CONCEPT OF OPERATIONS

for Commercial Space Transportation in the National Airspace System

NARRATIVE

FEDERAL AVIATION ADMINISTRATION

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Commercial Space Transportation
CONCEPT OF OPERATIONS
in the National Airspace System

Foreword

This is a concept document. It provides a conceptual overview of commercial space transportation (CST) operations in the National Airspace System (NAS) in 2005 and beyond. This document is intended to support evolution of a fully integrated, modernized NAS inclusive of commercial space transportation. Further, this overview concept is a living document and will be coordinated in a collaborative manner with industry and government stakeholders to ensure the viability of the concepts represented.

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Patricia G. Smith

Associate Administrator
for Commercial Space Transportation

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Acronyms

AAF	FAA/Airway Facilities Service
AAT	FAA/Air Traffic Service
ADIZ	Air Defense Identification Zone
AFS	FAA/Flight Standards Service
AIR	FAA/Aircraft Certification Service
AOC	Airline Operations Center
ARS	FAA/Air Traffic Requirements Service
ASD	FAA/Office for System Architecture and Investment Analysis
AST	FAA/Commercial Space Transportation
ATA	FAA/Air Traffic Airspace Management Program
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATO	FAA/Air Traffic Operations Program
ATS	FAA/Air Traffic Services
CDM	Collaborative Decision Making
CDTI	Cockpit Display of Traffic Information
CNS	Communications/Navigation/Surveillance
DoD	Department of Defense
DSS	Decision Support System
EELV	Evolved Expendable Launch Vehicle
ELV	Expendable Launch Vehicle
FAA	Federal Aviation Administration
FAS	FAA Flight Advisory Services
GEO	Geostationary Earth Orbit
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IIP	Instantaneous Impact Point
ISFO	International Space Flight Organization
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
NAS	National Airspace System
NAS-WIS	NAS-Wide Information System
RLV	Reusable Launch Vehicle
SpOC	Space Operations Coordinator
SATMS	Space and Air Traffic Management System
STC	Space Transition Corridor
SUA	Special Use Airspace
TM	Traffic Management
VFR	Visual Flight Rules

Nomenclature Page References

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1.0 INTRODUCTION

The demand for access to the nation's airspace is projected to rise sharply in the 21st century, due, in part, to growth of the commercial space transportation industry. This growth, coupled with significant increases in conventional air travel that are forecasted for the coming years, dictates re-examination of the current technology and methodology used for managing the National Airspace System (NAS). From a NAS service provider perspective, space and aviation operations must be seamlessly integrated in order to continue to provide efficient service to all NAS users. With this in mind, technological advances in areas such as communications, navigation, surveillance (CNS), and decision support must be leveraged to evolve a modernized NAS. Therefore, this *Concept of Operations for Commercial Space Transportation in the NAS* has been developed by the FAA Associate Administrator for Commercial Space Transportation (AST) in anticipation of the evolution of a NAS environment in the 21st century that fully integrates commercial space operations. It is intended to support achievement of the nation's goals in space, as well as the FAA's strategic goals for maximizing system efficiency. This document underscores the importance of providing safe, efficient, and equitable access to all NAS users, and provides a resource to establish a framework for collaboration among stakeholders in developing a cost-effective strategy to meet projected demand increases for NAS services.

1.1 Background

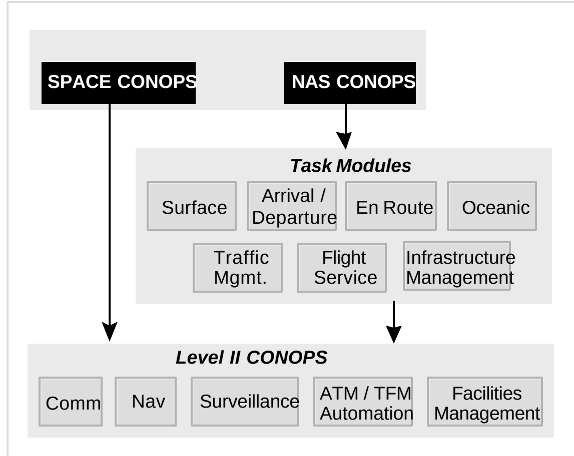
The Department of Transportation issued the first commercial launch operator's license in 1987, and the first U.S. commercial launch occurred in 1989. Since then, the total number of U.S. commercial launches has steadily increased, and in 1997 the number of commercial launch operations for the first time exceeded the number of launch operations conducted by the military. In the past, industry forecasters predicted that as many as 1200 launches would occur worldwide over a ten year period from 2000-2010, with a majority of the launches being conducted in the United States by U.S. launch vehicle operators. However, recent forecasts have been less robust, yet the expectation of commercial space transportation expansion and growth remains strong. The demand for space-based technologies (communications, navigation, imagery, etc.) will lead to the emergence of new Non-Geosynchronous (NGSO) commercial launch markets, and create opportunities for growth in Geosynchronous (GEO) commercial launch markets. The U.S. commercial space transportation industry will flourish as a consequence of these new markets. Competition to provide NGSO and GEO launch services will serve as a catalyst for innovative developments in launch and reentry vehicle technology and sites. This trend is currently evidenced by the emergence of a wide variety of new vehicle concepts that include evolved expendable launch vehicles (EELVs) and reusable launch vehicles (RLVs), and new launch and recovery facilities at both inland, and sea-based locations.

Changes in the magnitude and complexity of space operations will place new demands on the NAS as vehicles in route to and from earth orbit and beyond transition through airspace that is currently the near exclusive domain of aviation traffic. Historically, commercial launch operations have occurred at coastal federal ranges utilizing only ELVs. As a result, these space operations have had minimal impact on NAS operations due to their infrequent occurrence and offshore trajectories. However, the expected increase in frequency of commercial launches and re-entries, from a broad range of locations, in the U.S. will contribute substantially to competition for airspace amongst NAS users. Therefore, the FAA must now consider a 'Space and Air Traffic Management System' (SATMS) that equitably supports both the evolving commercial space transportation industry and the mature and continuously growing aviation industry in a systematic, integrated manner. Thus, the SATMS represents an evolutionary expansion of the U.S. air traffic management system to encompass the people, infrastructure, policies, procedures, rules, and regulations necessary to fully integrate space and aviation operations under a single infrastructure.

1.2 Concept Scope and Intended Use

The *Concept of Operations for Commercial Space Transportation in the NAS* provides a high-level description of future commercial space transportation operations, with an emphasis on the management of space transportation vehicles as they transition through the NAS. This operational concept takes into account fundamental changes in the delivery of NAS services based on technological capabilities (e.g., decision-support tools, advanced CNS systems) and operational initiatives (e.g., Free Flight, National Airspace Redesign). These capabilities and services are currently being developed and will be phased into service. Phased evolution of the NAS will result in distinct states of the NAS in the near (current through 2005), mid (2005 – 2010), and far (2010 – 2015) timeframes. It is expected that many of the commercial space transportation concepts presented in this document will significantly impact NAS operations in the late mid to far timeframe and beyond. Therefore, the ideas presented in subsequent sections of this document are intended primarily to support investment in new technologies and capabilities for mid and far NAS transitional phases. Subsequent sections (2.0 and 3.0) of this document are written entirely in the present tense for clarity.

This Operational Concept has evolved from discussions with various government and industry stakeholders, and research and analyses performed and sponsored by the FAA. It will be used to support development of lower-level concepts (i.e., Level II CONOPS) for NAS technical areas such as communication, navigation, surveillance, and automation and is complementary to the broader focused National Airspace System Concept of Operations[1]. The relationship among operational concepts is illustrated in Figure 1. To ensure its usefulness, this document will be subject to ongoing evaluation, validation, and refinement. Throughout this process, the FAA and the NAS user community will use the maturing document as a resource to help plan, develop, and coordinate activities related to user and service provider operations in the NAS.



Relationship Among Operational Concepts

Figure 1.

1.3 Organization

The *Concept of Operations for Commercial Space Transportation in the NAS* is organized as follows:

- Section 1.0, Introduction — Describes the purpose, background, scope, and intended use of this document, and defines the need for a concept of operations to accommodate both air traffic and space traffic.
- Section 2.0, Technical & Regulatory Environment–— Describes space transportation vehicles, spaceports, airspace, technologies and automation support, collaborative decision making (CDM) functions, and licensing and certification needs that will comprise the future operational environment.
- Section 3.0, Operational Environment–— Describes the manner in which commercial space transportation operations are accommodated in the NAS, covering operational phases such as mission planning, launch, transition to space, and reentry.

[1] The RTCA Free Flight Steering Committee approved the NAS Concept of Operations on December 13, 2000. The NAS ConOps combined elements of the Commercial Space Transportation Concept of Operations in the NAS, the Joint/Government Industry Concept, and the Air Traffic Services (ATS) Concept of Operations for the NAS in 2005. The NAS Concept of Operations supercedes the Government/Industry Operational Concept for the Evolution of Free Flight.

2.0 TECHNICAL & REGULATORY ENVIRONMENT

Transition is underway to a full Free Flight environment. 2005 sees the anticipated completion of the National Airspace Redesign, replacement of the Host computer system, transition to satellite navigation, and introduction of new decision support systems (DSSs). 2005 also marks the completion of the *first phase* of transition to the technologies and airspace structures required for Free Flight. With safety, workload, and efficiency as the driving forces, human factors analyses have determined the appropriate allocation of tasks between service providers, users, and automation. As a result, NAS throughput has increased significantly without an increase in the controller workforce. Contention for NAS resources is mitigated through improved technologies to predict and manage aviation and space traffic. DSSs and enhanced displays expedite information exchange amongst NAS systems, service providers, and users. This shared situation awareness facilitates a Collaborative Decision-Making (CDM) approach that ensures user participation in key decisions that impact delivery of services. Commercial space launches and reentries are increasingly commonplace and operationally complex. U.S. space transportation vehicle fleet consists of a variety of vehicles capable of delivering a wide range of payloads to orbit, and new launch and recovery facilities are in operation throughout the country.

The balance of this section discusses the elements that require NAS systems integration consideration (e.g., vehicles, spaceports), as well as those elements that are impacted by commercial space transportation operations into the NAS (i.e., airspace, CDM, etc.). These elements are 1) space transportation vehicles, 2) spaceports, 3) airspace, 4) automation, 5) CDM functions, 6) regulations, and 7) security.

2.1 Space Transportation Vehicles

A variety of space transportation vehicles exist, ranging from traditional rocket-types to those with conventional aircraft capabilities. ELVs and EELVs carry large and/or multiple payloads, while RLVs offer mission reliability and cost savings, and are generally used for smaller payloads. RLVs are increasingly common, benefiting from operational and economic advantages such as reduced cost, improved reliability, and decreased mission risk (i.e., ability to return to base if the mission is aborted). RLVs with varying operational concepts are available to meet the NGSO launch market demand. Some RLVs take off and re-enter under power on conventional runways. Others, for example, are ferried to high altitudes (e.g., 50K feet), launched from the air, and re-enter under power. A major operational factor that differentiates the various ELV, EELV, and RLV concepts is the ability of the vehicle to respond to air traffic control (ATC) clearances.[2] Vehicle characteristics that determine this ability include the method of launch/takeoff, method of reentry, mode of vehicle pilotage, vehicle communication, navigation, and surveillance (CNS) equipage, and trajectory predictability.

Generally:

- Space transportation vehicles launch/take-off vertically (i.e., from a launch pad) or horizontally (i.e., from a runway). Vehicles that launch/take off vertically include ELVs, EELVs, and RLVs that operate from a launch pad in a manner similar to the Space Shuttle. Vehicles that launch/take-off *horizontally* include RLVs that depart from a runway and fly conventionally in a manner similar to an airplane through airspace, or those that are assisted by a conventional airplane to reach an airborne point of separation from the assisting aircraft.
- The basic reentry techniques utilized by the various RLVs are powered flight to a landing site, gliding flight to a landing site, and ballistic flight to a landing site.
- Several types of pilotage techniques are employed, including on-board crew operations, remotely piloted operations controlled from the ground, and autonomous (i.e., preprogrammed) operations.
- The avionics equipage used by the vehicle (e.g., CNS systems) impact the vehicle's ability to respond to ATC, and the precision with which the vehicle can be monitored and tracked.
- Trajectory predictability (as determined by vehicle performance, pilotage, and equipage) determines the accuracy of NAS trajectory predictions for traffic planning and conflict detection processes.

[2] Vehicles that perform comparably to conventional aircraft *may* be controlled via positive ATC techniques. Vehicles with ballistic profiles (e.g., rocket-type vehicles) require reserved airspace to provide separation assurance.

2.2 Spaceports

Commercial spaceports are in operation at various coastal, inland, and sea-based locations. There are also joint-use facilities that accommodate both aviation and space transportation operations. Spaceports are similar to airports in that they provide services that include, but are not limited to, communications (voice, data link, etc.), telemetry, specialized weather forecasting and advisories. Spaceports also provide services found at federal ranges such as payload/vehicle processing. Spaceports accommodate both launch and reentry operations for various types of space transportation vehicle systems. Spaceports vary with respect to the types of commercial space operations that can be supported. The types of vehicle operations that can be accommodated at a given spaceport are determined by such factors as:

- Destination/mission objective (e.g., launching into LEO, MEO or GEO) and the preferred trajectory.
- Ability of the spaceport to accommodate the vehicle operational, performance, and support requirements.
- Spaceport scheduling assurance and range turn-around time (e.g., time to process successive operations).
- Environmental constraints (e.g., noise abatement requirements, hazard concerns).
- Economics (e.g., launch costs).
- Weather trends (i.e., the probability that weather patterns/trends will present a risk to the launch window).
- Traffic flow patterns (i.e., the constraints that must be dealt with due to contention for NAS resources).

2.3 Airspace

New traffic management tools and procedures allow frequent evaluation of airspace structures and traffic flows, with adjustments made accordingly. Thus sector configurations are unconstrained by current boundaries, particularly at high altitudes. The resulting dynamic reconfiguration of airspace within and between facilities increases operational flexibility, equitably distributes workload among sectors and facilities, and accommodates contingencies. In addition to these airspace changes, which are primarily intended to meet demand from aviation traffic, commercial space transportation drives the need for further changes in airspace philosophy and structure. First, an upper limit of the NAS is specified in order to demarcate the FAA's operational responsibilities. The FAA provides traffic flow management and separation assurance to vehicles as they transition through the NAS to and from this upper limit of the airspace.[3] Second, space vehicle operations *within* the NAS are managed using:

- *Space Transition Corridors* (STCs) provide dynamically reserved and released airspace that allows space vehicles to transition through the NAS. STCs are selected and determined based on performance characteristics of the vehicle and overall safety considerations. STCs may be tailored as mission needs or ATC needs dictate, and provide more flexibility than today's special-use airspace (SUA).
- *Flexible Spaceways* similar to today's airways and jet routes serve traffic transitioning to and from space. These are dynamically designated to meet specific mission objectives, such as transitioning to airborne launch points, aerial refueling, etc. Depending on the mission and vehicle profile, spaceways may be used in conjunction with an STC, to segregate different types of missions, to concurrently accommodate different mission phases (e.g., launches vs. re-entries), and to ensure safety in case of contingencies.

2.4 Automation

NAS modernization is based on an incremental implementation of new technologies that assist in the management and control of aviation and space operations by helping to absorb the increased demand for NAS resources, minimizing the impact of space operations on the ATC system, and enhancing productivity. This approach maintains safety as the first priority, while also increasing capacity, flexibility, and productivity in balance with airspace, airport/spaceport, and controller workload considerations. The primary enhancements that provide improved NAS services for Commercial Space are improved information distribution, decision support systems, system performance analysis tools, and infrastructure management tools.

2.4.1 Information Distribution

'*Shared situation awareness*' among users and service providers offers an efficient alternative to the parochial problem-solving process. The full range of relevant operational information is provided to traffic managers, controllers, and users. For example, STC schedules and status information are output to

[3] For operations *beyond the NAS upper limit*, acquisition of information pertaining to space objects that conflict with the space transportation vehicle is the responsibility of the space transportation vehicle operator.

controllers, supervisors, TM, and airline operations centers (AOCs), and may be accessed via the NAS Wide Information System (NAS-WIS). Spaceway data is available via the NAS-WIS and can be displayed at controller and traffic manager positions. Prevailing sector combinations and boundaries are depicted on the displays at all relevant operational positions. Planned combinations and configurations are directly available on supervisor, TM displays, and via the NAS-WIS to users. The major information sources are:

- Enhanced CNS Systems. Digital communications (e.g., datalink) provide a non-verbal means of disseminating information between users and service providers. The combination of Global Positioning System (GPS) and aircraft-broadcast position reports increases navigational and surveillance accuracy. This more precise tracking also enables the use of dynamic STCs, which are reserved and released as vehicles transition through the NAS to/from space. Finally, these systems facilitate increased use of pilot self-separation, and improved conflict prediction and resolution.
- Enhanced Weather Information. There is increasingly accurate weather data available to service providers and users, including hazardous weather alerts for wind sheer, microbursts, gust fronts, and areas of precipitation, icing, and low visibility. Enhanced steps for avoiding convective weather are made as weather prediction capabilities are improved and integrated into the decision support tools. Aircraft and spacecraft are both the consumers and sources of weather data. Improved weather 'forecasting' and 'nowcasting' increases scheduling precision (for air traffic operations, space launches, and reentry operations) and overall air traffic and space traffic management. Detailed weather information is available via the NAS-WIS, and is selectively presented on sector displays and flight deck displays.
- NAS Wide Information System. The NAS-WIS drives the exchange of information among NAS users and service providers. It expedites dissemination of information such as: 1) static data, including maps, charts, airport & spaceport guides, and Notices to Airmen, 2) dynamic data such as STC schedules and status, launch/reentry schedules and coordinates, current and forecast weather, radar summaries, traffic loading, hazardous condition warnings/advisories, airport and airspace capacity constraints, and infrastructure status, 3) aircraft information, including the flight information posting (FIP), estimated departure and arrival times, first movement of the aircraft, wheels-up, position data, flight cancellations, etc., and 4) space flight information, including the mission profile, launch/reentry windows and coordinates, STC information, payload, and trajectory.

2.4.2 Decision Support Systems

CNS advances present an abundance of real-time data that must be integrated to maintain situation awareness. Thus task performance is no longer data-limited, but rather it is constrained by the operator's ability to assimilate data to execute decisions. As a result, DSSs are needed to assist service providers in assimilating, interpreting, and exchanging information. This assistance reduces the burden of routine tasks, allowing service providers to apply more cognitive resources to the primary task of evaluating traffic situations and planning appropriate responses.

- Mission Planning Decision Support. The mission planning process is facilitated by a suite of capabilities that enhance CDM and expedite pre-flight communication, coordination, and analysis. These DSSs include an archive of NAS performance information, trajectory modeling/simulation tools, traffic and workload prediction capabilities, and CDM tools. The *archive of NAS performance information* provides inputs for planning aids (e.g., graphical depictions of airspace, trajectories, reserved airspace, traffic flows, planning charts/diagrams, etc.) and data visualization tools that graphically show the anticipated impact of space launch operations for various traffic profiles.

  To complement the database described above, *trajectory modeling/simulation tools* enable traffic managers and mission planners to anticipate conflicts between space traffic and air traffic, including conflicts with active STCs or spaceways. This capability to 'trial plan' launch and reentry trajectories against projected traffic provides an added level of fidelity in mission planning. Thus airspace contention can be anticipated prior to filing a mission profile. These simulations can be performed in fast-time to allow mission planners to explore alternative profiles. Outputs can be used in CDM between traffic management and mission planners to identify and review solutions given specific user needs and priorities.

With space mission trajectories accurately determined, *traffic and workload prediction capabilities* generate traffic demand/capacity, dynamic density, user-preferred trajectory data, and workload information. This information is used by traffic managers to ensure that the demand does not exceed airspace, airport, spaceport, or controller resources. Automation also provides traffic managers and controllers with strategic advisories (e.g., task prompts, event prompts) to facilitate proactive air/space traffic management and control.

The tools and capabilities discussed above are integrated within a *collaborative decision making tool* referred to in the ATS Concept as the TM Initiative Planner. This tool synthesizes the overall environmental and traffic data set and provides relevant information on a given mission. The mission-specific Planner is simultaneously available at relevant user and TM (site and national) positions, per predefined roles and responsibilities. By requesting the Planner on their displays, traffic managers and users may join in the same planning session, in order to determine when, where, and how to accommodate planned mission operations and contingencies.

- Mission Operations Decision Support. Once the space mission is in flight within the NAS, the system provides task prompts and event prompts to assist controllers and traffic managers in maintaining situation awareness. In addition, conflict prediction and resolution capabilities are provided to controllers, aircraft pilots, and space vehicle operators via their respective ground-based and on-board systems. *Task prompts* indicate to the controller the need for control actions such as handoffs, communications transfers, pointouts, etc. *Event prompts* provide controllers and traffic managers with an indication of general system events such as changes in infrastructure status, and of operational events such as changes in the status of STCs. Notifications of these events are also available to users via the NAS-WIS.

  Ground-based *conflict prediction & resolution capabilities* assist controllers to predict and resolve conflicts between space vehicles, aircraft, airspace, and weather. For space vehicles provided with an STC, conflict prediction is based on the active airspace rather than the vehicle. Controllers may also perform trial planning to preview the potential effect of prospective control actions prior to implementation. Flight deck systems such as collision and avoidance systems, cockpit display of traffic information (CDTI), etc., assist aircraft pilots and space vehicle operators to monitor and maintain separation between aircraft and space vehicles. In conjunction with information available via NAS-WIS/Datalink, these on-board systems also provide the capability for aircraft pilots and space vehicle operators to monitor and maintain separation from airspace and weather.

2.4.3 System Performance Analysis Tools

There are improved methods and tools to measure NAS performance and to identify user requirements. Performance tracking and measurement tools include a space operations database and archive that allows post-hoc analyses to be used in subsequent mission planning exercises. System performance analysis tools are geared toward 'mining' a vast array of data, integrating and assimilating information, and presenting this information in meaningful, readily accessible forms. Analytic capabilities include summary statistics for delays, conformance to optimal routes/trajectories, traffic loading and density information, etc. Outputs may be customized (e.g., based on airspace, time, spacecraft/aircraft type, airline, mission, etc.) to examine specific issues and consider alternative scenarios. These performance measurement and data visualization capabilities allow traffic managers and flight/mission planners to refine methods and strategies based on objective performance analyses.

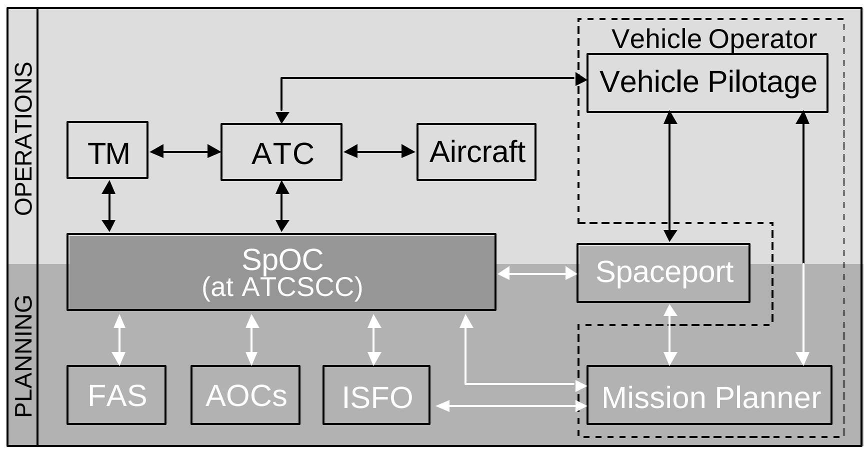
2.4.4 Infrastructure Management Tools

Since it is recognized that system components will fail, the NAS is a fault-tolerant system that maintains a balance between reliability, redundancy and procedural backups. This is achieved through safety and risk analyses that identify areas requiring higher reliability and backup. Thus the design provides a system that is not only available, but one that also requires minimal time to restore failed functionality. To facilitate infrastructure management, there are improved methods for collecting and processing system data. These data are available as an integral part of the NAS-WIS, and are used to prioritize and schedule NAS infrastructure activities. Users and service providers collaborate in this prioritization and scheduling, utilizing DSSs that provide information regarding the coverage and status of infrastructure components.

2.5 Collaborative Decision Making (CDM)

In concert with Collaborative Air Traffic Management initiatives (e.g., initiatives pioneered by RTCA Special Committee 191), the AST CDM model expands on the traditional CDM paradigm, and includes both the aviation commercial space users. New and enhanced functions in the areas of TM and ATC are essential in successfully executing a CDM process inclusive of commercial space operations. In this process, TM hosts the CDM interactions with users that are necessary to provide equitable service and safe operations for all NAS stakeholders, while ATC provides tactical separation assurance to space traffic as it transitions through the NAS. Figure 2 below depicts the CDM functions involved in mission planning, and the integration of the mission into the NAS. This CDM process extends from mission planning through launch/takeoff, in a process that is both strategic and tactical. This section describes the major responsibilities involved in CDM, while the detailed interactions for planning and implementing space operations are discussed in Section 3.0.

- The *Space Operations Coordinator (SpOC)* is a traffic manager at one of the existing operational positions within the ATCSCC whose duties include collaboration with commercial space operators to integrate space missions into NAS traffic flows. *Local and national TM* organizes major air traffic flows in order to prevent demand capacity imbalances on NAS resources, and they coordinate with the SpOC to integrate space transportation operations and air traffic.
- The *International Space Flight Organization (ISFO)* is an internationally-sanctioned organization that is the focal point for collaboration and information exchange for orbital or hypersonic point-to-point flights requiring international planning and coordination.
- The *Vehicle Operator (VO)* is the launch/reentry vehicle owner's operational representative. As a primary CDM participant, the VO provides the mission planning function.[4] In this process, the VO works with TM and the spaceport to define and file a mission profile that accommodates the preferred launch/reentry windows and trajectories, based on projected demand for NAS services, TM options, and the mission's inherent flexibility.



Collaborative Decision Making (CDM) Model
Figure 2.

- The *Spaceport Operator (SO)* is responsible for compliance with regulatory requirements for spaceport services rendered, including communications, telemetry, specialized weather forecasting and advisories, payload/vehicle processing, security, etc. As a primary CDM participant, the SO coordinates with the mission planner and TM to validate the feasibility of the planned operations.
- *Range Safety* is provided by personnel who monitor all factors related to the go/no-go decision, execute the functions necessary to assure the safety of people and property, and assure safety in the event of an abort.

2.6 Regulation of Commercial Space Transportation

Segments of the commercial space transportation industry are supported and regulated by a structure similar to that in place for the aviation industry. Appropriate approvals are granted for all flight tests, and operations that involve on board human operators or passengers, and/or flights over populated areas. Accepted levels of vehicle safety and public risk are identified for commercial space vehicles. Appropriate standards, based on these safety and risk levels, are used to evaluate safety. Space operations are performed from commercial spaceports operated by civilian personnel. Commercial space launch site infrastructure, including CNS systems, is safety-approved in a manner similar to approval of ATC communications and navigation facilities. Commercial spaceport personnel such as launch safety specialists, and commercial space transportation vehicle personnel such as mission planners, mechanics, and vehicle operators (including on-board vehicle pilots), receive FAA approved training, authorization,

4 The VO also fulfills the vehicle pilotage function (reference paragraph 2.1).

and medical qualification, in a manner similar to that received by aircraft pilots, dispatchers, and maintenance personnel.

2.7 Security

Security measures are in place at spaceports to prevent and/or respond to security risks such as bomb threats, hijacks, terrorist actions, and other criminal acts. Procedures are in place to carry out security measures for space operations that involve carraige of passengers or cargo. These procedures are similar, by comparison, to those carried out for commercial aviation operations. For airports that accommodate commercial space transportation operations, security procedures are developed, as required, to address unique or specific security risks associated with launch/reentry operations. These procedures supplement those already established for aviation operations that occur at these facilities.

3.0 OPERATIONAL ENVIRONMENT

Mission planning and mission operations are two major space transportation activities that impact NAS operational efficiency. Variables or factors that affect the execution of these activities are 1) vehicle performance, 2) mission profile, 3) traffic volume and controller workload, 4) environmental factors such as airspace design, weather, and infrastructure status, and 5) market forces.

- *Vehicle performance* determines the viability of traffic management options. This determination is based largely on the vehicle's ability to comply with ATC clearances. Vehicles that do not possess the capability to fully comply are provided reserved airspace for their transitions to and from space. More responsive vehicles may also be provided reserved airspace; but these vehicles are candidates for positive ATC. As discussed in section 2.1, Space Transportation Vehicles, several vehicle characteristics such as launch/reentry technique, mode of pilotage, and CNS equipage affect this ability to comply with clearances. Figure 3 compares the effect of the basic launch and reentry concepts on mission planning and operations.

LAUNCH & TRANSITION TO SPACE

Horizontal Takeoff	Vertical Launch
Typically can comply with ATC clearances	Typically can not comply with ATC clearances
Greater horizontal velocity	Greater vertical velocity
Large ground footprint	Small ground footprint
More time to transition through the NAS	Less time to transition through the NAS

RE-ENTRY & RETURN TO LANDING SITE

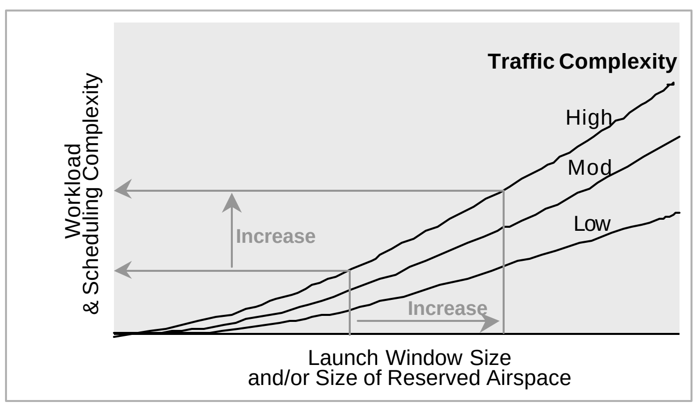
Powered Flight	Unpowered Flight	Ballistic Return
Typically can comply with ATC clearances	Can not comply with ATC clearances	Can not comply with ATC clearances
Discretionary committal to land	Committed to land shortly after de-orbit	Committed to land upon de-orbit
Large ground footprint	Moderate ground footprint	Small ground footprint
More time to transition from space	Moderate time to transition from space	Minimal time to transition from space

Figure 3.

- The *mission profile* helps determine the impact of launch/reentry on traffic flow through the NAS. Launch and reentry plans (e.g., departure location/ trajectory, reentry location/trajectory, landing location), and launch/reentry window sizes, are factors that determine the impact of the mission on NAS efficiency. The payload may also influence traffic management strategies.[5] The combination of the mission profile and vehicle performance also dictates the options available in case of an aborted mission.

- *Environmental factors* place constraints on commercial space operations. These factors include sector configurations, airport and spaceport configuration, weather conditions, noise abatement requirements, etc.[6]

- *Traffic volume and controller workload* at affected sectors influences the options for accommodating the vehicle during its transition through the NAS. Traffic variables such as demand/capacity, dynamic density, volume, and complexity will moderate controller workload and define the resources available for handling the mission. Figure 4[7] illustrates the effect of



Interaction Between Air Traffic and Space Traffic

Figure 4.

[5] For example, vehicles with hazardous payloads (e.g., nuclear, biological, chemical) may require increased buffer zones, and/or trajectories that minimize the ground footprint over populated areas.

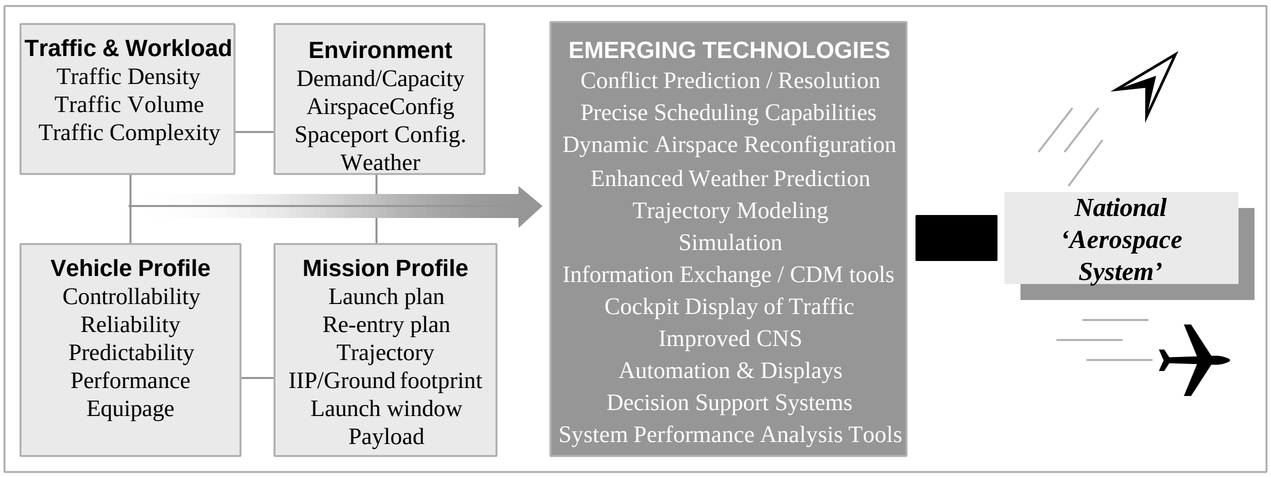
[6] For example, airports/spaceports have limitations as to the types of space vehicles they can accommodate, while airspace sectorization affects system capacity and controller workload.

[7] Adapted from a FAA sponsored study by Virginia Polytechnic Institute.

some of these variables on air traffic management and control. As shown, a given level of traffic complexity yields a workload level that varies directly with both the temporal launch window size and the physical size of reserved airspace.

Figure 5 illustrates the operational interactions of these variables, and the application of emerging technologies to integrate space and aviation operations in the NAS. The balance of this section discusses applications of these variables to the major space mission phases that comprise the mission planning and mission operations activities.[8]

- As discussed below, major mission planning activities are 1) initial mission profile development, 2) space vehicle and air traffic integration, and 3) mission profile finalization.
- Major mission operations activities are 1) launch/takeoff, 2) ascent through the NAS, 3) reentry, 4) descent through the NAS and landing, and 4) hypersonic point-to-point transportation.



Factors Influencing Space Transportation Operations

Figure 5.

3.1 Mission Planning

The objective of the mission planning process is to develop a mission profile that meets user requirements while being sensitive to TM conditions and constraints. Strategically, mission planning is a collaborative process that involves end-to-end mission analysis and communication among the vehicle operator, TM, and AOCs to identify and exploit the flexibilities of the NAS. The overall mission planning process consists of mission profile development by the vehicle operator, collaboration between the vehicle operator and TM to integrate the mission into predicted traffic environment, and finalization of both the mission profile and the TM Initiatives required to implement it.

3.1.1 Mission Profile Development

The mission profile is defined by the vehicle operator.[9] It is used to determine support service requirements such as radar coverage, weather information/services, surveillance and telemetry requirements, payload processing requirements, etc. Shared access to all scheduled U.S. commercial launches is provided via the NAS-WIS, allowing mission planners to synchronize their operations and mission support services. DSSs and data visualization tools assist the vehicle operator in mining and integrating scheduling data for spaceports and air traffic operations. Advanced simulations and trajectory modeling integrates both vehicle performance modeling and current/forecast weather and wind information, allowing the analysis of the feasibility and risks of specific launch and landing schedule windows. In this way, the viability of desired trajectories and windows can be determined from the outset of the mission planning process.

With the operational mission parameters defined, the vehicle operator coordinates with the spaceport to define support requirements. The vehicle operator also coordinates with TM to inform them of operational requirements. Since many missions are recurring and involve re-use of the same vehicles, the planning

[8] The concepts presented in these discussions are intended to stimulate discussion among various stakeholders to arrive at a mutually agreeable concept. They may be revised as incremental progress is made in the months and years leading up to 2005.

[9] The mission profile is developed before support services are contracted with the spaceport, since this information is required in the licensing process.

process becomes more concise for subsequent missions since baseline information exists in a space operations database. The product of this process is the end-to-end mission profile, which includes the launch and reentry information indicated on Table 1 below.

Payload/Manifest (e.g., passengers, hazardous cargo)	Mission duration
Vehicle type/Class and Launch/Reentry Techniqu8e	Launch window (primary, secondary)
Flight profile/Preferred route/trajectory (launch & reentry)	Reentry window (primary, secondary)
Launch location	Estimated Trajectory/Initial heading & azimuth
Destination (e.g., LEO, MEO GEO, pt-pt)	Air Defense Identification Zones (ADIZ)
Point of reentry	Instantaneous Impact Point (IIP)10
Landing location	Weather (current & forecast)
Traffic loading at time of launch & reentry—by stratum	Space & Solar Conditions (solar flares, etc.)
Airspace configuration (e.g., active MOAs, etc.)	Information pertaining to on-orbit traffic
STC information (e.g., coordinates, schedule)	

Mission Profile Information

Table 1.

3.1.2 Space Vehicle and Air Traffic Integration

Upon completion of its initial development, the proposed mission profile is filed in the same manner as a flight plan. But unlike flight plans, mission profiles are automatically routed to SpOC traffic managers at the ATCSCC for individual handling. The primary objective of the TM function is to prevent demand/capacity imbalances that adversely affect controllers or users. To meet this objective, traffic managers respond to predicted imbalances by developing and implementing 'Traffic Management Initiatives.' In addition to demand/capacity imbalances, TM Initiatives are also developed to support 'special events,' which today are defined as air shows, VIP flights, etc.

In preparation for a commercial space operation a TM Initiative is developed by SpOC. These TM Initiatives may consist of either a reconfiguration of NAS resources, and/or the implementation of traffic flow restrictions. NAS reconfigurations are used to increase the capacity of impacted resources, while traffic flow restrictions are used to restrain excess demand on those resources. These traffic flow restrictions may be imposed on aviation traffic, or upon the space mission itself within the limits of the mission's flexibility. After completing TM Initiative planning, SpOC distributes relevant information to the TM, ATC, ISFO, and users.

The primary automation support in this process is provided by the TM Initiative Planner (reference paragraph 2.4.2). Any CDM participant may transmit the Planner to the others, all CDM participants can manipulate the Planner's capabilities, and manipulations by any party are apparent to the others. The Planner's capabilities and information include 1) the initial mission profile information, 2) a graphic depiction of the NAS configuration, 3) a graphic depiction of user-preferred trajectories, 4) demand under current and alternative traffic situations, 5) relevant environmental information, and 6) trajectory modeling and fast-time simulation capabilities. The Planner allows collaborative analysis of the NAS configuration and traffic flow restrictions required to tailor the TM Initiative to the space mission, as follows:

- CDM participants use the Planner to de-conflict the mission from all other aviation traffic, space missions, airspace, and weather.
- CDM participants determine the most effective NAS configuration. The configuration elements that can be manipulated are airport/spaceport configuration, routings (aviation route structures, flexible spaceways, etc.), and airspace configurations (sectors, SUAs, STCs, etc.).

10 IIP is the impact point following thrust termination of a launch vehicle, calculated in the absence of atmospheric drag effects.

- The Planner's fast-time analysis capability allows any configuration element to be modified on a trial basis to determine the traffic effects that result. By comparing the traffic effects of each alternative, CDM participants select the configuration that best accommodates the operational objectives of ATC, TM, aviation users, and the space mission.

3.1.3 Finalization of the TM Initiative and Mission Profile

Working together via the TM Initiative Planner, the vehicle operator, TM, aviation users, and ISFO collaborate to refine the initial mission profile, and to finalize the associated TM Initiative, in order to accommodate the mission based on anticipated traffic demand, TM options, and the mission's inherent flexibility.[11] Fast-time simulations allow CDM participants to preview launch/reentry trajectories and air traffic flows, and to analyze variables such as vehicle performance, traffic loading, and weather. Upon analyzing the interactions between these variables, the TM Initiative Planner integrates the information and provides graphical outputs, including trajectory, scheduling, and buffer zone advisories to ensure safety of flight. Alternative scenarios and contingency plans are also evaluated to mitigate potential constraining factors such as adverse weather, traffic loading, etc.[12]

Contingency plans are also developed by the vehicle operator in the event the primary launch and reentry windows are unavailable (e.g., due to weather), if an off-nominal event occurs, or if the mission must be aborted. This precise and proactive planning reduces turn-around time between missions, optimizes spaceport capacity, minimizes schedule 'churning' (the ripple effect created by cancelled/rescheduled launches and re-entries), and reduces the complexity of accommodating transition to/from space. The planning process is completed well in advance of the mission in order to allow notification to other NAS users and pertinent domestic and international organizations. The required lead time depends on the mission profile and vehicle characteristics.

3.2 Launch/Takeoff

Upon completing the planning process, SpOC disseminates the mission profile via the NAS-WIS to notify airmen, mariners, and the military of the impending mission. AOCs and Flight Advisory Services (FAS) also receive this information. As the mission launch time approaches, SpOC distributes the TM Initiative Planner to all relevant TM, ATC, MP, ISFO, and AOC positions to coordinate the implementation of the TM Initiative (e.g., STCs, resectorization, traffic flow modulation, etc.) as required to accommodate the mission.[13] Notification of the approved mission profile is accompanied by event prompts that provide positive notification when updated information is received. To implement the launch/takeoff, general pre-departure actions that apply to both vertical and horizontal departures (reference section 2.1, Space TransportationVehicles) are as follows:

- DSSs facilitate the integration of the mission into the overall traffic situation. TM previews launch schedules for space vehicles. Sequencing and scheduling tools provide TM advisories and ensure that the launch is well coordinated with prevailing arrival and departure traffic.
- The NAS-WIS enables domestic and international users and service providers to access mission profiles and associated STC data. AOCs, airline pilots, and general aviation pilots access this data during flight planning, either by contacting the FAS or accessing the NAS-WIS, to ensure their flight plans are free of conflict with any space launch/reentry operation.
- The vehicle operator controls departure activities to ensure that the departure will conform to the mission profile. At a predetermined time before departure, the vehicle operator provides a status report to the SpOC, which in turn notifies ATC. The vehicle operator and TM/ATC establish the necessary communication links, and review the TM Initiative that will be instituted. Depending on the departure location, this may occur several hours in advance so that international traffic receives timely notification.
- Departure status is displayed to TM and controllers. Event prompts signal the need to activate STCs and clear traffic from the airspace. ATC then monitors STC status and separates traffic from active STCs. Conflict prediction tools assist ATC in detecting aircraft that will conflict with the STC.

11 Launch time flexibility is a function of payload destination (LEO, MEO, GEO) and orbital insertion point. Launch location/trajectory is influenced by payload destination and physical laws. Launch window size is affected by the movement of the earth relative to the target orbit, and launch site location.

12 For example, the preferred launch trajectory and window are compared against traffic predictions (e.g., based on historical data) to provide a high-level assessment of potential TM constraints and impacts to traffic flows. Similar analysis is performed for reentry phase.

13 For example, dynamic reservation of the STC is influenced by the lead time ATC needs to route aircraft around the reserved airspace, while the dynamic release of the STC is influenced by the airspace 'occupancy time' of the space vehicle as it transitions to/from space.

- Upon departure, the vehicle operator controls vehicle status and TM/ATC controls the traffic situation. [14] TM, ATC, and the vehicle operator collaborate to implement the appropriate contingency plan if a compromise to safety is detected.

[14] The VO requests ATC clearance for vehicles departing from a runway. ATC performs a final situation assessment and issues the clearance.

3.3 Ascent Through the NAS

Entry to orbit requires a nearly vertical, high-acceleration ascent that precludes the use of positive ATC. For vertical launches, this high-performance ascent begins immediately, while vehicles that depart horizontally transition through the NAS to an airborne point where a vertical, high-acceleration ascent to is initiated. The vertical ascent of all missions is accommodated through use of an STC. Therefore, the STC for vertical departures extends from the surface to the upper limit of the NAS, while the conventional portion of the trajectory for horizontal departures may be handled either with an STC *or* through positive ATC. The following paragraphs describe these basic options for handling ascents through the NAS.

3.3.1 Positive ATC from the Surface to A High-Altitude STC

The decision to use positive ATC is made by TM during mission planning.[15] The vehicle may be cleared on flexible spaceways to the point at which the vertical ascent begins. Once the vehicle reaches this vertical ascent point, the mission is then accommodated by an STC to the upper limit of the NAS.

- Initial Ascent Using Positive ATC. Upon departure, vehicle position is tracked on ATC situation displays. ATC issues clearances to the vehicle operator while the vehicle flies to the point at which the vertical ascent is initiated. Conflict detection tools recognize the vehicle's performance, and provide appropriate resolutions. If the mission involves a host aircraft (e.g., the vehicle is carried or towed, or involves aerial fueling), the vehicle operator assumes responsibility for separation of the launch vehicle from its host aircraft. Collision avoidance systems aboard interacting aircraft recognize the space transportation vehicle and provide conflict advisories to the aircraft flight decks.
- Final Ascent through A High-Altitude STC. As the space transportation vehicle approaches the vertical ascent point, a high-altitude STC is activated. The STC includes horizontal airspace to contain the route to the vertical ascent point, and vertical airspace to accommodate the transition to the NAS upper limit.[16] STC data is depicted on TM/ATC displays, along with weather and traffic data to provide a complete view of the situation. Controllers receive event prompts that signal STC status changes. Conflict prediction and resolution advisories provide notification of flights that conflict with the STC. [17]
  - As the vehicle approaches the STC, ATC assesses the traffic situation and activates the STC.
  - Upon entering the STC, the vehicle operator assumes responsibility for maneuvering the vehicle through the vertical portion of the STC. If a host aircraft is involved (e.g., the vehicle is carried or towed), the vehicle operator and host aircraft pilot are responsible for separating the vehicle and host aircraft.
  - If the launch system includes a host aircraft, the operator of the host aircraft contacts ATC after the space vehicle separates, to gain clearance to exit the STC.
  - The horizontal portion of the STC is released either when 1) the host aircraft exits the STC on its return to base, or 2) a non-hosted space vehicle enters the vertical portion of the STC.
  - The vertical portion of the STC is released as the space vehicle transitions through the upper limit of the NAS.

3.3.2 Ascent Through An STC From The Surface

Vehicles that are not controlled by positive ATC for their initial ascent are separated from other non-participating aircraft by an STC from departure on the ground to the upper limit of the NAS.[18] The STC's size and time of activation are tailored to meet the mission profile and vehicle characteristics. Ascent through a STC from the surface is conducted as follows:

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[15] For positive ATC, the vehicle must be able to be tracked; the vehicle operator must have direct voice or datalink communications with ATC, and affected ATC sectors must remain within acceptable levels of controller workload.

[16] To illustrate, this type of 'box & stovepipe' STC will have the basic physical characteristics of a 3-D polygon lying below a cylindrical column.

[17] Airspace contention is minimized since traffic in this altitude region consists only of other space vehicles, military aircraft, supersonic and hypersonic transports, and small numbers of new types of unmanned craft in geostationary positions.

[18] Alternatively, other means of separation (such 'moving ALTRVs,' etc.) may be also used based on operational conditions and necessity.

- The vehicle's position and STC status is available on situation displays at ATC, TM, and SpOC positions. STC strata are reserved and released as the vehicle progresses. STC schedule, status, and coordinates are depicted on integrated TM and controller displays, and complemented by weather and traffic information to provide a comprehensive view of the current and impending situation.
- TM/ATC receive event prompts for STC status changes. In addition, conflict prediction and resolution advisories indicate flights that conflict with the STC. Using DSS advisories and advanced situation displays, ATC anticipates future airspace status and directs flights through or away from the airspace based on its availability.
- STC information is provided on the flight decks of aircraft that are equipped with CDTI. These aircraft using CDTI may monitor and self-separate from active STCs, as directed by ATC. VFR flights access real-time STC status information by contacting FAS, or via NAS-WIS/Datalink.
- The vehicle operator informs ATC when the vehicle exits the NAS, and the STC is released.

3.3.3 Space Mission Abort

An ascent abort may become necessary if there is a failure that severely degrades vehicle performance. The vehicle operator during the mission planning phase plans for all feasible abort scenarios. Contingency trajectories and STCs are reserved and released by TM/ATC as the ascent progresses. Upon implementation of an abort mode, ATC handles the mission and interacting traffic according to the abort profile that is preplanned for that juncture of the ascent. Five general types of aborts are discussed below. The type and timing of the failure determines the type of abort mode selected. The five abort modes are:

- 'Contingency Abort' results from massive failure which allows the survival of the crew (if the vehicle is operated by an on-board crew), but the probable destruction of the vehicle. This abort mode is not chosen if another option exists.
- 'Abort to Orbit' allows the vehicle to achieve a temporary orbit that is lower than nominal. This allows time to evaluate problems and then choose either an early reentry or a thrusting maneuver to raise the orbit and continue the mission.
- 'Abort Once Around' allows the vehicle to fly one orbit and make a normal entry and landing.
- 'Return To Launch Site' involves continued flight downrange to dissipate propellant, then a course reversal under power to return for landing at or near the launch site.
- 'Cross-Country Landing' permits a landing at a downrange site, using a ballistic trajectory that does not require an orbital thrusting maneuver. This abort may place the vehicle at a site that cannot support a space launch, thus requiring the vehicle to be flown or transported through the NAS to its normal launch site. Except for ballistic or hypersonic-point-to-point vehicles, this operation is conducted using normal ATC/TM procedures. Vehicles making this transition on ultra-high-performance trajectories may utilize the mission planning processes used for space operations.

3.4 Reentry

Throughout the mission, the vehicle operator provides mission updates to the SpOC. This mission information may be accessed by other NAS users for strategic planning. For short duration missions (e.g., one week or less), the reentry plan is included in the initial mission profile. For longer missions, the reentry plan is coordinated at a predetermined time prior to the reentry.[19] If a reentry plan was included in the initial mission profile, the vehicle operator contacts SpOC at a predetermined time to confirm the reentry window and trajectory. If the reentry plan must be modified, the vehicle operator coordinates the revised plan with the SpOC, AOCs, military, and international ATC. Current reentry information is disseminated via the NAS-WIS, along with notices to airmen, mariners, and the military.[20] Shortly before reentry, the vehicle operator contacts SpOC and requests clearance to re-enter the NAS. The reentry is then conducted as follows:

- Reentry plans are used by TM to define appropriate STCs. Like the STCs used for transitions to space, baseline STCs exist to support typical vehicle reentries. These STCs are dynamically reserved and released, and may be tailored to satisfy specific mission or vehicle profiles.

[19] The lead time for this coordination depends upon the vehicle's reentry profile, trajectory, and destination.

[20] If an Air Defense Identification Zone (ADIZ) is affected, Air Defense Command (ADC) is notified by an event prompt.

- SpOC performs fast-time scheduling analyses to determine the reentry plan's feasibility, and coordinates with the appropriate sectors. ATC then issues the reentry clearance. For unpowered returns, reentry clearance is an implied clearance to land, since the vehicle is committed to its return upon de-orbiting.
- The SpOC disseminates notification to airmen, mariners, military, AOCs, FAS, and ISFO via the NAS-WIS. Affected sectors are notified by SpOC of the reentry. STC event prompts assist in establishing traffic awareness. Conflict prediction and resolution capabilities help controllers mitigate conflicts between air traffic and active STCs, and to resume use of the airspace as STC strata are released. Sequencing and scheduling advisories assist in managing traffic flows.
- NAS users may access mission and STC information via the NAS-WIS. VFR flights receive information on low-altitude STCs by remotely accessing the NAS-WIS, or by contacting the FAS.
- When the vehicle reenters the NAS, the vehicle operator ensures that the vehicle's trajectory conforms to the designated STC. The vehicle's position and STC status is available on situation displays at ATC and TM positions, at the SpOC, and on cockpit displays of traffic information.

3.5 Descent Through the NAS & Landing

The vehicle is protected during descent either 1) by an STC for the entire transition from the upper limit of the NAS to the surface, or 2) by an STC from the upper limit of the NAS to a point where positive ATC techniques are initiated, if the vehicle transitions to a conventional aircraft operational mode. The application of one of these options to a mission is largely determined by the reentry profile of the vehicle. The three classes of re-entry profiles are powered (i.e., conventional) flight, gliding flight, and ballistic return. In general, fully maneuverable vehicles that fly conventionally under power to a landing site are eligible for positive ATC, but the option exists to protect these vehicles by an STC for the entire return. STC protection for the entire return is the only option available for gliding and ballistic returns. The following paragraphs discuss these two options for handling descents through the NAS.

3.5.1 Positive ATC from A High-Altitude STC[21]

The vehicle is cleared on flexible spaceways through a high-altitude STC from the NAS upper limit to the point at which it assumes conventional performance. Thereafter the space transportation vehicle receives route, heading, speed, and altitude clearances from ATC. The decision to use positive ATC is made by TM during mission planning.

- Initial Descent Through High Altitude STC. As the vehicles enters the NAS, the operator ensures that its trajectory conforms to the STC. With the assistance of conflict prediction and resolution advisories, ATC ensures that non-participating aircraft remain separated from active STCs. STC schedule and status data is accessible to NAS users and service providers via the NAS-WIS, and is monitored by the TM, ATC, and the vehicle operator. The STC is completely released when the vehicle transitions to a conventional performance profile.
- Final Descent Managed by Positive ATC. As the space transportation vehicle exits the STC, DSSs assist controllers in integrating the space transportation vehicle into en route and arrival traffic flows. This sequencing and scheduling assistance continues throughout the vehicle's return. If the space transportation vehicle lands at an airport, it is managed by ATC as it transitions through terminal airspace. Terminal controllers provide a runway assignment and issue an approach clearance. The space transportation vehicle is then transferred to the tower, which issues a landing clearance and taxi instructions. If the vehicle will land at a dedicated site, ATC communicates with the vehicle operator for the transition through terminal airspace, then terminates air traffic services and transfers the vehicle to the appropriate authority for landing instructions.

3.5.2 STC From The Upper Limit Of The NAS To The Surface

Powered vehicles that are eligible for positive ATC *may* be accommodated by an STC for their entire return, based on the operational decision of the relevant traffic manager. Unpowered vehicles (i.e., gliding or ballistic) are *always* accommodated by an STC for the entire transition from space to the surface.

[21] For positive ATC to be used, the vehicle must be able to be tracked, the vehicle operator must have direct voice or datalink communications with ATC, and affected ATC sectors must remain within acceptable levels of controller workload.

- Powered Return. As the vehicle enters the NAS, the operator ensures that it conforms to the STC. With assistance of conflict prediction and resolution advisories, ATC ensures that aircraft do not penetrate active STCs. STC data is accessible to users and service providers via the NAS-WIS, and is monitored by the TM, ATC, and vehicle operator. As the vehicle progresses, ATC monitors STC status data to ensure maximum airspace utilization by aircraft as STC airspace is released. During the vehicle's descent, DSSs provide sequencing and scheduling advisories to ATC to coordinate the arrival times of other traffic in order to facilitate vehicle arrival. The dynamic nature of STCs minimizes impact on air traffic since higher altitude STC strata may be released as the vehicle begins its descent and final approach. Before beginning final descent, the operator of a powered vehicle contacts the tower for landing clearance. 'Managed arrival reservoirs' designated for space operations may be used to ensure that final descent into the airport can be coordinated with ATC.
- Gliding Return. Positive ATC is not an option for a gliding return since the vehicle cannot respond to the full range of ATC clearances. Upon reentry, these vehicles have a higher descent rate than powered vehicles, and they must anticipate any constraints to landing, since alternative trajectories must be exercised early in the reentry. Trajectory modeling identifies the point at which the vehicle is committed to land at the primary spaceport. This point represents the final opportunity to invoke a contingency plan to route the vehicle to an alternate site if operational conditions are undesirable at the primary site. The vehicle operator and TM maintain communications in case contingency plans must be implemented. When the spacecraft reaches its commitment point, it is handled as a priority vehicle since it does not have the option of deviating from its landing plan. DSSs provide sequencing and scheduling advisories to create an arrival 'slot' to accommodate the landing. If the vehicle lands at a dedicated spaceport, the appropriate authority assumes this responsibility.
- Ballistic Return. Vehicles with ballistic returns will free-fall to a predefined altitude, and then use a parachute or other mechanism to slow the vertical velocity for landing.[22] Positive ATC is not an option for these returns, since the vehicle has no ability to comply with ATC clearances. Due to the relatively slow descent, STCs must be reserved for a longer time, requiring more extensive planning and collaboration among users and service providers. In addition, ballistic returns are constrained to landing at ports that can support the unique descent profile with minimal impact to arrival and departure traffic. Once the vehicle deploys a mechanism to slow its descent rate, narrower STCs are dynamically reserved and released, and ATC provides horizontal and lateral separation of aircraft from these STC. When the vehicle touches down, the vehicle operator issues notification that the mission has been completed, and this notification is disseminated via the NAS-WIS.

3.6 Hypersonic Point-to-Point

'Hypersonic point-to-point' refers to missions involving ultra-high-altitude international transit of passengers and/or cargo. These operations may involve transition through the NAS, entry into international airspace, and return to base; this sequence is reversed for flights originating from other countries. These international missions involve reusable vehicles that are essentially very fast, very high-altitude, very long range airplanes that operate several times a day to regularly scheduled destinations. Since some of these missions involve the carrying of passengers, the reliability and safety of these vehicles is comparable to conventional aircraft. The concepts described below illustrate the collaboration and coordination that accompanies these international missions.

Like today's air carriers, commercial 'aerospaceline' companies coordinate flight plans and ensure that the vehicle's operation conforms to these plans. During the mission-planning phase, the aerospaceline's vehicle operator collaborates with the SpOC and ISFO to develop a mission profile for international travel. This collaboration includes the use of trajectory modeling to analyze the vehicle's trajectory, identify transition points at airspace boundaries, specify Air Defense Identification Zones (ADIZs) that will be penetrated, and define the ATM/ATC

[22] The concepts for managing ballistic returns represent variations of AT procedures used to accommodate unmanned free balloon flight, and recovery of booster stages from expendable launch vehicles or two-stage-to-orbit re-usable vehicles.

strategies that will be used to ensure safety of flight. Because of the recurring nature of these missions, nominal trajectories between specific origins and destinations are available as a baseline. These baseline mission profiles streamline the mission planning process, and may be tailored to unique mission requirements. Coordination and dissemination of the mission profile is expedited by the NAS-WIS, which facilitates international collaboration, notification, and information exchange to ensure that the trajectory and schedule are achievable.

The balance of this discussion describes missions departing from a U.S. point of origin for an international destination.[23] For these flights, the vehicle operator requests departure clearance from ATC. After ensuring the applicable TM initiatives are in place, ATC clears the flight to depart. As the flight transitions through the NAS, DSSs update scheduling information, which is available internationally via the NAS-WIS. Satellite-based surveillance allows the flight to be tracked and monitored throughout its trajectory. International communications are in place between the ISFO, SpOC, AOCs, ATC, and the space transportation vehicle to facilitate both silent and verbal coordination. The ability to exchange information electronically improves the timeliness and accuracy of international communications, reduces the communications workload burden, and reinforces/clarifies verbal instructions that may be confounded due to language barriers, etc.

The en-route trajectories for hypersonic missions departing from the U.S. may involve 1) ultra-high altitude flight within the NAS, and a transition directly to international airspace, or 2) flight above the NAS and reentry into international airspace. For flights cruising *within the NAS* at ultra-high altitudes, large ultra-high sectors provide positive ATC. These missions may request VFR (with or without flight following), VFR-On-Top, or IFR. The mission profile includes the trajectory, a defined ultra-high-altitude transition point within each Center, scheduled time of arrival at these transition points, spaceways, STC coordinates and schedules (if applicable), and any special procedures that the flight requires (e.g., aerial refueling). Ultra-high sector controllers provide ATC services, as requested, considering the vehicle class and flight profile. U.S. ATC coordinates with international ATC for approval for the flight to enter its airspace at pre-planned coordinates included in the flight's mission profile.

For flights operating *above the NAS*, the mission profile also includes 1) the vehicle's targeted point for insertion into space, and the corresponding STC coordinates and schedule, and 2) the reentry point and corresponding STC coordinates and schedule. Once the mission profile is approved and disseminated, DSSs assist in factoring the mission into arrival and departure schedules. If dynamic STCs are used, the times of STC activation are probed to mitigate conflicts. When the flight is ready to depart the upper limit of the NAS, the vehicle operator informs ATC of its intent to exit ATC controlled airspace. ATC uses conflict prediction and resolution tools to ensure that the STC is clear of traffic and clears the flight to launch. Mission status updates are available to the ISFO, SpOC, ATC, military and other interested users and service providers. Prior to the flight's reentry, the vehicle operator coordinates with the ISFO and international ATC for approval to re-enter at specified coordinates included in the mission profile. This coordination is performed at a predetermined time before reentry. Upon re-entering international airspace, coordination between the vehicle operator and international ATC continues until the flight reaches its destination.

[23] The same general process applies in reverse for a mission arriving at the NAS from an international point of origin.

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