model developed by the National Institute of Standards and Technology [DOE, 1995 and NIST, 1989]. This model illustrates relationships of information to the business and automation aspects of systems technology.

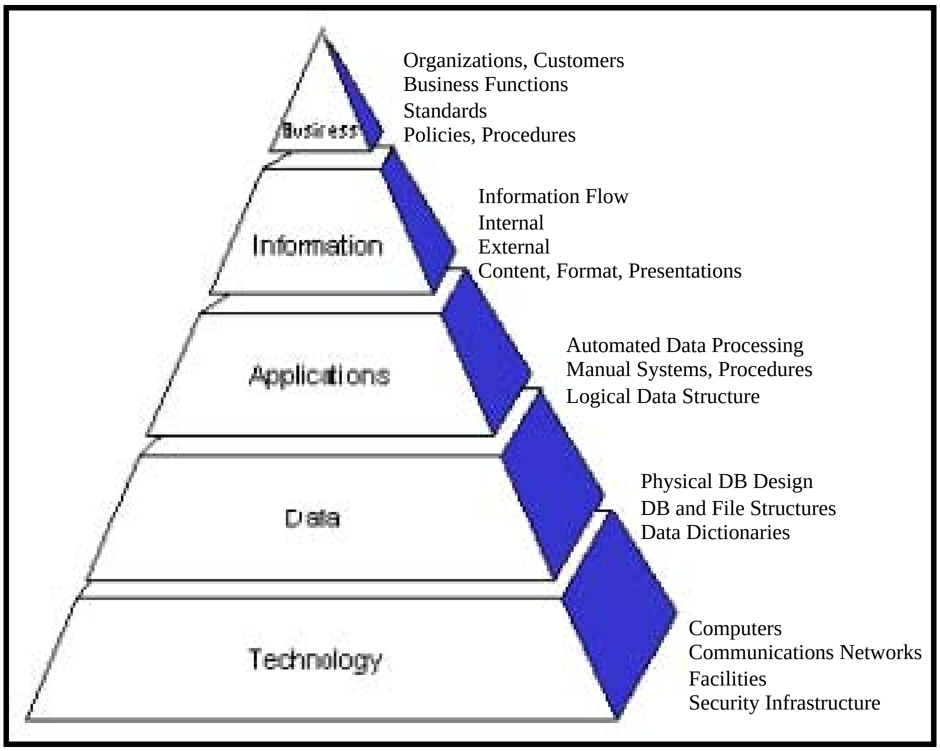

Figure 2-1. DOE Systems Technology Model

The business context is often represented partially through operational concepts. These operational concepts identify the policies, procedures, roles, and responsibilities necessary to accomplish the particular mission for which automation is to be developed.

The discipline of information engineering has been described as: "…a set of techniques which enable managers and users, with no computer experience, to work in a design partnership with data processing staff." [Finkelstein, 1992]. A more formal definition is:

- Information Engineering is an integrated set of techniques, based on corporate strategic planning, which results in the analysis, design, and development of systems which support those plans exactly." [Finkelstein, 1989]

The processes of information engineering follow the same analysis and synthesis approaches used for other types of engineering. The following engineering concepts as applied to information engineering [Mylls, 1994] include:

- Strategic and enterprise planning,
- Analysis and design,
- Synthesis and construction,
- The establishment of architectures, rules, and standards for information applied to systems implementation.

2.2 Information Engineering Applied to the National Airspace System

These engineering approaches, as applied to the realm of information, are just as valid as they are when applied to the development of specific systems. For example, defining the information architecture of a system involves the analysis of the data needs and components, and then a synthesis of information flows and usage.

In a distributed operational environment, such as in the NAS environment, the same data and information are accessed and shared by many systems as enterprise-wide resources. These common information resources must be carefully managed, exchanged, and maintained to provide the shared situational awareness necessary to support the information system needs. These activities are necessary to sustain the immediate needs of real-time Air Traffic Management (ATM) control system components of the NAS.

In the broader context of distributed information and control systems, these approaches take on the engineering contexts shown in Figure 2-2. The FAA mission overview is stated in the FAA Performance Plan [FAA, 1999a] as:

> The FAA helps enable a safe, secure, and efficient global aerospace system that contributes to the national security and the promotion of U.S. aerospace safety. As the leading authority in the international aerospace community, the FAA is responsive to the dynamic nature of customer needs, economic conditions, and environmental concerns. Key elements of that mission are: (1) the regulation of civil aviation and commercial space transportation to promote safety; (2) ensuring the security of passengers and cargo on U.S. aerospace and supporting the

Nation's security, and (3) the safe and efficient use of the airspace by both civil and military aircraft.

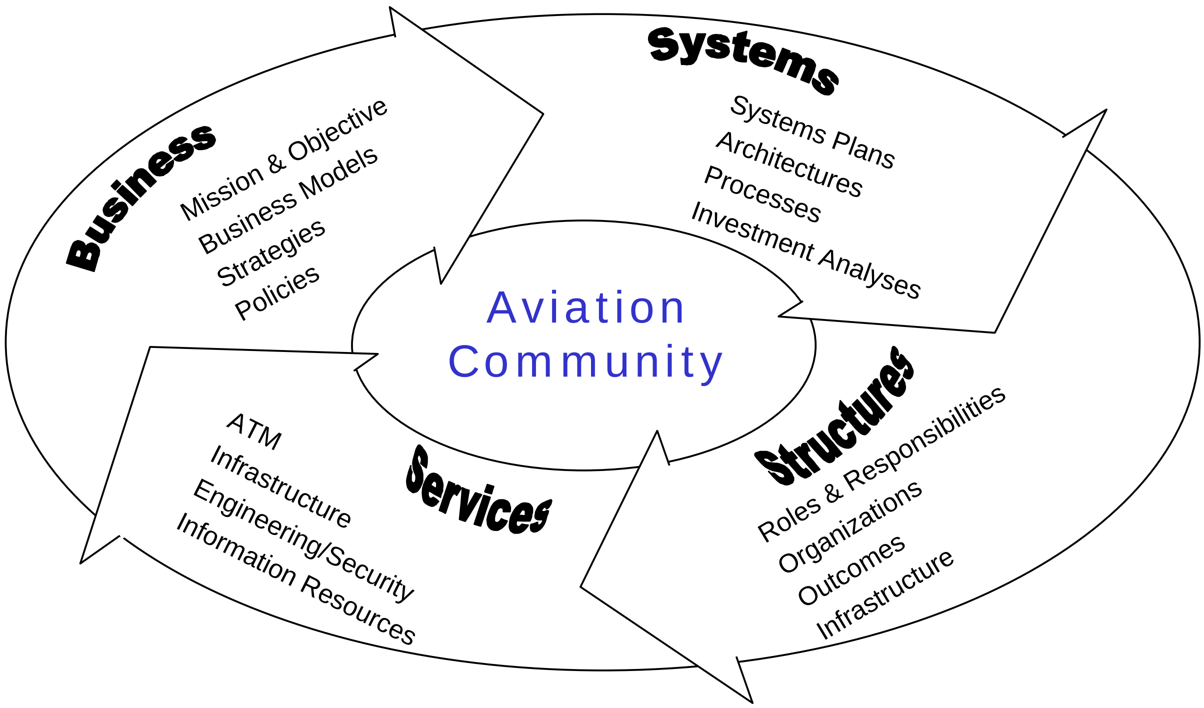

Figure 2-2. Information Engineering in an Air Traffic Management Context

The business aspects of Figure 2-2 illustrate the purposes behind achieving the mission of the FAA and for developing the FAA systems for managing the NAS (addresses the question, Why?). They also capture the constraints associated with the operation of the FAA, such as budgets and legal mandates. The systems perspective includes overall visions and drivers for managing the NAS (addresses the question, What?). The structures view relates to the components and elements needed to perform the mission (addresses the questions, How? and By Whom?). And finally, the services provided both internally to the FAA and externally to the aviation community reflect the actions taken to accomplish the mission (addresses the questions, Where? and When?)

Based on the mission of the FAA and the dynamic and complex aviation environment in which it operates, the information components of the NAS operate as a hybrid of an information system, which drives information relationships and flows, and as a control system, which drives access and performance demands.

2.2.1 NAS as an Information System

The context of the NAS as an information system is captured in the definition of an information system [IEEE, 1990]:

- A mechanism used for acquiring, filing, storing, and retrieving an organized body of knowledge.

Figure 2-3 illustrates the variety of users of and connections to the information flows in the NAS [FAA, 1999b]. Although in the current NAS, without the benefits of NAS-wide information engineering, the connections and information flows are much more complex. The NAS information flows cover a wide range of stakeholders, systems, architectures, and dynamics.

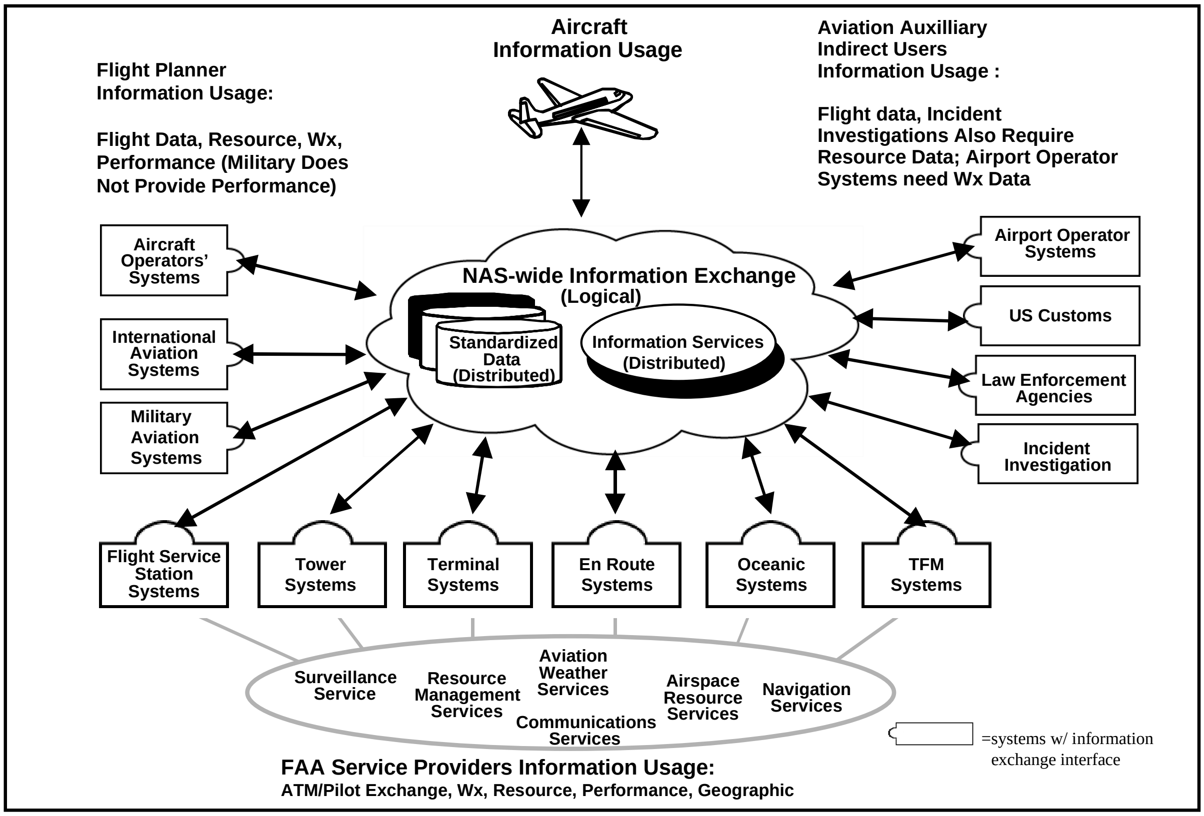

Figure 2-3. NAS as a Seamless Information System

Significant effort is expended to establish consistent interoperability among the multitudes of systems exchanging and handling the same data. The flight data, discussed in this paper, is one class of data being processed, manipulated, and filtered. This data provides the appropriate information for pilots, air traffic controllers, operators and maintainers of the automation systems, and managers, at the right place, and at the right time.

Additional issues of information and systems security, data synchronization and integrity, systems infrastructure management, and budget constraints influence the development and operation of the NAS information systems.

2.2.2 NAS as a Control System

The NAS is a dynamic constantly changing environment. The users of the NAS attempt to control those aspects that pertain to them and their business drivers. The FAA provides air traffic and associated services to control other aspects of the NAS. These NAS services are provided to insure safety and to manage NAS resources for efficiency and equitable benefit.

Consequently, in such a dynamic environment, no single user or service provider has total control over their aspects of the NAS. An understanding of the NAS as a control cycle is necessary to effectively factor into automation and procedures the activities and response parameters necessary for effective control. Figure 2-4 illustrates a simple form of the control cycle concept, which is described in more detail in Appendix A.

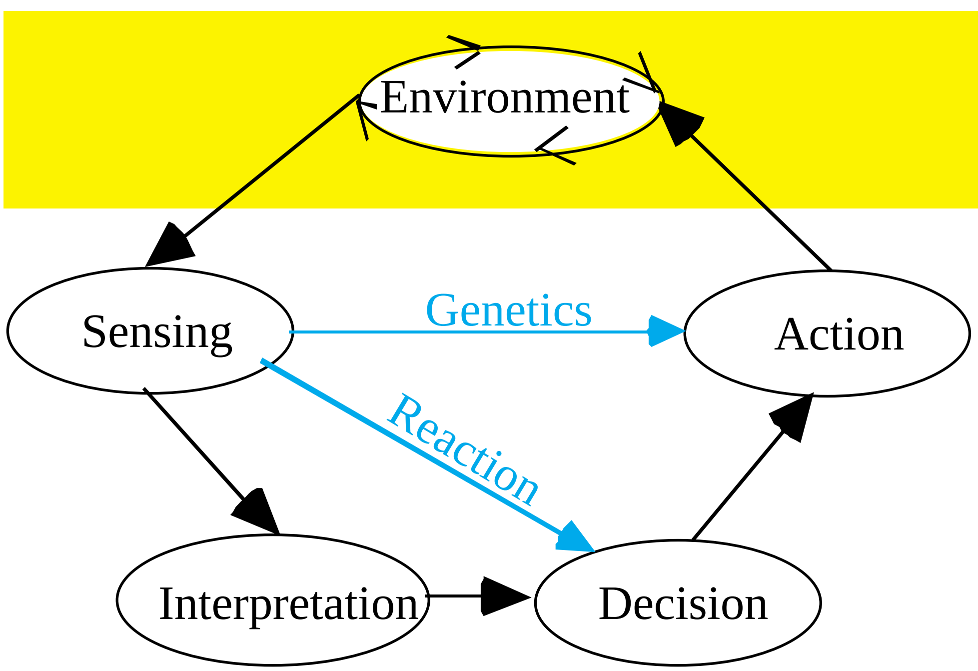

Figure 2-4. Simple Control Cycle

As is shown in the figure, information flows among the components. However, if a shortcut is taken, action can still be initiated in a shorter response time but the risk of a bad action is much greater.

The cycle of acquiring, processing, and applying information for influencing the outcome of events has been formalized in systems control theory and in large scale real-time operations. Examples of these processes include:

- The observe-orient-decide-act (OODA) loop or Boyd Cycle described for air-to-air and large scale combat [Bateman, 1998],
- The knowledge-based control cycles described for real-time intelligent and robotics systems [Albus, 1997].

Control theorists and developers of real-time systems have debated the details of control cycle concepts for generations but the basic control cycle can usually be reduced to the components shown in Figure 2-4. The real meaning of this control cycle becomes evident in the response time of the control cycle. In other words, to control activity in the environment, the managed cycle must complete before the environment can elicit a response.

The critical nature of this response time in the control cycle can be illustrated in the air traffic management environment. In an ideal environment with no other interference, a pilot can plan a flight, taxi the aircraft, depart, cruise, arrive, and park again without any interference from other environmental factors. The pilot’s control cycle and human response time is enough to assimilate the appropriate information, process it, and act to avoid complications and to execute the planned flight.

Now add the complications of weather, other aircraft, schedule similarity, mechanical failures, and basic physics. As the aviation system became more crowded and complex, electronics and avionics aided the controller and the pilot. Increasing levels of automation and decision support are now necessary to advance to Free Flight [RTCA, 1997b and RTCA, 1997c].

Figure 2-5 illustrates a control cycle based information flow for air traffic management. The flow of information from intent through execution and to conformance reflects the control cycle shown in Figure 2-4. The conformance information flow includes sensing of the environmental factors necessary for control. Perceptual assessment and interpretation against what was intended lead to decisions of intent to act. The intent is then put into action and the information flow cycles again. Collaboration ties all of these components together to insure that all parties act in concert.

The model shown in Figure 2-5 does not preclude the independent control cycles occurring in the Aeronautical Operations Centers (AOC) of competing airlines or military operations planning, nor does it impose more constraints than necessary on general aviation. The concept of Free Flight, to which the FAA is committed, states that the only constraints imposed by the FAA will be those necessary to safely and efficiently manage the NAS resources and provide equitable access to all parties.

The critical part of the information flow illustrated in Figure 2-5 is that the information flow must cycle more quickly than the NAS dynamics that are intended to be controlled. If the information loop slows, then conflicting activities occur at a higher rate than can be safely managed and constraints, such as ground stops or miles-in-trail, are imposed until the NAS environment becomes manageable again.

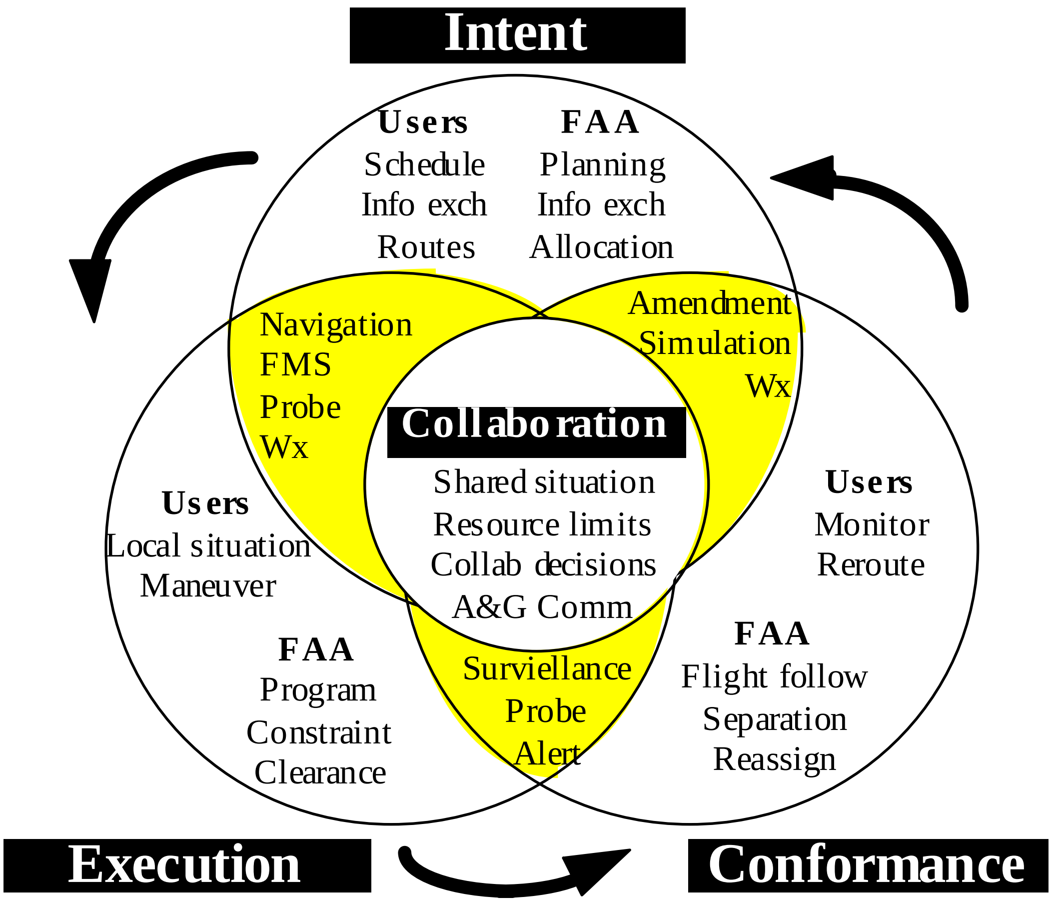

Figure 2-5. NAS Control-Cycle Based Information Flow Model

2.3 Information Engineering Applied to Flight Information

A number of information engineering activities, such as data modeling, are being undertaken by the FAA to establish consistency in exchanging, processing, and managing the data. The activities described in this paper resulted from the application of information engineering processes on the flight and infrastructure set of NAS information.

A broad spectrum of information is required to accommodate the NAS control-cycle shown in Figure 2-5. In the context of data modeling, an analysis of a large subset of this data identified several discrete data categories [Bolczak, 1998 and Schwarz, 1998]. These categories include:

- Flight (e.g., demand)
- Infrastructure (e.g., capacity, resources, adaptation)
- Weather
- Traffic Management (e.g., strategy)
- General Resources (e.g., time, geographic location)
- Performance (e.g., metrics)
- Administrative (e.g., personnel)

Another activity to manage the engineering of NAS information was the establishment of the NAS Information Architecture Committee (NIAC). The NIAC established a number of working groups to address different areas of information architecture, as shown in Figure 2-6.

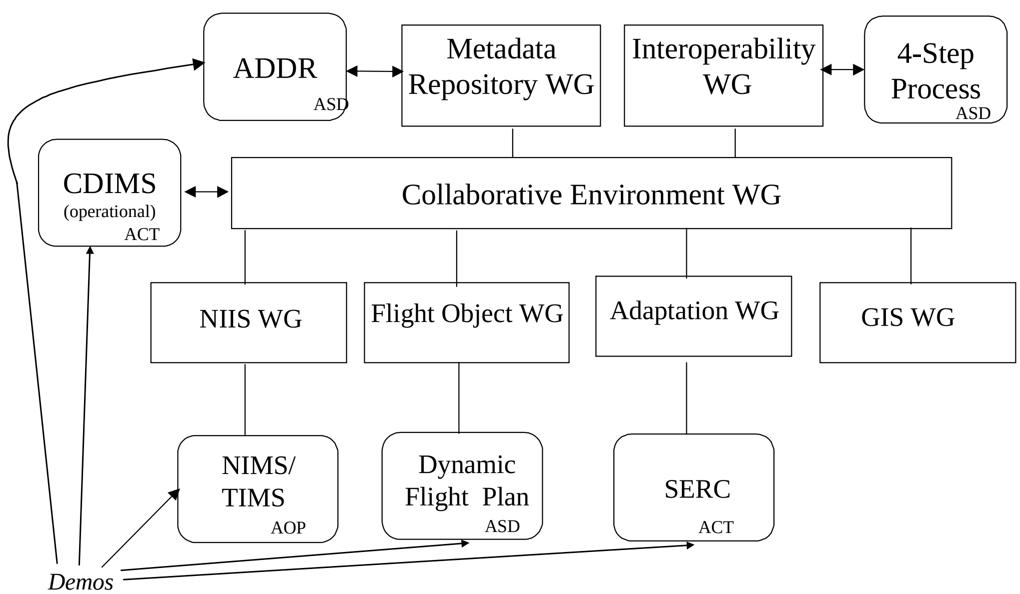

Figure 2-6. NIAC Working Group Relationships

The NIAC was formed to be an action group of FAA and contractor staff dealing with information issues and activities. The NIAC was established with the objectives of addressing [NIAC, 1998]:

- Information Interoperability (among NAS systems)
- Data Quality and Access
- Cost Effectiveness
- Responsiveness, Flexibility, and Scalability

To accomplish the NIAC objectives, chairs were selected for the working groups, funding from several different FAA organizations was proffered, and a basic infrastructure for information architecture was defined and initiated. The initial activities included:

- Development and initiation of an interoperability process (NAS Interoperability Process (NIIP)),
- Development and implementation of a tool to promote collaboration (Collaborative Data Integration Management System (CDIMS)),
- Development of metadata repository concept (Aviation Data Description Repository (ADDR)),
- And engineering of targeted aspects of NAS information.

The Interoperability Working Group (closely associated with the NAS Infrastructure Interoperability System Working Group – NIIS) developed a process to establish standardization of NAS data elements. The approach, called the 4-step process, included [Smith, 1999]:

- Identifying information needs from operational requirements,
- Collaborating on the information architectures necessary to meet requirements,
- Validating the architecture and verifying the operational suitability of the resulting standards for defining and representing the data (metadata),
- Registration of the data standards through an official FAA decision process (such as the NAS Configuration Control Board – CCB) and deposition of the standards in a managed metadata repository (ADDR).

After the registration and availability of the registered standards, the Integrated Program Teams (IPT) of the FAA must establish such standards as program requirements and validate their implementation in development activities. To insure implementation of the standards, an assessment of program architectures would determine compliance with metadata standards. This entire process, the 4-step standardization and the IPT implementation activities, would increase the interoperability among FAA NAS and NAS user systems.

Figure 2-7 illustrates this process as a pipeline for establishing and implementing standardization of NAS information within the FAA. The four step interoperability process of capturing requirements, collaboration, testing and validating, and registering metadata standards are shown as the upper pipeline in the figure. The lower pipeline represented the implementation and assessment activities. The ADDR provides a repository for data and standards information linking the activities.

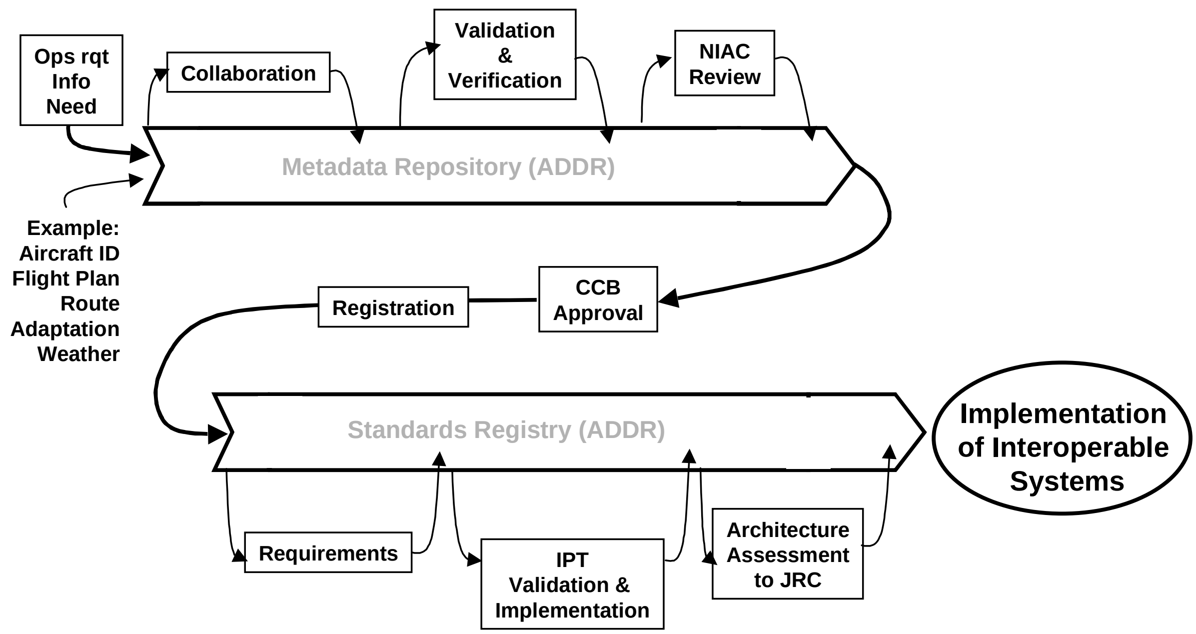

Figure 2-7. FAA Pipeline for Standardizing NAS Data

The Flight Object Working Group of the NIAC is engineering several aspects of NAS flight and infrastructure information. The activities described in this paper and sponsored in part by the Flight Object Working Group, resulted from the application of the information engineering process on the flight and infrastructure categories of NAS information. Information engineering by the Flight Object Working Group includes the identification of requirements and validation of data and information necessary for planning flights in the NAS and disseminating that intent information into the NAS control cycle.

Section 3

Application of Information Engineering to Flight Data Processing and Flight Planning

3.1 Overview

Flight data is ubiquitous across the NAS and among those providing air traffic management services from the FAA, the users of the NAS, and others in the aviation community (see Figure 2-3). To provide interoperability among the disparate systems used in these different contexts, collaboration among the stakeholders must occur to establish data standards, to define common procedures, and to specify respective roles and responsibilities. Many of these perspectives were necessarily considered to complete this information assessment.

Figure 3-1 illustrates many of the stakeholders using and concerned about standardization of NAS flight data. Stakeholder organizations, represented by circles, are a subset of actual NAS flight data stakeholders. The organizations shown are those with which the Flight Object Working Group is interacting. The size of the circles indicates the use of or amount of influence on the NAS flight data. The distance from the Flight Object Working Group center represents the closeness of the relationship with the Working Group.

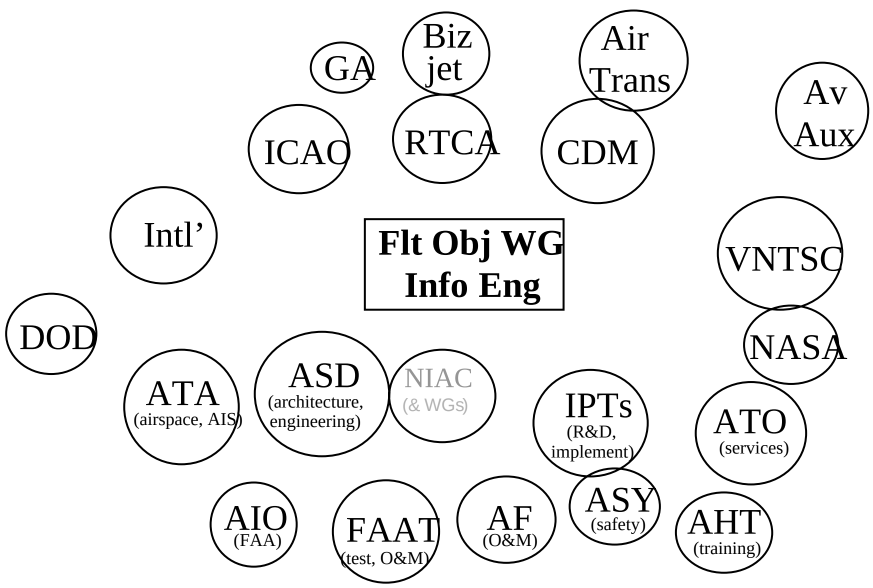

Figure 3-1. Stakeholders in Flight Information Standards

The FAA components of these stakeholders would influence the progress of standardization and be subject to the requirements based on data standards through the pipeline process shown in Figure 2-7.

Many of the stakeholders shown in Figure 3-1 are actively developing new automation systems or reengineering existing ones. Changes in one aspect of the information flow model (Figure 2-5) will necessarily affect elements and systems in other parts of the control-cycle based information flow. For example, if changes are made in the flight planning aspect of the flight data processing, these changes may have dramatic impacts in assessing the performance of the NAS in real-time and will be seen in post flight day analyses for the following:

- AOCs (including international and military AOCs),
- Flight Service Stations (FSS) providing flight planning services to general aviation pilots,
- Many FAA facilities and systems, and
- International ATC facilities.

The information flow related to interrelationships and interdependencies among the aviation community and the FAA must be well understood or information system modifications may have more negative impacts than benefits.

3.2 Complexity of Flight Data

Engineering the information aspects of flight demand, the subsequent influence of demand on the capacity of the NAS, and the measures necessary to balance demand versus capacity, is a complex undertaking. There are three major vectors necessary for consideration when engineering the information flows. These vectors include:

- Human Interaction
  - AOC
  - Air Crew
  - Controller
  - Traffic Management Specialist
  - Operations Command Center Specialist (infrastructure)
- Information Classes
  - Demand
  - Capacity

  - Constraints
  - Weather
  - Infrastructure
  - Adaptation
- Phase-of-Flight Automated Capabilities
  - Pre-flight
  - Departure
  - En route
  - Arrival
  - Post-flight

The evolution of aviation has significantly increased demands on the management of NAS resources. This evolution, as measured in terms of the number of passengers on certified air carriers, has increased steadily about 5% per year since the end of World War II, see Figure 3-2. Other measures of evolution, such as the number of aircraft handled, which measures FAA operations on all types of aircraft, show very similar increases. This growth has dramatically increased the demands on the NAS and its management.

The increased demand on the NAS is projected to reach gridlock in 2004 unless capacity improvements are made. Improvements in engineering and use of NAS information can balance demand with capacity.

Figure 3-2 also illustrates the advances in aviation technology that have spurred the pressures on the NAS. However, advances in FAA management and technology have not kept up with the advances in aviation. Management and availability of flight and flight related information is one area where significant efforts are being made to improve the automation and systems to support more efficient practices and procedures.

3.2.1 NAS User Flight Data Processing

Flight data processing for NAS users takes on two distinct but interrelated forms. A significant amount of processing of data and of using information to make or influence decisions is made on the ground. Another portion of flight data processing is done while flights are airborne. Flying, after all, is the point of all of this activity.

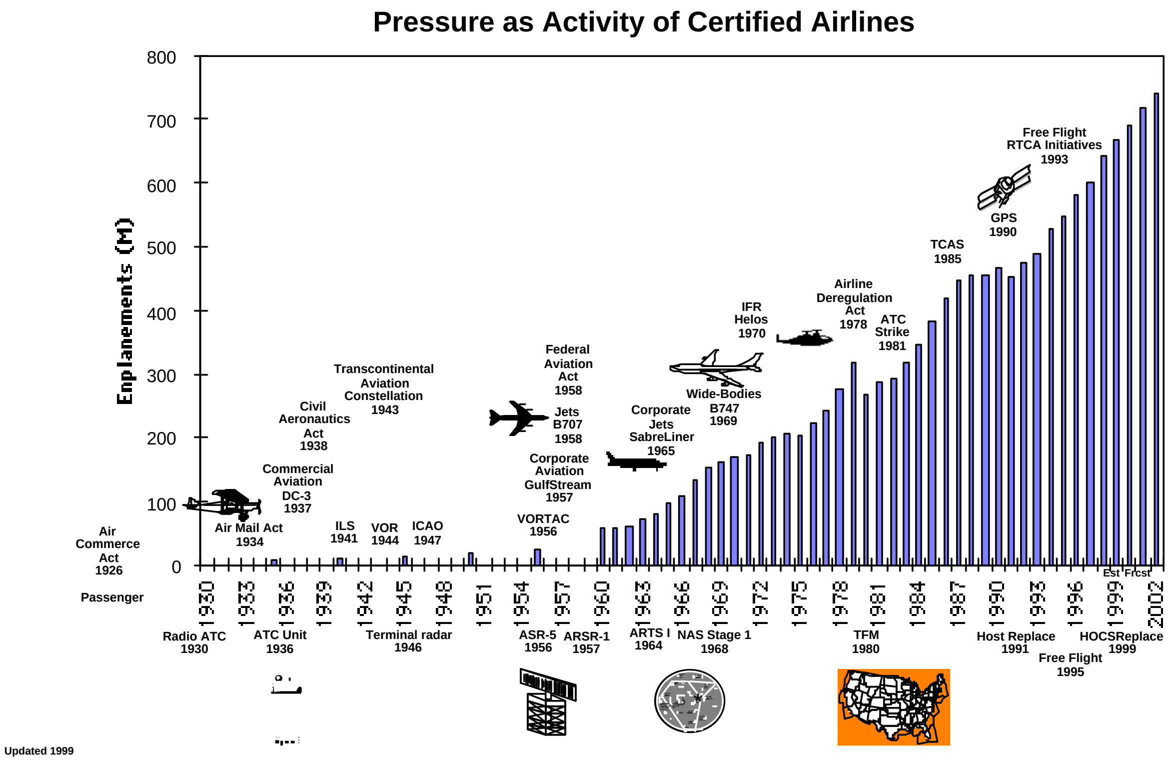

Figure 3-2. Evolution of Aviation in the U.S.

The AOCs, and other ground-based flight information processing, process and produce a prodigious variety and amount of flight data. This data is in turn accessed and used as information by decision makers, often in response cycle times on the order of minutes or sometimes seconds. Many large AOCs, usually commercial and military, have sophisticated automation to support flight planning and conformance monitoring. However, many pilots, usually general aviation or business jet operations, rely on paper maps and planning tools and on support from the FAA's flight service stations or even commercial flight services.

Ground-based flight data processing occurs prior to departure during flight planning, while the flight is active, and even afterwards during analysis of operations. Flight manuals, such as the Aeronautical Information Manual [FAR/AIM, 1998] and many other documents [RTCA, 1997b] provide additional detailed discussion on the use of flight data on the ground.

The other aspect of NAS user flight data occurs between the ground and airborne aircraft. Because of the communications constraints for radio communication and size and weight constraints onboard an aircraft, air/ground information exchange and processing is necessarily limited. Flight information is transferred from flight planning into onboard flight management systems or to the pilot. Data link capabilities are being developed to improve transfer of situation, air traffic control, and flight management information between air and ground [RTCA, 1997c].

3.2.2 FAA Flight Data Processing

The current FAA systems approach to flight data processing is highly distributed, see Figure 2-3. There are 20 Air Route Traffic Control Centers (ARTCC) in the continental United States (CONUS) and two additional in Alaska and Hawaii. The Host Computer Systems (HCS) in the CONUS ARTCCs act as the primary data sources for almost all of the flight data processing for the NAS. In addition, there are more than 70 major airports with Airport Traffic Control Towers (ATCT) and associated Terminal Radar Approach Control (TRACON) facilities. The national Air Traffic Control System Command Center (ATCSCC) and its associated Traffic Flow Management (TFM) data system hub provides a center for centralized and strategic management for the entire NAS. Flight Service Stations support flight planning for General Aviation pilots, and the ATCSCC and ARTCCs have flight data communications with commercial aviation and military AOCs. In addition, the ATCSCC and ARTCCs exchange flight data with international air traffic control centers.

3.2.3 Flight Data Model

NAS flight data, that are exchanged or defined among more than 30 different FAA automation systems, have been analyzed and modeled [Schwarz, 1998]. The logical flight data model illustrated in Figure 3-3 is a high-level entity-relationship representation of the data flowing among the systems analyzed [Broste, 1998]. The data structures and relationships among nearly 3500 data elements across 18 NAS systems interfaces and data standards were analyzed, normalized, and then logically modeled.

This data model has provided a baseline for assessing flight data necessary for the flight planning process. This entity-relationship model has also provided a starting point for the development of object classes in the development of the flight plan demonstration described in this document.

Flight data are used in all stages of pre-departure flight planning, in-flight management, and post-flight analysis. These data are acquired and processed by aviation planners, NAS users, FAA service providers, and ancillary aviation components, as shown in Figure 2-3. Flight data is disperse and complex, as illustrated in Figure 3-3.

3.3 Selection of Flight Planning for Assessment

The charter of the Flight Object Working Group of the NIAC was to demonstrate an information assessment of a subset of NAS flight data. A major challenge for the activity reported in this document was to select an activity important enough to contribute to the advancement of the NAS modernization initiative but also small enough to be achievable with limited resources. The flight planning process provided an opportunity to evaluate the information engineering approach and is a foundation for the operational concepts of Free Flight and air traffic management by the year 2005.

The following extracts reflect the motivation for selecting flight planning for this exercise:

FAA Air Traffic Systems ConOps [FAA, 1997]

> "In 2005, most aspects of this overall planning, coordination, and activation process can be managed either by NAS Pre-flight Advisors, or by the users themselves...automation plays a significant role in the entry and distribution of information... which enables the user to determine the most operationally desirable flight profile"

Government/Industry ConOps for Evolution of Free Flight [RTCA, 1997a]

> Flight planning in 2000 - "...users can probe against system constraints such as hazardous weather, SUA, flow restrictions (airspace facility demands), and infrastructure outages so that the flight planner has an improved awareness of conditions along the proposed route and whether the flight may need to be rerouted after departure."

RTCA ConOps for ATM-AOC G-G Information Exchange [RTCA, 1997b]

> "Preflight collaboration can result in the resolution of predictable conflicts with TFM constraints, and also the communication of likely conditions and negotiation of options for AOCs to use as conditions change and tactical TFM actions are initiated."

In addition, there were few FAA initiatives that were directly working on a reassessment of the entire process of flight planning. Flight planning evaluation activities in the following areas were recognized:

- The FAA's Free Flight Phase 1 office under Collaborative Decision Making (CDM), in conjunction with the CDM Group and the Volpe National Transportation Systems Center, is evaluating the early availability (24 to 48 hours) of flight plans from the NAS users.
- The evaluation of flight planning services will be addressed by the FAA Technical Architecture activities in the systems engineering office.
- The FAA en route Integrated Product Team (IPT) is investigating alternatives for flight data processing within the en route system.
- The international Object Management Group (OMG) consortium has broadcast a Request for Information from the aviation industry for object-oriented alternatives for processing flight planning data.

- Eurocontrol is evaluating flight planning process improvements as part of its overall European air traffic system architecture development.

These activities should be coordinated from a common information perspective. It was decided that an information assessment of flight planning could contribute to a broader understanding of the flight planning process and contribute to unifying some of the activities addressing improvements for the flight planning process.

3.4 Flight Planning Data

The current NAS approach to flight planning originated in the 1930's and was automated in the 1960's. Today's process, is illustrated in Figure 3-4 [McMillen, 1999].

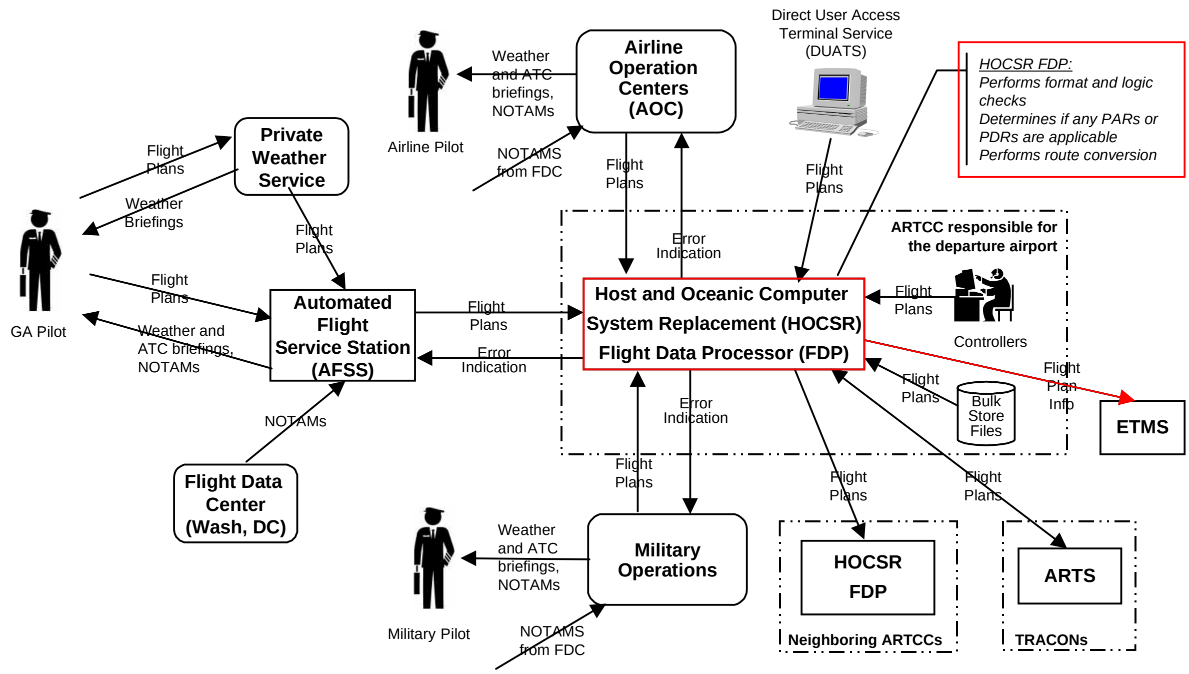

Figure 3-4. Domestic Flight Planning Data Flow

3.4.1 Current Flight Planning Process

Today flight planning is still based upon providing flight plan information to the air traffic management facility at the departure point for evaluation and further dissemination. This approach provides a subset of flight plan information and is limited by lack of availability of complete NAS constraint information to the flight planners.

Currently, many potential advances in flight planning are hampered by limitations of current flight planning procedures and automation. For example, much of the detail of the flight plans developed with much care by the NAS users are not passed on to the FAA. Examples of this additional data include 4-dimensional route and time at fixes, fuel burn profiles, and climb and descent profiles. All of this additional information would be invaluable for evaluating NAS demand and for developing traffic following and merging patterns. In addition, the FAA would be using intent data developed by the NAS users themselves rather than deriving these data from models based on assumptions different from those driving the users intent. These data have been recognized as important and are included as a "new age flight plan" in the RTCA information exchange document [RTCA, 1997b].

On the other hand, many of the constraints in the NAS are neither available to flight planners nor are they available to FAA flight service or traffic management specialists. Today's flight planning processes are constrained by a lack of critical information.

The objective of the Flight Object assessment reported in this paper was to evaluate the information flows necessary for effective flight planning without being limited by current flight planning procedures and limitations. This perspective of engineering, focusing on the needs of the customers and from the point of view of providing information stores and flows, allowed a fresh look at the entire flight planning process as well as at the automation necessary to support these activities.

3.4.2 Flight Schedules

Flight schedules are required to be published by commercial passenger airlines. These schedules, as reflected in the Official Airline Guide (OAG), provide limited insight into the true demand for NAS resources. The OAG provides a view of the long range intent of these NAS users. The OAG, is in fact, used to establish the baseline demand for resources during collaboration among air carriers and the FAA when NAS resources are constrained. For example, collaboration is conducted when arrival capacity at an airport is less than normal.

General aviation, business aircraft, cargo carriers, and military are not required to publish schedules. In fact, there is significant sensitivity about public access to private aviation intent and flight planning. If provided early enough and if properly protected, these private flight plans could provide significant additional information about demand on NAS resources.

3.4.3 NAS User Flight Planning

The original purpose for filing flight plans with a governmental agency (the FAA), prior to radio communications and electronic navigation, was to aid in search and rescue if an aircraft was overdue at its destination. The paper process evolved with the use of electronic flight planning and the advent of positive radar control that allowed aircraft to fly under instrument flight rules. However, the information required for flight plan submission to the

FAA remains very similar to that required for search and rescue. For example, the route of flight is provided but the arrival times at fixes, altitudes, and way points are not.

Flight planners from the commercial, private, and military sectors have intimate knowledge of the business drivers for their flight planning. The resulting detailed flight planning information, derived from individual intent and planning procedures, is highly sensitive and somewhat volatile. On the other hand, an aggregation of this detailed intent information could be used to develop an overall picture of demand on the NAS at any given time.

Much of the flight planning done by large commercial airlines and cargo carriers is supported by significant automation used to capture as much information as is available about schedules, fleet and personnel management (e.g., flight crews), historic flight paths, system constraints (such as weather), and flight regulations. Other advances in aviation technology, such as collaboration with the FAA on ground-delay programs and aircraft flight management systems (FMS) using detailed flight plans as aircraft control parameters, have improved the flight planning process.

Flight planning for general aviation is supported from the FAA by Flight Service Stations and also by many commercial weather and flight status service companies. Flights operating under visual flight rules are not required to file flight plans but most do, primarily to maintain the original search and rescue purpose for flight planning.

3.4.4 FAA Flight Plan Processing

Every FAA facility providing NAS flight services deals with flight information in one form or another. Flight plans, provided initially to the host computer systems (HCS) in the ARTCCs either from FSSs or from commercial sources, are disseminated to TRACONS and towers, and also to the ATCSCC.

After the NAS users submit flight plans to the FAA, the flight plans are reviewed by FAA service providers. The routes from the flight plans are expanded by the HCS to determine which air traffic control sectors will be controlling the flight. Not infrequently, the clearance for route or time of departure is significantly revised by FAA service providers in order to mitigate congestion in the NAS.

Flight plan information is most frequently provided to the service providers by automatically printing the information on paper flight strips generated for each specialist or controller station. Increasingly, flight plan data are processed through automation and provided to service providers electronically. For example, the User Request Evaluation Tool (URET) provides controllers electronic display of flight plan information in real-time.

Foldout here (figure 3-3) Strawman Flight Data Model–Logical

Section 4

Dynamic Flight Planning: Concept of Operations

4.1 Scope and Assumptions

Revisions in flight plan procedures and processes will have impact on all of the FAA's air traffic management and Flight Service Station flight data processors, on commercial and military AOCs, general aviation and business jet aviation, and on international air traffic and aviation concerns. Flight planning information is the baseline of intent for each flight, see Figure 2-5.

This intent information is propagated to all FAA facilities handling any given flight. The flight planning information is also used for assessing demand at these facilities. After flight departure, this flight planning information is used to assess the progress of each flight, to insure that each flight is navigating properly, and to support search and rescue in the event of a mishap.

This document primarily focuses on flight plan information for those commercial or military aviation elements having AOCs. General aviation and other small NAS users will be addressed in future work. In addition, this document is also oriented primarily for pre-departure flight planning. After a flight plan is committed or an aircraft departs, the dynamics of re-planning a flight become much more complex and are beyond the scope of this assessment.

The basic assumptions for this information assessment of flight planning processes include:

- The basis for the information assessment were the Free Flight and year 2005 Operational Concepts already developed by ATS and RTCA.
- Ideas beyond these concepts would be explored as they became evident.
- All of the information stores and flows for flight planning were included in the assessment (even those not used in current systems).
- The activity was not limited to improving current flight plan processes.

4.2 Need for the New Capability

The FAA has committed to the concept of Free Flight to drive NAS modernization. Free Flight is based on the premise that NAS users would plan and fly the trajectories of their choice, with FAA intervention only when necessary to insure safety or protect equitable access to NAS resources. In this context, the current approach to flight planning and flight plan execution is significantly outdated.

The current processes for flight planning were developed in the 1920s and 1930s, and were automated in the 1960s, as discussed in Section 3 above. However, after airline deregulation in the 1980s, the continued increase in demand for aviation services, and the advent of the Free Flight concepts (see Figure 3-2), new approaches for flight planning must be explored.

4.2.1 New Capability Environment

The ATS and the Industry/Government Concepts of Operations for Free Flight call for increased information exchange and probing flight plans against NAS constraints (see Section 3-4). However, in the context of open exchange of flight planning information, the situation is much more dynamic.

The major premise of Free Flight is that NAS users be allowed to follow their intent, as defined by their own business needs, and only be constrained in the interests of safety and equitable access to NAS resources. This premise is not fully addressed in the approaches identified in the current set of Concepts of Operations, which describe development of flight plans against a restricted set of information and then passed on to the FAA to probe against a different set of constraints. These assumptions may be based on an even more primitive assumption, that flight plans would be processed in the same local way that they are processed in today's environment.

The open sharing of information, the use of NAS user intent data to evaluate NAS demand system-wide, and the acquisition and management of a much broader range of NAS constraints information will provide a different environment for flight planning than is currently available.

4.2.2 Current System Situation

In many cases, the limited information provided in flight planning is extrapolated by FAA automation to produce entire trajectories. These simulated trajectories may or may not correspond to those developed by the NAS users themselves. This often results in differences in expectations between the NAS users and the FAA service providers.

The constraints on the NAS resources, both inherent constraints such as weather impacts and congestion constraints imposed by user demand, are most often understood only locally. The integration and control of impacts of such constraints across facilities will only be understood at the system level when consistent information sources are tapped and collated. Much of this information is not available to the FAA service providers today nor is the limited constraint information that is available to the FAA made available in a usable form to the flight planners.

There are several areas in the current flight planning system where information engineering could improve the flight planning process:

- Identify flight information relevant for flight planning and not currently accessible, in FAA and in NAS user data store.
- Leverage modern automation technology, such as databases and Internet-based communications, for managed access to the right information when and where it is needed.
- Leverage the control system paradigm to use NAS user intent data (which is also used as control parameters in aircraft on-board control systems) to better assess demand on the NAS and FAA intent and use strategy data to better assess system constraints and capacity.
- Establish information sharing rules to provide open information sharing and access to needed information while protecting the privacy needs of all parties.

4.2.3 Role of the New Capability in Future Environment

Dynamic flight planning would provide a common basis for shared situational awareness that is very limited in today's environment. In addition, dynamic flight planning would recognize the control systems aspect of flight planning in relation to balancing the demand against capacity that is provided as an FAA service. These flight planning improvements would also extend collaboration among the NAS users and FAA service providers that is occurring, on a limited basis, as part of CDM in the Free Flight Phase One program.

The following assumptions were made about the development and implementation of dynamic flight planning:

- NAS users and FAA service providers would be willing to share information not currently shared.
- Information sharing would require access control and data management to protect sensitive information.
- The technology and communications infrastructure would be available for the information sharing and collaboration.
- All parties would accept that NAS user intent represents the best estimate of demand on the system, rather than model extrapolations.
- Flight plans across the NAS would be aggregated centrally to assess the user demand NAS-wide and to identify constraints resulting from excess demand at limited resources.

4.2.4 Anticipated Impacts

Dynamic flight planning could have the following benefits, many of which are identified in the FAA Fiscal Year 2000 Annual Performance Plan [FAA, 1999a]:

- Flight clearances that more nearly match flight plans as developed by the users (flexibility)
- Greater predictability for NAS user and FAA service provider operations
- Reduction in delays NAS-wide as demand is better balanced against constraints
- NAS user participation in responding to NAS constraints (flexibility)
- An improved view of user demand on the NAS (delays)
- Timely access to all known constraints on NAS resources

The following difficulties could be encountered with dynamic flight planning:

- A more distributed and collaborative environment for flight planning could potentially increase vulnerabilities to security threats
- Sensitivities to procedural inadequacies or competitive gaming could emerge
- If flight planning is centralized, single point of failure issues must be addressed.

4.3 Functional Architecture

The charter of the Flight Object Working Group necessitated an assessment of how flight information was used, as well as how the data was structured. An object-oriented approach was followed to allow a simultaneous assessment of action and information.

The object-oriented approach requires that actors, processes, and timing among processes be defined, as well as information flows. Actors are those components, either human or automation, which accept and produce data, as well as manipulating it in some way that is not detailed by the automation under study. In other words, actors are information customers. The functional architecture is a description of functions, data, and their interrelationships that provide capabilities to users, their evolution over time, and the principles and guidelines governing their design. [Hermes, 1998]

4.3.1 Functional Components

Automation provides capabilities to systems users. System users and interoperational system components interact with system functions. The actors shown in the use case diagrams in Figure 4-1 were identified as the components under consideration for the dynamic flight planning exercise.

A dispatcher was identified as an actor in the role of developing and managing flight plans for an AOC. The dispatcher interacts with a number of flight planning functions in the AOC through a user interface. The data access and processing required to select and display information in support of the dispatcher activities are transparent to the dispatcher.

The AOC automation, also considered an action, interacts with FAA automation, and possibly other AOC automation, to enable updates to the system and NAS environments quickly enough for the dispatcher to assess changes and adjust decisions as necessary to meet their own business goals. Potential flight alternatives can be assessed and revised in real-time collaboration with FAA and in response to NAS environmental changes.

In general aviation (GA), the actor was identified as the pilot. In this situation, pilots usually develop flight plans based on their needs, the capabilities of their aircraft, and constraints identified in the NAS, such as weather or runway conditions. The general aviation component, shown in grey in Figure 4-1, was not evaluated in this activity.

Several actors were identified as providing services for the FAA. A specialist in the Operations Command Center (OCC) monitors and manages the automation and communications infrastructure on the FAA side of the NAS. This specialist is trained to identify the impact of equipment or system failure, to engage remedial action, to assess potential impact on the NAS, and to notify appropriate traffic management specialists.

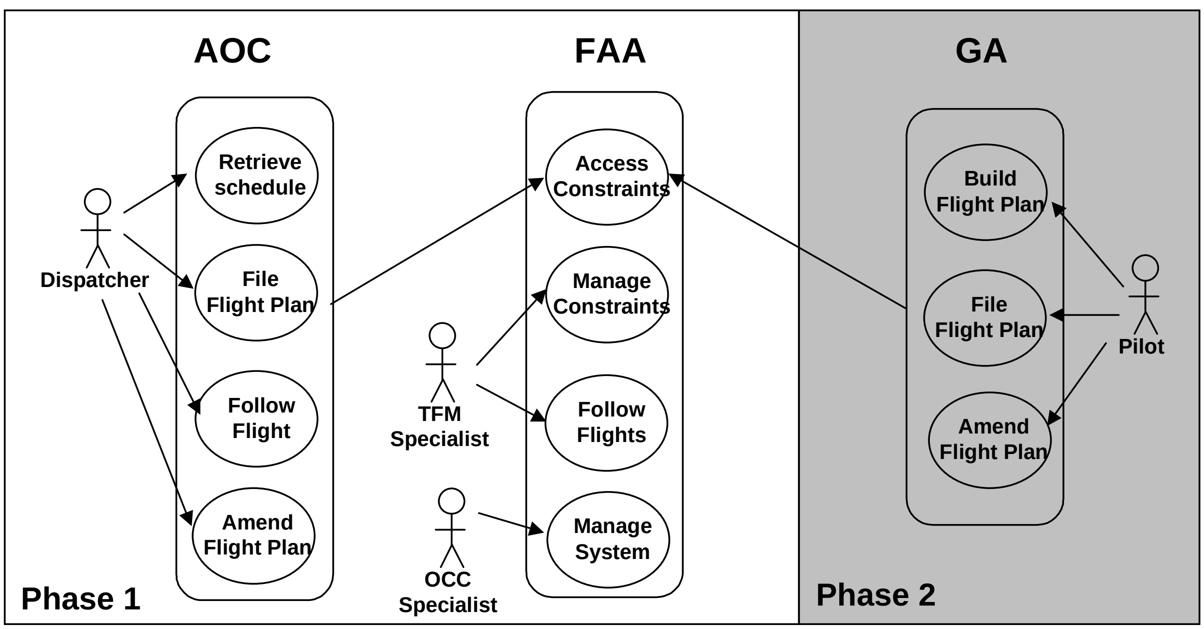

Figure 4-1. Actor Interactions in Flight Planning Activities

A TFM specialist works in FAA air traffic facilities large enough to require traffic flow management activities or at the ATCSCC. In the context of flight planning, an ATCSCC specialist would evaluate overall demand from flight plans against NAS constraints, including constraints caused by demand, and notify flight planners of conflicts not identified by users.

4.3.2 Situations of Use

The operations considered during the information assessment of flight planning were dissected into those activities occurring prior to an aircraft's departure (pre-operational) and those occurring after an aircraft begins to move in the NAS environment. That is, after and aircraft becomes operational. There is considerable latitude for collaboration and negotiation before an aircraft pushes back from a loading gate or tarmac tie-down.

Figure 4-2 illustrates the relationships for flight planning (FP) across pre-operational and operational status. Pre-operation adjustments, such adding fuel or adjusting weight, may be required as a result of a flight plan change, while rerouting changes for the on-board flight management system can occur in either state. Many of these options are not available once an aircraft is airborne. Flight re-planning may be necessary after a flight plan is submitted to convey changes in NAS user intent.

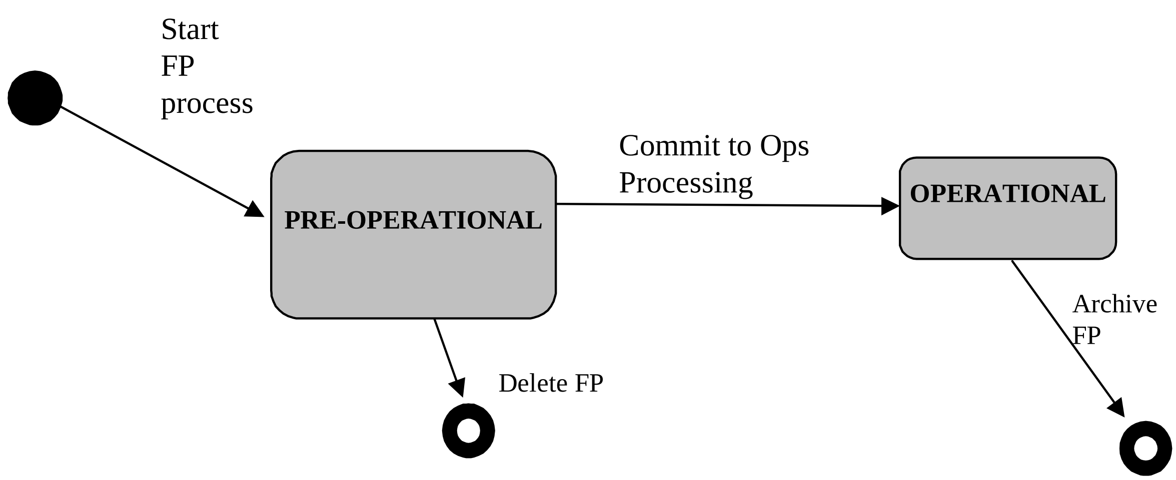

Figure 4-2. Distinctive Flight Planning Activity Environments

The pre-operational state covers the various forms a flight plan may have before the user and service providers commit to executing that flight plan. Safety critical decisions are never made on the basis of a pre-operational flight plan. Pre-operational flight plans can be deleted or withdrawn from the systems and leave no history.

The operational state covers forms of a flight plan that represent the flight planners intent, are "official", and could become the basis for safety-critical decision making. In today's NAS, operational flight plans are defined in the ARTCC host computer system. Operational flight plans never die, they just retire into an archive.

4.3.3 Pre-Operational Processing

Figure 4-3 illustrates high-level functions occurring in the pre-operational state, as defined for the demonstration. The figure represents activities for both a flight plan probe approach and for dynamic flight planning. As more constraints information is available for the flight planner, the number of "unusable" flight plan probes will be reduced at the time they are developed.

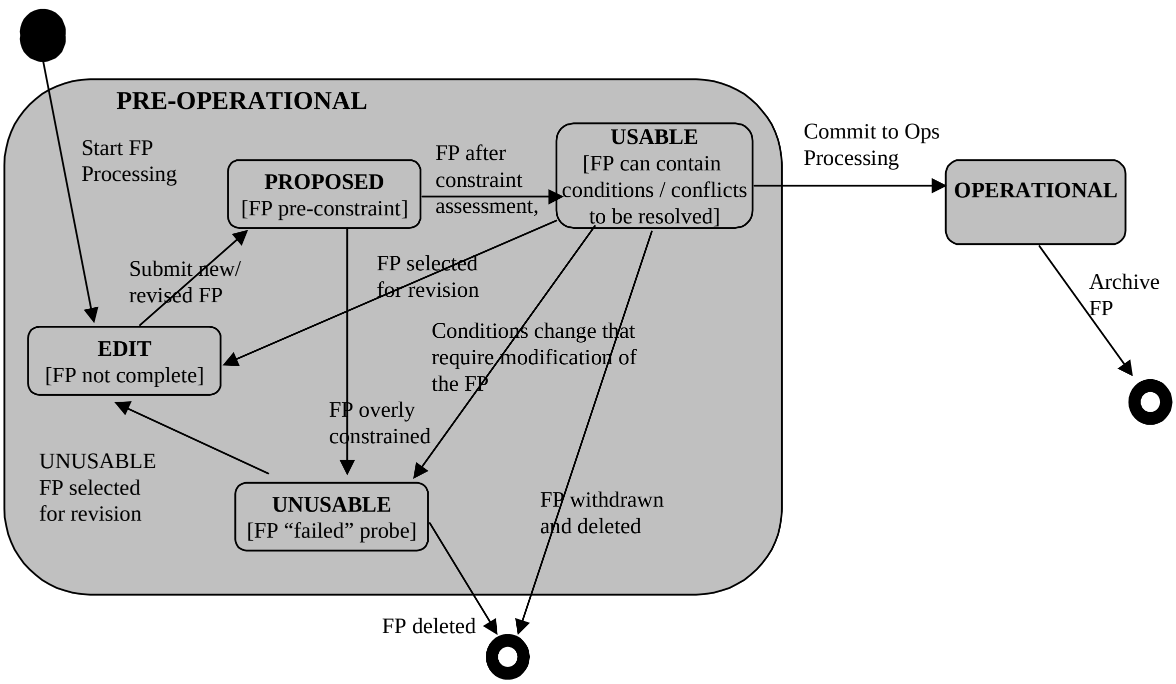

Figure 4-3. Collaborative Pre-Operational Flight Planning Functions

In dynamic flight planning, the distinction between pre-operational and operational states may blur. As higher fidelity information becomes available in a more timely manner, flight plan probing and adjustment may occur almost continuously prior to gate push-back.

An analogy to these dynamics is now in operation with the Ground Delay Program-Enhancement collaboration evolving in the CDM project in Free Flight Phase 1. The collaborating airlines continuously adjust, substitute, or cancel their own flight plans (based on their own business drivers) in response to shifting arrival spaces at constrained airports. The FAA sets arrival acceptance rates (constraint) at these airports based upon weather, runway configurations, and other local conditions. The proportion of arrival spaces for each participating airline is fixed by previously published flight schedules (the OAG). This is one mechanism for establishing equitable and fair use of these NAS resources. At given times, aircraft depart from other airports to meet the arrival times set by this program.

This adjustment of flight plans, based upon arrival airport constraints, illustrates one element of dynamic flight planning. Dynamic flight planning in the pre-operational state could extend this kind of collaboration from the arrival into the en route and departure airspace, and possibly even onto airport surfaces.

4.3.4 Operational Processing

With the dynamics of the NAS, demand and constraints change and will affect flight plans already developed. Database triggers can ensure that flight plans affected by such changes are reviewed and changed as appropriate. In the collaborative environment, airlines can adjust, substitute, or cancel flight plans as appropriate based on constraints in any phase of flight.

Figure 4-4 illustrates flight planning activities during the operational state. These activities could occur prior to or after an aircraft pushes-back from a gate. After push-back, the aircraft is generally committed to early portions of the flight plan as cleared by air traffic control. However, options are open while en route to re-plan for later segments of the flight.

4.3.5 Integration of New Capability

The flight planning concepts discussed here could be integrated into NAS automation as systems are enhanced or replaced. However, some activities, such as reengineering the flight data processing components of the en route HCS and the traffic flow management system, must recognize and integrate the centralized flight plan demand evaluation concepts presented here to make dynamic flight planning viable.

The CDM activity is currently planning to collect flight plans from participating airlines into the centralized Enhance Traffic Management System from 24 to 48 hours prior to departure. Although this flight plan acquisition activity does not include the four-dimensional (route and fix times) flight plan data, it does mark the beginning of a centralized flight plan database.

4.4 Comparative Scenarios for Flight Planning

For the purposes of understanding the role that information could play in flight planning, three scenarios will be described. The scenarios are simple with a focus on information. The first scenario, entitled Today’s State, provides a description of information sharing between OCC Specialists, TFM Specialists, and AOC Specialists (dispatchers) as it is performed in today’s environment. The second scenario, entitled Flight Plan Probe, describes an upgrade of today’s state by providing a view of limited information sharing while flight planning is being performed. The third scenario, entitled Dynamic Flight Planning, describes the future state when all necessary data is shared and flight planning is more interactive.

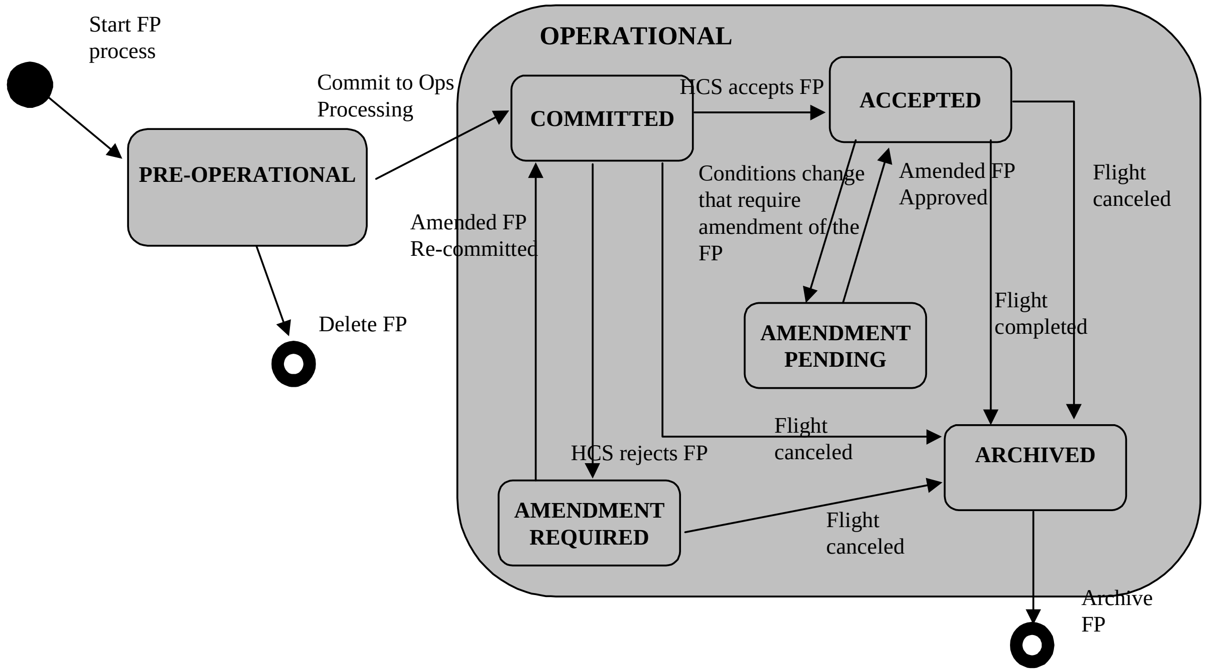

Figure 4-4. Dynamic Operational Flight Re-Planning Activities

These scenarios represent the validation process taken by the Flight Object Working Group in assessing the information necessary to evolve from the current day's flight planning process (Scenario 1) to achieve the flight plan probes (Scenario 2) described in Free Flight Concepts of Operations [FAA, 1997, RTCA, 1997a, and RTCA, 1997b]. While pursuing this objective, the Working Group recognized that significant gains could be realized by pursuing the validation process to its natural conclusion, in Dynamic Flight Planning (Scenario 3).

4.4.1 Scenario 1 - Today's State Demonstration

The flight planning of today, as modeled in the demonstration, is limited by the information shared and used by NAS users and by FAA automation and service procedures. For example, an AOC Specialist determines a flight's or set of flight's routes, altitudes, times, and speeds with little information about FAA constraints, limitations, routes availability, or planned outages. All negotiations are performed via phone calls and none of the parties involved has a visible picture providing shared situational awareness.

4.4.2 Scenario 2 - Flight Plan Probe Demonstration

The flight plan probe scenario explores the limited electronic sharing of information. A flight plan will be filed as today. After the flight plan has been filed, the service provider converts the route and probes the plan against known constraints. If there are constraints that effect the flight, the AOC will be notified. An electronic message will be provided with the flight and constraint identified. The AOC Specialist will be able to visually look at the problem and make amendments. The amendment is filed and the process continues.

4.4.3 Scenario 3 - Dynamic Flight Planning Demonstration

The dynamic flight planning scenario provides for the full sharing of constraints, limitations, routes availability, or planned outages at all times. The flight plan would be shared even during the development of that plan. Most negotiations would be performed electronically. This scenario is more fully developed in Sections 5 and 6, and in Appendix B.

Section 5

Dynamic Flight Planning: Information Architecture

Figure 5-1 provides a pictorial view of the information flow for dynamic flight planning. The items to note are the virtual database that is utilized by both the FAA and AOC. This is not intended to indicate that each party will have exactly the same information but they will share data necessary to perform flight planning by the FAA and the AOC.

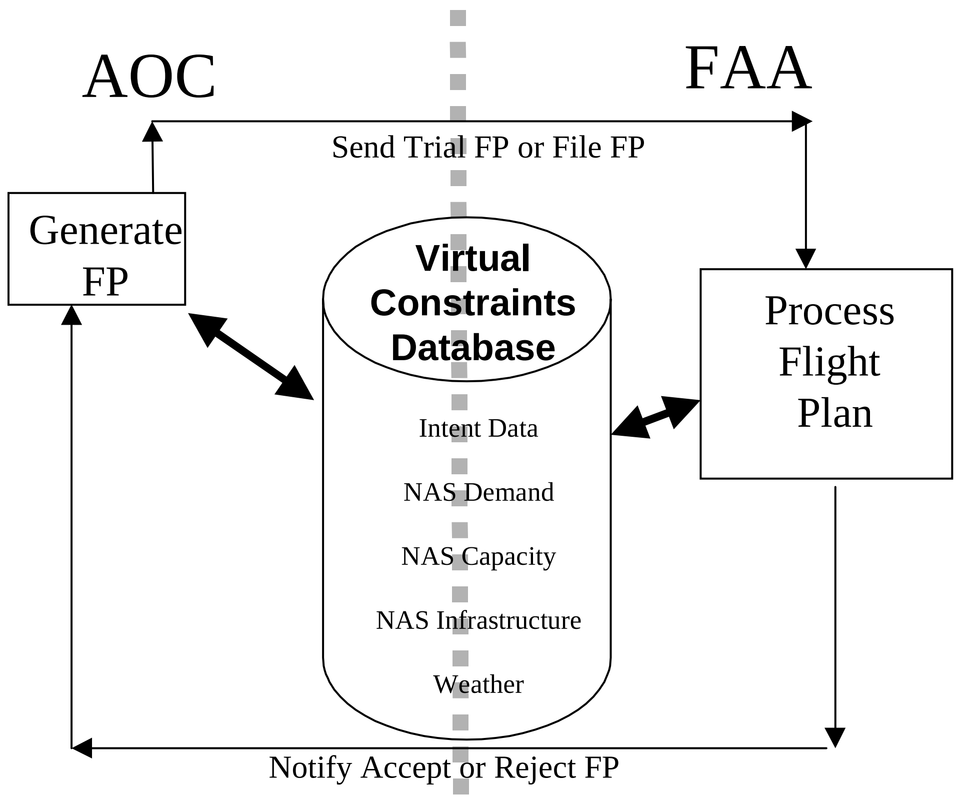

Figure 5-1. Sharing Flight Plan Data

The process of submitting a flight plan, either trial or desired, is still basically the same. The AOC would have better data with which to make decisions about the flight prior to submission to the FAA. The FAA in turn would have better data with which to make decisions about the flight prior to notification of acceptance or rejection of the flight plan.

The process of flight planning changes, as stated in Section 4.4, by sharing constraints and performing electronic negotiations. The database items are described in more detail in the following sections.

5.1 Intent Data

For the FAA to really understand the needs of the user community and their constraints during the planning process, more data is necessary. This data is known as intent data. Intent data includes four-dimensional flight data (position, time, speed, altitude), preferred climb and descent profiles, and fuel burn. Intent data is considered to be sensitive by the user community. To share this data, it will be need to be protected so that only FAA and the user who supplies the data can obtain access to the detailed data.

5.2 NAS Demand

Demand data is used by the NAS for determining problem areas. Demand includes flight segments as determined from the flight plans. In order to better assess the current and future situations, especially during high demand times, full intent data will be utilized. The intent data will provide a more accurate picture for each NAS resource that is being accessed.

5.3 NAS Infrastructure

Communications equipment (including phone and data lines), navigation equipment, major computers (e.g., HCS), and surveillance equipment are considered infrastructure. This information about infrastructure failures can be used to identify resulting constraints on NAS resources. These constraints may affect NAS capacity.

5.4 NAS Capacity

NAS capacity data includes airport acceptance rate, departure rate, sector limit, Flow Control Area (FCA) restrictions, and Special Use Airspace (SUA) specifications. This data will accessible by the users for flight planning purposes. This provides the users the ability to alter routes, speeds, departures, detours around SUA, or other alternatives that meet their business considerations prior to submission of the flight plan.

5.5 Weather

Weather includes NOTAMS, ASD-I, NASSI, WARP, and other products used by the NAS users and the FAA service providers. These products and reports need to be integrated together to provide a coordinated picture of possible weather problem areas.

Section 6

Dynamic Flight Planning: Validation Demonstration

6.1 Overview

The scope of the Dynamic Flight Plan demonstration was very limited relative to the scope of the entire flight planning activity. The scope of the demonstration was constrained to a flight planning position at an AOC and a flight plan assessment position at the FAA command center. There is also capability to indicate the status of certain NAS infrastructure equipment, such as a NAVAID, that would impact the navigation ability of an aircraft or the capacity of an air traffic control component. General aviation and military components would be evaluated in an expanded demonstration.

The validation demonstration was established to provide a visual tool that illustrates the three scenarios described in Section 4.4. The demonstration shows the information used in each scenario and how improved information increases efficiency during the flight planning process. The tool was based on the flight data model described at a high level in Section 3.2.3. This model is object based and is described further in the following sections.

6.2 Object-based Development

The development of the Dynamnic Flight Planning demonstration integrated elements across many different NAS user and FAA domains. These domains included NAS and engineering elements. Figure 6-1 illustrates many of these elements and their inter-relationships.

The NAS operations were reviewed to identify and develop scenarios for assessment. The NAS services and capabilities provided definition for the prototype. The object-oriented prototype development required the definition of sequence diagrams and use cases. The assessment of information sources, sinks, and flows required reevaluation of scenarios and use cases. Several iterations were required to produce the final demonstration.

The Ptech Framework object modeling tool was used to develop the Dynamic Flight Plan framework and rules for moving and processing information. Figure 6-2 is a high-level view of the much more detailed object models developed for the demonstration [Rumbaugh, 1991]. The shaded portions of Figure 6-2 were the focus of this study. The detailed models reside in the tools themselves and are to be documented at a later date. Many of the objects were derived from the entity-relationship model developed for the NAS data model analysis, see Figure 3-4.

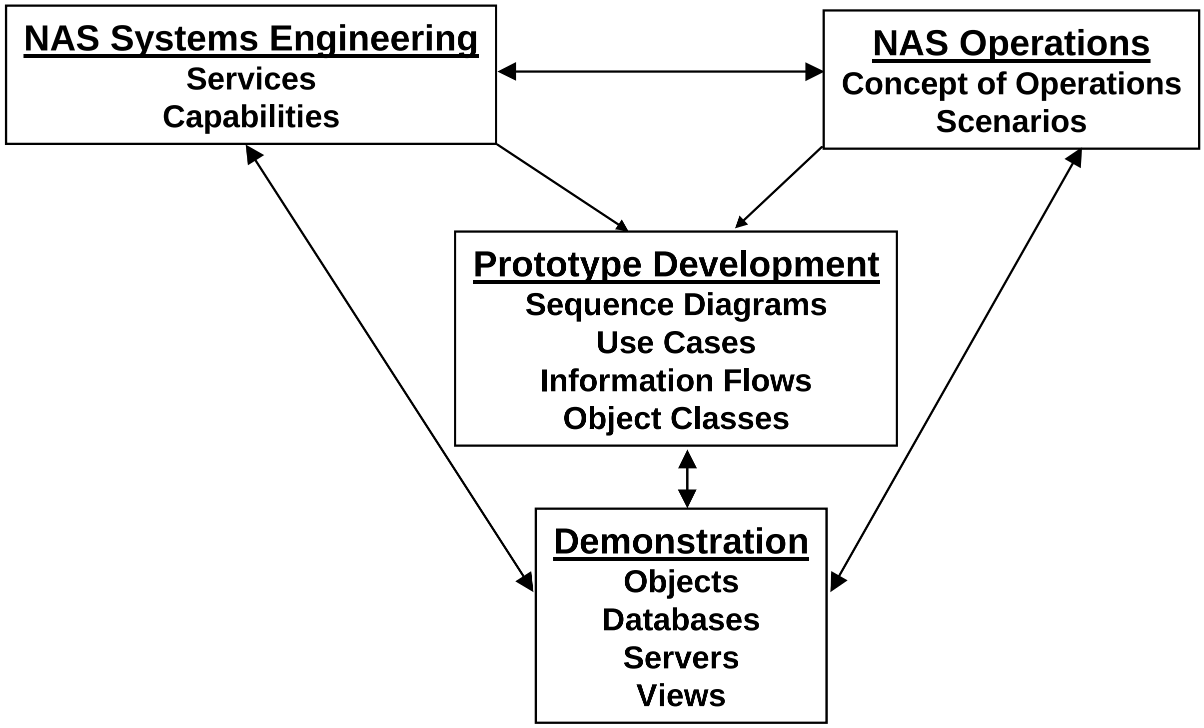

Figure 6-1. Dynamic Flight Planning Demonstration Development Components

6.3 Scenario and Demonstration Development

The use cases developed for the Dynamic Flight Plan demonstration are shown at a high-level in Figure 6-3 and presented in detail in Appendix B. There were three scenarios of flight planning implemented in this demonstration, see Section 4.4.

The OCC presentation is a set of monitor and control stations for monitoring, evaluating, and managing the many automation, communications, and other electronic devices used by the FAA to provide air traffic management services to the NAS users. The primary flight planning presentation for the FAA in this demonstration is the ATCSCC representing the FAA service provider. The third presentation evaluated for the demonstration is the AOC representing the commercial, and perhaps aspects of the military, flight planning operations. Another presentation considered, but not addressed, is the general aviation and business jet community that does not have access to a formal AOC. These flight planners use the FAA's Flight Service Stations and other commercial information providers. They will be evaluated in later iterations of the flight plan demonstration.

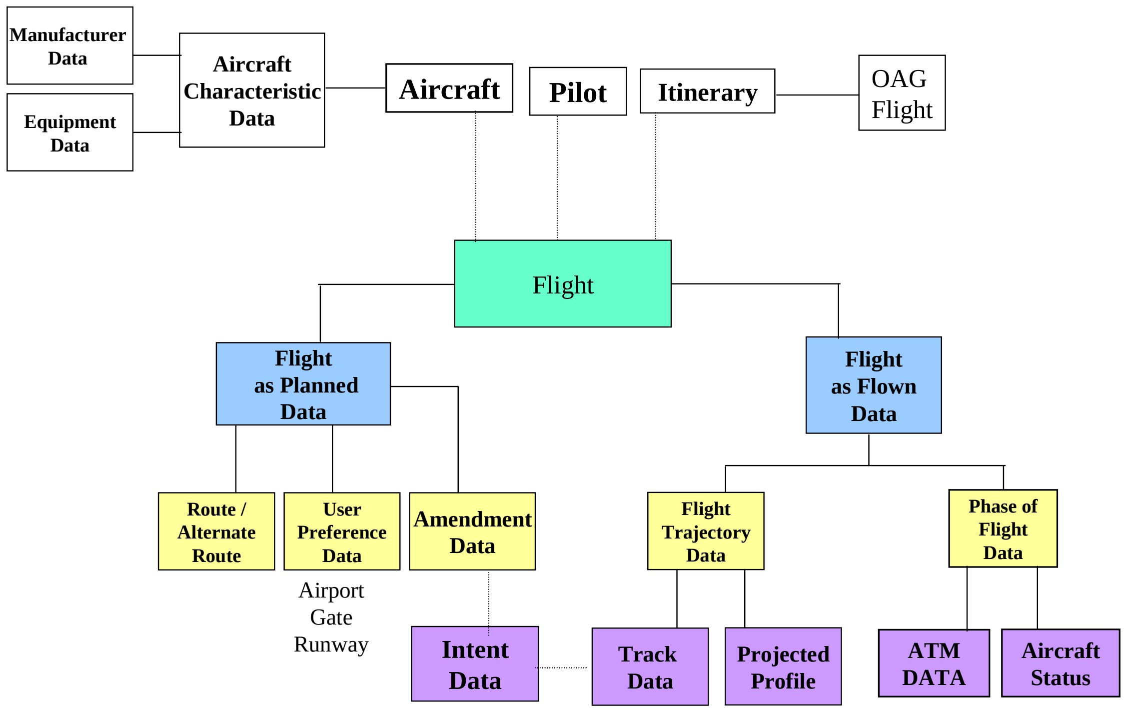

Figure 6-2. High-Level Dynamic Flight Plan Object Model

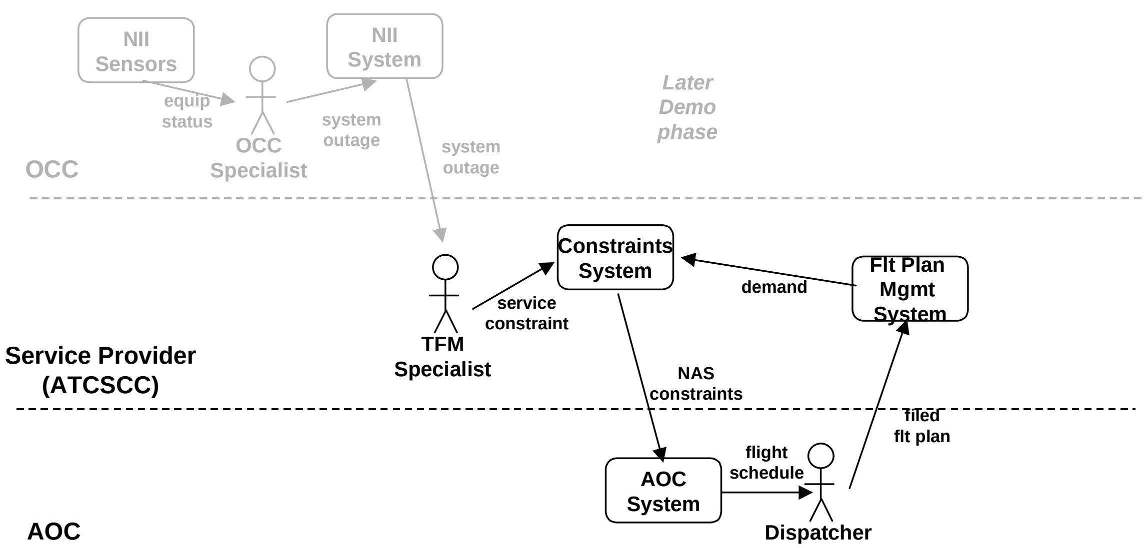

Figure 6-3. High-Level Scenario Flow

The Dynamic Flight Plan demonstration was developed with a commercial set of prototype development tools. This tool set, from ILOG Inc., used the object models developed with the Ptech Framework modeling tool to populate the object core, see Figure 6-4. The use cases and sequential meetings of the development team allowed the evolution of the views and validation of the core objects and rules.

As the actor views were developed, the scenarios were played out. Each session uncovered more opportunities for improvement in the demonstration, and even more importantly, a broader conception of the extent that dynamic flight planning could be exercised under the appropriate circumstances.

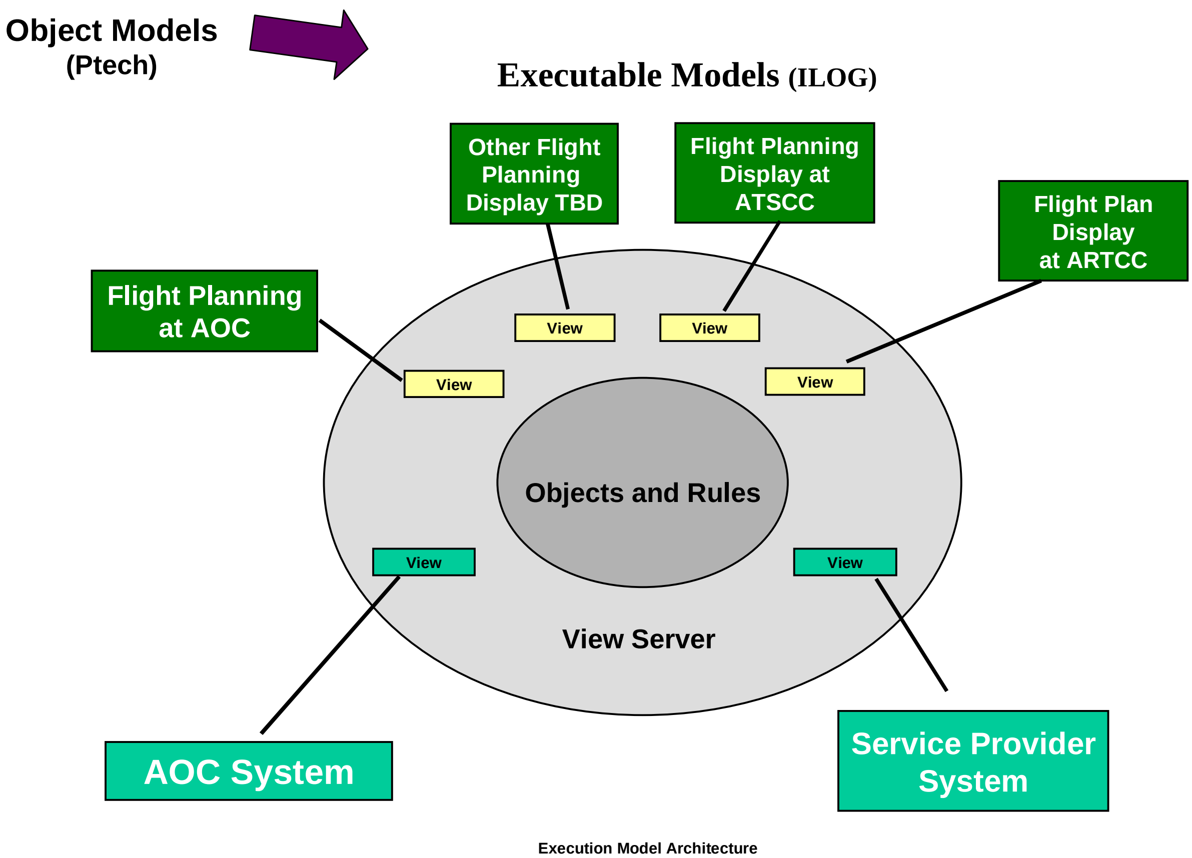

Figure 6-4. Dynamic Flight Plan Demonstration Components

6.4 Dynamic Flight Planning Demonstration

The dynamic flight planning demonstration was designed to be interactive and observed directly. There will be no attempt to document all of the dynamics of the demonstration nor of all of the elements of the demonstration. Public demonstrations have been provided at meetings for the NIAC and the NAS architecture forums. A detailed documentation of the prototype itself will be developed at a later date. The descriptions below are intended only to provide an overview the types of screens viewed during the demonstration.

6.4.1 AOC Display

The demonstration display for the AOC position includes similar views of the flight plan database as the FAA provider display. However, the AOC position can only view the flight plans developed by that AOC. Flight planning data are sensitive among competing airlines and care must be taken to protect privacy.

Figure 6-5 shows several tabular displays of flight information and mechanisms for entering and editing the information in the database.

6.4.2 FAA Service Provider Display

Figure 6-6 illustrates a wide-view and a zoomed close-in view of some routes of a flight that are being modified by the AOC workstation and reflected through the database.

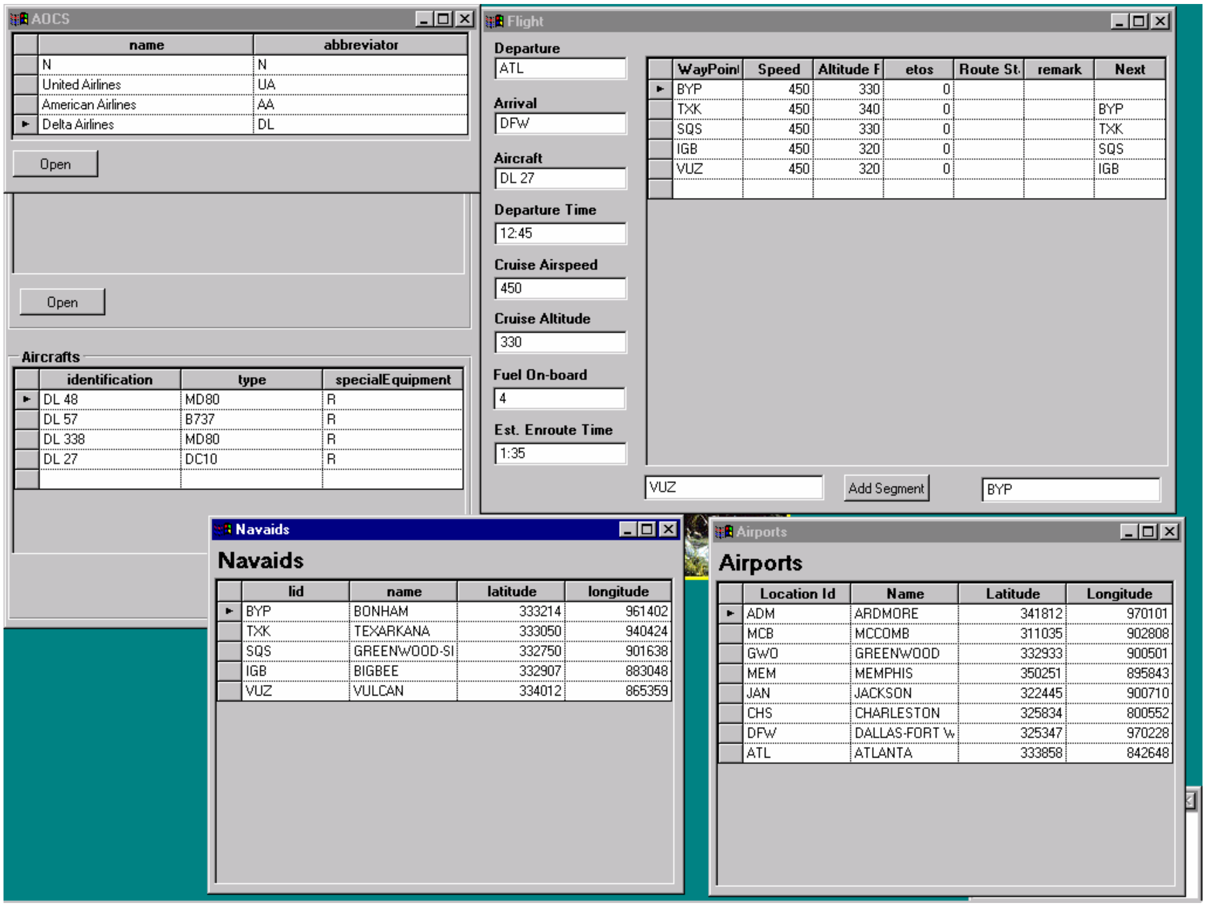

Figure 6-5. Dynamic Flight Plan AOC Display Screen

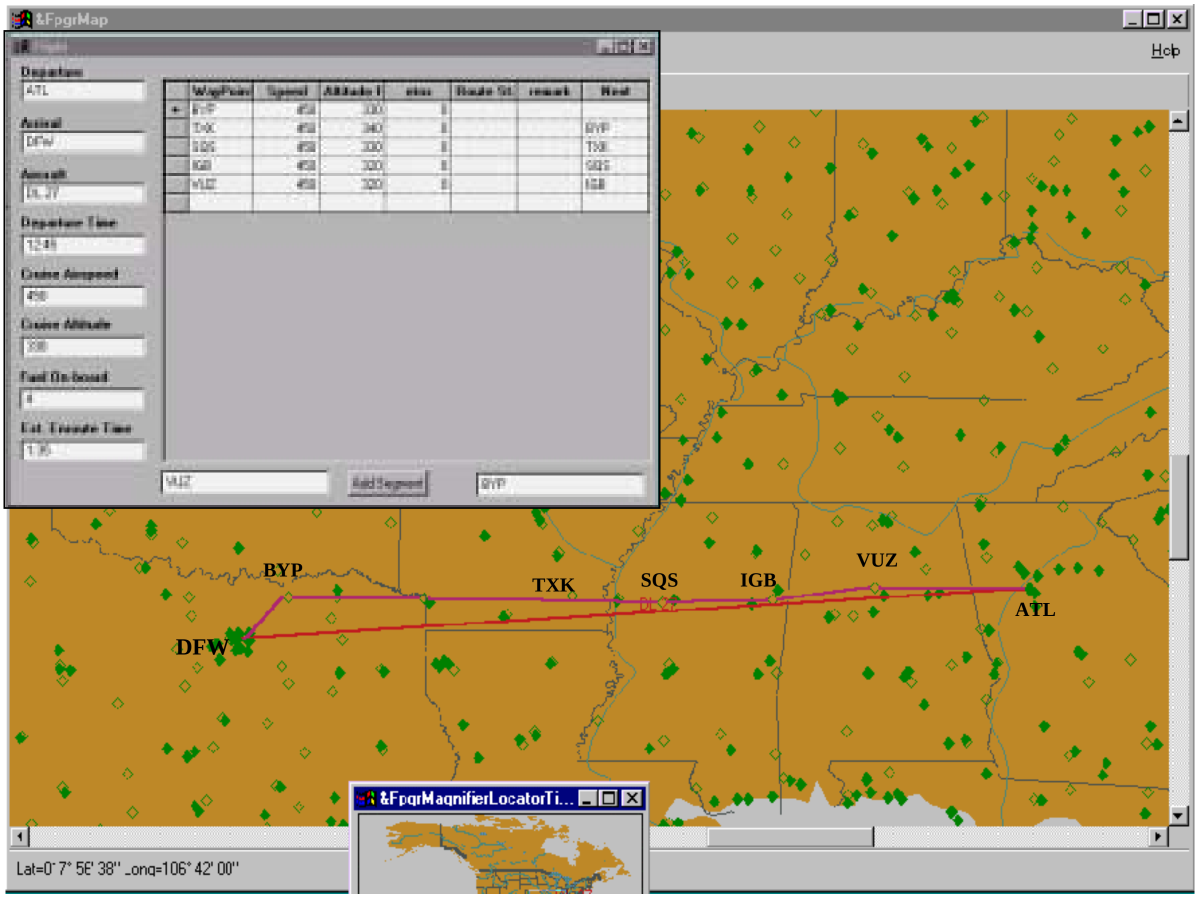

Figure 6-6. Dynamic Flight Plan FAA Service Provider Screen

Section 7

Significant Findings and Conclusions

The intent of the Flight Object demonstration was to validate information engineering concepts against the flight planning subset of NAS flight data. However, as the development of the demonstration proceeded, airline dispatcher, private and commercial pilot, and air traffic specialist expertise were consulted. It became evident that the information assessment was identifying a number of significant findings. Although operational experts were consulted during this information assessment, an operational assessment of the demonstration was not conducted. The conclusions listed below are based upon the information assessment.

These findings not only validated some of the objects and data elements necessary for flight planning, they also validated that an advanced approach to flight planning was necessary to achieve the goals of Free Flight. The principle recommendations of this demonstration, and their supporting findings, are listed below.

7.1 Reassess Entire Flight Planning Process

Both the flight plan probe approach, described in both Free Flight Concepts of Operations, and dynamic flight planning will require that the current approach to flight planning be reassessed. To achieve the Free Flight concepts, NAS demand and constraints must be determined from a NAS-wide, broad-based view using better flight information.

The scenarios identified in this demonstration activity can be implemented in an incremental evolutionary fashion. Each of the increments can accrue a significant portion of the overall benefits.

7.2 Fully Share Flight Planning Data

All pertinent data developed during the flight planning process by NAS users can be of real value for evaluating NAS demand, flight characteristics, and flight stream integration. Since NAS user flight plan data are used as control parameters for aircraft on-board flight management systems, the ability of these flight plans as predictors of actual flight routes can provide a large potential advantage over the current approach. If such information were shared, as suggested in the new age flight plan [RTCA, 1997b], and used appropriately, significant improvements in access, predictability, flexibility, and system capacity may potentially accrue [FAA, 1999a].

7.3 Apply Potential Improvements in Demand Assessments

NAS users invest significant business acumen in the development of flight plans. These flight plans reflect the best goals for the flights, based on all business drivers. Using these flight plans, the FAA can develop better estimates of the demand on NAS resources and more accurately identify system constraints. These improved estimates can then be shared with the NAS users. These advances could potentially improve flexibility for user planning and improve predictability for flight routes [FAA, 1999a].

7.4 Extend Free Flight Concepts of Operations

The dynamic flight plan demonstration illustrated that by extending flight plan dynamics beyond the flight probe described in the Free Flight Concepts of Operations significant potential advantages can be gained. This extension is in the spirit of the Free Flight concept and flight plan probe capabilities can be used as an incremental step to dynamic flight planning.

7.5 More Broadly Implement Information Engineering

The extrapolation from existing Concepts of Operations to the recommendations for dynamic flight planning demonstrates the power of the information engineering process in assessing system requirements.

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Appendix A

Control System Overview

The importance of information used to control system dynamics was described 2500 years ago by Sun Tzu in his treatise often referred to as *The Art of War*. The cycle of acquiring, processing, and applying information for influencing the outcome of events has been formalized in systems control theory and in large scale real-time operations. The observe-orient-decide-act (OODA) loop or Boyd Cycle was described for use in air-to-air and large scale combat in the 1960s. More recently, knowledge-based control cycles were described for real-time intelligent and robotics systems in the 1990's.

The Control Cycle Process

The control cycle process, which is fundamental to command and control, is complex; that is, it balances a fine line between chaos and stagnation. To control any environment, the functional capability of a control cycle must operate faster (higher frequency) than cycles of the environment itself. In applying control cycle processing to an environment, the controlling entity must sense, understand, and act on anticipated changes in the environment faster than the environment changes, see Figure A-1. Otherwise, reaction cycles (short circuits of analysis and decision in functional capability) set in. This results in falling into chaos or else maintaining status quo, which engenders stagnation.

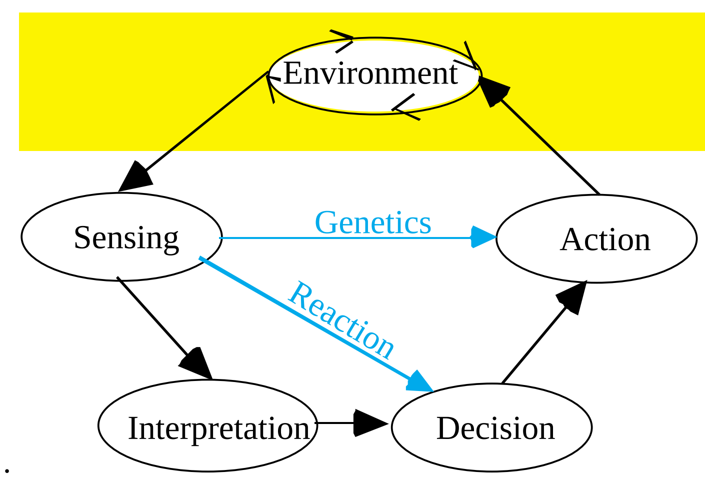

Figure A-1. Operating in the Control Cycle

The Environment

The definition of the environment, shown in the figure, determines the scope of the rest of the process to be understood. For example, if the environment is warfare, the scope of the process could be the Army or another military organization. If the environment is the National Airspace System (NAS), the scope of the process could be the FAA, air traffic control, or NAS users (airlines or general aviation pilots). Or the environment could be the government implementation of complex automation systems, in which case the scope would encompass the process of adjusting an organization to maintain or resume the control cycle as systems are fielded.

In the broadest sense, the environment could be nature. In which case the contingency process describes the evolution of life as an emergent system in which organisms with the best adaptations, that endure environmental changes, survive while less adaptive organisms die. Genetics provides the process.

Natural evolution does not have the perspective of the vision of humans. This vision replaces genetics in the process with the mission, technology, goals, strategies, and objectives shown in the figure. These components humanize the process of the control cycle, which can be good and bad.

But when the function of the control cycle is not recognized, or not accepted, interpretation and decision is bypassed and reaction sets in. This is little better than genetic evolution. Instincts can be trained to provide effective reaction, but they are of limited scope and not adaptable to significant changes in the environment.

The Control Cycle

Ultimately, in dynamic systems, the control cycle process is the key element. If the control cycle is not effective, then the remaining process is invoked to adjust the control cycle for the desired effectiveness. Failure to adapt the control cycle to changes in the environment can initiate failure of the entire service or organization. The timing of the control cycle, the sensors, the functional capability, and the user interaction are variables eligible for adjustment. However, the timing of the cycle is dependent upon the other adjustable elements in the control cycle as is part of the user interaction with the functional capability.

Control cycles have several salient features, several of which are accomplished by functional capabilities which provide users, or participants, with an interface with the environment. An operational view of a generic control cycle is illustrated in Figure A-1.

Elements sensing an environment can include biological senses, as well as enhancements of those senses and other sensors provided by technology. A more fundamental sensing of environmental changes involve organism deterioration or survival and natural selection. Technology can provide enhanced senses, such as radar, that can provide sensing at increased distances or higher sensitivities. These enhancements may allow a speed up in the response cycle, at least until the environment catches up, which is usually the case given time.

Action includes any change that is exposed again to the environment under the changing environmental conditions. Action includes manipulating the environment. The response cycle is closed when sensing the environment is the mechanism through which the effect of actions on the environment are measured. Inaction is also a form of action. If nothing is done, the environment will still change and have a different impact on the control in the next response cycle.

Decision is a conscious process of selecting a course of action based upon sensation or interpretation of changes in the environment. Interpretation includes the acquisition of sensed data, detection of differences or patterns (often called perception), analysis of that information, and comparison of all of the above with previous experience, which in turn provides alternatives for decision. The analysis may include simple response to events sensed in the environment. Or this analysis may include anticipation of environmental cycles, determination of contingencies, and development of alternatives to respond to the most likely changes expected in the environment. Thus, identifying contingencies, that if acted upon might stay ahead of events in the environment and provide a measure of control, is often a successful survival mechanism.

Evolving the Contingency Control Cycle

As an environment evolves, the functional capabilities and sensors driving the control cycle must also evolve. The contingency response process describes a mechanism for understanding how the environment evolves and adapting these functional capabilities accordingly.

Domain expertise from operation of the control cycle is necessary to determine not only what happens in an environment, but to also determine the extent that contingencies might be effective and the necessary response to them in an effort to control the environmental cycles. Control cycle knowledge is needed in system providers to adapt the control cycle system to stay ahead of the evolution of the environment.

It is often not enough to just react to the inevitable changes in an environment. The only constant is change itself. Understanding the dynamics and complexity of the control cycle and recognizing that the interpretation of contingencies is a complex process in itself. This is necessary for adapting the control cycle components to this change. The contingency response process is a tool to aid in that understanding. Military and business strategists have recognized such processes as invaluable since the time of Sun-Tzu in his *Art of War*. The process is fundamental but regular reemphasis and reformulation of it aids in the application of the process.

Appendix B

Dynamic Flight Planning: Use Cases

The use cases detailed here provided a basis for developing the rules for data processing and exchange for the Dynamic Flight Planning demonstration. The use cases were developed based on the format established by Rumbaugh for object-oriented analysis. [Rumbaugh, 1991]. The relationship of sequence diagrams and use cases to the demonstration development is illustrated in Figure 6-1.

The use cases provided here were constructed to initiate development of the dynamic flight planning demonstration. They are not complete and they will not be updated until further development requires. They are included to illustrate the process required for object-oriented development. Other use cases are being developed in support of the ASD Technical Architecture activity and will possibly obviate the need for expanding these cases.

Scenario 1 Overview:

The first scenario for the Dynamic Flight Planning demonstration reflects a pre-flight planning operations (i.e. prior to flight departure) under normal conditions, no severe weather or other special circumstances, with operational capability at:

1. the NAS Operations Command Center (OCC),
2. the Air Traffic Control System Command Center (ATCSCC),
3. and at a ‘typical’ Aeronautical (Airline) Operations Center (AOC).

This scenario reflects the enhanced dynamic flight planning capabilities identified from an information engineering analysis of the current flight planning process and potential improvements identified in discussions with AOC and TFM experts, as well as general aviation and commercial pilots. Figure B-1 illustrates the sequence of events covered by the use cases for scenario 1.

The NAS OCC specialist continuously monitors NAS infrastructure activity and identifies failures that may affect the aviation activity in the NAS. However, a level of reliability is engineered into NAS critical and essential systems such that equipment failures very seldom have impact on flight planning. One example occurred in 1998 when telecommunications was interrupted at an airport tower for several hours resulting in flights being diverted to other airports. Such interruptions are usually transmitted to the aviation community through the NOTAMS mechanism.

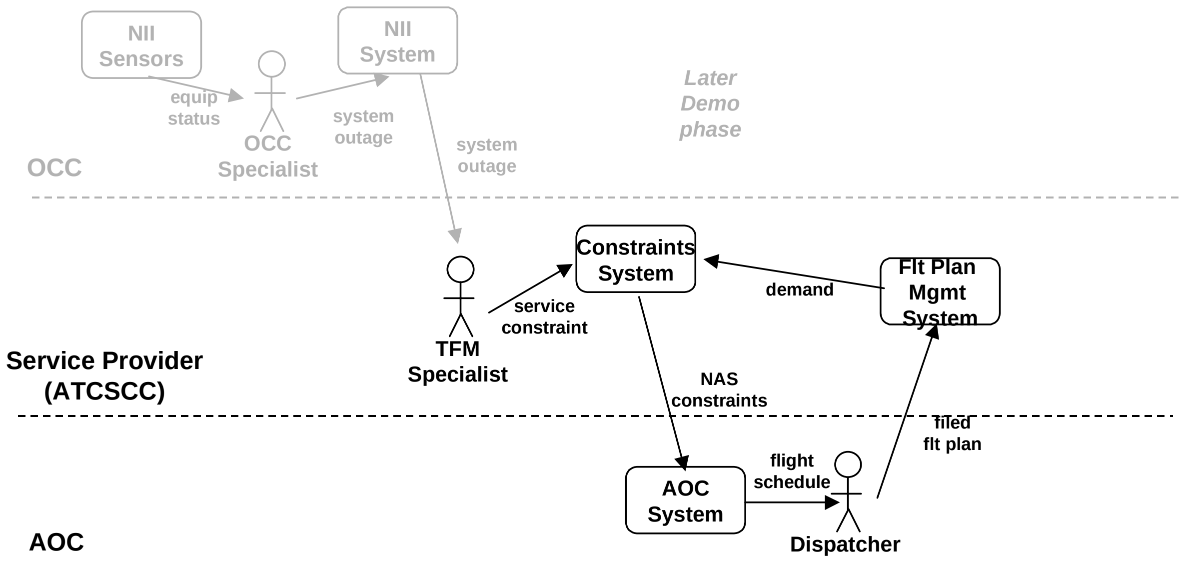

Figure B-1. Scenario Event Sequence

Additional Scenarios:

The pre-flight planning activities at the ATCSCC will remain similar as in Scenario 1 with the addition of more complex constraints, AOC, flight plan management systems, and dynamic flight following. However, in addition to the OCC other activities would be occurring to identify and quantify constraints as follows:

- Scenario 2 – Special use airspace (SUA) activity as a source of constraints.
- Scenario 3 - Severe weather and attendant flow constrained areas (FCAs) as a source of constraints.

The following scenarios involve operations in addition to commercial aviation AOC operations beyond the scope of the demonstration described here:

- Scenario 4 – Small commercial or business aviation AOC operations.
- Scenario 5 – Military and international AOC operations.
- Scenario 6 – General aviation and Flight Service Station operations.
- And in addition to pre-departure flight planning would be:
- Scenarios 7-? – Dynamic in-flight following and flight plan amendments for the above scenarios.

Flow of Scenario 1 Demonstration:

- An equipment outage will be identified from NAS infrastructure information (NII) sensors by the OCC specialist as potentially causing a constraint in NAS aviation operations.
- An outage will be entered into the NII system by the OCC specialist.
- The TFM specialist will assess the impact of the outage on NAS operations and identify a NAS constraint.
- In addition to NOTAMS notification, the TFM specialist will enter the constraint into the constraints system database.
- A flight schedule system at an AOC will pick up the new NAS constraint from the constraints system and factor the new constraint into its flight scheduling process.
- The AOC dispatcher will receive processed flight schedules from the flight schedule system and process each flight against his/her additional information derived from shift-change, situation, and weather briefings.
- The dispatcher will then adjust each flight as necessary.
- The adjusted flight information will then be submitted to the flight plan processing system.
- The flight plan processing system will integrate new flight plans with existing flight plans and assess the probabilities of new NAS constraints based on demand/capacity imbalance.
- The flight plan processing system will then forward the potential for new constraints to the constraints system for evaluation by the TFM specialist.

Scenario 1 provides one context for systems constraints, namely NII constraints. The events corresponding to the above flow for Scenario 1 are as follows:

Event	Use Case	Actor	Activity
1-5	UC6	OCC Specialist	Assess component failures, identifies system outages, and notifies ATM
6-12	UC5	TFM Specialist	Assesses outages, assesses flight demands, identifies and confirms service constraints,
13-15	UC4	AOC System	Accesses FAA constraints and models schedule with constraints
16-17	UC1	Dispatcher	Retrieves and adjusts flight schedule
18-19	UC2	Dispatcher	Enters adjustments and files flight plans
20-23	UC3	Flight Plan Management System	Accepts new flight plans, integrates new flight plans with system demand, assesses new constraint probabilities, and forwards probabilities to TFM specialist for consideration.

This flow of events is translated into object-oriented use cases below. The events shown for this scenario, and illustrated in Figure B-1, are reflected by the steps in the use case methodology.

Dynamic Flight Planning Use Cases for Scenario 1

Use Case Overview:

The Dynamic Flight Planning use cases are a summary of interaction requirements among “actors” in the description. Figure B-2 illustrates the use case relationships. The ovals in the diagram below identify the use case that will be described. The arrows identify triggering events.

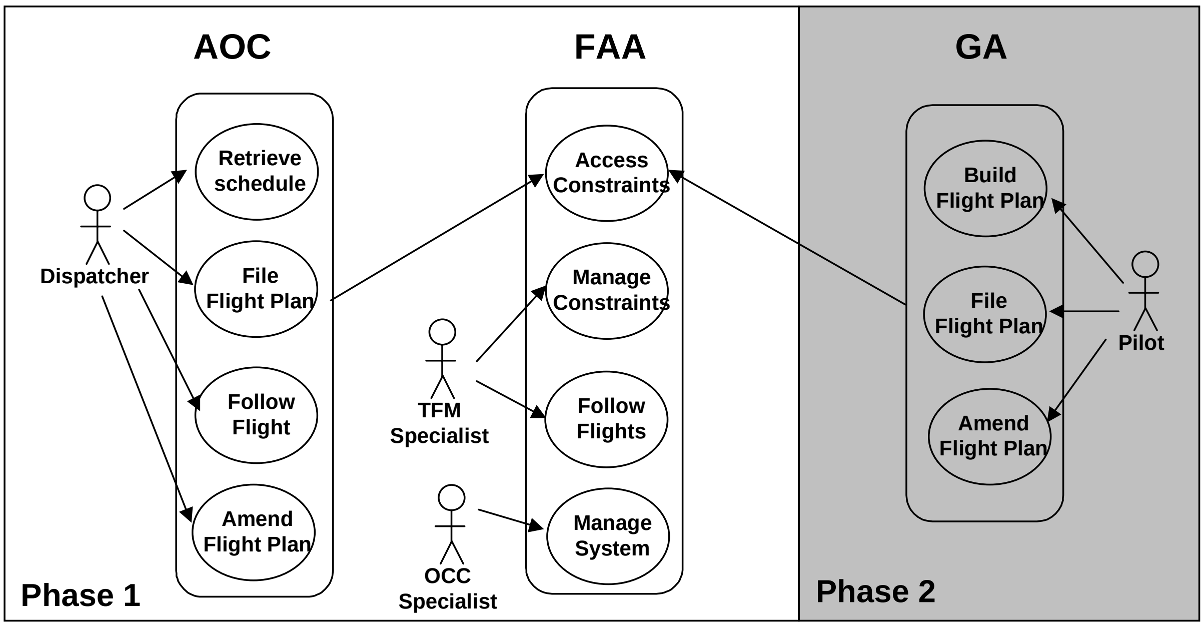

Figure B-2. Dynamic Flight Planning Use Case Relationships

Use Case 1

Name: Dispatcher retrieves schedule

1. Characteristic Information

Goal in Context	Describe the sequence of steps the dispatcher takes in retrieving a schedule for a flight and adjusting the flight schedule
Scope:	Describes interaction between dispatcher and AOC flight schedule system.
Level:	Task
Pre-Condition:	Dispatcher has been pre-briefed by prior shift and situation staff, has flight schedule system access, and flight schedule system has processed current flight data.
Success End Condition	A viable flight schedule is successfully displayed to the dispatcher and the dispatcher can make adjustments to the schedule in order to generate flight plans.
Failed End Condition	A flight schedule is not displayed or obvious errors exist in the displayed schedule.
Primary Actors:	Dispatcher, AOC flight schedule system
Trigger Event:	Flight planning is required for operations.

2. Main Success Scenario

Step	Actor	Action Description
16	Dispatcher	Retrieves flight schedule. The flight schedule is displayed by the AOC flight schedule system.
17	Dispatcher	Adjusts flights as necessary to meet constraints. The dispatcher assesses the displayed flight schedule against the additional pre-briefing information, experience, and business criteria not available to the flight schedule system. He/she adjusts flight schedule data to generate scheduled flight plans for each flight.

3. Scenario Extensions

Step	Condition	Action Description
16a	A flight does not have a flight schedule.	The dispatcher develops an initial flight schedule from OAG information and operational knowledge.

4. Scenario Variations

Step	Variable	Possible Variations
17	A flight schedule is acceptable without adjustment.	The dispatcher will accept the flight schedule data as a flight plan without adjustment. (Ideal case)

5. Related Information

Schedule	Demo 1
Priority	Demo 1 component
Performance Target	None
Frequency	For every flight
Super Use Case	None
Sub Use Case	None
Channel to Primary Actor(s)	AOC flight schedule system
Channel(s) to Secondary Actor(s)	Shift-change briefing Weather briefing Special situation briefing

6. Open Issues

Issue ID	Issue Description
UC1-1	Does not reflect all AOC operations

Use Case 2

Name: Dispatcher Files Flight Plan

1. Characteristic Information

Goal in Context	After identifying changes to be made to a flight schedule, describe the sequence of steps the dispatcher takes to enter changes into the prepared flight schedule and then to submit the amended flight schedule to the FAA as a flight plan.
Scope:	Describes the interaction between the dispatcher and the AOC flight schedule system to enter changes and between the dispatcher and the flight plan management system to submit flight plan.
Level:	Task
Pre-Condition:	Adjustments to be made in specific flights in a flight schedule have been identified and a connection to the flight plan management system exists.
Success End Condition	Adjustments to a flight schedule are successfully entered into the AOC flight schedule system and a flight plan is successfully submitted to the flight plan management system.
Failed End Condition	Adjustments to the schedule for a flight cannot be made or a flight plan cannot be submitted to the flight plan management system.
Primary Actors:	Dispatcher, AOC flight schedule system, flight plan management system
Trigger Event:	Adjustments to a flight schedule have been identified and a flight plan needs to be submitted

2. Main Success Scenario

Step	Actor	Action Description
18	Dispatcher	Enters adjustments into flight plans. The flight schedule is changed in the AOC flight schedule system to reflect adjustments.
19	Dispatcher	Files constrained flight plans. A flight plan reflecting known constraints is constructed from the flight schedule to conform to flight plan standards and is submitted to the flight plan management system.

3. Scenario Extensions

Step	Condition	Action Description
18a	An additional constraint affecting multiple flights is identified.	The dispatcher determines that a constraint derived from information not available to the AOC flight schedule system exists and will affect several flights.
18b	Addition constraint information is entered.	The dispatcher enters additional information on the constraint into the AOC flight schedule system. It is a business decision whether to share this constraint with other aviation users.

4. Scenario Variations

Step	Variable	Possible Variations
19	The schedule for a flight is acceptable with adjustment.	No schedule adjustments are necessary for a flight and a flight plan is generated directly from the original AOC flight schedule system data. (Ideal case)

5. Related Information

Schedule	Demo 1
Priority	Demo 1 component
Performance Target	None
Frequency	For every flight
Super Use Case	None
Sub Use Case	None
Channel to Primary Actor(s)	AOC flight schedule system Flight plan management system
Channel(s) to Secondary Actor(s)	None

6. Open Issues

Issue ID	**Issue Description**
UC2-1	Criteria for sharing additional identified constraints should be developed.

Use Case 3

Name: Flight plan system manages flight plan

1. Characteristic Information

Goal in Context	Describe the processing necessary to accept a filed flight plan, integrate a flight plan with system demand, assess new constraint probabilities, and forward probabilities to TFM specialist
Scope:	Describes interaction between AOC flight plan filing system and FAA flight plan management system.
Level:	Task and script
Pre-Condition:	Flight plan is filed.
Success End Condition	Filed flight plan meets format criteria, can be integrated with other flight demand, and new constraint probabilities can be quantified.
Failed End Condition	Flight plan does not conform to format criteria. Flight plan cannot be integrated with other demand.
Primary Actors:	AOC flight schedule system, FAA flight plan management systems
Trigger Event:	AOC files flight plan

2. Main Success Scenario

Step	Actor	Action Description
20	Flight Plan Management System	Accepts new flight plan. Check whether format of flight plan conforms to standard with known characteristics (AOC ID, A/C type, known dep/arr airports, known fixes/airways/etc. in the route of flight.
21	Flight Plan Management System	Integrates new flight plans with system demand. Parses flight plan into flight database. Rejects flight plan if parsing or database entry errors show up.
22	Flight Plan Management System	Assesses new constraint probabilities. Assesses NAS resource demand across the route of flight and assess combined demand against resource capacity to identify potential constraints.
23	Flight Plan Management System	Forwards probabilities to TFM specialist for consideration. Identity, demand, capacity, and probabilities of resource constraints are sent.

3. Scenario Extensions

Step	Condition	Action Description
22a	If times in route data are available	Assess demand using additional time of route data not currently available.

4. Scenario Variations

Step	Variable	Possible Variations
21	Flight plan parse	Script flight plan parsing into database
22	Demand assessment	Script resource demands for each flight and combined demand for multiple flights
22	Demand/capacity	Script demand/capacity comparisons to generate probable resource constraint

5. Related Information

Schedule	Demo 1
Priority	Demo 1 component
Performance Target	None
Frequency	For every flight plan
Super Use Case	None
Sub Use Case	None
Channel to Primary Actor(s)	AOC flight schedule system FAA flight plan management system interface
Channel(s) to Secondary Actor(s)	Flight demand database NAS resource capacity database

6. Open Issues

Issue ID	Issue Description
UC3-1	Do we use ‘enhanced’ route time and altitude data not current available to in FAA flight plans?
UC3-2	Where does dynamic resource capacity data come from?

Use Case 4

Name: AOC Flight Schedule System accesses constraints

1. Characteristic Information

Goal in Context	Describe how the AOC system accesses the FAA constraints database and the process of factoring these constraints into the flight modeling to generate flight schedules
Scope:	Describes the interaction between the AOC flight schedule system and the FAA constraints system
Level:	Task and scripting
Pre-Condition:	Flight schedule needing to be done
Success End Condition	Valid constraints information exists in the constraints system, any constraints can be applied against a flight schedule, and a flight schedule is generated
Failed End Condition	Constraints in constraints system are not valid or it can not be determined whether they apply to a flight
Primary Actors:	AOC flight schedule system, FAA constraints system
Trigger Event:	Flight schedule needs to be evaluated against a constraint

2. Main Success Scenario

Step	Actor	Action Description
13	AOC Flight Schedule System	Accesses current FAA constraints. Access is allowed and current applicable constraints are transferred.
14	AOC Flight Schedule System	Factors constraints into flight modeling. Constraints are parsed into a form usable to local AOC flight schedule systems. A flight schedule is evaluated against constraints to identify if a flight will be affected. FAA and local AOC constraints are compared with the tightest constraint taking priority (assumption).
15	AOC Flight Schedule System	Models flights from local and FAA constraints. Adjustments are made to a flight schedule to accommodate the FAA and other local constraints.

3. Scenario Extensions

Step	Condition	Action Description
14a	Compare FAA and local constraints	Provide a local constraints database to model this comparison

4. Scenario Variations

Step	Variable	Possible Variations
13	Constraint access	Script constraints database
14	Constraint evaluation	Script constraints that will affect given flight schedules
14	Local vs FAA constraints	Script the selection of local AOC vs FAA constraints
15	Adjust flights	Script adjustments to a flight schedule resulting from a constraint

5. Related Information

Schedule	Demo 1
Priority	Demo 1 component
Performance Target	None
Frequency	For each flight or constraint change
Super Use Case	None
Sub Use Case	None
Channel to Primary Actor(s)	Constraints system
Channel(s) to Secondary Actor(s)	FAA constraints database AOC local constraints database Flight schedule

6. Open Issues

Issue ID	Issue Description

Use Case 5

Name: TFM specialist manages constraints

1. Characteristic Information

Goal in Context	
Scope:	
Level:	
Pre-Condition:	
Success End Condition	
Failed End Condition	
Primary Actors:	
Trigger Event:	

2. Main Success Scenario

Step	**Actor**	**Action Description**
6	TFM Specialist	Is alerted to system component failure outages
7	TFM Specialist	Assesses impact of outages on operation services
8	TFM Specialist	Identifies service constraints from outages
9	TFM Specialist	Confirms service constraints from outages
10	TFM Specialist	Assesses flight demands on system operations
11	TFM Specialist	Identifies service constraints from flight demands
12	TFM Specialist	Confirms service constraints from flight demands

3. Scenario Extensions

Step	Condition	Action Description

4. Scenario Variations

Step	Variable	Possible Variations

5. Related Information

Schedule	
Priority	
Performance Target	
Frequency	
Super Use Case	
Sub Use Case	
Channel to Primary Actor(s)	
Channel(s) to Secondary Actor(s)	

6. Open Issues

Issue ID	Issue Description

Use Case 6

Name: Operations Command Center specialist manages system

1. Characteristic Information

Goal in Context	
Scope:	
Level:	
Pre-Condition:	
Success End Condition	
Failed End Condition	
Primary Actors:	
Trigger Event:	

2. Main Success Scenario

Step	Actor	Action Description
1	OCC Specialist	Is alerted to system component failure
2	OCC Specialist	Assesses system component situation
3	OCC Specialist	Assesses alternative system services
4	OCC Specialist	Identifies component failure system outages
5	OCC Specialist	Notifies operations of component failure outages

3. Scenario Extensions

Step	Condition	Action Description

4. Scenario Variations

Step	Variable	Possible Variations

5. Related Information

Schedule	
Priority	
Performance Target	
Frequency	
Super Use Case	
Sub Use Case	
Channel to Primary Actor(s)	
Channel(s) to Secondary Actor(s)	

6. Open Issues

Issue ID	Issue Description

Glossary

ADDR	Aviation Data Description Repository
AIM	Aeronautical Information Manual
AOC	Aeronautical Operations Centers
ARTCC	Air Route Traffic Control Centers
ATCSCC	Air Traffic Control System Command Center
ATCT	Airport Traffic Control Towers
ATM	Air Traffic Management
CAASD	Center for Advanced Aviation System Development
CDIMS	Collaborative Data Integration Management System
CDM	Collaborative Decision Making
CONUS	Continental United States
FAA	Federal Aviation Administration
FCA	Flow Control Area
FP	Flight Plan
FSS	Flight Service Stations
GA	General Aviation
HCS	Host Computer System
IPT	Integrated Program Teams
NAS	National Airspace System
NIAC	NAS Information Architecture Committee
NII	NAS Infrastructure Information
NIIP	NAS Interoperability Process
OAG	Official Airline Guide
OCC	Operations Command Center
OMG	Object Management Group
OODA	Observe-Orient-Decide-Act

SUA	Special Use Airspace
TFM	Traffic Flow Management
TRACON	Terminal Radar Approach Control