SPACE VEHICLE OPERATORS CONCEPT OF OPERATIONS

FUTURE INTERAGENCY RANGE AND SPACEPORT TECHNOLOGIES

FIRST

Reducing the Cost of Sustained Operations Through Technology Infusion

SPACE VEHICLE OPERATORS CONCEPT OF OPERATIONS

A Vision to Transform Ground and Launch Operations

Future Interagency Range and Spaceport Technologies

October 2004

FOREWORD

The Future Interagency Range and Spaceport Technologies (FIRST) initiative is a partnership and interagency working group of NASA, the Department of Defense (Air Force Space Command and Office of the Secretary of Defense), and the Federal Aviation Administration. The partnership was established to guide transformation of U.S. ground and space launch operations toward a single, integrated national "system" of space transportation systems that enables low-cost, routine, safe access to space for a variety of applications and markets through technology infusion. This multi-agency consortium is formulating plans to create a national program office that will coordinate individual agency plans to produce an integrated national space transportation system infrastructure comprised of spaceports, ranges, and space and air traffic management systems.

A set of concepts of operations, or CONOPS, has been produced to articulate a cohesive interagency vision for this future space transportation system in support of FIRST program formulation efforts. These concepts are intended to guide and support the coordinated development of technologies that allow multiple launch vehicle architectures and missions to be supported by the same ground and launch systems without significant modification. These documents reflect the interests of the partners in the working group, and are not intended to imply final approval or policy of any of the participating agencies.

These visionary CONOPS documents have been built on the foundation that was established over the past two years by the Advanced Range Technology Working Group (ARTWG) and Advanced Spaceport Technology Working Group (ASTWG). This foundation was, in turn, built on relevant corporate knowledge contributed by literally hundreds of participants in these two working groups, consisting of experts from across the country representing a wide variety of DoD organizations, NASA Centers, large and small companies in the U.S. aerospace industry, state governments and spaceport organizations, as well as academic institutions. Based on this foundation, ZHA International and Booz Allen Hamilton collaborated with FIRST government partners to create the FIRST CONOPS.

October 2004

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EXECUTIVE SUMMARY

The purpose of this CONOPS is to outline a common national vision for conducting space flight operations in the future. Space flight operations includes the planning, scheduling, coordination, and management of space transportation activities, including the shared use of spaceport and range support elements worldwide, to accommodate multiple simultaneous flights of different types of vehicles to, through, and from space using a variety of control centers tied together through a network-centric Central Control Function to coordinate ground and flight operations and support. The vision described in this CONOPS resembles today's management of the commercial air transportation system. The processes and activities presented in this CONOPS are described from the perspective of future space flight operators at various types of control centers and flight crews aboard space flight vehicles.

Time Frames

In formulating and planning the FIRST program, three timeframe, or eras, are addressed.

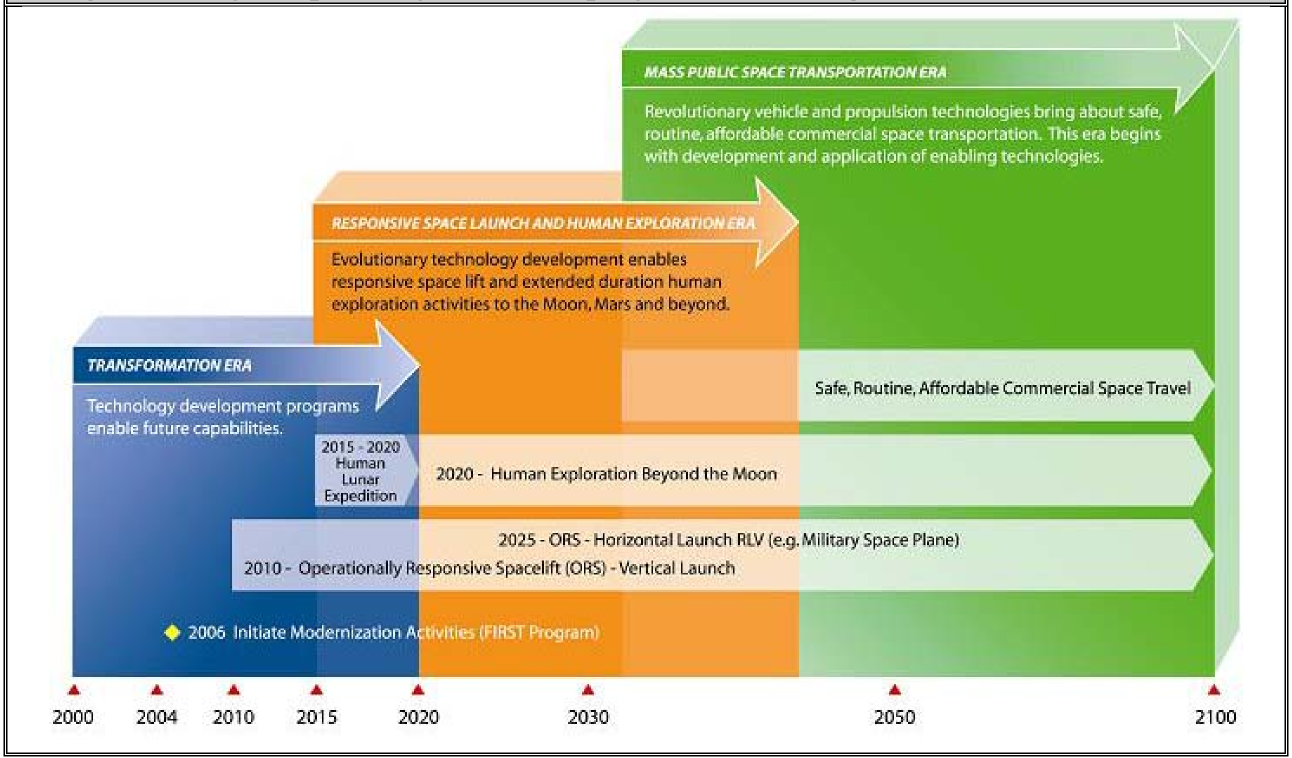


Figure ES-1. Future Space Transportation System (FSTS) Program Eras

The nation's space flight operations capabilities will evolve through a series of incremental spiral development steps, implemented through three eras as depicted in Figure ES-1. The first era is called the transformation era. Transformation refers to fundamental change involving advanced technologies to enable new concepts of operation that are implemented and institutionalized through collaborative organizational change. New types of space flight operations characterize the second, or Responsive Space Launch and Human Exploration Era. This era is poised to begin in the next decade. The third era, mass public space transportation, is envisioned to begin when the economics and technology of space travel align with the demands of a mass market characterized by safe, routine, affordable commercial space travel—like air travel today.

This CONOPS is based on several key assumptions, including:

- A variety of new space transportation vehicles and programs will be deployed and operated concurrently in the coming decades.
- Traditional functions provided by today's ranges, spaceports and operations organizations will merge into a comprehensive, integrated FSTS.
- In the Mass Public Space Transportation Era, launch vehicle reliability will approach that of current airline reliability.

<u>Conceptual Architecture</u>

The Space Flight Operations architecture consists of a network-centric capability to coordinate and control space transportation assets and activities around the world using a variety of control centers and user facilities connected through a Central Control Function.

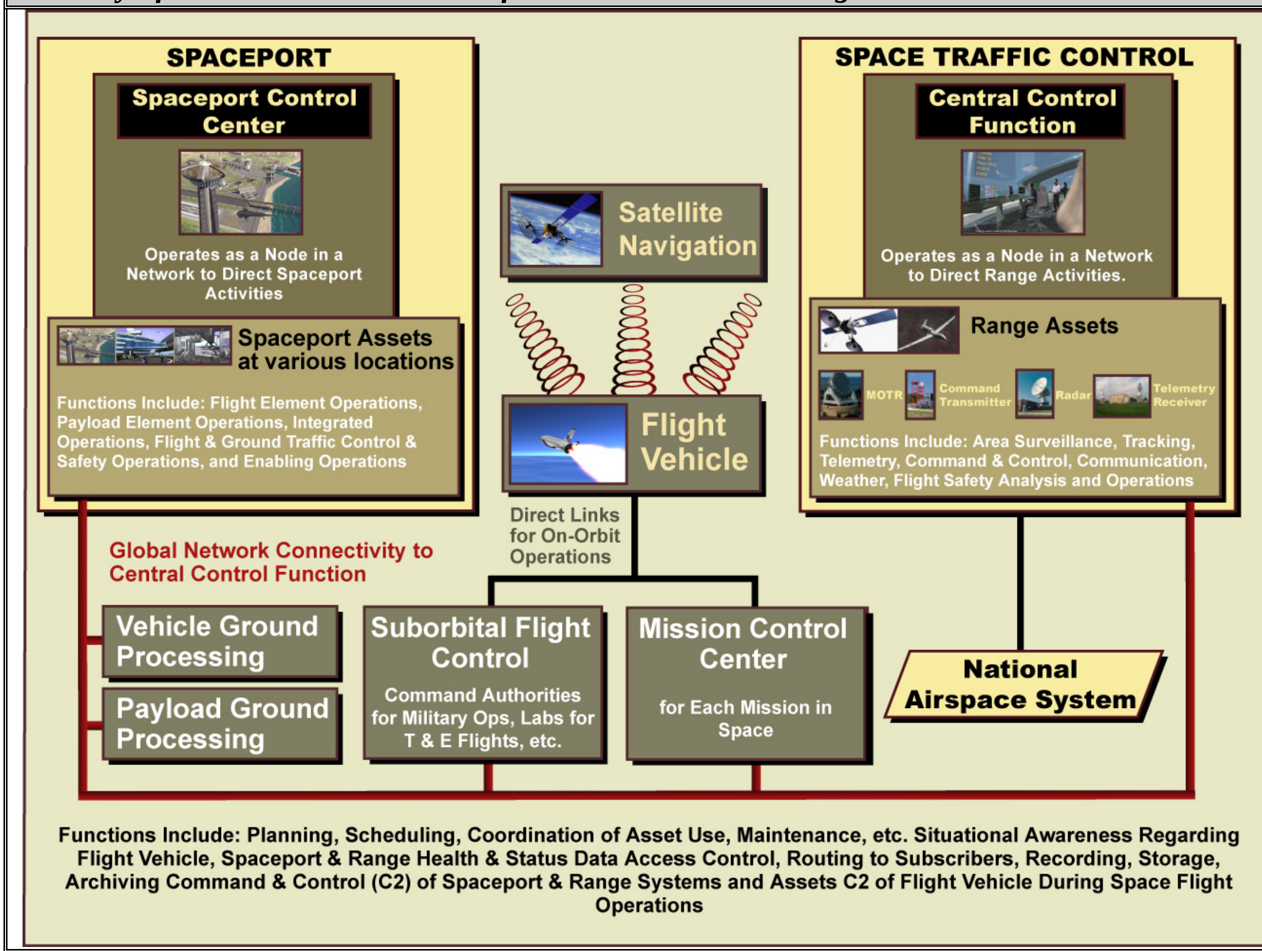


Figure ES-2. Conceptual Architecture to Support Space Flight Operations

As shown in Figure ES-2, the future space flight operations architecture must accommodate the same types of test and operational activities that are supported today, plus a variety of additional space flight operations and activities. To support these activities, future systems take advantage of an open architecture, interoperability, and standards (as appropriate) to enable the transition of new systems, technologies, and capabilities into operational use as they become available. The primary elements of the future space flight operations conceptual architecture are:

- Spaceports at various locations around the world, operating as nodes in a global network.
- Global space launch and test range assets, including shared-use satellites and airborne platforms, plus ground-based assets at various locations.
- The Central Control Function—an integrated, centrally-managed, network-centric capability to coordinate support for space flight operations, as described below.
- A hierarchy of control centers and associated controllers to manage the various operational aspects of space flights.
- User Facilities, including those that are operated by a flight vehicle owner, a payload owner, command authorities for military operations, laboratories and program offices.
- Automated planning, scheduling, coordination systems supported by automated decision support tools to provide course of action options and recommendations.
- A variety of sensor systems, and self-diagnosing, self-reconfiguring, and self-healing systems to provide situational awareness information through the global network.

An essential part of the vision for future space flight operations described in this CONOPS relies on the Central Control Function and the hierarchy of control centers.

<u>Central Control Function</u>

The Central Control Function is an integrated, centrally-managed, network-centric capability to coordinate and control space transportation assets and activities around the world during flight phases associated with transportation—launch, takeoff, reentry, and landing.

The Central Control Function provides central repository and clearing house roles in support of space flight operations.

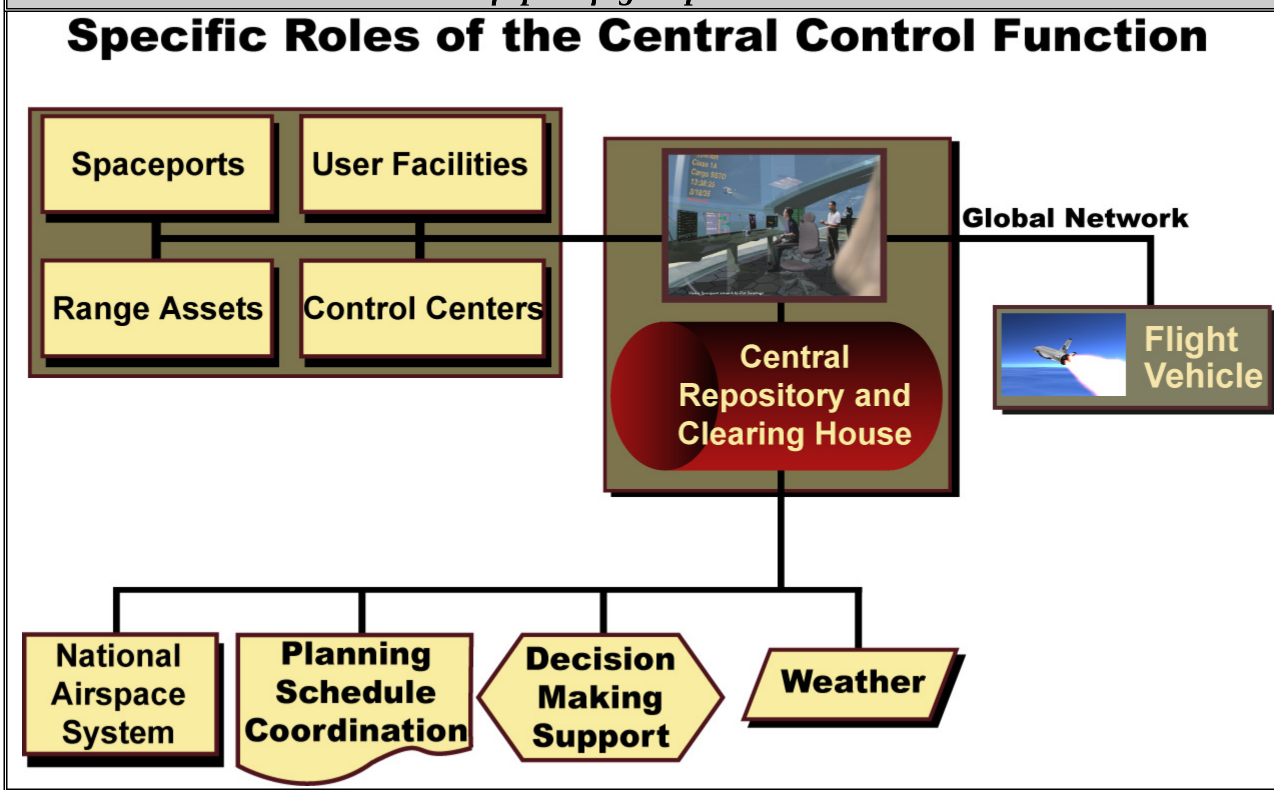


Figure ES-3. Specific Roles of the Central Control Function

The Central Control Function directs and coordinates range and spaceport operations and provides a central clearing house for situational awareness information. As illustrated in Figure ES-3, the specific roles of the Central Control Function, and the technical capabilities that enable them, include:

- Acting as a central repository and clearing house for information pertaining to the health and status of flight vehicle, spaceport and range systems.
- Acting as a central repository and clearing house for situational awareness information with regard to ground and flight vehicle traffic of interest, areas that must be cleared for safety and security reasons, and current and forecasted weather conditions.

<u>Hierarchy of Control Centers and Controllers</u>

The FSTS architecture relies on a hierarchy of control centers to conduct safe, reliable, and routine space flight operations.

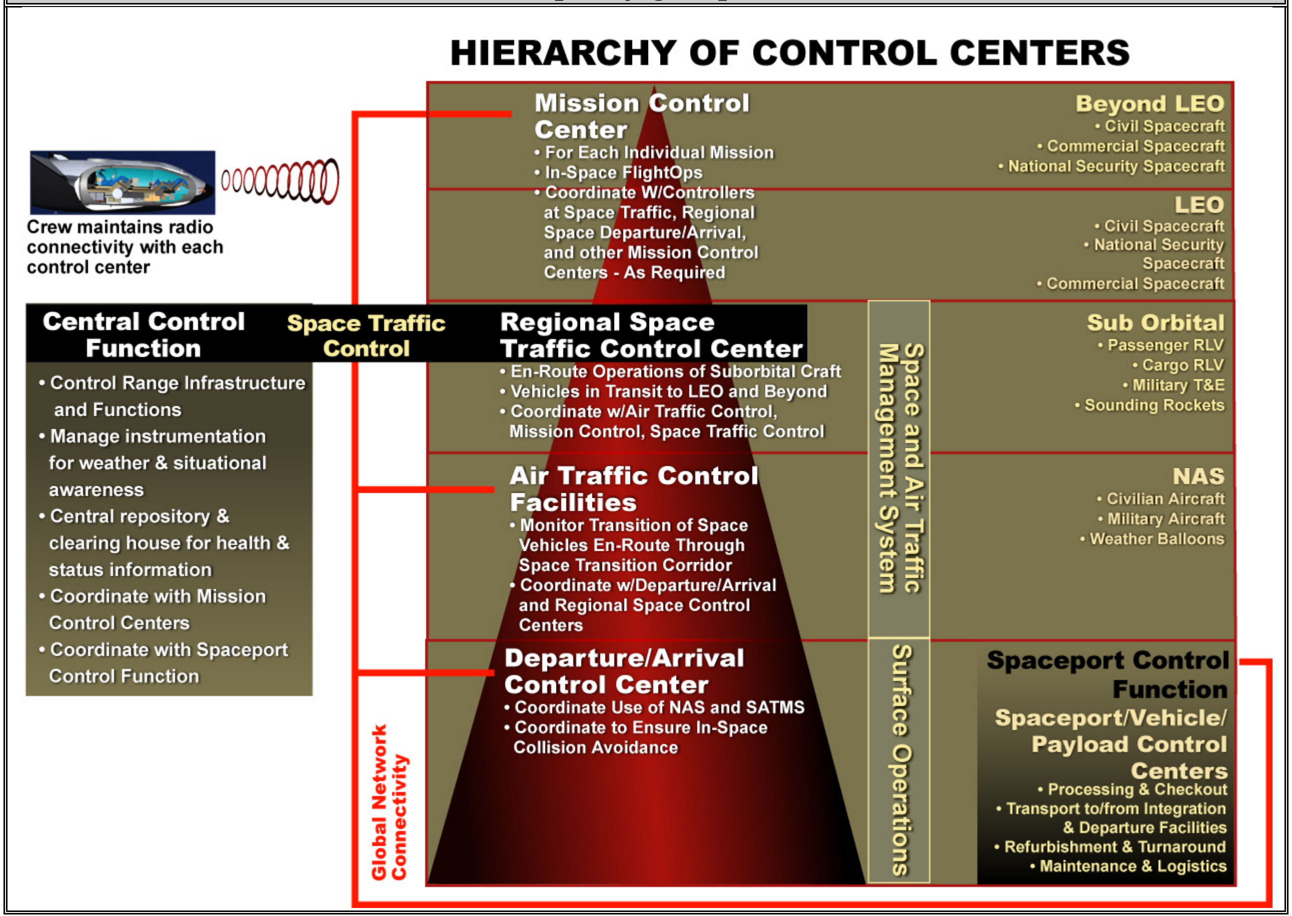


Figure ES-4. Hierarchy of Control Center Functions

As depicted in Figure ES-4, there are five different types of control centers involved in managing the operation of space flight vehicles and their payloads, cargo, and passengers:

- Vehicle and Payload Processing Control Centers control the pre- and post-flight processing and checkout of flight vehicles and payloads, along with ground movement.

- Departure/Arrival Control Centers (DACC) coordinate range support, use of the National Airspace System (NAS), and information on collision avoidance with objects in space.
- Air Traffic Control Facilities (ATC Facilities) coordinate and manage use of the National Airspace System (NAS).
- Regional Space Traffic Control Centers (RSTCC) monitor, coordinate and manage flights to, through, and from space.
- Mission Control Centers (MCC) for operations in orbit rely on dedicated links for voice, video, and data for national security, civil, and commercial satellites, deep space probes, and crewed missions in orbit, to the Moon, and beyond.

To implement the concept of a hierarchy of control centers, all space flight operations are managed by control centers with jurisdiction over specific regions as illustrated in Figure ES-5.

Each type of control center has its own region of authority.

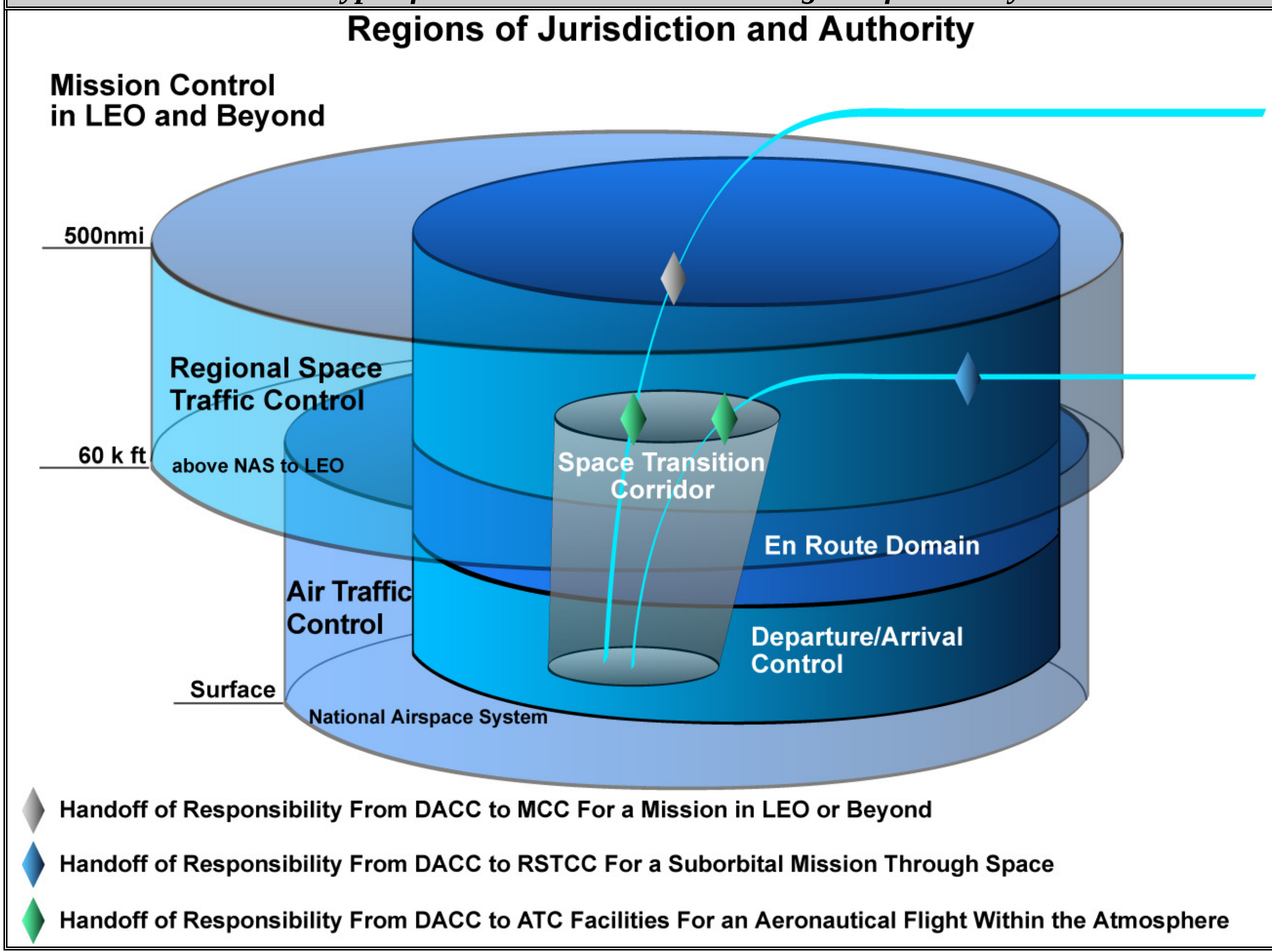


Figure ES-5. Regional Authority for Each Type of Control Center

Future Space Flight Operations

Space flight operations are typically conducted in six sequential phases.

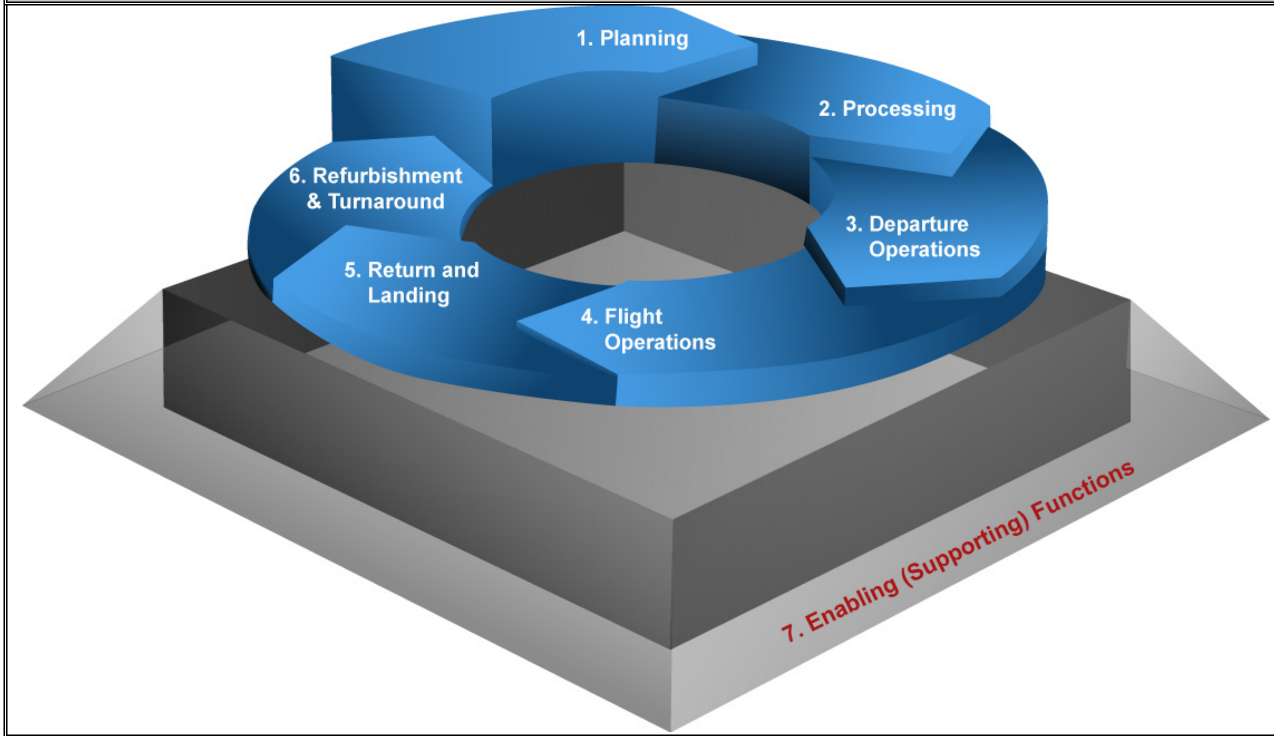


Figure ES-6. The Six Phases of Space Flight Operations.

Several space flight operations functions are performed in each phase, as shown in Figure ES-7.

Phase	Space Flight Operations Functions
Planning	• Flight Planning and Scheduling • Training and Certification
Processing	• Flight Readiness Verification • Transportation Between Facilities
Departure Operation	• Countdown and Final Launch Commit • Launch/Takeoff and Initial Flight
Flight Operations	• In-flight activities • Monitoring in “Notification” Mode
Return and Landing	• Reentry • Return Flight • Landing/Recovery
Refurbishment and Turnaround	• Post-Flight Processing • Data Archival, Analysis and Reporting

Figure ES-7. Space Flight Operation Functions in Each Phase

The following paragraphs describe how each of the space flight operations functions will be carried out in the Responsive Space Launch and Human Exploration Era.

Planning & Scheduling: Automated decision support systems analyze weather data with vehicle performance and characteristics to determine the operational limits on each planned space flight operation. Assignments for use of airspace are derived from automated simulations of the flight profile and its effects on air traffic. The centralized planning and scheduling system uses software tools to standardize recurring schedule items, expert systems for workload planning, and models to project the availability of spaceport and range assets and other support resources.

<u>Training and Certification</u>: Generic training includes requirements that remain consistent over time regardless of the purpose of a particular flight, vehicle or facility. Flight-specific training includes training requirements that are unique to a given flight, vehicle or payload. As the space transportation architecture becomes more standardized and interoperable over time, there will be fewer vehicle-centric training requirements, and most training and certification requirements will fall into the generic category. Automated processes, self-diagnosing/self-healing systems and decision support systems will reduce the amount of training needed by operations personnel.

<u>Flight Readiness Verification</u>: Intelligent computing systems assess readiness in real-time based on information from all elements of the space transportation system to enable responsive space launches. Advanced computing techniques and intelligent system support responsive operations.

<u>Transportation Between Facilities</u>: Operators at Vehicle and Payload Control Centers maintain communication with spaceport facilities, support equipment, and the flight vehicles, payloads, cargo, crew, and passengers to maintain situational awareness and direct control of all ground processing activities associated with the elements they're responsible for. The Central Control Function retains responsibility for directing spaceport and range assets to provide support for the ground processing activities being directed by the Vehicle and Payload Control Centers.

<u>Countdown and Final Launch Commit</u>: Operators in the Departure/Arrival Control Center monitor the status reports from automated health monitoring systems and, like airport control tower operators today, monitor departures and arrivals in the terminal area of the spaceport. They also monitor integrated situational awareness displays to ensure weather is acceptable for launch or takeoff.

<u>Launch/Takeoff and Initial Flight</u>: Operators in the Departure/Arrival Control Center monitor launch/takeoff and ascent to ensure vehicles are flying in accordance with approved flight profiles. Air Traffic Control Facilities and Regional Space Traffic Control Centers provide routing instructions as required to clear the airspace and ensure separation from other aircraft and traffic and/or debris in space as vehicles transit their regions of jurisdiction. Space vehicle operations within the NAS are managed using space transition corridors and flexible spaceways.

<u>In-flight Activities</u>: Air Traffic Control Facilities and Regional Space Traffic Control Centers monitor and issue routing instructions to suborbital hypersonic point-to-point flights as they fly en route between spaceports to ensure safety and separation from other traffic and potential hazards including weather systems and orbiting debris.

<u>Monitoring in "Notification" Mode</u>: For space flight operations in LEO or beyond, the Mission Control Center maintains continuous contact with the flight vehicle (and crew, if applicable) and with the global network that's managed by the Central Control Function. All other control centers passively monitor the network in "notification" mode in case the Mission Control Center issues a message requesting support for an unscheduled return and landing/recovery.

<u>Reentry</u>: The Mission Control Center (and the flight crew, if applicable) maintains direct contact with control centers that have authority and jurisdiction over the regions being traversed along the flight path. Regional Space Traffic Control Centers monitor and ensure safety and separation during deorbit and reentry maneuvers. For vehicles returning to Earth, the applicable Air Traffic Control facility works with the applicable Regional Space Traffic Control Center to clear the airspace.

Return Flight: Once the vehicle enters the National Airspace System, the responsible Regional Space Traffic Control Centers hands off responsibility to the applicable Departure/Arrival Control Center at the spaceport where the vehicle will land. The Departure/Arrival Control Center coordinates with the applicable Air Traffic Control Facilities to ensure safety and separation during the descending flight through the atmosphere.

Landing/Recovery: The Departure/Arrival Control Center maintains responsibility for issuing routing instructions to the flight crew (when applicable) and/or to the ground control center responsible for the flight, throughout return flight and landing/recovery at the spaceport.

Data Archival, Analysis and Reporting: After the completion of a space flight operation, automated expert systems generate post-flight anomaly reports and to schedule maintenance and repair activities. The central archival database makes data available at user request as needed to complete post flight analysis and reports.

Space Flight Operations in the Third Era, to Support Mass Public Space Travel

Space flight operations in the third era are conducted so frequently and routinely that some of the steps in the lifecycle described above are combined and compressed.

Planning and Scheduling: Flight routes between major destinations are well-defined and established for frequent and routine flights. The Central Control Function manages the functions of dozens of spaceports and hundreds of flights each day, supported by the same types of control centers that operated during the first two eras.

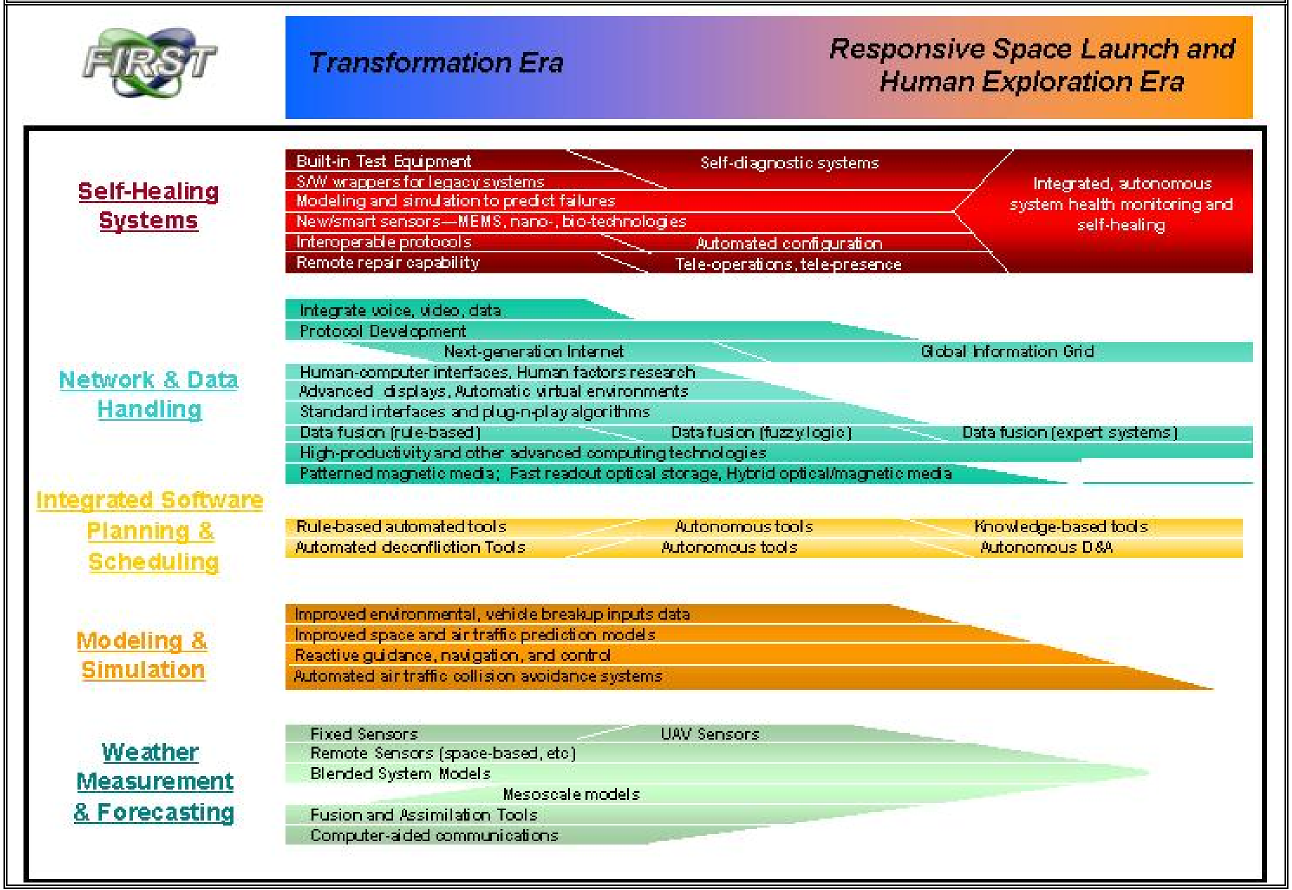
Processing, Refurbishment, and Turnaround: Accommodating such a busy flight schedule drives the need for processing, refurbishment, and turnaround of reusable space flight vehicles (and their support systems) between flights in ways that resemble airline processing operations at airports today. Integrated health monitoring systems enable as-needed maintenance actions to be detected and conducted quickly on an exception basis. Most processing and turnaround operations between flights are conducted in parallel using adjustable ground support equipment to accommodate different vehicle configurations.

Departure and Arrival, Return and Landing Operations: The Departure/Arrival Control Center at each spaceport operates much like the Terminal Control Center at airports today, controlling departure, arrival, return, and landing operations. As the flight vehicle leaves its area of responsibility, the DACC hands off responsibility for routing routine suborbital flights to the Regional Space Traffic Control Center. For longer flights, it in turn, hands off responsibility to the next Regional Space Traffic Control Center along the intended flight path, and so on, until the DACC at the spaceport where the vehicle is scheduled to land takes over responsibility.

Flight Operations: As vehicles depart the spaceport, space-based and ground-based systems in the third era have the capacity to support increased space transportation traffic. Increasingly sophisticated automated decision support systems allow control center operators and flight crews to concentrate on only those critical decisions and flight-unique operations that actually require human intervention. The use of intelligent expert systems and sensors to improve situational awareness increases safety and reliability and decreases operator workload. Consequently, operators in control centers are able to support more flights simultaneously.

Enabling Capabilities

This enabling technology roadmap presents a time-phased approach to addressing the technical challenges associated with achieving the necessary capabilities for the envisioned future space flight operations described in this CONOPS.



Source: ARTWG Baseline Report

Figure ES-8. Enabling Technology Roadmap

A variety of enabling capabilities will be necessary to enable future space flight operations as described in this CONOPS. This CONOPS describes new ways of operating with technologies or capabilities that are likely to exist in the future. It describes a variety of technology areas and standardization approaches that address the technical challenges that stand in the way of achieving the necessary capabilities to enable future space flight operations as envisioned.

The enabling technology roadmap depicted in Figure ES-8 presents the recommended time-phased approach to pursuing these technology development and demonstration activities over time. The five technology areas addressed in this section are: Self-Healing Systems, Network and Data-Handling, Integrated Software Planning and Scheduling, Modeling and Simulation, and Weather Measurement and Forecasting.

In addition, standardization is another enabling element. The body of the CONOPS describes many opportunities and recommendations regarding development and demonstration activities that should be pursued to address each of these areas and enable the future capabilities envisioned in this CONOPS.

Conclusion

Pursuing opportunities for technology development and demonstration activities will enable the development of the future capabilities described in this CONOPS. Only by developing these capabilities will future space flight operations be able to satisfy the future demands for space transportation from the civil, commercial, and national security space sectors, including eventual mass public space travel to rapidly move people and cargo between points on the globe and into space.

1.0 PURPOSE

The purpose of this CONOPS is to outline a common national vision for conducting space flight operations in the future. Space flight operations includes the planning, scheduling, coordination, and management of space transportation activities, including the shared use of spaceport and range support elements worldwide, to accommodate multiple simultaneous flights of different types of vehicles to, through, and from space using a variety of control centers tied together through a network-centric Central Control Function to coordinate ground and flight operations and support.

This CONOPS differs from the top-level "Transformational Spaceport and Range CONOPS: A Vision to Transform Ground and Launch Operations" in that this document describes how spaceports and ranges operate together with a hierarchy of control centers to support and enable space flight operations, whereas the top-level document provides a broader perspective on the vision for the overall Future Space Transportation System (FSTS). As shown in Figure 1, the FSTS vision establishes a common framework for defining and building detailed CONOPS for each of the major elements of a national space transportation system.

The FSTS vision establishes a common framework for defining and building detailed CONOPS for each of the major elements of a national space transportation system.

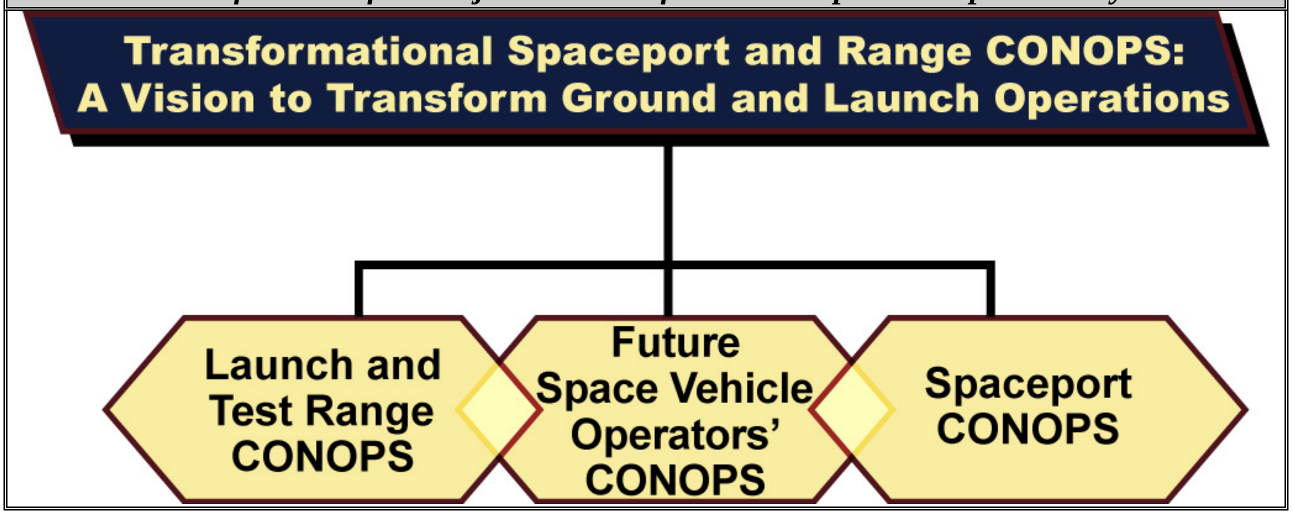


Figure 1. Hierarchy of FIRST CONOPS Documents

The vision described in this CONOPS offers an integrated, interoperable approach for conducting future civil, national security and commercial space transportation operations in ways that resemble today's management of the commercial air transportation system. This approach envisions a space flight operations model that is independent of vehicle architecture, making it more economical and streamlined than today's approach to space flight operations. Consequently, this approach will enable the FSTS to accommodate more frequent flights with shorter lead times, manage multiple flights and activities simultaneously, be less manpower-intensive, and integrate seamlessly with the National Airspace System (NAS) via the Space and Air Traffic Management System (SATMS).

By necessity, ranges, spaceports, vehicles, payloads, and control centers must continue to evolve to meet new space transportation needs. Their progress over time will directly impact the way space flight operations are conducted in the future. Advance planning in the near-term will help to identify emerging and projected future needs along with more efficient ways to accomplish space flight operations tasks that today are manpower intensive, costly, and complex. Near-term planning will also help to identify research and technology areas that would enable more efficient and cost-effective capabilities to enable and support future space flight operations.

The processes and activities presented in this CONOPS are described from the perspective of future space flight operators at various types of control centers and flight crews aboard space flight vehicles, emphasizing their actions and interactions with other elements of the FSTS: spaceport and range assets and flight vehicles. This CONOPS describes a future network-centric control center conceptual architecture and operating model for future space flight operations. It also discusses some technology areas that would enable and enhance the nation's ability to more effectively support current emerging, and projected future national security, civil, and commercial space flight operations to, through, and from space.

2.0 TIME FRAMES

The nation's space flight operations capabilities will evolve from their current state (relying almost exclusively on vehicle-specific, fixed-location, ground-based assets), through a series of incremental spiral development steps. These steps will be implemented through three eras as depicted in Figure 2.

The first era is called the transformation era. Transformation refers to fundamental change involving advanced technologies to enable new concepts of operation that are implemented and institutionalized through collaborative organizational change. FIRST is one example of an advanced technology development program seeking to enable new concepts of operations for employing transformational capabilities to support future space flight operations.

In formulating and planning the FIRST program, three timeframe, or eras, are addressed.

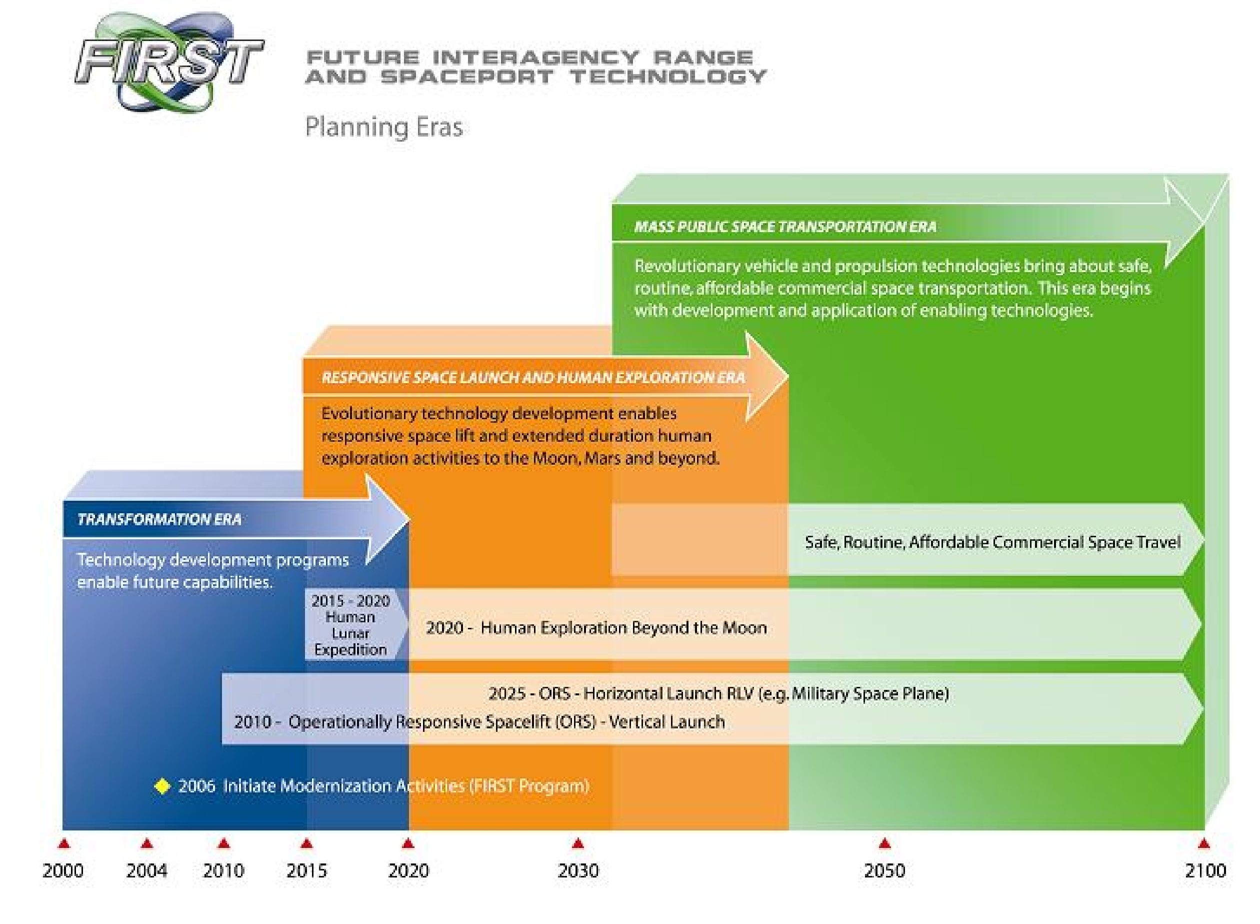


Figure 2. Future Space Transportation System (FSTS) Program Eras

As noted in Figure 2, such future space flight operations make the second era, or Responsive Space Launch and Human Exploration Era, possible. This era is poised to begin soon, with activities ramping up on a schedule that overlaps with the current era. Within this overlap, future space flight operations will be enabled by the Operationally Responsive Spacelift (ORS) and Crew Exploration Vehicle (CEV) development efforts that began in the Transformation Era. These capabilities enable prompt global strike in support of military objectives as well as human space exploration of the moon, Mars, and beyond.

The third era, the Mass Public Space Transportation Era, is envisioned to dominate the latter half of this century. It is distinguished by safe, routine, affordable commercial space travel—much like air travel today. In this era, it is anticipated that space transportation will become an integral part of the global mass public transportation system of the future. Such capabilities are recognized as being both visionary and revolutionary in terms of their ability to significantly improve the ability of future generations to rapidly move people and goods when and where they are needed anywhere in the world.

3.0 ASSUMPTIONS

This CONOPS is based on several key assumptions:

A variety of new space transportation vehicles and programs will be deployed and operated concurrently in the coming decades.

- *Programs now underway in the civil, national security, and commercial space sectors will lead to new space transportation vehicles and activities, including NASA exploration of the moon, Mars and beyond, operationally responsive space (ORS) activities for national security, and commercial sub-orbital reusable launch vehicle (RLV) flights to carry passengers to, through, and from space. Collectively these new types of vehicles and operations will drive the need for a FSTS made up of spaceport and range capabilities and various control centers linked together by a Central Control Function. To support these future vehicles, the FSTS must be more responsive than today's spaceport and range capabilities, and capable of providing global connectivity using standardized and interoperable systems to support multiple concurrent operations involving different types of vehicles at a variety of locations while cost-effectively accommodating fluctuations in projected workload.*

The trend in future space flight operations will be toward "airport-like" operations similar to today's national air transportation system and space flight operations in the third era resemble today's air transportation system.

- *As space travel and access to space become more routine (with new vehicles, increased traffic, and concurrent operations), traffic and capacity will increase. This will push the operating model toward standardization for pre-flight preparation, departure and return. Pre-approved flight paths and regulation of space travel will become mandatory to ensure orderly, safe transportation to, through, and from space while ensuring safety of life and property. In the third era, space flight operations are expected to include frequent point-to-point flights to transport people, payloads, and cargo. Space flight operations are envisioned to be an integral part of the world's transportation capability.*

Traditional functions provided by today's ranges, spaceports and operations organizations will merge into a comprehensive, integrated FSTS.

- *Traditional definitions, and the strict delineation of functions that are today assigned to ranges, spaceports or space flight operations will blend together more seamlessly as future developments lead toward a global space transportation capability. While each of the traditional functions will still be performed, future vehicles and activities are expected to require global coverage in support of point-to-point operations to and from a variety of locations around the world. This will drive the evolution of traditional functions toward a more integrated set of capabilities.*

In the Mass Public Space Transportation Era, launch vehicle reliability will approach that of current airline reliability.

- *Future sub-orbital and orbital reusable launch vehicles (RLVs) will be so reliable as to be able to fly over populated areas without elevating risks to public* *safety above the currently acceptable levels associated with commercial air traffic today.*

Space flight operators participate in or perform operations functions during the lifecycle associated with the space flight operations.

- *Personnel specifically dedicated to performing functions or tasks in support of a particular space flight operation include flight crew, planners and schedulers, flight controllers, trainers, vehicle and payload processing and range operations controllers. Personnel who operate shared supporting range, spaceport and operations support functions (e.g., maintenance, modernization, infrastructure support functions, etc) not needed to support a specific flight are not considered space flight operators.*

Space flight operations includes the phases of a mission that relate to preparing for and conducting transportation to, through, and from space near the vicinity of Earth.

- *Space flight operations include all tasks performed in the course of preparing a vehicle, payload, cargo, crew, and passengers to conduct a space flight operation. It also includes establishing requirements for the flight, scheduling assets to meet them, ensuring all FSTS elements are ready to support, and supporting actual space flight operations including final commit to launch, countdown, launch/departure, reentry, landing or recovery, and post-flight activities.*

- *In some cases, the "mission" is to provide transportation, so in these cases the "mission" is completely encompassed by the term "space flight operations." (This is analogous to civil aviation and commercial airline operations today where the "mission" is transportation.) Examples in this category where "space flight operations" address the entire "mission" include:*

  - *Flights of commercial reusable launch vehicles to deliver passengers and/or cargo from point to point*

  - *Operationally responsive space (ORS) missions conducted by the national security space sector to deliver sensor platforms and/or munitions to target areas on short notice*

  - *Flight test and evaluation (T&E) missions*

- *In other cases, the "mission" itself includes more than the "space flight operations" (or near-Earth space transportation operations conducted over a period of hours) addressed in this CONOPS. For example:*

  - *Satellite processing and expendable launch vehicle operations are included in "space flight operations," along with the launch itself. However, the actual "mission" is to operate the satellite for a period of days to years once it reaches its intended orbit. This CONOPS does not address the mission of the satellite while it is operating in Earth orbit.*

  - *NASA missions to conduct experiments in low Earth orbit, to conduct operations associated with the International Space Station, and to explore the moon or Mars (with or without a crew) include "space flight operations" to get to and return from LEO, and those activities are* *addressed in this CONOPS. However, the "mission" itself is conducted in or beyond low Earth orbit over a period of days to years so it is not addressed by this CONOPS.*

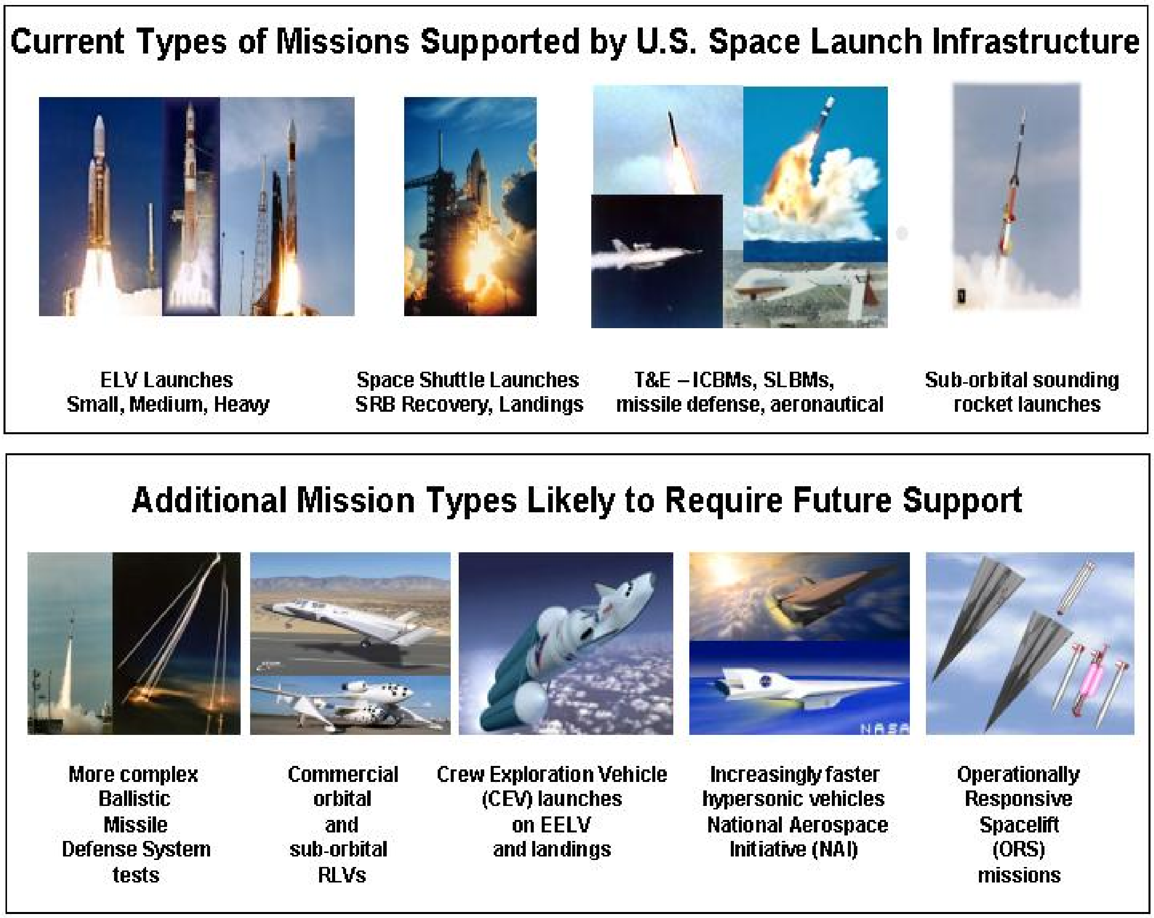
Shared use of common infrastructure makes standardization an important consideration.

- *The expectation is that space flight operations in the third era will share use of facilities and infrastructure for support, enabling shared use of various types of facilities, instrumentation, command, control, and communication systems, etc, among other things.*

4.0 DESCRIPTION OF ARCHITECTURE

The future space flight operations architecture must accommodate the same types of test and operational activities that are supported today, plus a variety of additional space flight operations and activities as illustrated in Figure 3 and described in the ***FIRST Program Needs Assessment*** associated with this CONOPS.[1]

Accommodating the variety of projected future activities will drive needs for new approaches to space flight operations.



Source: FIRST Needs Assessment

Figure 3. Current and Future Space Flight Operations

Future Operationally Responsive Spacelift (ORS) missions for national security, crew rescue missions, and emerging Suborbital Reusable Launch Vehicles (RLVs) for space tourism are all likely to drive needs for more responsive spaceport, range, and operations support. New spaceports in non-traditional locations, hypersonic flight testing, and more operationally realistic ballistic missile defense testing will drive needs for hemisphere-scale coverage to provide tracking and communications. ORS missions will require global coverage to enable re-targeting or mission aborts. New missions (especially for test and evaluation) will transmit telemetry data at higher rates at the same time as other users of the frequency spectrum are also continuing to expand their interests and demands for bandwidth, driving needs for improved use of frequency spectrum. Standardization and interoperability will be essential to efficiently accommodate the routine operations being conducted by diverse users of the future space transportation system with shared-use infrastructure. Approaches to ensuring safety will also have to be enhanced to accommodate routine operations of diverse flight vehicles (including NASA crewed missions for exploration) flying over population centers on their way to and from a variety of new and traditional spaceport locations. Flexibility and adaptability in the design and operation of the future space transportation system will enable it to efficiently accommodate fluctuations in workload, new and diverse activities, and unanticipated future capabilities. Supporting routine operations at high flight rates will require the FSTS to have the capacity to support concurrent operations, just as today's airports routinely support multiple simultaneous flights and numerous ground operations.

To support new types of space flight operations and associated activities, future systems take advantage of an open architecture, interoperability, and standards (as appropriate) to enable the transition of new systems, technologies, and capabilities into operational use as they become available.

The Space Flight Operations architecture consists of a network-centric capability to coordinate and control space transportation assets and activities around the world using a variety of control centers and user facilities connected through a Central Control Function.

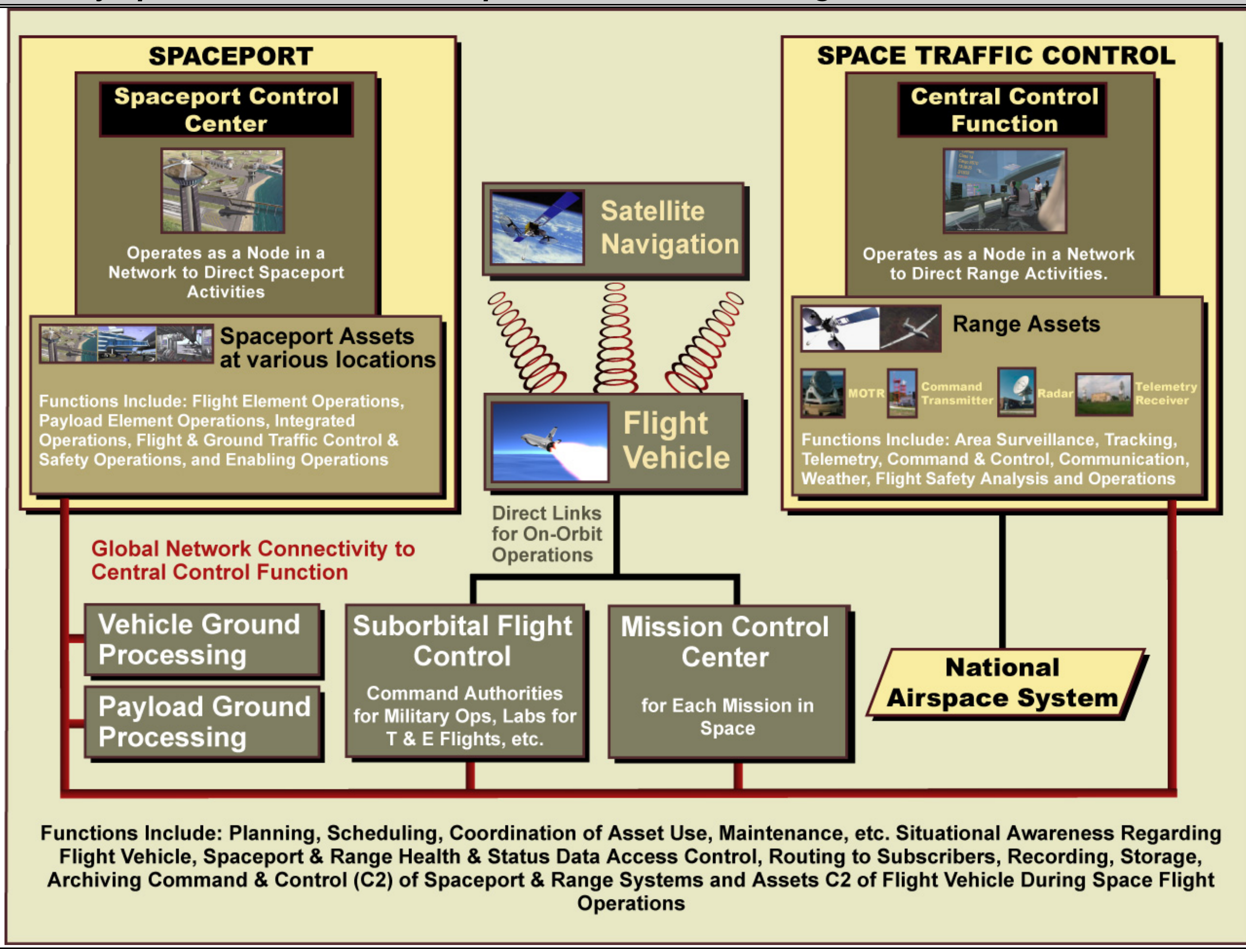


Figure 4. Conceptual Architecture to Support Space Flight Operations

As shown in Figure 4, the primary elements of the future space flight operations conceptual architecture are:

- Spaceports at various locations around the world, operating as nodes in a global network.
- Global space launch and test range assets, including shared-use satellites and airborne platforms, plus ground-based assets at various locations.
- The Central Control Function—an integrated, centrally-managed, network-centric capability to coordinate support for space flight operations by acting as an information clearinghouse on a global network, and to control range assets around the world in support of space traffic control.
- A hierarchy of control centers and associated controllers to manage the various operational aspects of space flights and interface with each other to maintain seamless and safe flight operations throughout all phases and altitudes of the flight, from operations within the National Airspace System to operations beyond low Earth orbit.
- User Facilities, including those that are operated by a flight vehicle owner, a payload owner, command authorities for military operations (like operationally responsive space flights), laboratories and program offices that are conducting test and evaluation, and others as required to support particular space flight operations. In some cases, User Facilities also support on-orbit operations using a direct interface through a Mission Control Center for particular space flight operations.
- Automated planning, scheduling, coordination systems supported by automated decision support tools to provide course of action options and recommendations based on modeling, simulation and analysis of potential implications.
- A variety of sensor systems, and self-diagnosing, self-reconfiguring, and self-healing vehicle and support systems to provide situational awareness information through the global network.
- Improved telemetry, command, control, monitoring, and communication systems to provide:
    - Continuous data access control, routing, recording and archiving from spaceport and range assets and flight vehicles.
    - Command and control of spaceport/range assets worldwide
    - Bent-pipe routing of command and control data from control centers to flight vehicles during space flight operations

An essential part of the vision for future space flight operations described in this CONOPS relies on the Central Control Function and the hierarchy of control centers. These elements play integral parts in the ways space flight operations functions are conducted. The following sections discuss these, and the other elements of the conceptual architecture, in detail.

4.1 Conceptual Architecture

4.1.1 Planning, Scheduling, and Coordination

Future space flight operations rely primarily on a centralized, network-based automated planning, scheduling, and coordination system that's accessible through the Central Control Function to integrate and coordinate the schedules for use of all spaceports, ranges, and control centers to ensure one planned activity will not impact another.

As illustrated in Figure 5, the conceptual architecture for the planning, scheduling, and coordination function consists of an integrated suite of automated, network-based processes and capabilities to enable all users of range support to interactively access the centrally-managed, automated schedule to understand and stay abreast of schedule constraints and availability. This conceptual architecture also allows users and operators to enter information through secure network connections regarding their planned activities involving space flight operations and off-line maintenance, modifications, and upgrades of spaceport and range assets.

Planning, scheduling, and coordination systems rely on automated decision support tools.

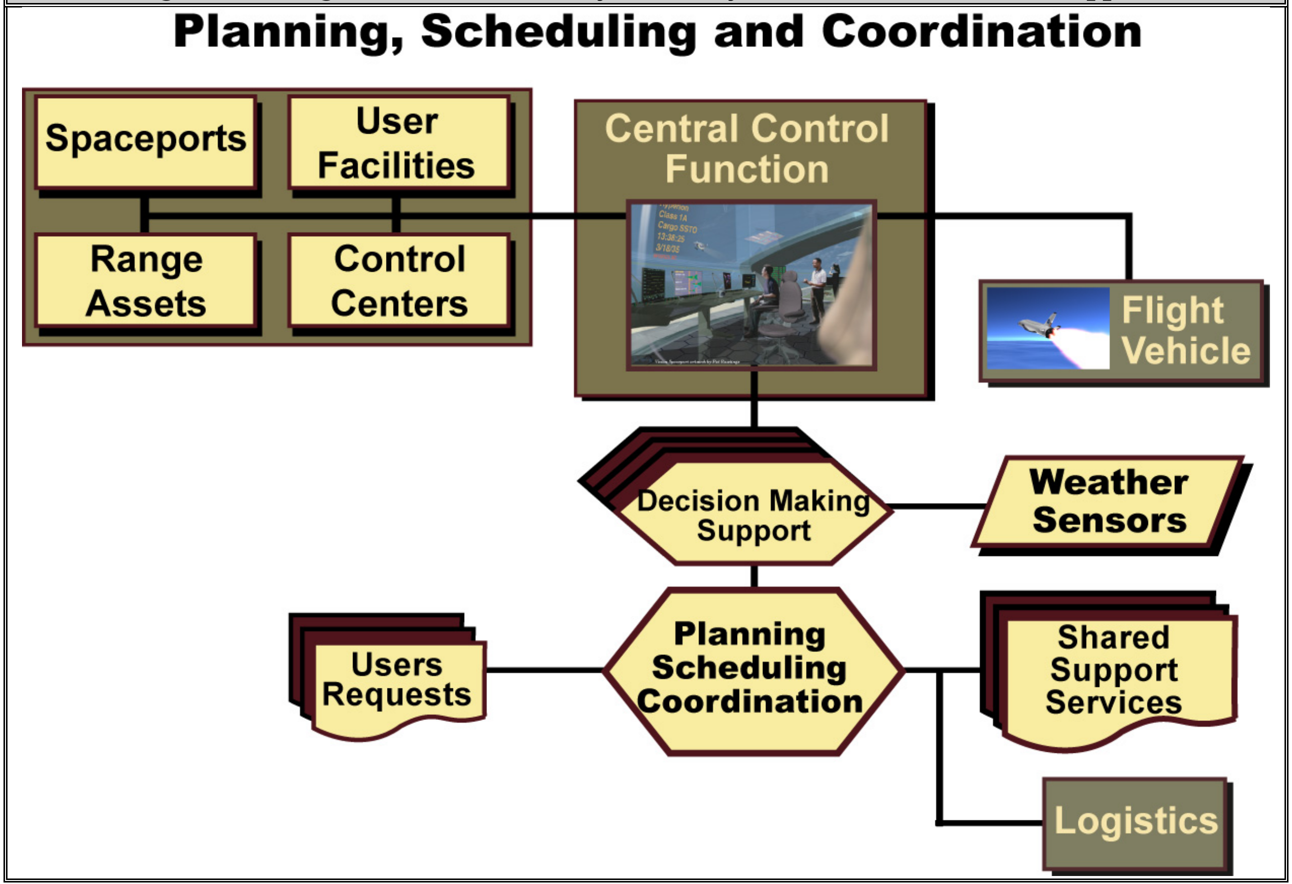


Figure 5. Conceptual Architecture for Planning, Scheduling, and Coordination

The automated planning and scheduling system consists of advanced software programs that accept user and operator inputs using standard Internet protocols through the global network. The automated scheduling system processes these inputs by taking into account real-time constraints and historical trend data through the global network to calculate plans and schedules for use of spaceport and range assets. This system relies on high-speed computing capabilities based on increasingly fast commercial processors, embedded coding, and serializer/deserializer (SerDes) chips[2] and associated protocols.

This automated system generates schedules for spaceport and range assets to support of space flight operations and for off-line maintenance, modifications, and upgrades. The scheduling software automatically coordinates operations, maintenance, modifications and upgrades with the automated logistics system and shared support services. This automated scheduling capability is enabled by commercial schedule de-confliction engines, data fusion and information extraction/mining techniques being developed by the U.S. military for processing intelligence data, and learning databases with applications in lossless data compression techniques.

The end result is that the software automatically produces and regularly updates an integrated (and de-conflicted) schedule for the use of all spaceport and range assets as its output on the global network. It also notifies and keeps users, operators and maintainers informed through the global network regarding any changes to plans and schedules that involve them.

The automated planning, scheduling, and coordination system is supported by automated decision support tools to provide course of action options and recommendations based on modeling, simulation and analysis of potential implications. The scheduling function uses these automated decision support tools to automatically assess plans and schedules for range asset capacity and availability based on all user and operator requests, as well as maintenance and repair schedules and other constraints. These decision support tools rely on more complete input data based on empirical information regarding flight vehicle performance, potential toxic and debris hazards, environmental sensitivities, population density and location, traffic patterns, and weather conditions. They also rely on advanced modeling and simulation programs based on expert systems and artificial intelligence, including three-dimensional dispersion models and propellant combustion models, for example.

The automated scheduling system also enables users and operators to coordinate flight profiles with proper authorities to ensure that each space flight operation will be conducted safely without impacting other scheduled air and space traffic.[3] This capability is enabled by ensuring all control centers have continuous and secure access to the high-capacity global communication network that's managed by the Central Control Function.

4.1.2 Situational Awareness

As shown in Figure 6, a variety of weather sensors, area surveillance systems, and integrated health monitoring systems aboard vehicle and embedded in spaceport/range systems provide information through the global network where it is fused and distributed as integrated situational awareness information through the Central Control Function. Weather measurement and forecast information is provided by a central hub facility based on integrated inputs from a variety of site-specific and regional weather sensors and models. Weather measurement and forecasting capabilities rely to a large extent on cooperative arrangements with external providers for sensors, instrumentation, systems, data, formats, and models. The centralized hub function analyzes and provides display data from weather radars, satellite imagery, and a variety of sensors to provide forecasts and hazardous weather watches, advisories, and warnings for ground processing, launch, flight, landing, and recovery operations.

The Central Control Function provides situational awareness information by integrating weather, air traffic and system health and status inputs.

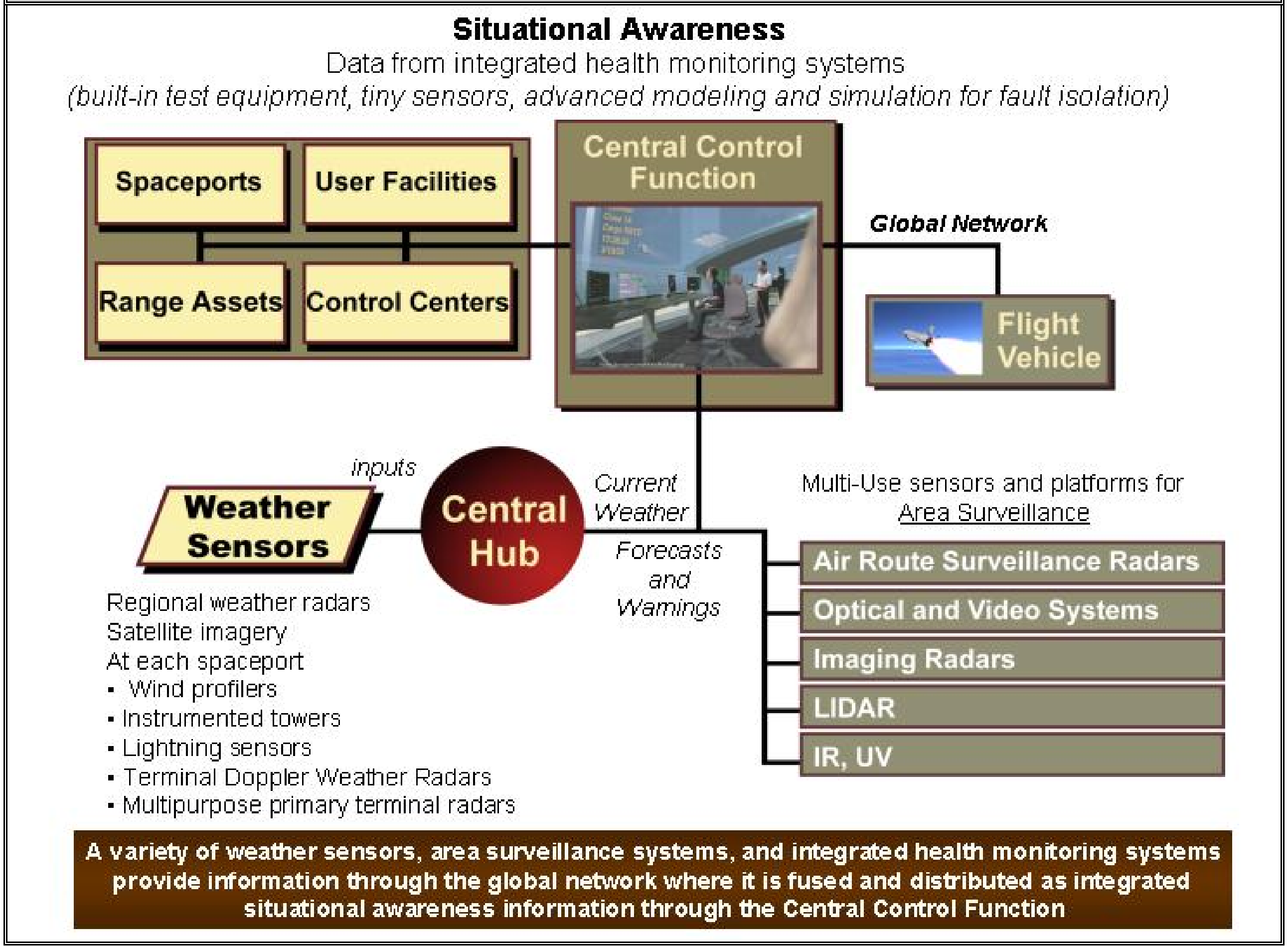


Figure 6. Conceptual Architecture for Situational Awareness

Systems in the vicinity of each primary takeoff/launch/landing/recovery site to collect weather data include ground-based and mobile airborne wind profilers; instrumented towers with sensors from 6 to 500 feet above ground level to gather enough wind, temperature, humidity and pressure data to provide inputs for mesoscale weather models; sensors to detect, measure, and predict the potential for lightning, including surface and airborne electric field mills, airborne optical pulse sensors, peak-gated, wideband magnetic direction finders (MDF), and VHF receiver sites to detect radiation from inter-cloud and intra-cloud lightning. Re-tuned Terminal Doppler Weather Radars (TDWR) and multipurpose primary terminal radars at each active takeoff/launch/landing/recovery site also provide weather data.

Area surveillance data for safety, security, and mission assurance in any potentially hazardous land, sea, or airspace areas, and along the entire intended flight path, is provided by a variety of multi-use sensors and platforms. Examples include ground-based air route surveillance radars, as well as various systems that can be ground-based or mounted aboard UAVs or high-altitude airships (HAAs). Examples include optical and video systems, imaging radars, LIDAR to detect objects through smoke and clouds, and detection/imaging systems that operate at other wavelengths (e.g., IR, UV). Data from these various systems and sources is fused to provide real-time situational awareness with regard to air traffic in areas of interest.

Spaceport and range systems, as well as flight vehicles, include integrated health monitoring systems to continuously generate and report status and needs for maintenance and repair through their connections to the global network. These capabilities are enabled by built-in test equipment to perform fault detection and isolation as inputs for self-diagnostic systems. Micro-electromechanical sensors, enabled by nanotechnology, make these systems practical. Advanced modeling and simulation capabilities (based on expert systems, learning databases, and artificial intelligence) better predict component and system failures as means of enhancing the self-diagnostic capabilities.

4.1.3 Data Access Control, Routing, Recording and Archiving

Another element of the conceptual architecture for future space flight operations is the global network that's managed by the Central Control Function. This global network routes all the data that flows to and from spaceport and range assets in real time, controls access to restricted data, routes data (as requested) to valid network subscribers, and records, stores, and archives data for later retrieval. The design of this global network addresses information assurance (IA) by ensuring its systems and networks provide:

- Availability: assured and timely access to data and information services for authorized users.
- Data Integrity: protection of data to ensure it has not been destroyed, changed, modified, or altered from its original state as a result of any unauthorized, accidental, or malicious action.
- Authentication: security measures designed to establish the validity of a transmission, message, or originator, or as a means of verifying an individual's authorization to receive specific categories of information.
- Confidentiality: assurance that information is not disclosed to unauthorized persons, processes, or devices.
- Non-repudiation: undeniable assurance that the sender of data is provided with proof of delivery and the recipient is provided with proof of the sender's identity, so neither can later deny having received or processed the data.

The network addresses these IA principles by using improved encryption and defense-in-depth strategies, enhanced firewalls and password protection, screening software and intelligent agents, and technologies for detecting and tracing attempts at system intrusions (e.g., biometrics).

The FSTS relies on interconnected information systems, which results in sharing of security risks among all interconnected elements. Consequently, coordination of IA efforts across all systems, operators, and users is important to maintain adequate security.

The communication architecture to support future space flight operations relies primarily on ground-based networks for data transfer among ground-based locations, with some long-distance data relay provided using space-based assets. The range communication system of the future can relay data at rates up to 40 Gbps through space-based and mobile assets, while ground-based networks are handling data at rates in the tera- (i.e., trillion, or 10^{12}) bits per second. The most economical approach for this future architecture is to share use of communication relay satellites with other users to offset the costs associated with development, acquisition, deployment, and operation.

In addition, local area networks within spaceport facilities include wire, cable, umbilical, fiber optic, and wireless (e.g., IR, ultra-wideband, etc) connections to provide interfaces between launch vehicles/payloads/cargo and ground support equipment, and to connect all of these elements to the global network.

4.1.4 Command and Control of Spaceport/Range Assets and Flight Vehicles

The same ground network and satellites that make up the communication architecture also provide continuous, redundant global coverage for the relay of command and control data to spaceport and range assets as well as flight vehicles. Command and control includes the ability to (1) manually, automatically or autonomously abort or terminate flight when a vehicle equipped with a flight termination system (FTS) poses unacceptable risk to people or property, (2) provide remote guidance, attitude, payload control, and other uplink communications functions for some vehicles, and (3) configure, position and operate range assets to support operations or perform maintenance from a remote location. (Some vehicles—particularly reusable vehicles designed to carry people—include autonomous capabilities for intact abort and emergency landing instead of flight termination systems.)

The ground network and satellites are used to provide "bent pipe" relay services for sending data and information to operators providing and overseeing command and control of flight vehicles during the transportation phases of each space flight operation. The Central Control Function provides this "bent pipe" command and control relay service from start to finish for some space flight operations, including for example:

- Suborbital flights when the purpose is to transport people and/or cargo from point to point. In some cases, the flight crew may pilot the vehicle according to a pre-approved flight profile and (to the extent possible) to comply with instructions from control centers with proper authority.
- Some military operationally responsive space (ORS) missions, including prompt global strike (PGS) and other activities with sufficiently short duration as to make a transfer of operational responsibility impractical during the course of the space flight operation.
- Flight test and evaluation (T&E).

The ***FIRST Spaceport CONOPS*** further explains that "the spaceport shall provide the management and organization framework necessary to effectively oversee all spaceport operations to maintain an operationally effective, technologically advanced and financially viable base of operations in support of program and mission operations."

4.2 ORGANIZATIONAL ARCHITECTURE

The control of space flight operations is aligned and organized to facilitate coordinated interactions among the Central Control Function, various types of control centers, and the flight vehicles themselves, including their crews when applicable. This section explains the major roles of each of these control centers, including the Central Control Function.

4.2.1 Central Control Function

One of the primary elements of the conceptual architecture for future space flight operations is the Central Control Function. The Central Control Function is an integrated, centrally-managed, network-centric capability to coordinate and manage access to shared-use space transportation assets around the world during flight phases associated with transportation—launch, takeoff, reentry, and landing.

The network-centric Central Control Function is at the core of the concept for future space flight operations that are enabled and supported by future spaceports and the envisioned global space launch and test range. It is one of the most fundamental distinguishing features that enable future operations to be conducted more efficiently and responsively than today's systems by enabling concurrent operations and increased operations tempo. Without a Central Control Function, it will be difficult to build an integrated system that coordinates the operations of new users with existing users with sufficient capacity to enable and support more ambitious and frequent space launch and flight test activities.

The Central Control Function directs range operations and coordinates spaceport support by providing a central clearing house for situational awareness information. Operating as a node in a global network, it provides a variety of services using network-based user interfaces, and automated intelligent decision support systems to produce information for output displays. Its major focus is directed toward safely and efficiently managing the use and condition of spaceport and range assets, while also serving users' information needs on a subscriber service basis.

The Central Control Function provides central repository and clearing house roles in support of space flight operations.

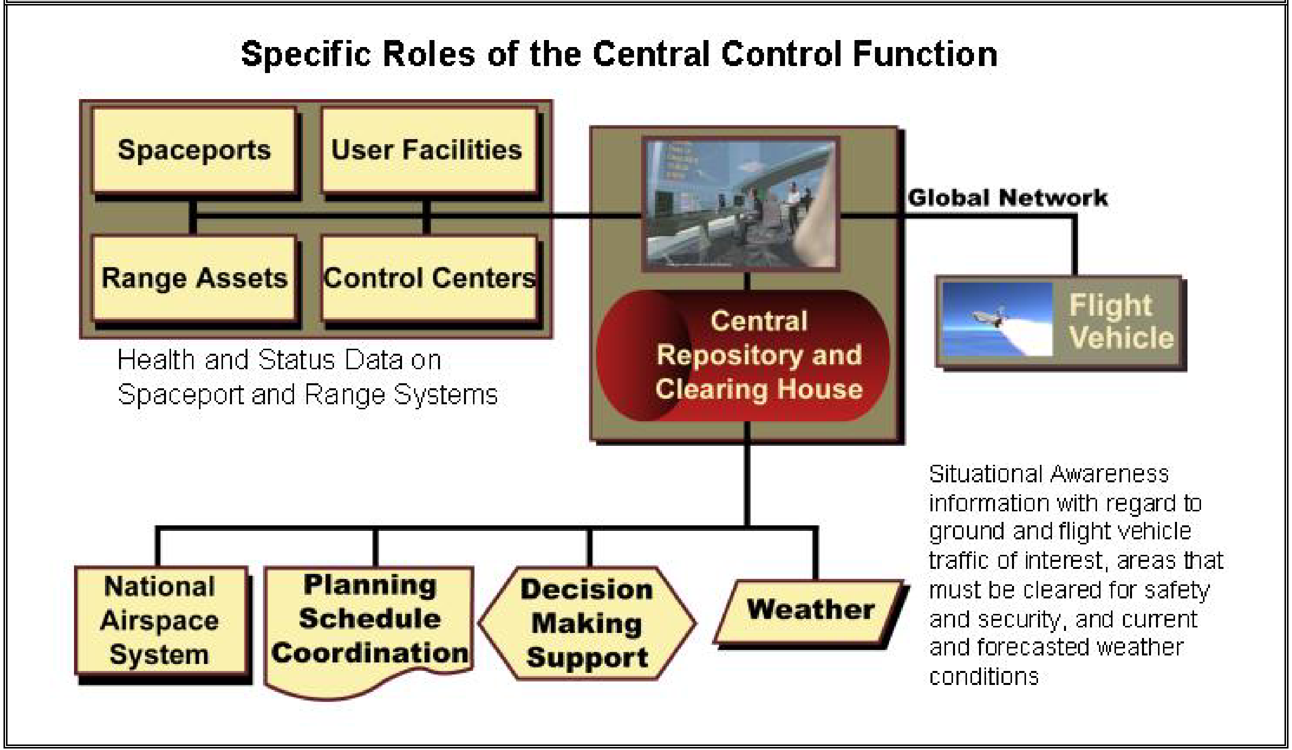


Figure 7. Specific Roles of the Central Control Function

As illustrated in Figure 7, the specific roles of the Central Control Function, and the technical capabilities that enable them, include:

- Acting as a central repository and clearing house for information pertaining to the health and status of flight vehicle, spaceport and range systems, except for those spaceport systems that are only used to support ground processing between flights. (Those facilities are managed by the Spaceport Control Center at each spaceport.) This capability is enabled by advanced network management technologies being developed for the next-generation Internet, and new optical, magnetic, and hybrid data storage technologies (e.g., blue laser/fast optical readout, patterned magnetic media, silicon and anti-feromagnetically coupled arrays).

- Acting as a central repository and clearing house for situational awareness information with regard to ground and flight vehicle traffic of interest, areas that must be cleared for safety and security reasons, and current and forecasted weather conditions. This capability is enabled by on-board and satellite-based navigation to generate tracking information, a primarily space-based telemetry receiving capability providing global coverage, a network of ground-based and airborne weather sensors coupled with sophisticated meso-scale models, an integrated suite of modeling and simulation tools based on expert systems and artificial intelligence to take real-time and historical data into account to generate and evaluate alternative courses of action and present recommendations to support decisions, and a high-capacity global communication network to distribute this information.

4.2.2 Hierarchy of Control Centers and Controllers

Another element of future space flight operations is a hierarchy of control centers and the controllers who operate them. These control centers and controllers manage the various operational aspects of space flights and interface with each other to maintain seamless and safe operations throughout all phases of a space flight operation, including transitions through the National Airspace System on the way to and from space.

The FSTS architecture relies on a hierarchy of control centers to conduct safe, reliable, and routine space flight operations.

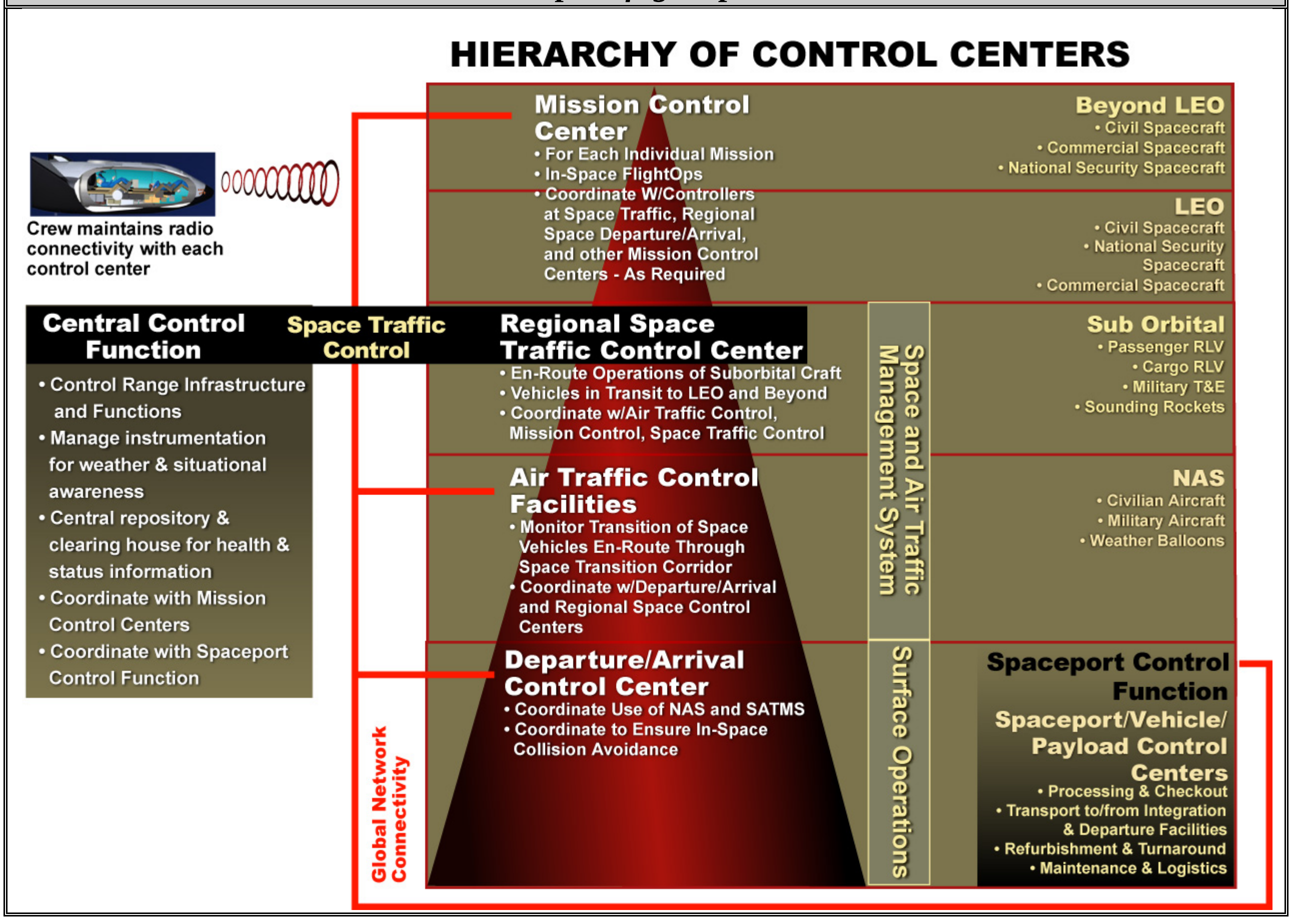


Figure 8. Hierarchy of Control Center Functions

Space flight operations rely on a distinct set of functions accomplished by a hierarchy of control centers and controllers. These control centers are linked through a global network to facilitate interfaces through the Central Control Function.

As depicted in Figure 8, in addition to the Central Control Function, there are five different types of control centers involved in managing the operation of space flight vehicles and their payloads, cargo, and passengers:

- Vehicle and Payload Processing Control Centers (i.e., space vehicle operators) interact with the Spaceport Control Center to coordinate all surface operations, including control of the pre- and post-flight processing and checkout of flight vehicles and payloads, along with movement between facilities, and maintenance and logistics between flights. The Spaceport Control Center controls the spaceport infrastructure involved in supporting surface operations.
- Departure/Arrival Control Centers (DACC) coordinate range support, use of the National Airspace System (NAS), and information on collision avoidance with objects in space for departing and arriving flights.
- Air Traffic Control Facilities (ATC Facilities) coordinate and manage use of the National Airspace System (NAS) to ensure that space flight vehicles transiting the NAS on the way to or from space can be safely integrated with scheduled air traffic.
- Regional Space Traffic Control Centers (RSTCC) monitor, coordinate and manage flights to, through, and from space, to ensure that flight vehicles operating in or through space can be safely accommodated along with other vehicles flying in space, while avoiding debris hazards.
- Mission Control Centers (MCC) for space flights that include operations in orbit, include dedicated links for voice, video, and data connectivity to flight vehicles to provide tracking, telemetry, and commanding for national security, civil, and commercial satellites, deep space probes, and crewed missions in orbit, to the Moon, and beyond.

To effectively implement the concept of a hierarchy of control centers, each space flight operator—and the flight crew (if applicable)—must fully understand and act within the bounds of clearly-established roles, responsibilities, and procedures commensurate with the bounds of their authority. For instance, all space flight operations are managed by control centers with jurisdiction over specific flight regions:

- On the surface of the Earth (Vehicle and Payload Processing Control Centers)
- Through the NAS (Departure/Arrival Control Centers, in coordination with Air Traffic Control Facilities)
- On suborbital trajectories (Departure/Arrival Control Centers, in coordination with Regional Space Traffic Control Centers)
- In LEO (Mission Control Centers, in coordination with Regional Space Traffic Control Centers)
- Beyond LEO (Mission Control Centers)

As depicted by the shape of the pyramid in Figure 8, a greater number of control centers are required to control traffic at lower altitudes because the volume of traffic is greater in these regions and flight operations in these regions have a more immediate potential to impact public safety if there is an incident or accident. In LEO and beyond, fewer control centers are required to support space flight operations because there is less total traffic in a much larger volume of space, and orbiting objects are less likely to impact public safety as immediately as flight vehicles operating along suborbital trajectories or in the Earth's atmosphere (i.e., during launch and reentry).

For this hierarchy of control centers to function effectively, rules and regulations are established to accommodate frequent space traffic, a variety of spaceports, various types of vehicles, and additional control centers of each type as they become operational. These rules and regulations define roles and responsibilities, the boundaries of space flight regions (suborbital, LEO, beyond LEO, etc.) and clearly distinguish the authority of each control center.

Each type of control center has its own region of authority.

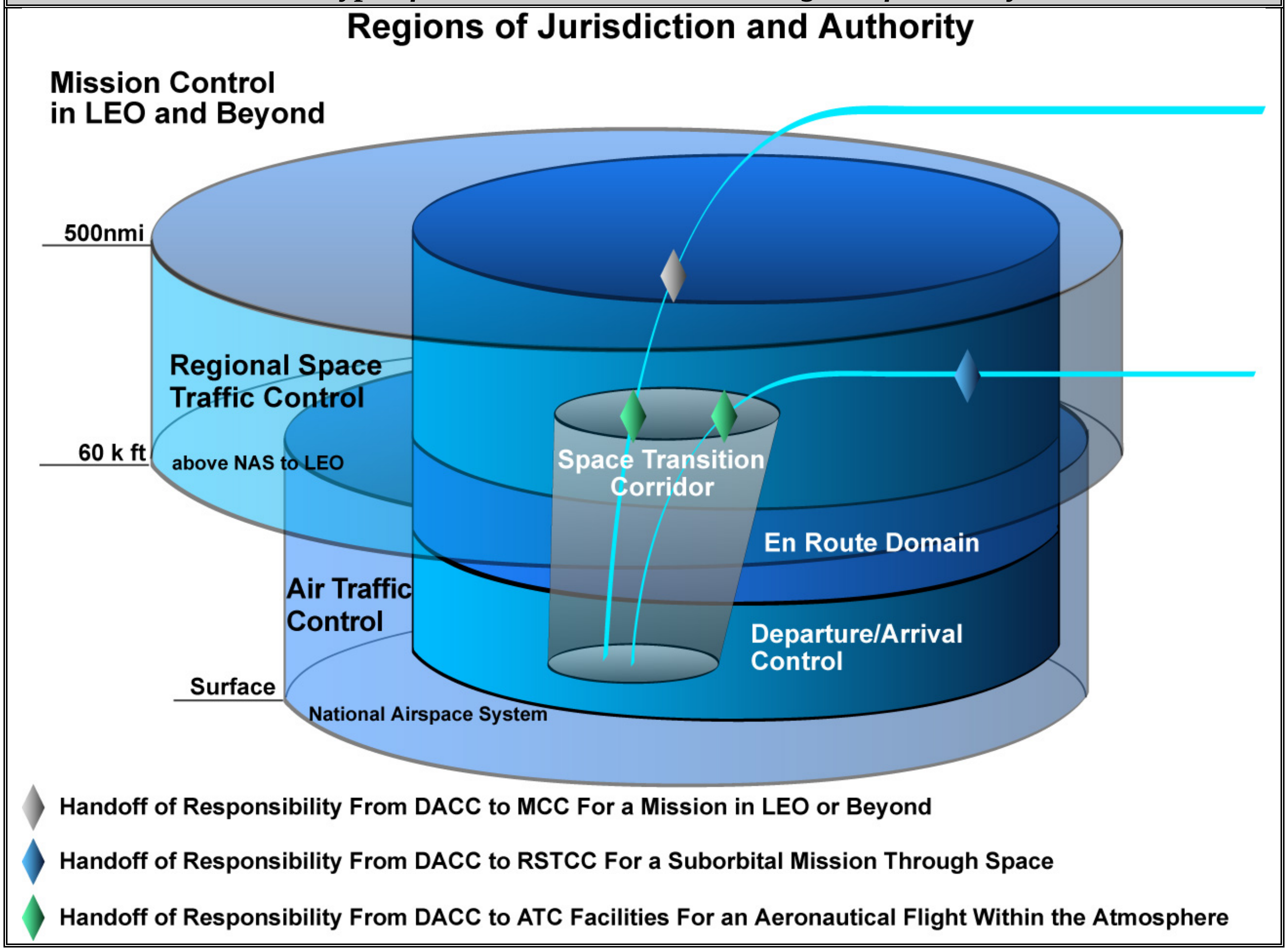


Figure 9. Regional Authority for Each Type of Control Center

The boundaries of authority for each type of control center are illustrated in Figure 9.

The control centers maintain contact and actively work with each other. These rules and regulations enable operators to work more smoothly with each other based on a common understanding of each control center's authority and the appropriate protocols for transferring and receiving control of a space flight vehicle.

All of the control centers supporting space flight operations are connected through a global network that's managed by the Central Control Function, so their physical locations are not as important as their functions. In some cases, control centers are located in proximity to each other, or to physical takeoff/launch/landing/recovery sites, but there is no strict requirement that they be co-located.

For vehicles that carry a crew, the pilots and support crew are assisted by various controllers on the ground to control the flight of the vehicle during all phases of its space flight, to include launch or takeoff, ascent, suborbital flight, reentry, return flight, and landing or recovery on Earth. The degree of control in the hands of the crew varies depending on the type of vehicle and operation. In some cases, flight crew operations are predominant, while in other cases, more control may be exerted by automated systems on board the flight vehicle or from one or more of the ground-based control centers.

The concept of functional regions and control centers accommodates and complements the Space and Air Traffic Management System (SATMS) concept where space flight and aviation operations are seamless and fully integrated. Some of the control center functions described here could be merged where practical and desirable, as determined by key stakeholders with proper authority. For example, a Regional Space Traffic Control function could be merged with the local NAS Air Traffic Control function to form one integrated air and space traffic management control center to support commercial suborbital RLV traffic within a particularly active region.

The following subsections discuss the functions of each of the types of space flight operations control centers and operators in more detail.

4.2.2.1 Vehicle and Payload Processing Control Centers

While the Central Control Function is the information and management hub for coordinating all spaceport, range, and flight vehicle activities, the functions associated with monitoring and controlling flight vehicle and payload/cargo/passenger operations on the Earth's surface are provided by Vehicle and Payload Processing Control Centers. These functions include flight vehicle and payload processing (including assembly) and checkout, transporting flight vehicles and payloads/cargo/passengers from one facility to another, taxiing on runways, integration of payloads/cargo/passengers with flight vehicles, refurbishment and turnaround between flights, maintenance and logistics.

Vehicle and payload controllers at the Vehicle and Payload Processing Control Centers are responsible for preparing space flight vehicles and payloads/cargo for flight. Vehicle controllers have a detailed understanding of the vehicle or payload systems and operational specifications and limitations. Vehicle and payload controllers are responsible for command and control of the vehicle or payload systems and related ground support equipment during preparation for flight. Vehicle and payload controllers are also responsible for planned maintenance and major modifications to their vehicles or payloads, as required.

Payload and cargo processing can be conducted at the manufacturing location, with the integrated health monitoring system keeping track of the system status from that point on. This enables compressed processing schedules at the launch site, streamlining payload and cargo handling.

The vehicle and payload processing control centers are connected to other control centers performing other functions through the network that is managed by the Central Control Function.

4.2.2.2 Departure/Arrival Control Centers (DACC)

A DACC is typically located at each active spaceport, though one DACC can provide the required functions for more than one spaceport. The DACC is responsible for managing the immediate pre-flight checkout (and countdown, if required), including coordination of all departure, flight plan approval, and landing activities with Air Traffic Control Facilities and

Regional Space Traffic Control Centers (RSTCC), including those that would support any emergency return/recovery/landing operations in the event of an abort early in the flight.

The DACC operators are analogous to Terminal Controllers in the air traffic control system, who control air traffic operating near airports. Terminal Controllers give pilots instructions for use of taxiways and runways for takeoff and landing. They also communicate routing and spacing instructions to pilots to ensure safe and efficient operations during initial departure and arrival near the airport. Once the aircraft depart the geographic area of responsibility near the airport, the Terminal Controller hands off responsibility for managing the traffic to an Air Traffic Control Facilities. Similarly, DACC operators are responsible for coordinating and issuing clearances for flight profiles and for communicating instructions to other control centers (and flight crews, as appropriate) to coordinate and control safe and efficient departure and arrival operations.

The DACC also operates as a node in the network controlled by the Central Control Function.

4.2.2.3 Air Traffic Control Facilities

In the future operational environment, ATC Facilities will be responsible for maintaining the safe and efficient flow of both air traffic and space traffic within the NAS. ATC Facilities work with DACCs and Regional Space Traffic Control Centers to ensure safe and efficient operations within the NAS as space flight vehicles depart and return on their way to or from space. ATC Facilities have the authority to impose airspace restrictions, reroute air traffic, instruct DACCs to hold space flight vehicles on the ground, or (in emergency situations) divert flight vehicles to alternate destinations, as means of accommodating space flight vehicle departure and return operations through the NAS.

Air traffic controllers are responsible for en route air traffic, receiving control of aircraft coming into their airspace from controllers at adjacent facilities. As aircraft operate en route between airports, Air Traffic Controllers communicate directly with flight crews to provide routing instructions, air traffic clearances and advice regarding flight conditions. Air traffic controllers ensure separation between aircraft in flight or operating in and out of airports not serviced by terminal (control tower) facilities. Air traffic controllers transfer control of aircraft to controllers in adjacent centers, approach control, or terminals, when the aircraft enters that facility's airspace. Air traffic controllers also interface with flight crews and Departure/Arrival Controllers to manage space flight operations as they move through the NAS.

ATC Facilities are connected to all other control centers as nodes in the network controlled by the Central Control Function.

4.2.2.4 Regional Space Traffic Control Centers

The Regional Space Traffic Control Centers (RSTCC's) primary responsibility is to manage suborbital space traffic within a designated geographic region as space flight vehicles transit orbital altitudes. The RSTCC's functions and responsibilities are similar to those of Air Traffic Control Facilities managing traffic within the NAS—to ensure safe and efficient traffic flow.

RSTCCs manage space flight operations along suborbital trajectories and coordinate in-space transportation operations to and from LEO and beyond. Similar to the ATC Facilities functions in managing the safe and efficient use of the NAS, the RSTCC has the authority to ensure adequate separation between planned flight profiles in space and orbiting objects. The RSTCC provides information on space weather, orbital object tracking, and warning notifications when conjunctions are possible.

Examples of suborbital space flight operations include commercial tourist and cargo transport flights, flight test and evaluation activities involving ballistic missiles, and operationally responsive space (ORS) activities conducted by the national security space sector to deliver munitions and/or intelligence, surveillance, and reconnaissance (ISR) payloads to a target location on Earth.

Six Regional Space Traffic Control Centers have defined geographic areas of responsibility for safe and efficient suborbital space flight operations around the world.

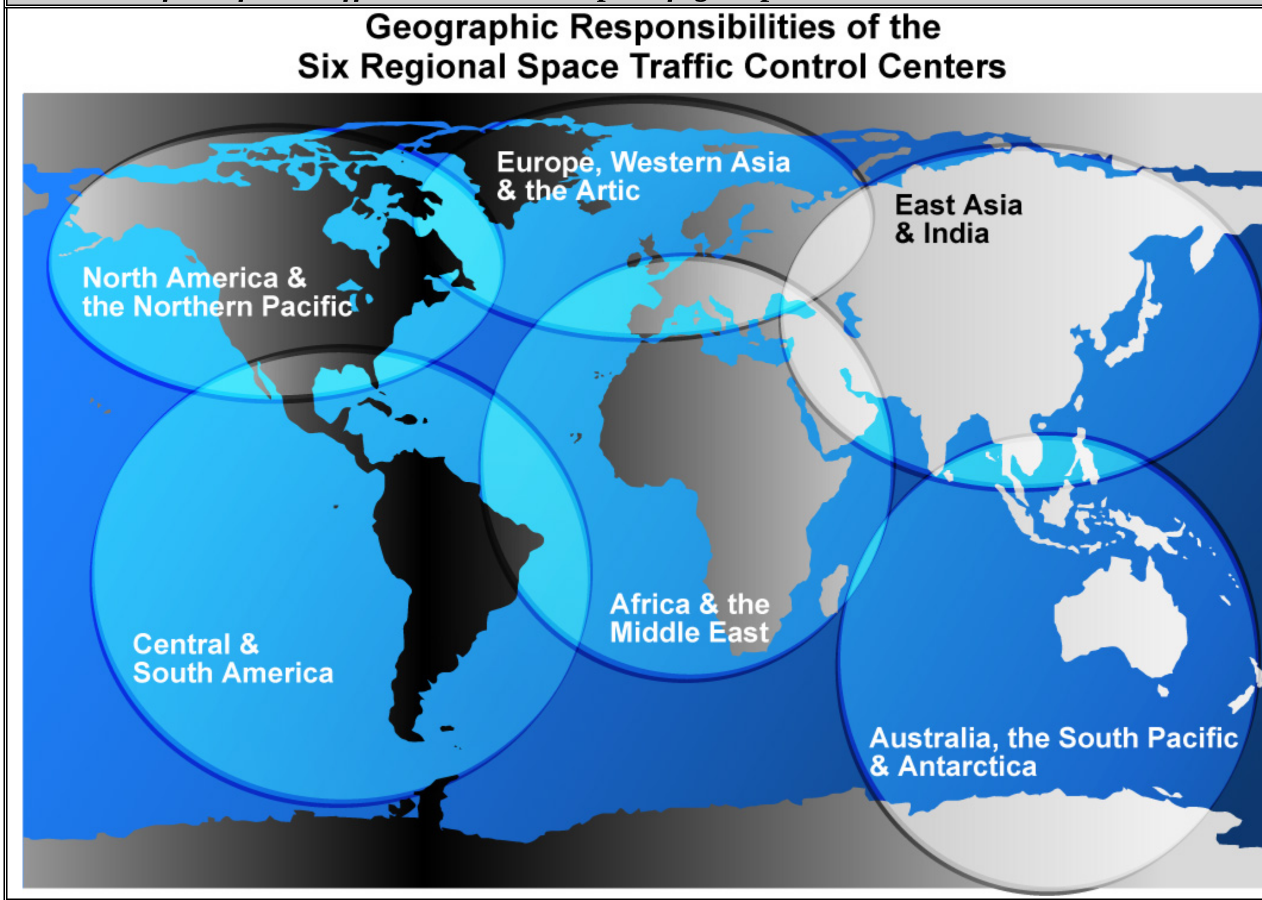


Figure 10. Geographic Responsibilities of Regional Space Traffic Control Centers

As illustrated in Figure 10, the initial architecture includes six RSTCC's, one for each of the following geographic regions:

- North America and the Arctic
- South and Central America
- Europe and Western Asia
- Africa and the Middle East
- East Asia and India
- Australia, the South Pacific, and the Antarctic

Each RSTCC works with ATC Facilities, Mission Control Centers, and Space Traffic Control Centers to ensure safety and ensure collision avoidance as space flight vehicles travel at altitudes where other vehicles are operating in LEO or beyond.

Space Traffic Controllers in RSTCCs monitor and coordinate all space transportation traffic in near-Earth space by providing instructions to flight crews and control centers (as appropriate) to ensure traffic separation. This includes issuing warnings when conjunctions are approaching among spacecraft, orbital debris and naturally occurring celestial bodies. Space Traffic Controllers interface with other controllers and space flight vehicle crews through the Central Control Function during departure and return operations, and through Mission Control Centers during on-orbit operations. Space Traffic Controllers interface directly with air traffic controllers, mission controllers, and crew during on-orbit operations.

Each RSTCC is connected to all other control centers through the Central Control Function for departure and return operations of vehicles traveling to space and back. For activities in orbit, the RSTCC has a direct link to the Mission Control Center for each flight to report pertinent data such as collision warning notifications.

4.2.2.5 Mission Control Centers

Mission Control Centers (MCCs) are responsible for managing the in-space activities associated with space flight operations in LEO and beyond for days to years at a time. (As discussed above, not every space flight operation has a Mission Control Center.) Mission controllers manning positions in these centers monitor systems and activities aboard space flight vehicles and payloads during satellite deployment and operation, retrieval, repair, human exploration, and in-space assembly or repair of structures in orbit or on planetary bodies.

Mission managers have the authority to make decisions about the status of a space flight operation during all phases of the space flight operations lifecycle. This includes certifying flight readiness of their flight vehicle, making the final launch commit decision and approving alternative courses of actions for unplanned events during flight. Not every space flight operation will have a mission manager. Mission managers will most likely be associated with civil, national security, and flight test activities. Commercial suborbital flights, being more similar to airline point-to-point flights, will not need the same formal flight readiness and launch commit approvals that are needed for civil and national security space flight operations.

During departure and return operations, the MCC’s connection to all other control centers goes through a node on the global network controlled by the Central Control Function. The MCC monitors and participates in the countdown.

Mission controllers staff Mission Control Centers in support of orbital space flights to LEO and beyond. Each mission controller is trained and certified in specifics of the on-orbit operational phase and the vehicle and payload systems for that mission. Each mission controller works as part of a mission control team to provide monitoring, communication, command, control and overall situational awareness during orbital mission operations.

In the case of space flight vehicles without a crew, mission controllers command and control the flight vehicle, its systems and payloads from the ground. For space flight vehicles that do include a crew, the mission controllers work in collaboration with the flight crew to carry out the specific objectives of the space flight operation.

The controllers in the MCC work actively with the flight controllers in the Departure/Arrival Control Center and the RSTCC until the vehicle safely reaches orbit. Once a flight vehicle is safely on orbit, the MCC retains primary responsibility for the space flight operations.

Before the vehicle reaches orbit, the MCC establishes direct communications and data links with the space flight vehicle, using separate paths and capabilities from those that are accessed and managed through the Central Control Function. From the time the space flight vehicle enters orbit until the vehicle prepares for reentry, the MCC maintains contact with the vehicle and/or crew to direct and/or assist in managing all of its in-space operations.

In the event a vehicle must return to Earth unexpectedly, the MCC works through the Central Control Function to inform the appropriate RSTCCs, ATC Facilities, and the DACC where the vehicle is expected to return, to plan and prepare for the vehicle's reentry and return flight, landing and recovery.

Mission controllers interface with flight controllers, mission managers, and space and air traffic controllers (as required) to coordinate the return flight of the vehicle (and crew) safely to Earth after its orbital operations are completed.

5.0 FUTURE SPACE FLIGHT OPERATIONS

While the previous section described the functions of the major elements that make up the future space flight operations conceptual architecture, this section describes the processes associated with performing future space flight operations. This section is divided into two parts:

- The first part describes future space flight operations during the first and second eras, characterized by transformation and responsive space launch/human exploration, respectively.
- The second part describes how future space flight operations are conducted for routine operational RLV flights operating as part of a global space transportation system in the third era, characterized by mass public space transportation.

Space flight operations are typically conducted to align with the six sequential phases depicted in Figure 11.

Space flight operations are typically conducted in six sequential phases.

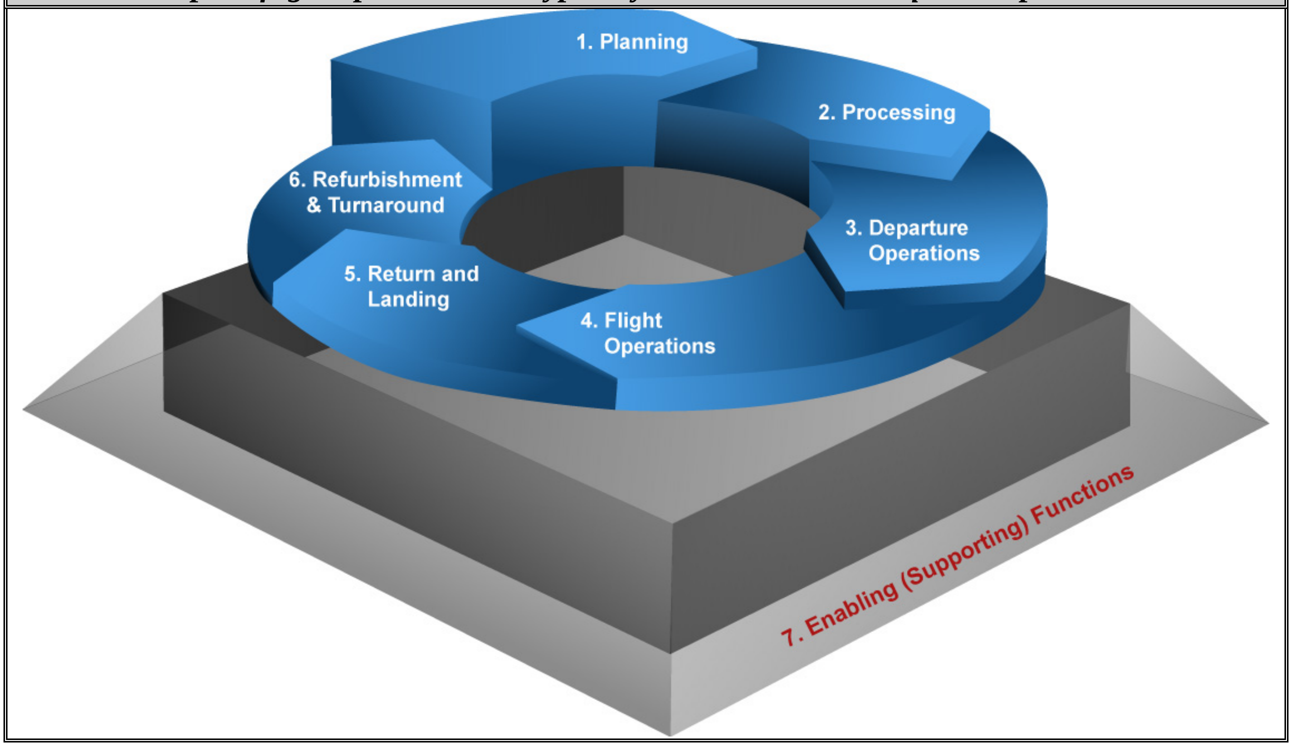


Figure 11. The Six Phases of Space Flight Operations.

As illustrated in Figure 11, there are six phases of space flight operations. The major functions in space flight operations are:

1. Planning space flight operations (including flight profiles) to meet requirements within applicable constraints, and scheduling the use of assets and resources to meet those requirements. This phase of activity also includes training and certification of various types of operators to work effectively in control centers within the bounds of their clearly defined roles, responsibilities, and authorities.

2. Processing, including coordinating, controlling, and supporting pre-flight ground operations to ensure that each flight vehicle and payload/cargo element, as well as crew and passengers (when applicable), are ready to fly.
3. Departure operations, including coordinating, (in some cases, controlling), and supporting initial flight operations in the vicinity of the takeoff/launch site.
4. Flight operations, including coordinating and supporting space flight operations between departure and arrival. In some cases, this also includes controlling in-flight operations (e.g., to conduct a prompt global strike). In other cases, it only involves monitoring the in-flight operations on an exception basis (i.e., in "notification" mode during the conduct of the space flight in LEO or beyond), to be prepared to coordinate support for return flight and landing/recovery in the event of an emergency or in-flight abort.
5. Arrival operations, including coordinating, (in some cases, controlling), and supporting flight operations in the vicinity of the landing/recovery site.
6. Refurbishment and turnaround, including coordinating, controlling, and supporting operations for each flight vehicle and payload/cargo element, as well as crew and passengers (when applicable) after each flight. This also includes data processing and analysis as well as post-flight reporting.

These six phases of space launch and flight test activities are explained in more detail in Appendix 1. Within each of these phases, several space flight operations functions are performed. These functions align with the phases as shown in Figure 12.

Phase	Space Flight Operations Functions
Planning	• Flight Planning and Scheduling • Training and Certification
Processing	• Flight Readiness Verification • Transportation Between Facilities
Departure Operation	• Countdown and Final Launch Commit • Launch/Takeoff and Initial Flight
Flight Operations	• In-flight activities • Monitoring in "Notification" Mode
Return and Landing	• Reentry • Return Flight • Landing/Recovery
Refurbishment and Turnaround	• Post-Flight Processing • Data Archival, Analysis and Reporting

Figure 12. Space Flight Operation Functions in Each Phase

The remainder of this section explains each of these space flight operations function in more detail.

5.1 TRANSFORMATION, RESPONSIVE SPACE LAUNCH AND HUMAN EXPLORATION

In the Transformation Era, the incremental deployment of evolutionary technologies begins to enable more responsive space flight and human exploration activities in space using new vehicles and spaceports by improving interfaces and network operations. Flexibility, standardization and interoperability become developmental drivers required to meet increasing complexity in space flight operations, along with increased traffic.

As a result of these developments, future space flight operations during the Responsive Space Launch and Human Exploration Era are supported by an integrated, centrally-managed, network-centric capability (orchestrated by the Central Control Function). The Central Control Function as depicted in Figure 13 coordinates, (in some cases, controls), and manages interactions among range assets, spaceports, and control centers around the world during each phase of a space flight operation. Each flight vehicle, range and spaceport asset, and control center is addressable as a node in the network that's managed by the Central Control Function.

Space flight operations are coordinated, and in some cases controlled, through a Central Control Function.

Figure 13. Central Control Function

A variety of control centers work in conjunction with the Central Control Function. Some examples exist and operate as they do during the Transformation Era, including Air Traffic Control Facilities throughout the nation and NASA's Mission Control Center in Houston, while others only begin operating during the Responsive Space Launch and Human Exploration Era (e.g., Regional Space Traffic Control Centers).

During the Transformation Era, new standards are developed and applied incrementally throughout the systems that are used to support space flight operations. Standards are applied and implemented first at each spaceport/range/control center, then regionally, then nationally, and finally globally. Over time, as new spaceports and vehicles are added to the overall FSTS, they are designed, built, and operated in ways that comply with the existing set of established and accepted standards for space flight operations.

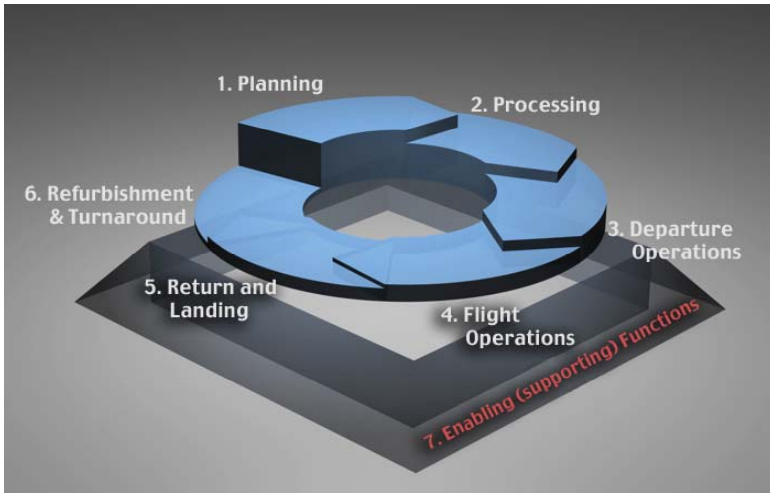
The following sections describe in more detail how each of the space flight operations functions will be carried out during each phase of a space flight operation in the Responsive Space Launch and Human Exploration Era.

5.1.1 Planning

5.1.1.1 Planning & Scheduling

Planning for space flight operations includes:

- Defining the scope, objectives and requirements for a space flight operation, along with strategies for accomplishing them
- Developing flight profiles based on an understanding of the flight environment and accounting for programmatic and operational constraints and/or dependencies



- Identifying support requirements, including processing and takeoff/launch facilities, data relay and command and control rates, etc
- Integrating this plan into the master schedule along with all other planned flights and activities.

Figure 14 is a process flow diagram illustrating the relationships among these steps in planning space flight operations.

Flight scheduling takes the products of flight planning and breaks them down into the individual tasks to be completed for each individual flight. It also includes assigning the available resources to support each task, accounting for availability and constraints. Finally, it includes integrating the resulting schedules for individual flights into a single master schedule for all scheduled flights and available resources. Scheduling is an iterative process due to the dynamic nature of space flight operations; therefore these schedules require numerous updates as events impact original requirements and plans.

Automated decision support systems analyze forecasted weather data along with vehicle performance and other characteristics (including breakup and debris data) to determine the restrictions and operational limits on each planned space flight operation. Flight profiles are filed and treated as flight plans to coordinate the integration of space flight operations within the National Airspace System. During the responsive space launch and human exploration era, flight profile inputs are treated individually to drive the assignment of air traffic control resources and restrictions, as necessary to provide effective support without adversely affecting the usual flow of air traffic.

Planning space flight operations accounts for flight-specific parameters and constraints to generate a Flight Profile, then the Central Control Function generates support requests.

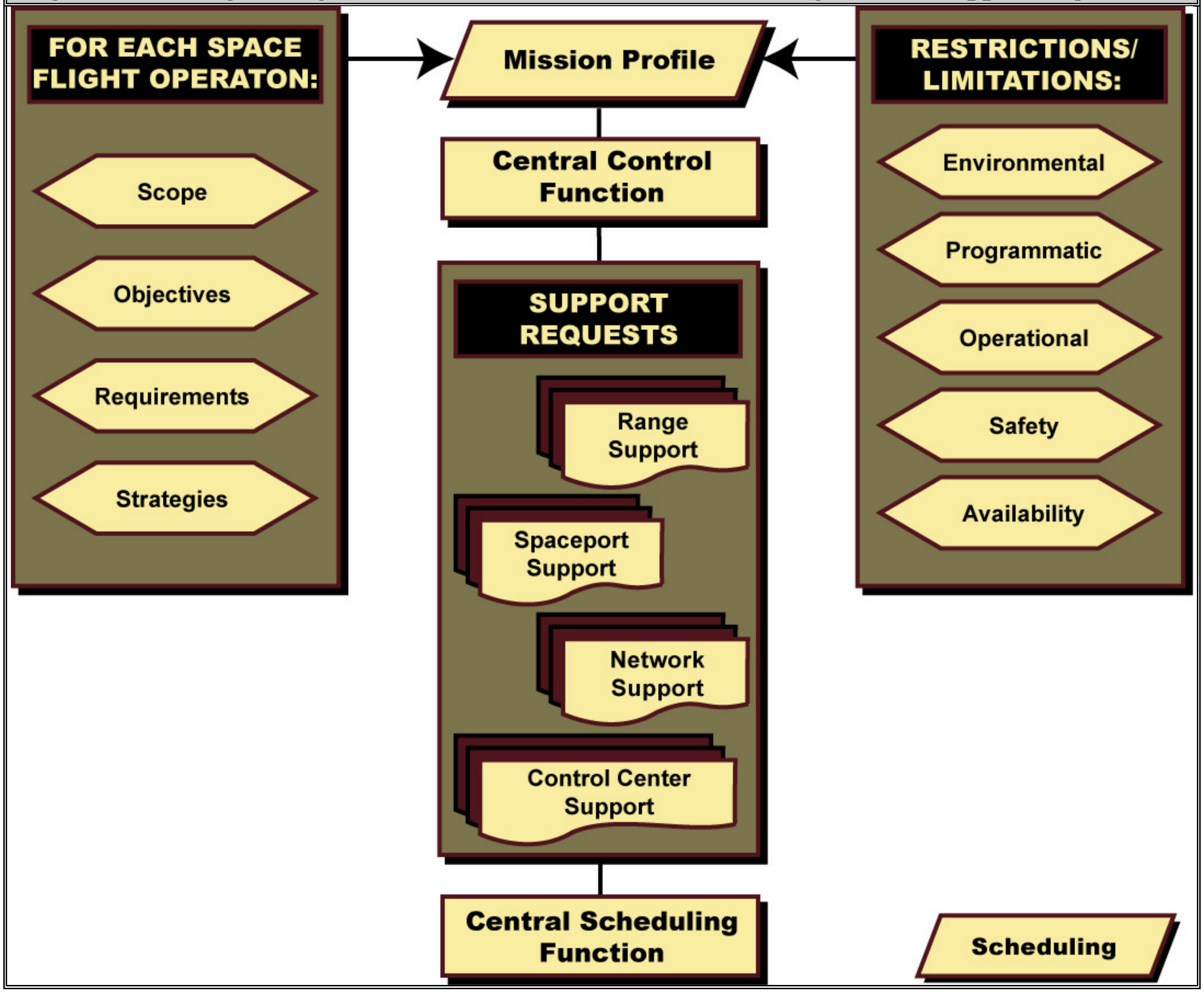


Figure 14. Planning Process for Space Flight Operations

Assignments for use of airspace are derived from the results of automated simulations that address the flight profile (within a calculated set of limitations based on weather, performance, and other vehicle characteristics) and its effects on air traffic. These simulations assess alternative courses of action and recommend primary and alternative (or contingency) solutions that minimize disruptions to other traffic, minimize the potential for re-scheduling, and preserve safety.

As envisioned and illustrated by Figure 15, the job of the planner and scheduler in the future will be greatly simplified by this centralized planning and scheduling system. This automated system uses software tools to standardize recurring scheduling functions and notify users and operators of schedule changes. The ability to handle dynamic changes and forecast impacts to plans or schedules is enhanced by implementing expert systems for workload planning and models to project the availability of spaceport and range assets, ground processing, facilities, and other support resources. As these processes become more efficient using these advanced capabilities, the number of planners and schedulers required by all elements of the space transportation system can be reduced. At the same time, these schedulers can also handle more space flight operations and schedules while coordinating with users and operators in real time as required.

Space flight operations are scheduled using an automated decision support system to generate alternative courses of action and recommendations.

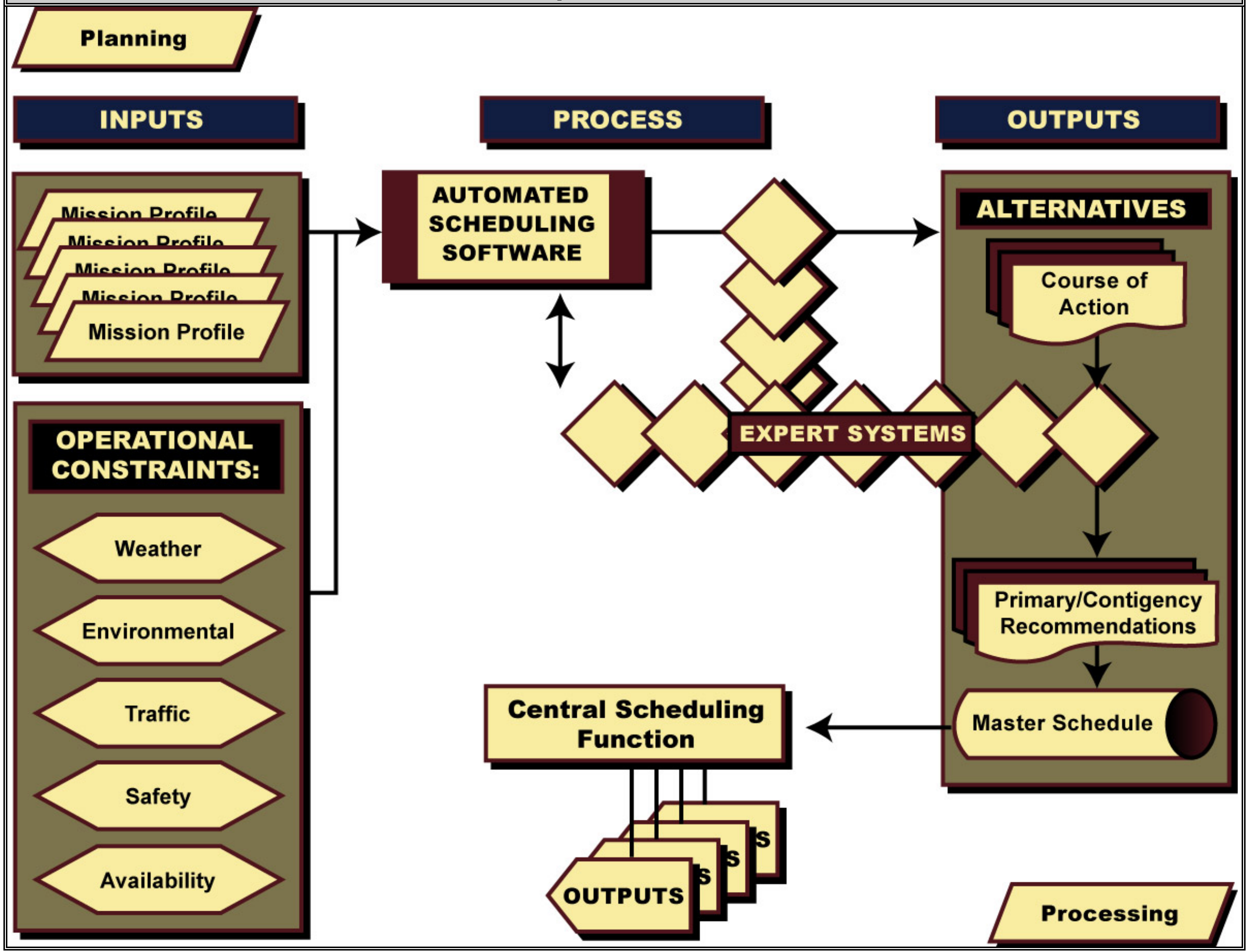


Figure 15. Scheduling Process for Space Flight Operations

Using this network-based automated system, authorized users and operators make inputs for individual flights regardless of location (local or remote) and interface method (computer, workstation, wireless or handheld device). The architectural elements of this centralized function provide a secure interface to the system, as required, for those flights requiring secure operations. Users receive real-time feedback notifying them whether the request is approved, whether it conflicts with other events or resource schedules, or if the request is disapproved due to resource constraints.

The planning and scheduling system enables collaborative planning among multiple organizations simultaneously. The system quickly generates complex, concurrent plans while ensuring maximum flexibility and capability for re-planning to accommodate equipment problems, changing weather conditions, or short-notice changes to a space flight operation. When schedule conflicts do arise, the system automatically adjusts the schedule for optimum use of all flight and support elements. This automated capability uses advanced modeling and simulation techniques and constraint-based computer algorithms to assign priorities, identify areas of conflict, automatically repopulate the schedule, and notify all users of any changes. All users affected by any adjustment are notified in real-time of any changes affecting their activities, enabling them to have continuous access to the latest master schedule and plans through the global network that's controlled by the Central Control Function.

5.3.1.2 Training and Certification

Training for space flight operations includes all activities required to prepare flight crews and control center operators to perform assigned flight-specific tasks. Training seeks to build a set of skills to enable crew members and control center operators to perform a particular job. As shown in Figure 16, training includes identifying a realistic scope of what the job entails, clearly stating performance objectives, selecting an appropriate methodology (such as simulation, part-task training, classroom instruction, etc) to meet the performance objectives, and creating opportunities to practice the skills with feedback and suggestions for improvement.

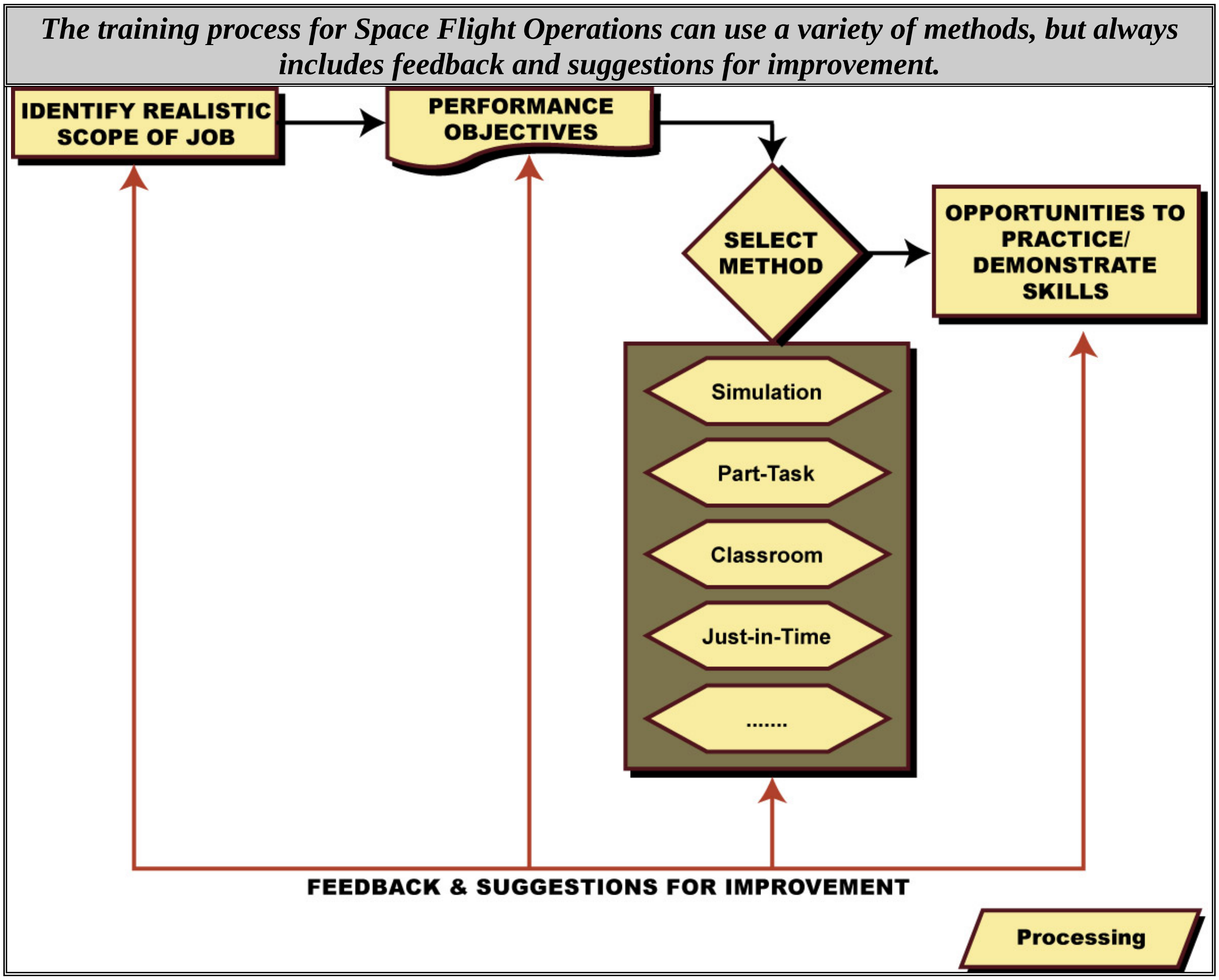


Figure 16. Training Process for Space Flight Operations

Certification for space flight operations requires that crew members or control center operators to meet certain performance criteria indicating they can adequately perform the assigned tasks. Certification includes the assessment of a person's learned skills after training to determine if that person can adequately perform a particular job. The certification process ensures that crew members and control center operators understand and are capable of safely, reliably, and routinely performing their assigned functions and responsibilities with competence and professionalism, particularly in the face of off-nominal conditions and situations.

As shown in Figure 17, the training and certification of future space flight operators is divided into two categories: generic operations training and flight-specific operations training. Generic training includes training requirements that remain consistent over time regardless of the purpose of a particular flight, vehicle or facility. Examples include management of ascent/departure or reentry/return flight operations. Flight-specific training includes training requirements that are unique to a given flight, vehicle or payload.

Training for Space Flight Operations includes generic and flight-specific elements.

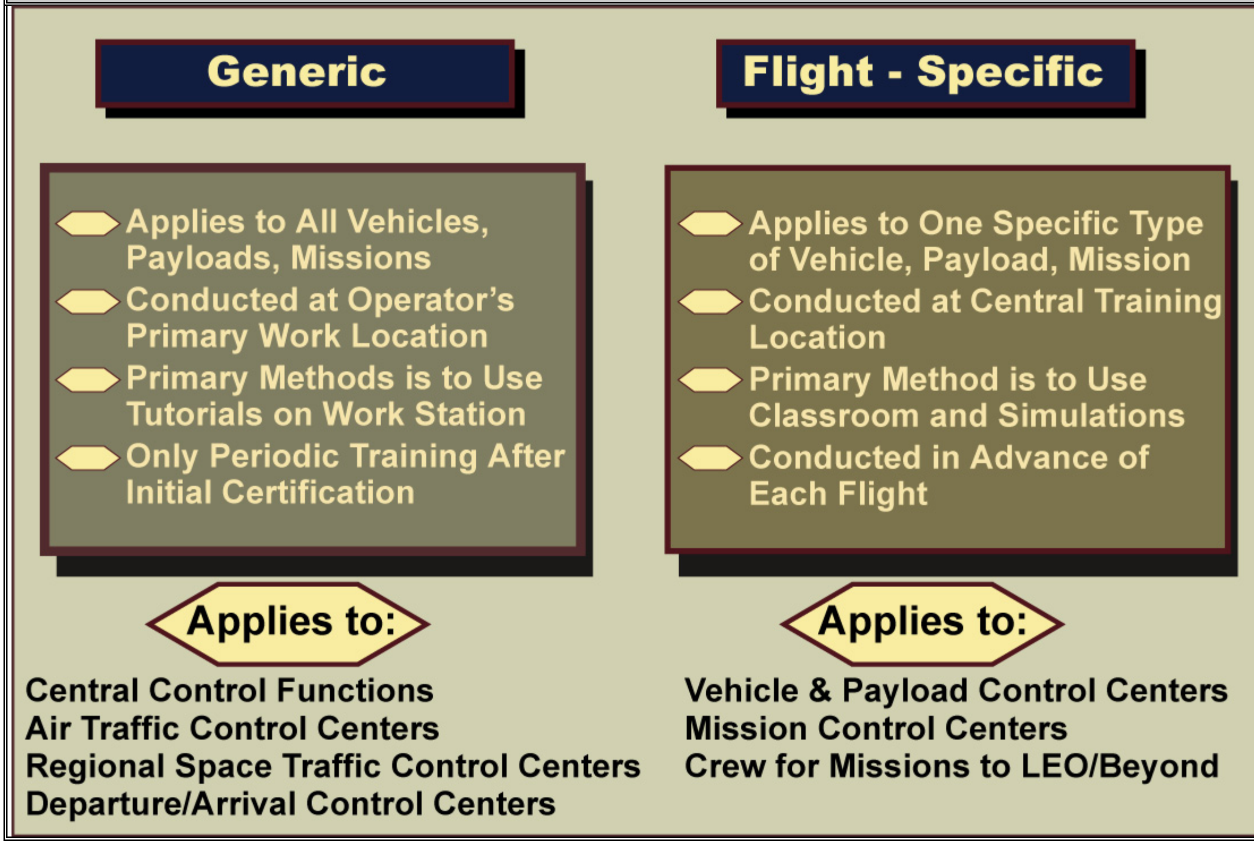


Figure 17. Generic and Flight-Specific Training for Space Flight Operations

Generic training is conducted at the location where the operator works (such as the spaceport, range, particular type of control center, etc). It is delivered by a variety of methods and supplemented by intelligent training tutorials built into workstations. Operators also receive initial training on the standard transportation systems and standardized vehicle and payload interfaces at the spaceport, range or operations center. After they're certified, operators only receive periodic refresher training or additional training when system design changes are implemented.

Flight-specific training requirements for specific vehicles, payloads and flight objectives is provided on an exception basis, and only for specific flights (or types of flights) when such training is required to deal with unusual or unique attributes. The vehicle operators are responsible for the flight-specific training of their flight controllers or crew for a space flight operation that falls into this category. These operators are responsible for addressing any flight-specific issues through all phases of the space flight operation. They subscribe to the centralized control function to access vehicle and payload data and send commands or communicate with the vehicle via a node on the web.

In this era, as the infrastructure becomes more standardized and interoperable between space transportation facilities, the need for each facility to maintain its own specialized operations personnel for many functions greatly diminishes. For example, commercial RLV flights taking passengers and cargo from point to point will resemble commercial air transportation today. Generic training is provided to departure/arrival controllers and regional space traffic controllers who will staff control centers around the country, similar to air traffic controllers, who monitor the vehicles as they transit to, through and from space. They will not be tasked with monitoring the vehicle and its systems, just getting it safely from point A to point B. That task will fall to the crew member flying the RLV.

There is still a need for flight-specific training for civil, national security and development and test activities during this era. The training that NASA or the military provides to flight crews and flight controllers on a particular vehicle or particular type of space flight operation objectives is flight-specific operations training. In these cases, the vehicle operator (NASA, DoD, industry) will still be responsible for providing training and certification for crew and flight controller training requirements for these space flight operations. In cases where NASA or the DoD chooses to purchase the services of a launch vehicle provider to carry payloads or other space vehicles (such as the Crew Exploration Vehicle), they may find it more cost-efficient to contract those services directly from the vehicle operator rather than maintain a staff of vehicle specific training personnel.

As the space transportation architecture becomes more standardized and interoperable over time, there will be fewer vehicle-centric training requirements, and most training and certification requirements will fall into the generic category. Vehicle operators, especially in the civil and national security space sectors, will still be required to provide training for specific unique requirements.

For unique or critical requirements, traditional training methods such as simulations continue to be used, but new methods accommodate new needs. The space flight operations tempo of the future will make the training and certification of personnel more difficult because in many cases there will be very little lead-time to prepare and train for a flight. Training and certification for future space flight operations, to include the ability to meet shortened training timelines, will rely on just in time (JIT) training tools and job aids, artificial intelligence and intelligent tutoring systems.

Just in time training tools and job aids eliminate the need for lengthy training lead time for flight requirements peculiar to a specific vehicle or payload. JIT will be accessible through the Central Control Function and will enable users to access training information on demand for various flight elements and processes from their office, remote locations, workstations (consoles), wireless and handheld devices. Based on the individual user inputs, the user receives basic, intermediate or advanced training that is tailored to his or her specific needs—and is able to put that training to use immediately after receiving it. Flight-specific training needs can also be supplemented using JIT tools prior to or during real-time space flight operations and in cases where long training lead times are not possible, for instance to support crew or satellite rescue. These tools will provide the capability and flexibility for operators to be called upon and ready to support short notice, responsive space launches as well.

Artificial intelligence and intelligent tutoring systems aid space flight operators by providing "expert" guidance in real time for vehicle and payload systems as well as providing decision-making support and course of action determination given failure indications or other unexpected events. Removing the need for humans to perform these tasks based on pre-defined courses of action will allow them to focus on those critical decisions and unique operations that do require human focus and interaction. Training requirements are reduced because the humans no longer have to go through the time-consuming step-by-by decision-making actions that the artificial intelligence systems perform for them. These artificial intelligence and intelligent tutoring systems will be available to all subscribers, local or remote, via the global network that's controlled by the Central Control Function, enabling continuous availability to all users regardless of location or workstation setup.

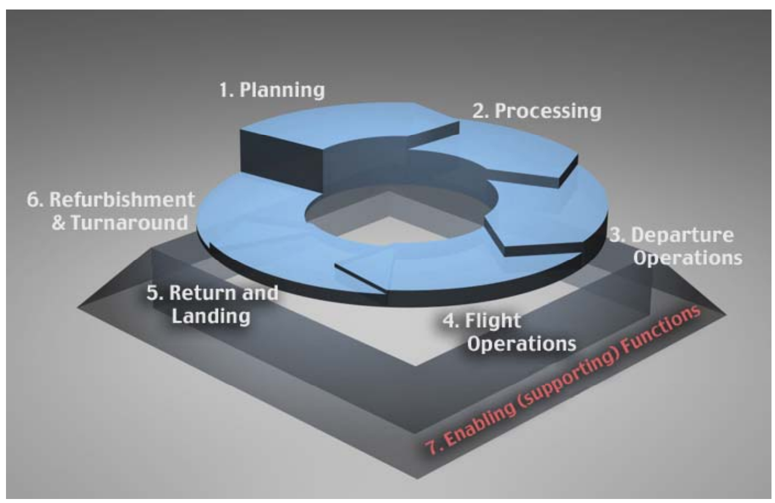
In addition to the training systems mentioned above, training and certification of space flight operations personnel benefits greatly from the conceptual architecture principles set forth in the Spaceport and Range CONOPS such as standardization, automation and self-healing systems.

The use of standardized interfaces, or modular plug-and-play components, eliminates the need for lengthy training programs associated with unique or proprietary hardware and software systems. Standardized components, processes, and functions allow operators to receive initial training and certification for a particular job regardless of the flight, vehicle or payload. Rather than having to retrain operations personnel from scratch every time there is a different vehicle, payload or flight, only periodic re-qualifications will be required to ensure that operations personnel have maintained proficiency.

The emergence of automated processes/tools, self-diagnosing/self-healing systems and decision support systems will reduce the amount of training needed by operations personnel. Automating numerous, repetitive, manual processes and tasks performed by operators will reduce the need to train these personnel to perform those tasks. Employing self-healing systems will also reduce the need to train operations personnel on the critical signature recognition, decision-making and course of action determination required for systems without self-diagnosis/self-repair capability.

5.1.2 Processing

5.1.2.1 Flight Readiness Verification



Processing includes flight readiness verification, meaning the assembly, testing, checkout, and examination of all flight hardware, software, operations organizations and procedural elements to ensure each is ready for flight. It also includes a formal process of surveying all flight organizations, functions and elements to formally certify and document readiness for flight.

Flight readiness verification uses the global information network that's managed Center (and the flight crew by the Central Control Function to initiate and analyze results from automated processes. It also relies on standardization and intelligent computing systems to assess readiness in real-time based on information gathered from all elements of the space transportation system. These processes and connections are depicted in Figure 18.

Processing operations include flight readiness verification and transferring vehicles, payloads, cargo, and passengers between facilities.

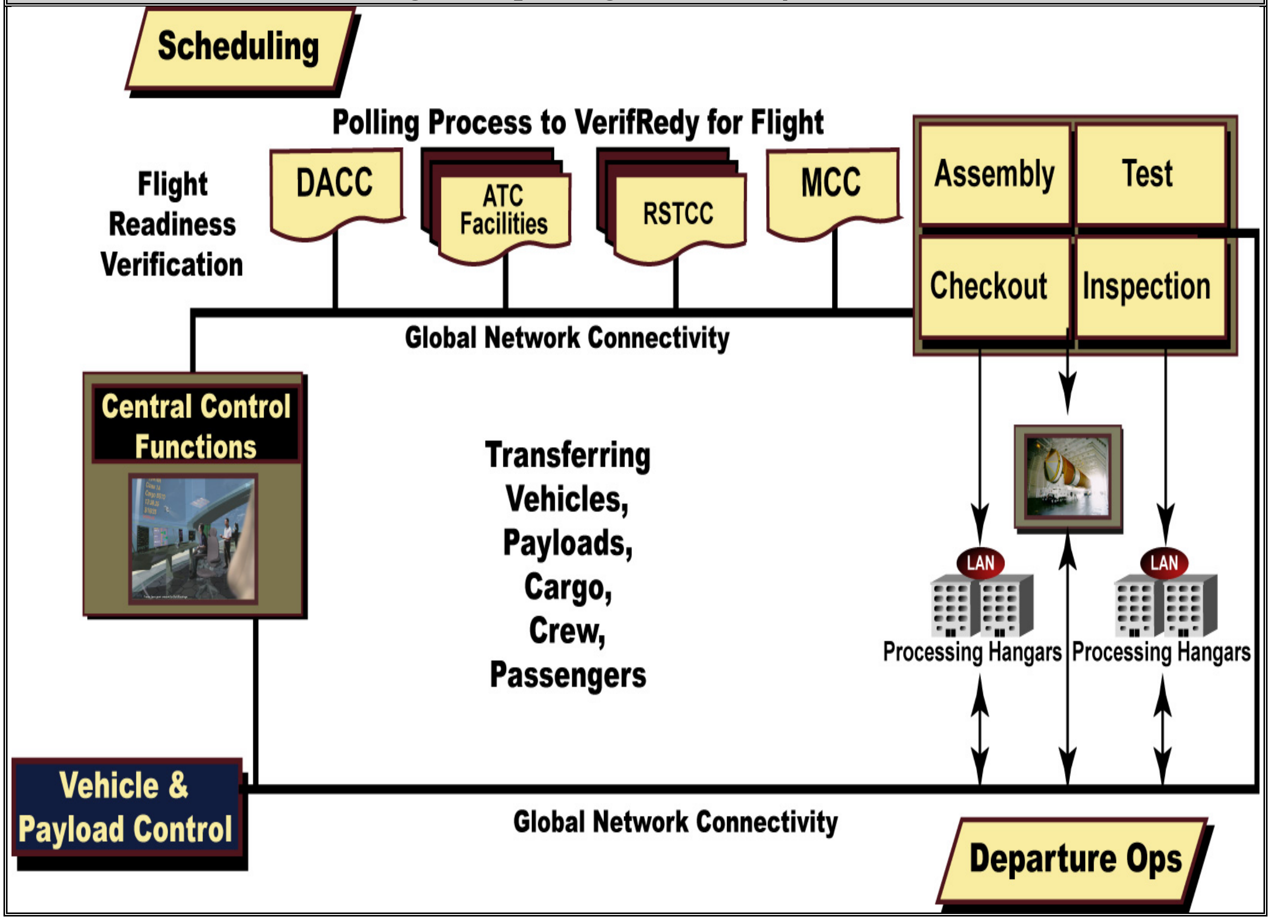


Figure 18. Processing Operations

Problems are highlighted and anticipated by automated processes to support management decisions. This sort of automated capability is necessary to enable responsive space launches. Because the time from notification to launch is extremely compressed, advanced computing techniques and intelligent system play a crucial role in enabling real-time verification and certification of system readiness to support responsive operations.

Through the use of automated processes, standardization and intelligent computing systems, flight readiness can be tracked in real-time based on information gathered from all elements of the space transportation system through the global network that's managed by the Central Control Function. Problems are highlighted and anticipated by automated processes to support management decisions.

Managers at dispersed locations will subscribe to data to be displayed at their location, receiving immediate status of all required functions and an indicator of which items are complete or incomplete. Should decisions need to be made, the automated system provides instant video teleconferencing capabilities to all flight managers for a particular space flight operation. This sort of automated capability is necessary to enable responsive space launch missions. Because the time from notification to launch is extremely compressed, advanced computing techniques and intelligent system play a crucial role in enabling real-time verification and certification of system readiness to support responsive space flight operations.

5.1.2.2 Transportation Between Facilities

Processing also includes the transfer of vehicles, payloads, cargo, crew, and passengers between facilities, as required, to prepare for departure operations. The Vehicle and Payload Control Centers retain primary control of these ground transportation operations between facilities during processing.

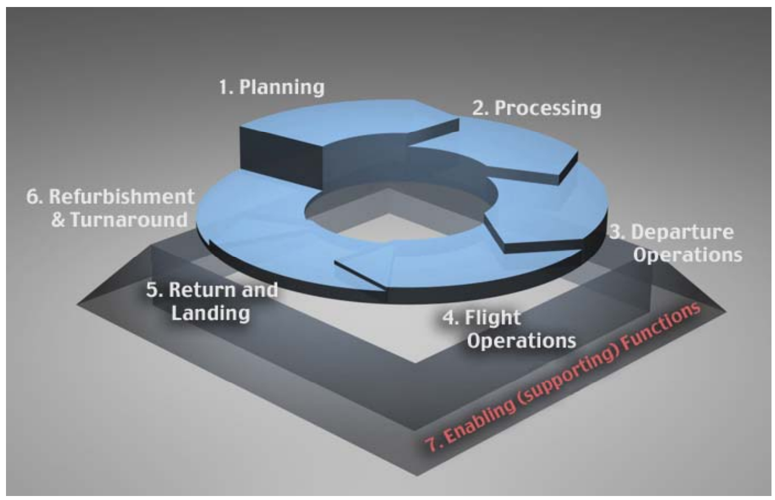
Operators at these Vehicle and Payload Control Centers maintain communication interfaces with spaceport facilities, support equipment, and the flight vehicles, payloads, cargo, crew, and passengers through the global network that's managed by the Central Control Function. Using these interfaces, these operators maintain situational awareness and direct control of all ground processing activities associated with the elements they're responsible for.

The Central Control Function retains responsibility for directing spaceport and range assets as required to provide support for the ground processing activities being directed by the Vehicle and Payload Control Centers.

5.1.3 Departure Operations

Departure operations include countdown and final launch commit, as well as launch or takeoff, and initial flight.

The Departure/Arrival Control Center retains primary responsibility for these operations, using the Central Control Function to interface with the other types of control centers involved in managing various aspects of the flight.



5.1.3.1 Countdown and Final Launch Commit

Countdown and final launch commit includes propellant loading and late stowage of items onto vehicle, final range interface checks, official launch commit based on vehicle and weather conditions, final range/airspace safety checks and collision avoidance verifications. Some future space flight operations could be called up and ready to launch within hours of notice. To accomplish the shortened timeline for countdown and launch commit (which begins days prior to liftoff in most cases involving current systems), new approaches to accomplish this function are employed.

Departure operations are controlled primarily by the Departure/Arrival Control Center. It polls the other control centers through the Central Control Function during countdown for final launch commit, and coordinates with them during launch/takeoff and initial flight.

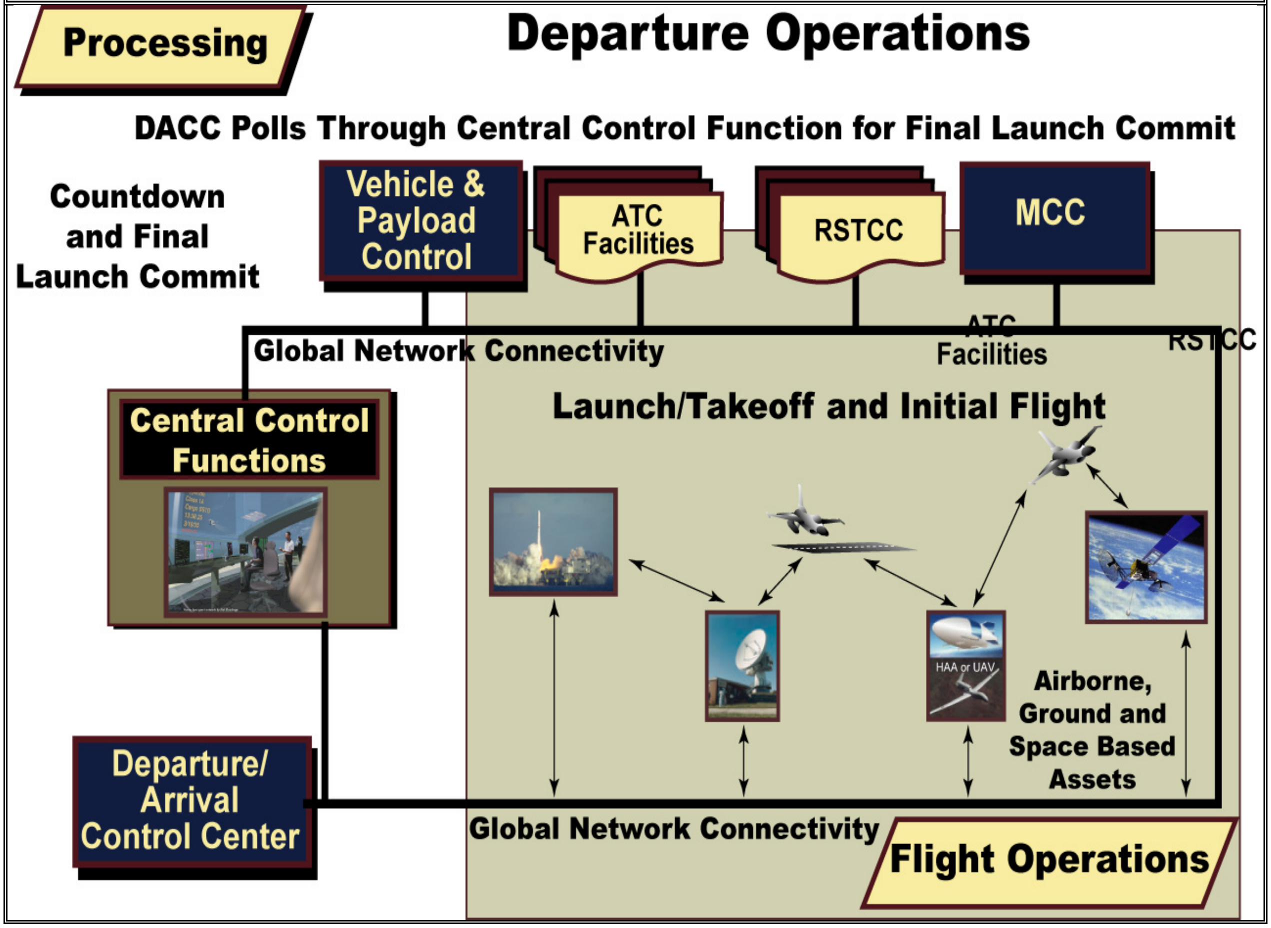


Figure 19. Departure Operations

As illustrated by the global network connectivity depicted in Figure 19, vehicle, ground support systems, and range systems are monitored by built-in test and integrated health monitoring equipment during the countdown. Vehicle or ground support equipment detecting system, hardware or software problems automatically identify failures, and reconfigure to a redundant system or repair themselves autonomously, eliminating the need to halt the countdown.

Propellant and consumable loading are accomplished using on-demand propellant servicing to the flight vehicle while the automated vehicle and ground health monitoring systems verify that the loading operations and outcomes are proceeding as expected.

Operators in the Departure/Arrival Control Center monitor the status reports from these automated health monitoring systems through the Central Control Function and global network. These controllers, like airport control tower operators today, monitor all space vehicle departures and arrivals in the terminal area of the spaceport.

Working through the Central Control Function and in coordination with applicable Air Traffic Control Facilities and Regional Space Traffic Control Centers, the Departure/Arrival Control Center operators ensure the proper flight profile approvals and flight route clearances have been obtained. They also monitor integrated situational awareness displays to ensure weather is acceptable for launch or takeoff.

Typically, only civil and national security sector space flights that involve long-duration activities in LEO or beyond are controlled through Mission Control Centers. Operators in Mission Control Centers are connected to the global network that's managed by the Central Control Function, so they have access to all the data on the network that's applicable to their vehicles and flight operations.

For suborbital space flights—whether civil, national security, and commercial, and with or without crews and/or passengers aboard—the Central Control Function maintains primary responsibility for managing the interfaces and approvals among all involved control centers (and the crew, in cases involving vehicles with flight crews aboard).

Commercial vehicle operators at remote locations can access voice, video, and data relating to the flight vehicle and payload/cargo through the global network as needed.

As the countdown proceeds toward liftoff, all participating control centers are polled by the Central Control Function to provide their final launch commit through the global network. Various launch commit criteria are established during the planning phase of the flight, and all relevant considerations and data are continuously monitored by automated systems and the results and recommendations of expert system analysis are displayed as part of the overall situational awareness information available to all operators on the network.

If the system determines that all launch commit criteria are "go", the countdown continues. If the system determines that a particular criterion is "no-go" even after system self-diagnosis and recovery, then the Central Control Function issues a "hold" command and notifies all users on the global network. Automated expert systems evaluate all of the available data using modeling and simulation tools to generate a list of alternative courses of action. These systems also provide a recommended primary and contingency course of action.

Depending on the option chosen, the launch countdown may be resumed, held for a time until a course of action or workaround is selected and implemented, or the launch is scrubbed and re-scheduled. Upon initiation of a scrub, the Central Control Function issues a shutdown command that starts a series of events to safe and reconfigure all vehicle, spaceport and range systems for the next scheduled event. The Central Control Function also notifies the planning and scheduling systems of the scrub, placing the flight back in the queue for whatever actions may be needed before another launch attempt.

5.1.3.2 Launch/Takeoff and Initial Flight

Launch/takeoff and initial flight include departure of a space vehicle from a launch site and flight through the NAS into a desired orbit or along a sub orbital trajectory (for point-to-point flights). Aborts are also included in this phase in the event the vehicle must make an unscheduled return to the launch or takeoff site because of system failures or vehicle ascent performance problems that are unable to be fixed.

Figure 19 also shows that operators in the Departure/Arrival Control Center monitor tracking and telemetry data during the launch/takeoff and ascent of the flight vehicle to ensure it is flying in accordance with its planned and approved flight profile. Operators in applicable Air Traffic Control Facilities and Regional Space Traffic Control Centers also monitor the progress of the flight as it ascends within their regions of jurisdiction.

Operators in the Departure/Arrival Control Center work closely with Operators in applicable Air Traffic Control Facilities and Regional Space Traffic Control Centers and the flight crew (if applicable) during initial flight.

During departure operations, the flight crew communicates directly with the Departure/Arrival Control Center. If the crew is conducting a space flight operation in LEO or beyond, then the Mission Control Center will also be in contact with the crew throughout the flight.

Applicable Air Traffic Control Facilities and Regional Space Traffic Control Centers monitor the ascent and provide routing instructions as required to clear the involved airspace to ensure safety and separation from other aircraft and traffic and/or debris in space while as vehicle transits their regions of jurisdiction. Space vehicle operations within the NAS are managed using space transition corridors and flexible spaceways. Depending on the flight profile and vehicle performance characteristics, the corridors and spaceways are used to segregate different types of flights, to concurrently accommodate different phases of activity (e.g., launches versus re-entries), and to ensure safety in the event of in-flight anomalies or emergencies. Air Traffic Control Facilities maintain contact with Regional Space Traffic Control Centers to hand off responsibility once the vehicle reaches the upper limit of the National Airspace System.

For flights along suborbital trajectories, the Departure/Arrival Control Center also works closely with Air Traffic Control Facilities and Regional Space Traffic Control Centers to hand off responsibility for monitoring and routing the vehicle once it flies over the horizon from the launch/takeoff site. Before the vehicle proceeds the horizon from the launch/takeoff location, the Departure/Arrival Control Center hands off responsibility for issuing routing instructions to the applicable Regional Space Traffic Control Center. In most cases, the Central Control Function retains primary authority for coordinating and controlling suborbital flights.

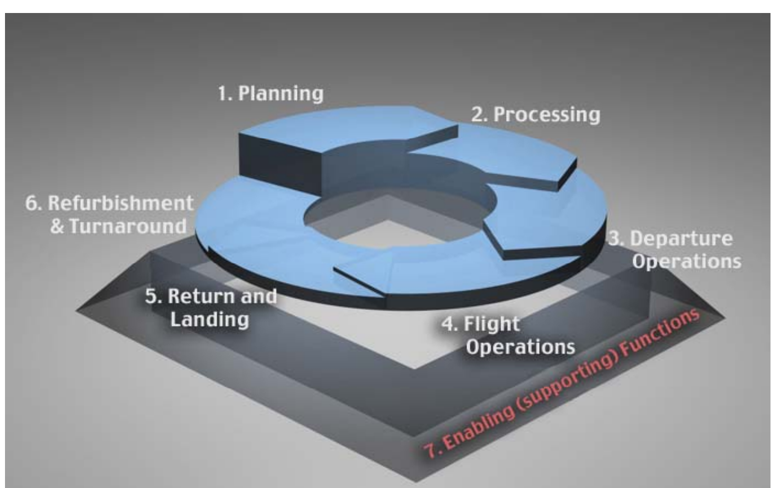
For launches to low Earth orbit and beyond, the Departure/Arrival Control Center maintains communications with the Mission Control Center and the vehicle (through the Central Control Function and range assets) until the vehicle has passed beyond the jurisdiction of the Regional Space Traffic Control Center that monitored its ascent and injection into orbit. At that point, the Departure/Arrival Control Center hands off responsibility to the Mission Control Center and the Mission Control Center takes over responsibility for managing on-orbit or in-space activities.

Once a vehicle is in Earth orbit or beyond, the Departure/Arrival Control Center, Air Traffic Control Facilities, and Regional Space Traffic Control Centers only monitor and contact the Mission Control Center on an exception basis in "notification" mode. In this mode, automated alerts notify these center operators only if the flight is cut short in orbit (e.g., due to an anomaly or an emergency) and requires support for an unscheduled reentry and landing/recovery.

5.1.4 Flight Operations

5.1.4.1 In-flight Activities

In-flight activities include maintaining the control, monitoring, coordination and overall situational awareness with regard to flight-specific activities conducted while a vehicle is conducting a space flight operation.



Because the nature of flight to, through, and from space is intrinsically dangerous, it is unlikely that fully autonomous launch, in-space and re-entry operations will occur in the foreseeable future. Human operators will still be needed to manage and control flights to, through and from space but utilizing advanced technologies, tools and architectural concepts described in the Spaceport and Range CONOPS, the number of operators required to support all flights will decrease as these improvements enable operators to handle the increased capacity, multiple vehicles and simultaneous, and dispersed operations.

While all space flight operations involving transportation to, from, or through near-Earth space are coordinated using this Central Control Function, some are controlled through it as well. This is the case when the mission is to provide transportation and the space flight operation is conducted using a vehicle without a crew on board. For suborbital flights, the Central Control Function provides support throughout the entire space flight operation, interfacing with the Departure/Arrival Control Center, Air Traffic Control Facilities, and Regional Space Traffic Control Centers, as required, as the vehicle moves from one region of jurisdiction to another.

When a flight vehicle providing transportation has a crew on board, the crew controls the vehicle. For flights of vehicles with a crew aboard, the Central Control Function works in collaboration with the flight crew and mission controllers (in cases involving a Mission Control Center) during departure and return operations or in the event of an early in-flight abort, leading to an emergency return and landing/recovery.

When the mission is conducted over an extended period of time in or beyond Earth orbit, then a Mission Control Center provides the control. The functions of a Mission Control Center are separate from the functions of the Central Control Function, though the Mission Control Center does interface with other control centers through the Central Control Function during the transportation phases of the mission. The Central Control Function is typically not involved in the routine on-orbit operations in LEO or beyond (except to monitor them on an exception basis, in “notification” mode) to coordinate and prepare to support emergency or unplanned reentry and return flight, along with landing/recovery.

Figure 19 illustrates the connectivity and interactions among the various types of control centers during in-flight activities.

The Central Control Function has primary authority for suborbital flights. For a long-duration space flight in LEO or beyond, the Mission Control Center has primary authority. Air Traffic Control Facilities and Regional Space Traffic Control Centers have authority to provide routing instructions during flight through their regions of jurisdiction.

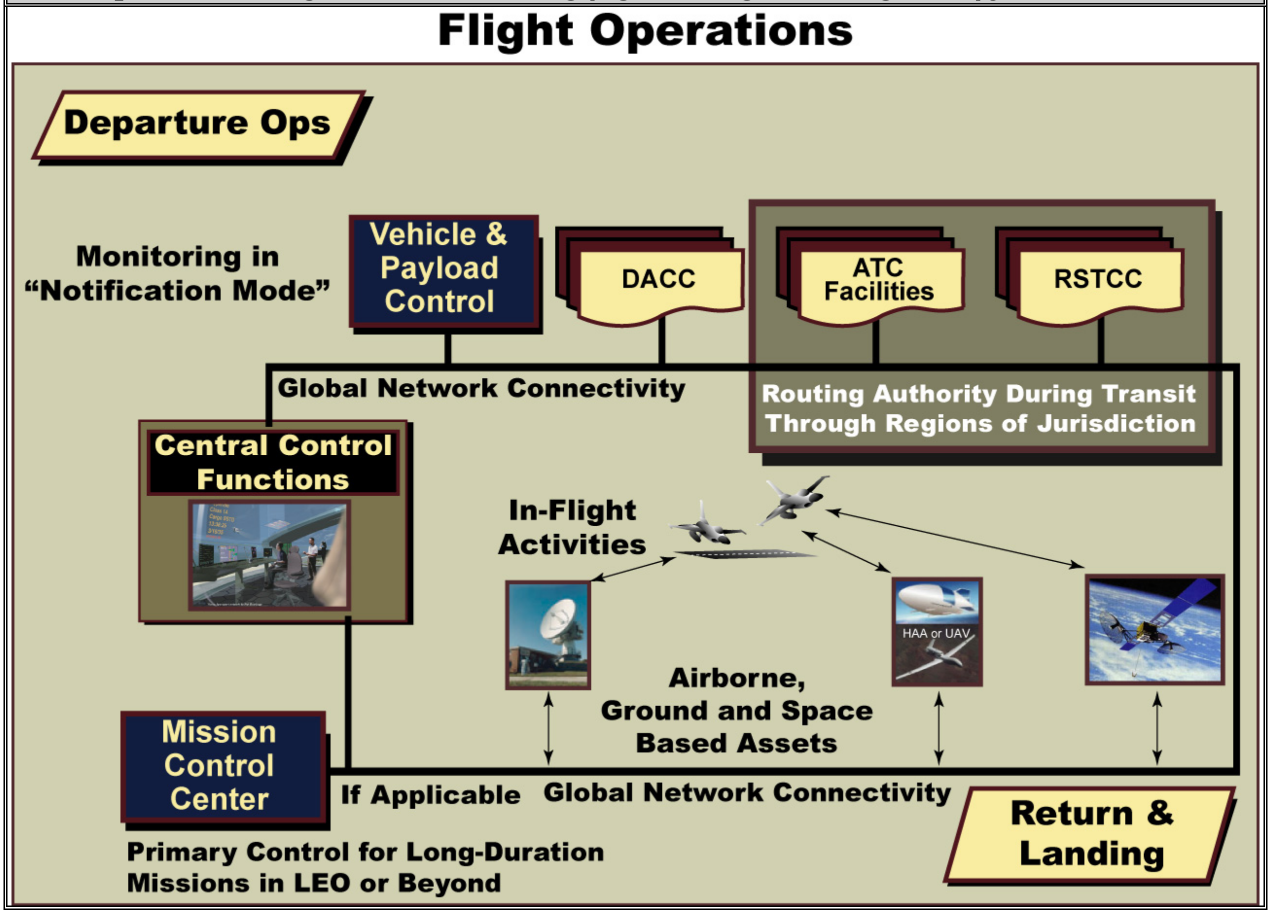


Figure 20. Flight Operations

As noted in Figure 20, Air Traffic Control Facilities and Regional Space Traffic Control Centers monitor and issue routing instructions to suborbital hypersonic point-to-point flights as they fly en route between spaceports to ensure safety and separation from other traffic and potential hazards including weather systems and orbiting debris.

Further, automated on-board systems perform flight control activities according to the predefined (and approved) flight profile. In the event of in-flight anomalies, onboard vehicle and payload diagnostic systems identify the problem, notify the vehicle operator (i.e., the flight crew or a ground controller) and autonomously switch to redundant systems or implement self-healing processes, as applicable. These onboard systems generate a notification to all concerned parties and distribute the findings through the vehicle's telemetry stream to the Central Control Function, where it's distributed to all interested parties on the global network. If required based on the automated analysis of expert systems, the Central Control Function also passes the information to the scheduling function to revise post-flight maintenance and refurbishment schedules, order parts through the automated logistics system, etc.

During flight operations in LEO and beyond, the Mission Control Center is responsible for monitoring and controlling space flight activities such as payload deployments, on-orbit repair of space-based assets, and the assembly of space vehicles and systems for exploration. During on-orbit operations, the crew maintains contact with the Mission Control Center via a direct link. The MCC works with the crew to carry out all of its objectives and to respond to unexpected events.

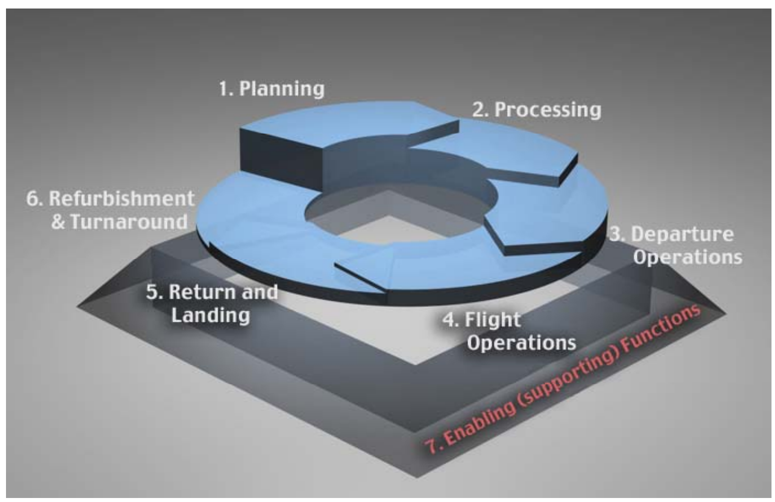
5.1.4.2 Monitoring in "Notification" Mode

For space flight operations in LEO or beyond, the Mission Control Center maintains continuous contact with the flight vehicle (and crew, if applicable). The Mission Control Center remains connected to the global network that's managed by the Central Control Function. All other control centers (including the Central Control Function) passively monitor the network in "notification" mode in case the Mission Control Center issues a message requesting support for an unscheduled return and landing/recovery through the Central Control Function.

When such a request is received, the Central Control Function requests emergency support from Regional Space Traffic Control Centers, Air Traffic Control Facilities, and Departure/Arrival Control Centers, as required. Each of these centers actively monitors the operation from that point until its conclusion. It also tasks automated expert systems to modify the schedule for spaceport and range support to ensure assets will be available to support the emergency reentry, return flight, and landing/recovery.

5.1.5 Return and Landing

The return and landing function includes the monitoring, commanding, and control of a space vehicle as well as the execution of operations related to deorbit, reentry and return flight through the NAS. This also includes the safe return of expendable stages during launch and reusable flight vehicles after in-space operations are complete.



For vehicles returning to Earth, the DACC (and MCC, if applicable) work in conjunction with the applicable RSTCC and ATC Facility to hand off (i.e., positively transfer responsibility) from one control center to another as the vehicle transitions from space flight to atmospheric flight during the reentry phase. In every case, this handoff process requires a request from the control center that is handing off responsibility, an acknowledgement from the center that is picking up the responsibility, and a confirmation from the original center.

Figure 21 illustrates the roles of each type of control center in supporting return and landing operations.

The Departure/Arrival Control Center retains primary control over return and landing operations, while Air Traffic Control Facilities and Regional Space Traffic Control Centers (in coordination with Mission Control Center, if applicable) provide routing instructions during transit through their regions of jurisdiction.

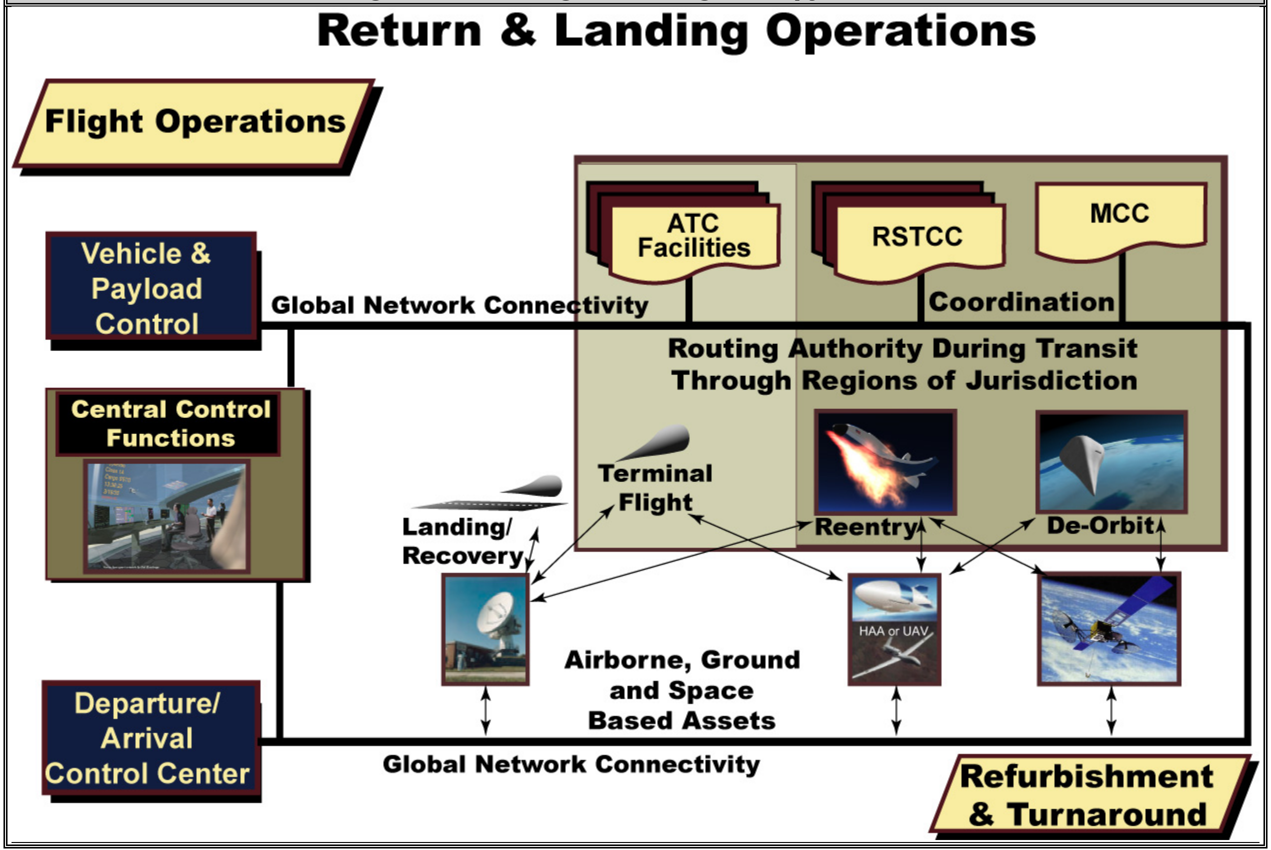


Figure 21. Return and Landing Operations

Emergency reentry/return/landing/recovery operations are implemented to accommodate unscheduled return flights in case of system failures or vehicle performance problems that result in flights being aborted. 5.1.5.1 Reentry

Prior to deorbit, the Mission Control Center has the primary responsibility for all preparation activities leading up to reentry into the Earth's atmosphere, including coordination (through the Central Control Function) of all required support from other control centers that are responsible for the regions the vehicle will transit on its way toward landing/recovery.

The Mission Control Center (and the flight crew, if applicable) maintains direct contact (through the global network that's managed by the Central Control Function) with control centers that have authority and jurisdiction over the regions being traversed along the flight path. Regional Space Traffic Control Centers monitor and ensure safety and separation during deorbit and reentry maneuvers. For vehicles returning to Earth, the applicable Air Traffic Control Facility works with the applicable Regional Space Traffic Control Center to clear the airspace as the vehicle transitions to gliding, powered, or ballistic flight after the reentry phase.

5.1.5.2 Return Flight

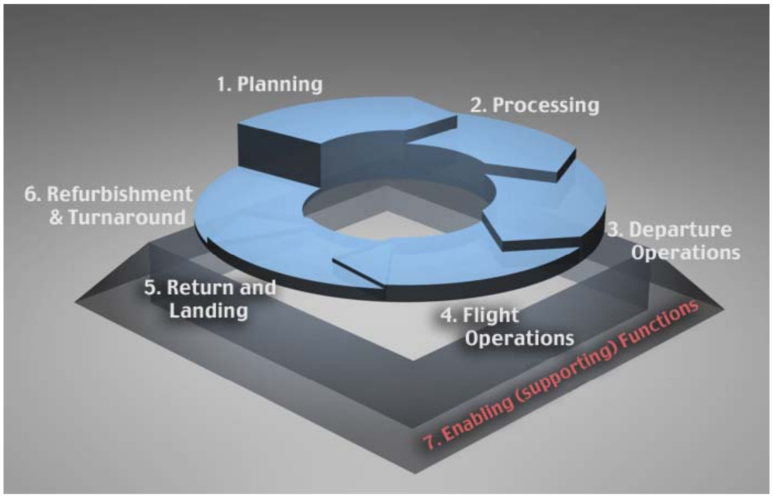
Once the vehicle enters the National Airspace System, the responsible Regional Space Traffic Control Centers hands off responsibility to the applicable Departure/Arrival Control Center at the spaceport where the vehicle will land. The Departure/Arrival Control Center coordinates with the applicable Air Traffic Control Facilities to ensure safety and separation during the descending flight through the atmosphere.

5.1.5.3 Landing/Recovery

The Departure/Arrival Control Center maintains responsibility for issuing routing instructions to the flight crew (when applicable) and/or to the ground control center responsible for the flight, throughout return flight and landing/recovery at the applicable spaceport.

5.1.6 Refurbishment and Turnaround

5.1.6.1 Post-Flight Processing



Post-flight processing includes deactivating the flight vehicle and support systems that were engaged in managing its safe return and landing/recovery.

It includes activating the facilities and ground support systems that will be used in safing and de-servicing the flight vehicle and payload/cargo to eliminate potential hazards.

It also includes ensuring the safe egress of the flight crew and/or passengers from the flight vehicle. It also includes taking actions to address any anomaly reports or repair orders that were generated during the flight by the on-board health monitoring system.

Upon completion of a space flight operation, automated health management systems report status to the Central Control Function. This information is used to generate and distribute routine post-operation reports on operations center usage and performance. These reports are used to generate bills for users and provide updated inputs to the automated scheduling system to generate maintenance and repair orders.

As is the case during pre-launch processing, problems are highlighted and anticipated by automated processes to support management decisions. Through the use of automated processes, standardization and intelligent computing systems, post-flight processing requirements can be tracked in real-time based on information gathered from all elements of the space transportation system through the global network that's managed by the Central Control Function.

Figure 22 illustrates the processes and interactions involved in refurbishment and turnaround operations.

The Vehicle and Payload Control Centers have primary control over refurbishment and turnaround operations.

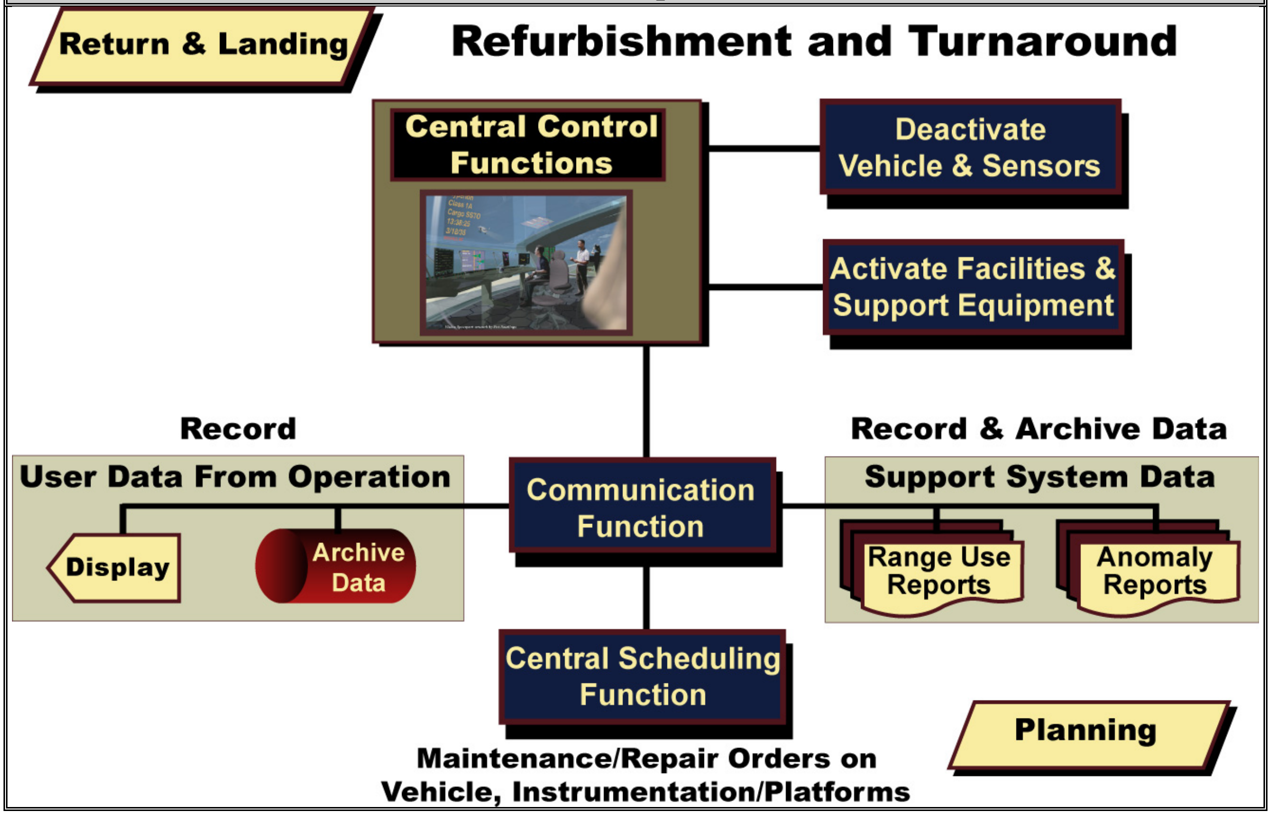


Figure 22. Refurbishment and Turnaround

<u>5.1.6.2 Data Archival, Analysis and Reporting</u>

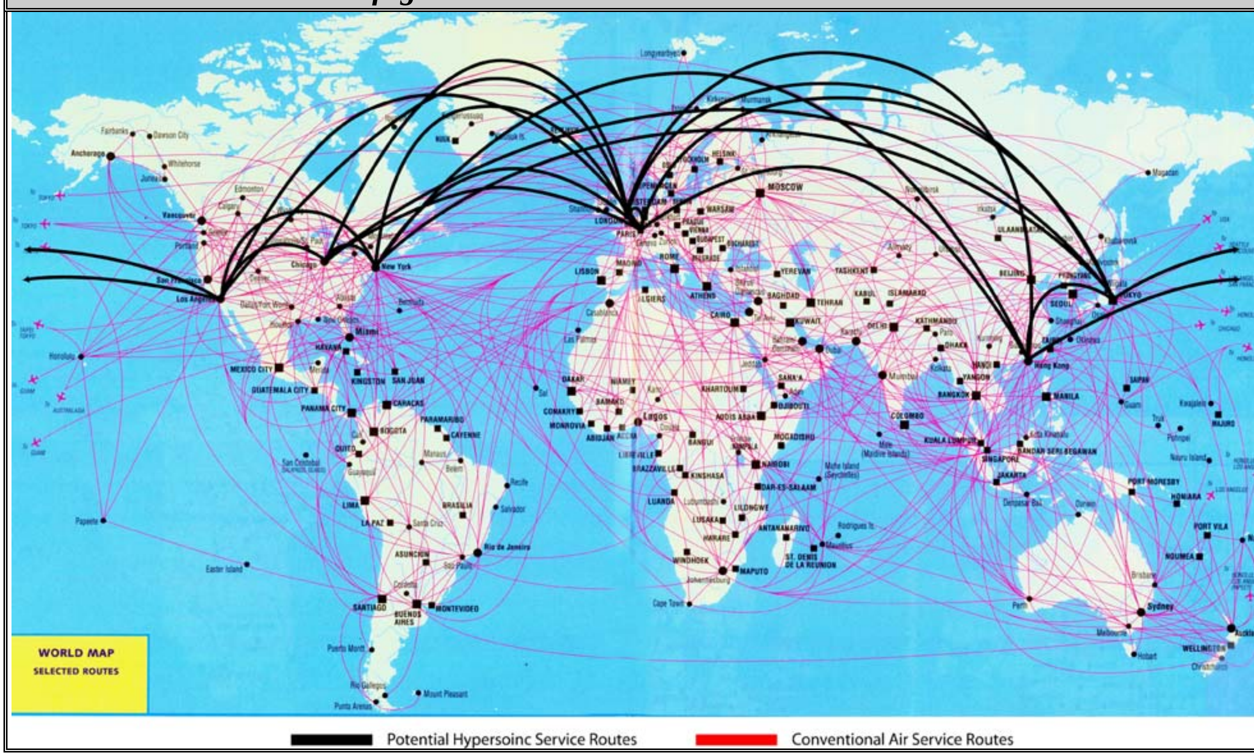
Data archival, analysis and reporting includes preserving flight operations and vehicle data. After the completion of a space flight operation, this data is analyzed by automated expert systems to provide more complete understanding and insight into such things as vehicle performance, trends, system anomalies, and maintenance or repair actions. The results from this analysis are used to generate post-flight anomaly reports and to schedule maintenance and repair activities.

Data is digitally recorded, stored, archived using expandable, modular, network-accessible systems for mass storage of voice, video and data streaming from each flight. This data is stored in the central archival database and is available at user request without bandwidth and data latency limitations. Final flight data is retrieved as needed by various users in completing post flight analysis and reports.

5.2 MASS PUBLIC SPACE TRANSPORTATION

Space flight operations in the first two eras are transformed over time through incremental technology development steps to make space flight safer, more responsive and cost-effective. As a result, in the third era, space travel is transformed from an occasional occurrence to a routine and frequently-used mode of mass public space transportation using a variety of spaceports around the world, as illustrated in Figure 23. This transformation is reminiscent of the growth of the global commercial air transportation system that emerged and grew through the second half of the twentieth century.

The incremental deployment of technologies and standards throughout the previous two eras can be viewed as an incremental, spiral development approach toward a global space transportation model that provides routine, affordable travel to, through, and from space. Spaceports and vehicles comply with compatibility standards in this era, resulting in global interoperability across spaceports, vehicles and various types of control centers. This degree of interoperability allows practically any type of reusable space flight vehicle to be processed, launched from, or landed/recovered at virtually any spaceport worldwide. The global network of spaceports—each with standardized interfaces—enables routine hypersonic point-to-point flights to destinations around the world.



Source: FIRST Spaceport CONOPS

Figure 23. Spaceports Around the World[4]

Space flight operations in the third era are conducted so frequently and routinely that some of the steps in the lifecycle described above are combined and compressed, as explained in the following paragraphs.

5.2.1 Planning and Scheduling

An important feature of the FSTS in the third era is that flight profiles for suborbital point-to-point flights are constrained by orbital mechanics, so the flight routes between major destinations are well-defined and established for frequent and routine flights. These constraints help to bound the planning and schedule de-confliction processes, helping to make them manageable by automated systems. These automated systems rely on artificial intelligence and sophisticated computer models using real-time situational awareness information to analyze alternative courses of action and automatically develop solutions with a minimum of human intervention.

To enable planning and scheduling during the third era, all launch and support systems are part of an integrated, high-capacity, redundant, self-configuring, secure, worldwide network. This network is controlled and managed by the Central Control Function, as in the previous eras, but the network is much more extensive in the third era, requiring even more automation and capacity than before to support greater numbers of nodes and operations. The network is accessible by all authenticated operators and users, regardless of their locations, including those who manage spaceport and range support for space flight operations, as well as those who provide transportation services by conducting routine space flight operations.

The Central Control Function now manages the functions of dozens of spaceports and hundreds of flights each day. These activities are supported by the same types of control centers that operated during the first two eras. This control center architecture is still analogous to today's air traffic management system, with Departure/Arrival Control Centers managing traffic in and out of spaceports (analogous to today's Terminal Control Centers for airport approaches and departures), and with Regional Space Traffic Control Centers analogous to today's Air Traffic Control Facilities managing en route traffic through pre-defined and well-established corridors.

However, the operators in these control centers in the third era rely on even more heavily on sophisticated automated capabilities to manage more types of vehicles and more frequent flights, including multiple simultaneous operations. Automated data fusion and data mining techniques enable users and operators at each type of control center to quickly extract relevant information from the data that's being collected and routed on the global network.

State-of-the-art weather forecasting and decision support systems nearly eliminate launch delays and scrubs due to conservatism and buffers to account for the lack of precision in weather forecasts, improving the availability of spaceport facilities and systems to support the routine launch and landing of space flight vehicles.

5.2.2 Processing, Refurbishment, and Turnaround

The efficiency of vehicle processing and operations during the third era enables the commercial space flight market to flourish and become an integral part of the worldwide multi-modal transportation system. Dozens of flights per day are common at each active spaceport around the world, with takeoffs and landings occurring multiple times per hour. Thousands of passengers depart and arrive on hundreds of hypersonic RLV flights around the world each day, servicing dozens of destinations across the country and all over the globe.

Accommodating such a busy flight schedule drives the need for processing, refurbishment, and turnaround of reusable space flight vehicles (and their support systems) between flights in ways that resemble airline processing operations at airports today. That means integrated health monitoring systems are reliable and accurate enough to enable as-needed maintenance actions to be detected and conducted quickly on an exception basis without requiring the flight vehicle to be transported to specialized maintenance facilities. It also means most processing and turnaround operations between flights are conducted in parallel to accommodate tight turnaround schedules. Finally, it means that Vehicle and Payload Processing Control Centers and dedicated facilities are only used for major depot-level maintenance and periodic overhaul or fleet modernization activities—not for routine between-flight maintenance.

Instead, safer and more automated vehicle and ground systems enable more efficient parallel processing and maintenance actions between routine flights. Propellant loading operations use safe, automated, efficient, standardized interfaces and procedures, requiring less time and reduced standoffs compared to today's systems. All vehicle interfaces at spaceports, including electrical power and air conditioning from ground systems, cargo loading/unloading, and crew/passenger ingress and egress paths, rely on adjustable ground support equipment to accommodate different vehicle configurations, within the limits defined by the widely-accepted standards. In short, in the third era, RLV processing between flights resembles airline operations at gates on the ground at airports today.

5.2.3 Departure and Arrival, Return and Landing Operations

The Departure/Arrival Control Center at each spaceport operates much like the Terminal Control Center at airports today, controlling departure, arrival, return, and landing operations. The DACC coordinates departing and arriving flights with Air Traffic Control Facilities in the area, and with the Regional Space Traffic Control Center with jurisdiction over its part of the world. As the flight vehicle leaves its area of responsibility, the DACC hands off responsibility for routing routine suborbital flights to the Regional Space Traffic Control Center. For longer flights, it in turn, hands off responsibility to the next Regional Space Traffic Control Center along the intended flight path, and so on, until the DACC at the spaceport where the vehicle is scheduled to land takes over responsibility.

5.2.4 Flight Operations

As vehicles depart the spaceport, future range capabilities (now integrated seamlessly with the spaceport capabilities through the Central Control Function) provide continuous, robust, and redundant worldwide tracking, telemetry, commanding, and communications coverage. As a result of the spiral development over the previous two eras, space-based and ground-based systems in the third era have the capacity to support increased space transportation traffic. As a result, uncrewed aerial vehicles and high altitude airships are still used to provide additional tracking telemetry, command, control and communications for some specific operations (mainly flight test and evaluation), but these supplemental capabilities are typically not used to support the routine and frequent space flight operations between well-established spaceports that characterize the bulk of the activity in the third era.

Incremental technology development over the first two eras reduces the human workload involved in supporting space flight operations in the third era. Increasingly sophisticated automated decision support systems allow control center operators and flight crews to concentrate on only those critical decisions and flight-unique operations that actually require human intervention. The use of intelligent expert systems and sensors to improve situational awareness increases safety and reliability and decreases operator workload.

Consequently, operators in control centers are able to support more flights simultaneously. Another benefit is the reduction in human errors from misdiagnosis of anomalous data signatures, lack of complete situational awareness with regard to system health and status, and errors in entering or communicating instructions or commands. Additionally, using standard interfaces and commercial off the shelf (COTS) products to deliver data provide shared situational awareness in real-time for operations personnel dispersed across the nation and the globe, enabling them to work together to achieve a smooth flow of operations and handoffs from one control center to another.

Space flight operations in the third era still require a certain amount of human involvement in some activities, however, the use of artificial intelligence and expert systems and self-diagnosing, self-healing systems both on the ground and onboard vehicles, provide rapid anomaly identification and resolution so operators make informed, well-timed decisions during all aspects of flight operations.

6.0 "DAY IN THE LIFE" SCENARIO

The "day in the life" story in this section describes how future space flight operations and activities are conducted to support multiple types of space transportation and flight test activities. These examples were chosen from the three Design Reference Missions (DRM) categories illustrated in Figure 24.

Three Design Reference Mission categories address routine and responsive ops plus T&E.

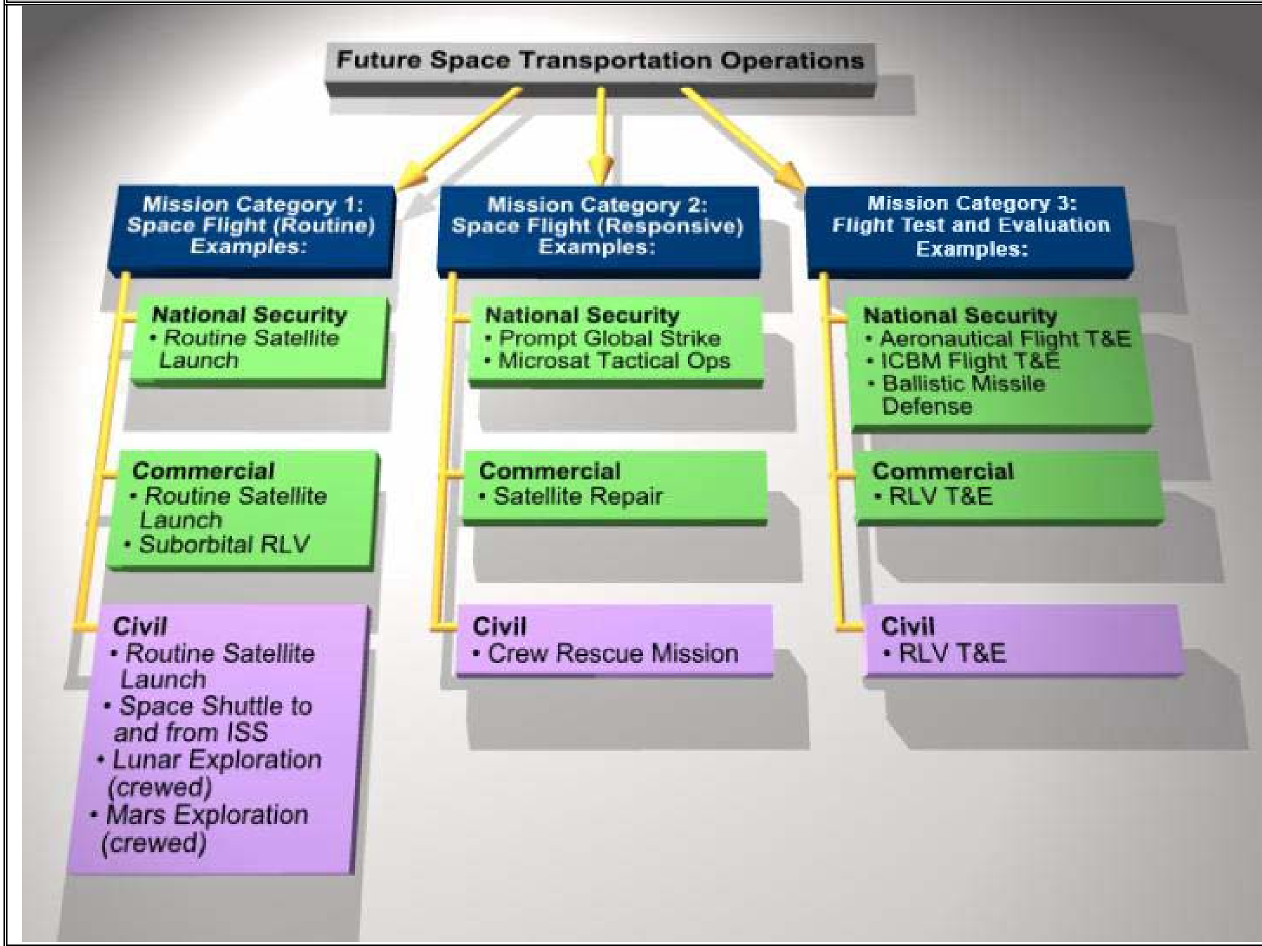


Figure 24. Design Reference Missions and Example Scenarios

The scenario described in this section highlights several examples of space flight operations derived from the DRMs, but it only depicts one day's operations. The context for that day's operations is depicted in the year-long schedule of activities in Figure 25.

A typical future year, as envisioned for the third era, will include many routine, responsive, and flight test and evaluation activities, with frequent overlapping and concurrent operations.

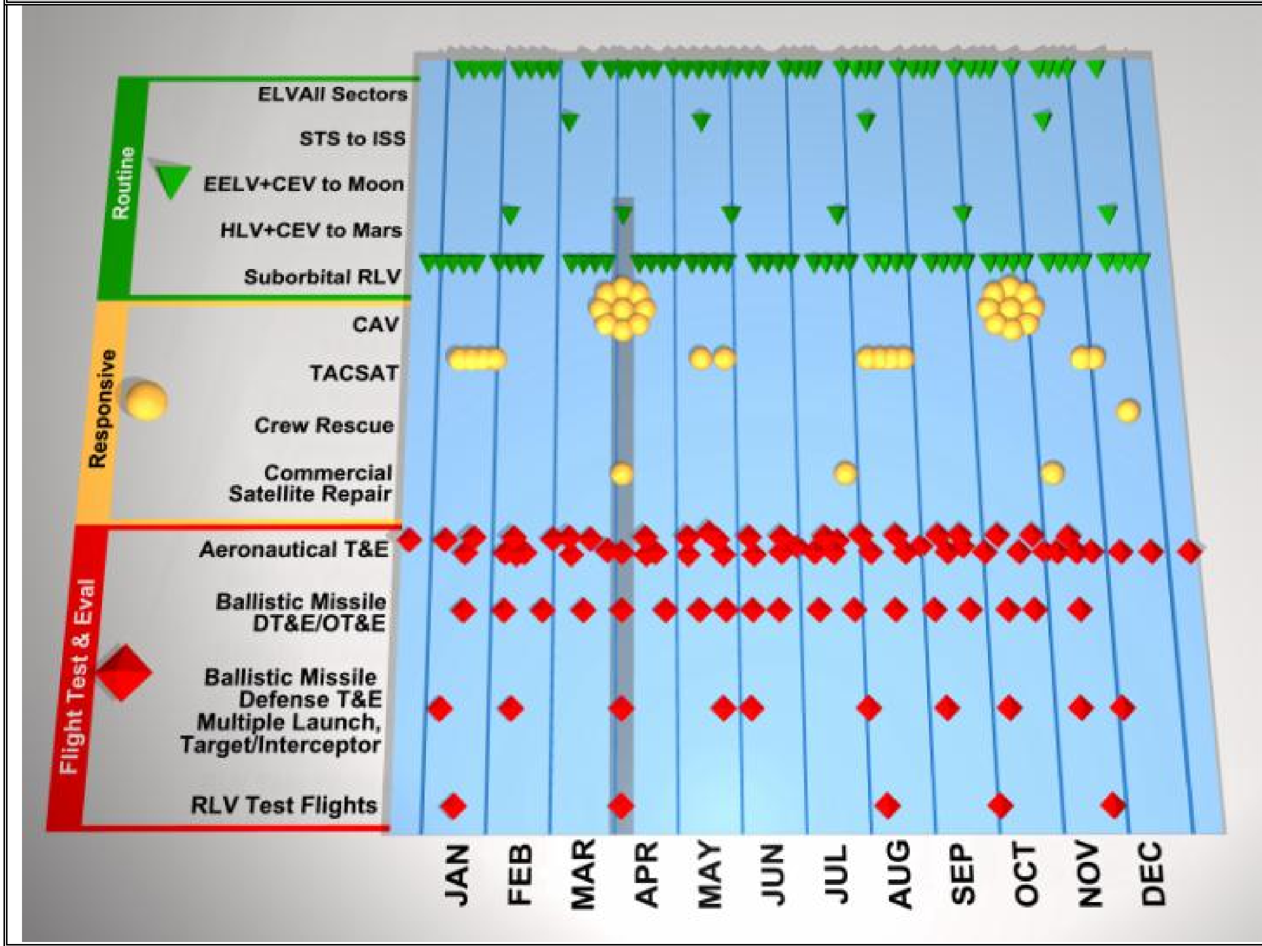


Figure 25. Example Scenario for a Future Year in the Third Era

Each space flight operation described in this section was chosen to illustrate how particular functions and capabilities are employed in support of each of the DRMs in the third era, and how the space flight concept of operations provides responsive, flexible, adaptable capabilities to support a variety of space flight operations and activities, when needed anywhere in the world. As highlighted in Figure 26, the six specific example flights are:

1. Routine commercial suborbital RLV flight
2. Routine scheduled NASA launch to support a crewed space flight to the Moon
3. Routine scheduled NASA launch to support a crewed space flight to Mars
4. Operationally Responsive Space (ORS) Prompt Global Strike (PGS)
5. Flight test of a new prototype DoD Hypersonic Cruise Vehicle (HCV)
6. Ballistic Missile Defense System (BMDS) flight test involving two targets and two interceptors

Flight #1 Routine Commercial RLV Flight - A routine, regularly scheduled sub orbital commercial tourist flight from Oklahoma to California illustrates the need for the future range to provide enhanced capabilities in terms of:

Flight Rate	Dozens of sub orbital flights per year in the second era, characterized by responsive space launch and human exploration, and dozens per week in the third era, characterized by mass public space travel
Responsiveness	Frequent flights, changes to flight plans, contingency operations
Global Coverage	To accommodate takeoffs and landings at dispersed locations
Standardization/ Interoperability	To enable point-to-point flights using multiple spaceports
Evolve Safety	To enable flights of commercial RLVs over populated centers
Flexibility/Adaptability	To support operations to and from new locations
Concurrent Operations	To routinely accommodate multiple simultaneous flights
Minimize Cost Growth	To enable development of commercial tourism, package delivery, and other markets

Flight #2 Routine NASA launch supporting a crewed space flight to the Moon - A scheduled launch of a NASA crew exploration vehicle (CEV) aboard an Evolved Expendable Launch Vehicle (EELV) to embark on a crewed space flight to the Moon illustrates the need for:

Evolve Safety	To enable flights of crewed vehicles on expendable boosters
Flexibility/Adaptability	To support operations with virtually instantaneous launch windows
Concurrent Operations	To routinely accommodate multiple simultaneous flights
Minimize Cost Growth	To enable an affordable human exploration program

Flight # 3 Routine NASA launch supporting a crewed space flight to Mars – A scheduled launch of a NASA Shuttle-derived super heavy lift launch vehicle to lift some spacecraft elements into orbit to support a crewed space flight to Mars illustrates the need for improvements in the following areas:

Global Coverage	To accommodate two-way high data-rate voice, video, telemetry data, command, control, and communication to and from multiple vehicles virtually worldwide, through launch and on-orbit operations, and throughout the course of extended duration deep-space missions
Evolve Safety	To enable flights of crewed vehicles on expendable boosters
Flexibility/Adaptability	To support operations with virtually instantaneous launch windows

Concurrent Operations	To routinely accommodate multiple simultaneous flights
Minimize Cost Growth	To enable an affordable human exploration program

Flight # 4 Operationally Responsive Space (ORS) Prompt Global Strike (PGS) – Operationally Responsive Spacelift (ORS) to inspect a damaged spacecraft in orbit and to deliver Common Aero Vehicle (CAV) prompt global strike platforms in response to foreign acts of aggression on United States interests illustrate the need for future space flight operations to provide enhanced capabilities in terms of:

Flight Rate	Up to dozens of sub orbital flights per week in the second era, characterized by responsive space launch and human exploration, and dozens per week in the third era, characterized by mass public space travel
Responsiveness	Launch within hours of notification in the first and second era and within minutes of notification in the third era
Global Coverage	To provide continuous, reliable, secure communications connectivity worldwide for telemetry and positive command and control between the operations control center and the launch vehicle, inspection spacecraft, and CAV throughout the duration of the mission, including through plasma during reentry
Standardization/ Interoperability	To enable use of multiple launch sites in the continental U.S. as well as airborne platforms over the Oceans
Evolve Safety	To enable responsive launches during development, operational testing, and operations in response to threats
Flexibility/Adaptability	To support operations to and from new locations
Concurrent Operations	To routinely accommodate multiple simultaneous flights
Minimize Cost Growth	To enable development and use of CAV when needed

Flight #5 - Flight Test of a New, Prototype DoD Hypersonic Cruise Vehicle - A flight test of a new, prototype DoD Hypersonic Cruise Vehicle (HCV) in development illustrates the need for future space flight operations to provide enhanced capabilities in terms of:

Responsiveness	Aeronautical systems typically undergo multiple flight tests per day, requiring constant schedule flexibility and short-notice re-scheduling of operations and range support
Global Coverage	To support concurrent operations, each with its own high data-rate telemetry requirements, within the limits of available spectrum
Standardization/ Interoperability	Aeronautical systems (including hypersonic vehicles) operate point-to-point using multiple takeoff and landing sites

Evolve Safety	To enable responsive launches during development, operational testing, and operations in response to threats
Flexibility/Adaptability	To support operations to and from new locations
Concurrent Operations	With various aeronautical systems typically undergoing multiple flight tests per day (resulting in thousands of flight tests per year), it's very common to have to provide range support for multiple simultaneous operations

Flight # 6 Ballistic Missile Defense System (BMDS) flight test involving two targets and two interceptors - A ballistic missile defense system (BMDS) flight test involving two targets and two interceptors, each flying over the Pacific Ocean from different launch locations, tests the ability of the interceptors to engage and destroy the targets during all phases of flight, and illustrates the need to provide enhanced space flight operational capabilities in terms of:

Global Coverage	Telemetry, optics, radar, IR/UV coverage over most of the Pacific Ocean
Standardization/ Interoperability	To enable target and interceptor test launches from multiple locations, to support realistic test scenarios that are representative of actual threat scenarios
Evolve Safety	To enable launches and complex intercepts in multiple locations, again in support of realistic and representative threat scenarios
Flexibility/Adaptability	To accommodate frequent flight test operations using multiple locations

The scenario described in this section includes examples to illustrate the operations associated with each of these space flight operations, including interactions among them when operations overlap and require concurrent support as shown in Figure 26.

The day in the life scenario described in this section includes a variety of overlapping and concurrent space flight operations.

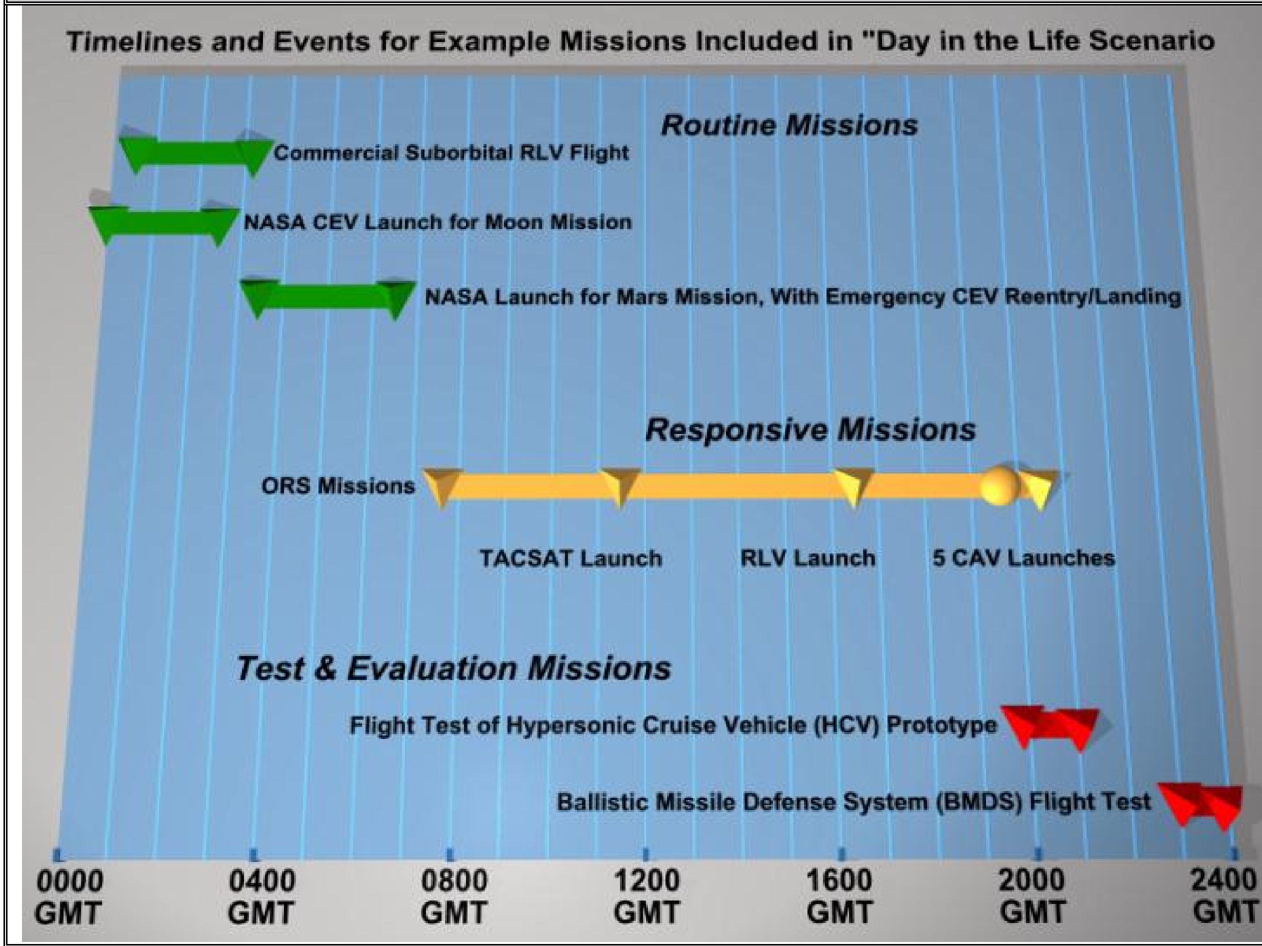


Figure 26. Overview of Day in the Life Scenario

While it is unlikely any actual single day would be quite as eventful as the day described in this scenario, the examples are intended to illustrate how a future network-centric range with global connectivity is able to responsively support various types of concurrent space flight operations and activities, using its inherent flexibility and adaptability to transition from one operation to another.

The following "day in the life" story is told from the perspective of operators within FSTS control centers.

Based on the assumptions listed in Section 3.0, as well as the description of the capabilities in the Architecture section, this scenario is intended to illustrate an integrated, interoperable approach for conducting future civil, national security and commercial space transportation operations that is more:

- Similar to the operation of today's commercial air transportation system
- Independent of vehicle architecture
- Economical and streamlined than today's approach to space flight operations
- Able to accommodate more frequent flights with shorter lead time

- Able to manage multiple flights and activities simultaneously
- Automated and less manpower-intensive
- Seamlessly integrated with the National Airspace System (NAS) via the Space and Air Traffic Management System (SATMS).

This scenario illustrates how operations are conducted in the third era characterized by mass public space transportation. This section emphasizes the actions of space flight operators (whether on-board flight vehicles or in various types of control centers) and their interactions with other elements of the FSTS: spaceports and ranges. It builds on the conceptual architecture and operating models for future space flight operations described above, to conduct current, emerging, and projected future national security, civil, and commercial flight operations to, through, and from space.

6.1 ROUTINE COMMERCIAL SUBORBITAL RLV FLIGHT

A routine commercial suborbital flight from Oklahoma to California highlights needs for responsive support from various Control Centers with the capacity to support frequent and concurrent flights, standardization & interoperability to support point-to-point flights, safety approvals for overland flight, flexibility and adaptability to accommodate schedule changes, and low-cost operations to sustain and expand commercial markets.

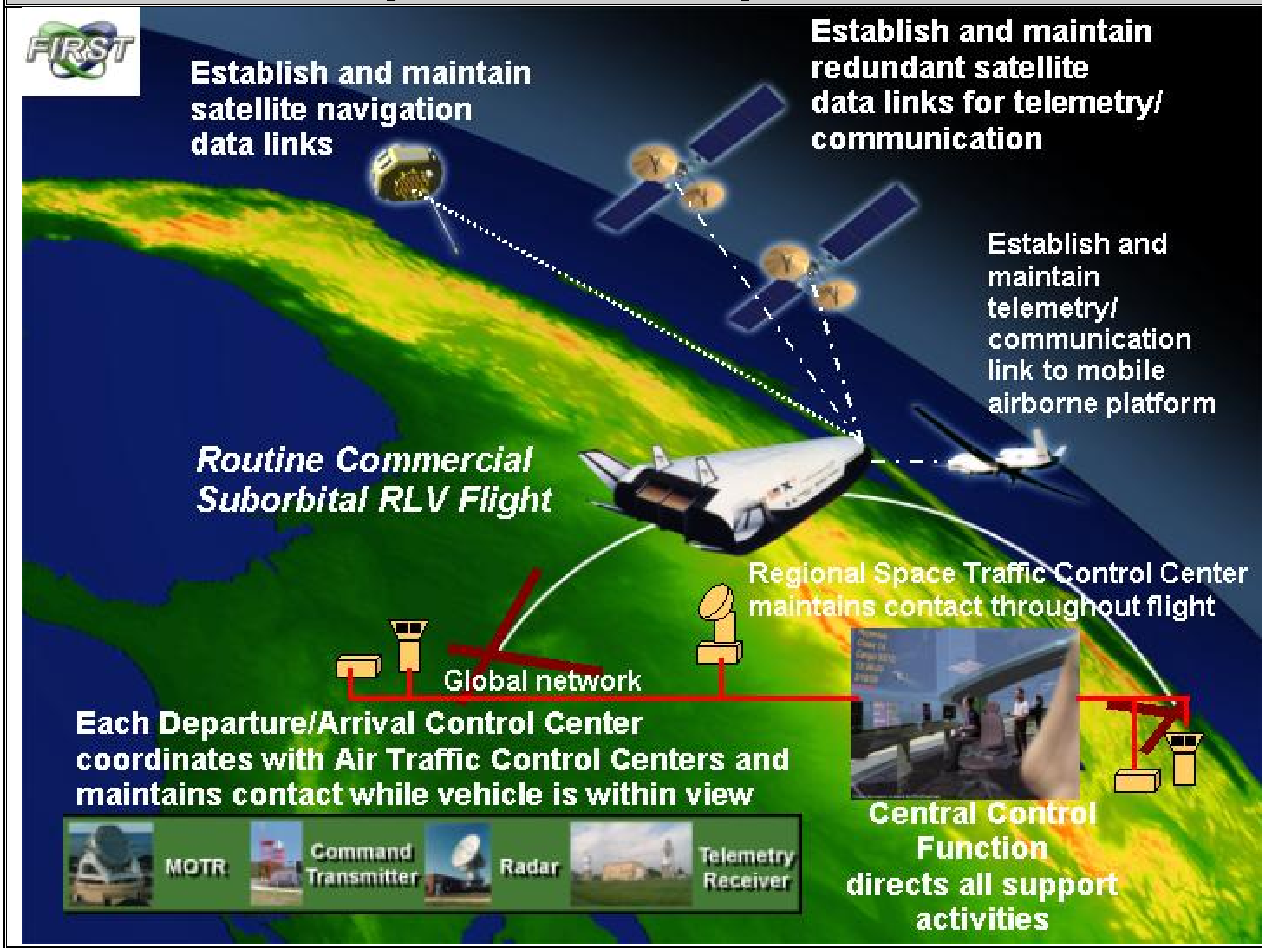


Figure 27. Operations Support for Commercial Suborbital RLV Flight

Time	Scenario Description	Space Flight Operations Actions
0001 GMT	Normal air and space traffic data is being monitored at various operations centers by government and commercial vehicle operators planning operations in the coming 24-hour period.	Operators at various control centers and user facilities around the nation are monitoring the ascent, orbit and entry phases of several space flights. All are tied into the Central Control Function's global network. This centrally-managed network automatically alerts them of any new operations that impact their workload or ongoing operations. It also provides continuous updates regarding the planned flight schedule and activities for the day. All of these operators are aware of an upcoming commercial sub-orbital passenger flight from Oklahoma Spaceport to California (Spacequest Spacelines flight number 6402) but the operators at the California and Oklahoma Spaceport Departure/Arrival Control Centers pay particular attention

		because they will be the two centers with primary responsibility for the safe takeoff, ascent and landing of this vehicle and its passengers. The vehicle operator (Spacequest) filed a flight profile through the global network where automated decision support tools calculated a support plan and posted it through the central planning and scheduling function. The global, automated planning and scheduling system entered the flight profile and support plan into the overall master schedule for the relevant Departure/Arrival Control Centers, Air Traffic Control Facilities, and Regional Space Traffic Control Centers (in this case, only the one for North America). This scheduling action initiated orders for automatic processing, fueling, and transport of the flight vehicle to the runway as designated by the Departure/Arrival Control Center. Automated health monitoring systems track and report on vehicle and support system status to ensure everything is ready for takeoff at the scheduled departure time. The Departure/Arrival Control Center also requested and received the proper clearances through the Air Traffic Control Facilities responsible for the national airspace system regions around the departure and arrival sites, and coordinated clearances through the Regional Space Traffic Control Center for North America to ensure there would be no conjunctions with other orbiting objects (including spacecraft and debris) during the planned flight through space.
0050 GMT	A commercial sub orbital flight from Oklahoma to California is scheduled for takeoff at 0230 GMT. This routinely scheduled monthly flight is timed to give passengers dramatic views from space of the Grand Canyon, the mountainous western United States, the west coast, and the Pacific Ocean during sunset.	Ground support systems are automatically reconfigured from supporting the previous takeoff. Operators in the Vehicle Processing Control Center and in the Departure/Arrival Control Center at the Oklahoma Spaceport monitor the orderly progression of pre-flight procedural steps as indicated by the status indicators on their displays screens changing from “red” for incomplete, to “green” for complete as each step is accomplished. Events are progressing smoothly; only 5 events remain before a “go” for takeoff is annunciated on all displays and to all users monitoring this flight. At the headquarters of Spacequest Spacelines (a commercial company that owns and operates a fleet of suborbital RLVs for passenger and cargo transport), an operator on duty in the user facility tied to the global network is preparing for the day’s activities. She electronically requests information on the day’s space flight operations pertaining to her company’s flights. Her display automatically configures the information (based on her pre-defined preferences) in a graphical map depicting vehicles, flight numbers, departure and landing locations. By clicking on the icon for any vehicle on the map, she can view all relevant vehicle status, schedule, and performance information including weight, crew names, total passengers, flight processing status and other information. She will be monitoring the progress of 20 Spacequest flights over the next 12 hours, (two are en route now). If all goes according to plan, that is all she will be required to do because the Departure/Arrival Control Center will do all the

		coordinating necessary with the involved Air Traffic Control Facilities and Regional Space Traffic Control Centers to obtain all necessary approvals for the flights, and the flight crews will respond to any routing instructions from these centers as the vehicle progresses through their regions of jurisdiction.
0100 GMT	Begin sub orbital RLV propellant loading.	The Oklahoma Departure/Arrival Control Center operator continues monitoring the flight status of the five flights on his display field. A yellow status indicates that propellant loading is in progress for Spacequest Flight 6402. The flight crew aboard the vehicle is steadily scrolling through onboard displays viewing data regarding the winds and weather conditions at the departure site and forecasted weather at the landing site in California. The pre-flight procedures are automated, so as each is completed a computer-generated voice updates them regarding vehicle systems status. The flight crew contacts the Oklahoma Departure/Arrival Control Center to initiate voice contact and confirm approval for their planned route (preprogrammed by onboard systems monitoring the space and air traffic along their intended flight path). The Oklahoma Departure/Arrival Control Center requests confirmation from the local Air Traffic Control Facilities and the Regional Space Traffic Control Center for North America through the Central Control Function. The decision making support tools that are integrated into the Central Control Function quickly compares the flight profile against all expected traffic in the NAS and all cataloged orbiting objects in LEO at that time. In less than a minute, the Central Control Function confirms to all participants that the flight profile is approved. From start to finish, the global network was used to initiate, review and confirm real-time approval for the flight profile within 2 minutes.
0130 GMT	Continue pre-flight checkout processes. Passengers board the sub orbital RLV at the Oklahoma Spaceport.	At the Vehicle Processing Control Center at the Oklahoma Spaceport, the vehicle operator in charge of flight 6402 sees on his display that all pre-flight checkout processes are complete. There was one small glitch during propellant loading, but the vehicle health monitoring system recognized it as a faulty leak detection indication. In response, it reconfigured onboard systems and computers to ignore the faulty pressure sensor. At the same time, it issued a repair order through the Central Control Function, which in turn initiated a logistics action to ensure a spare part is at the California Spaceport, and that the repair is on the post-processing schedule for the California Vehicle Processing Control Center. Meanwhile, all systems are go.
0230 GMT	Sub orbital RLV takes off from Oklahoma for a 20-minute flight to California.	The Oklahoma Departure/Arrival Control Center instructs the flight crew to taxi the vehicle into position on the spaceport's runway and take off as planned. At the scheduled time, the vehicle takes off from the runway. As the vehicle ascends through the National Airspace System, the local Air Traffic Control Facility monitors the flight (along with many others in the area) to ensure sufficient separation for safety. The Spacequest vehicle moves quickly out of the jurisdiction of the Oklahoma Departure/Arrival Control Center and Air

		Traffic Control Facility. The operator at the Oklahoma Departure/Arrival Control Center bids them "good day" and positively confirms the handoff of responsibility for the flight to the North American Regional Space Traffic Control Center.
0240 GMT	Sub orbital vehicle ascends along planned flight path and reaches apogee, beginning descent and reentry.	As the vehicle flies above the upper limit of the NAS, the Regional Space Traffic Control Center monitors the flight and issues instructions as required to avoid conjunctions with other objects in space. The vehicle reaches apogee, offering the passengers vast, breathtaking views across the Western United States as the sun sets over the Pacific Ocean. The flight crew, meanwhile, calls up the onboard weather system to monitor conditions for reentry, descent, return flight, and landing at the California Spaceport. The onboard flight control system automatically generates a preferred flight path based on weather and air and space traffic in the region based on data being communicated to the flight vehicle through the command, control, and monitoring system. The Regional Space Traffic Control Center operator sees an indication that the vehicle has begun its descent. It will enter the NAS in 10 minutes.
0250 GMT	Sub orbital RLV descends through the atmosphere, approaches the California Spaceport and lands on the runway.	As the vehicle reenters the upper limit of the National Airspace System on a trajectory toward its planned landing at the California Spaceport, the Regional Space Traffic Control Center hands off responsibility to the California Spaceport Departure/Arrival Control Center, ensuring that it is in contact and coordination with the local Air Traffic Control Facility in California to monitor the flight through the National Airspace System. The California Spaceport Departure/Arrival Control Center communicates with the flight crew to confirm that the vehicle is cleared for landing at the California Spaceport. The vehicle descends and lands safely. After the vehicle decelerates and pulls off the runway, it proceeds to the Vehicle Processing facilities at the California Spaceport. The Central Control Function has already scheduled the required post-flight processing activities (including the sensor replacement). The Central Control Function reminds the Vehicle Processing Control Center that maintenance is due on the faulty pressure sensor that was detected prior to take-off. Tool and other logistics items (including a spare part) have already been allotted in the schedule.

6.2 NASA Crew Exploration Vehicle (CEV) Launch to the Moon

A NASA launch of a crew exploration vehicle (CEV) for a human expedition to the moon highlights the need for evolved safety to enable flights of crewed vehicles on expendable boosters, flexibility and adaptability to support operations with virtually instantaneous launch windows, concurrent operations to routinely accommodate multiple simultaneous flights, and minimized cost to enable an affordable human exploration program.

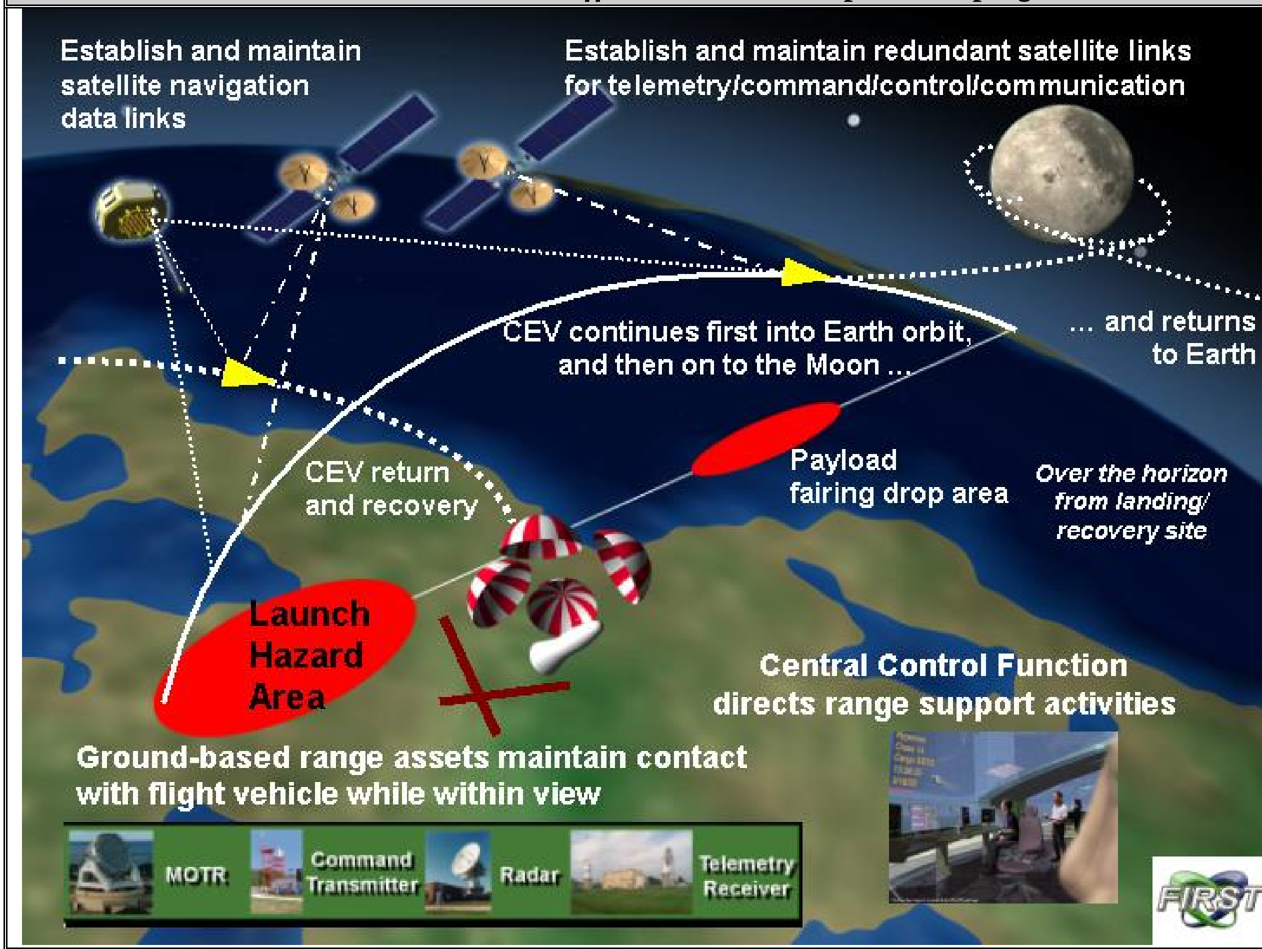


Figure 28. NASA Launch of Crewed Space Flight to the Moon

<u>Time</u>	<u>Scenario Description</u>	<u>Space Flight Operations Actions</u>
0010 GMT	An evolved expendable launch vehicle (EELV) is scheduled for liftoff from the Cape Canaveral Spaceport, Florida at 0140.	The automated scheduling system issues an order through the Central Control Function to generate required support from all control centers and support assets. Operators scheduled to support the countdown and launch at the Cape Canaveral Spaceport report to the Vehicle Processing Control Center and the Departure/Arrival Control Center, relieving the crews working on the shift before them. From their displays, they see all integrated health monitoring systems reporting nominal status as automated processing activities continue. They reconfigure the displays at their consoles to present the information according to each operator's personal preference.

0050 GMT		Network connectivity is automatically verified among all involved Control Centers assigned to support the scheduled launch through the Central Control Function. Operators in the Departure/Arrival Control Center request verification from through the Central Control Function that airspace is assigned and cleared for the vertical ascent of the EELV and for all contingency abort landing sites for the Crew Exploration Vehicle (CEV). The Central Control Function receives verification of from the Air Traffic Control Facility responsible for the National Airspace System near the spaceport. Similarly, the North American Regional Space Traffic Control Center confirms that there are no conjunctions expected between the flight profile for this flight and any cataloged items in orbit.
0100 GMT	Pre-launch checkout process begins.	The Vehicle Processing Control Center generates a command to start the final countdown process. A notification is automatically issued by the Central Control Function to all users on the global network that the Cape Canaveral Spaceport has begun the final countdown for this flight. Upon receiving this notification, the local Air Traffic Control Facility issues routing instructions to aircraft operating along routes near the area to ensure the pre-defined airspace is clear along the EELV's intended flight path (plus safety margins). Pilots filing flight plans for airplane flight find NOTAMS describing the impending airspace restrictions. On operator displays at the Vehicle Processing Control Center and at the Departure/Arrival Control Center, the status indicators for the step-by-step procedures that make up the countdown change from red to green, one by one, as each is completed. The flight crew, already strapped into the vehicle, begins communications checks with the Departure/Arrival Control Center at the Cape Canaveral Spaceport and the Mission Control Center for this flight. While this is happening, the countdown reaches the step in the process for propellant loading. The automated ground and vehicle systems configure themselves and initiate loading of the propellants. All integrated health monitoring systems and built-in test equipment continue to indicate "go" for launch. From offices and user facilities in locations across the country and the world, NASA managers, flight and payload element managers, and operations support personnel have logged into the global system and requested access to the EELV launch designated CEV-3 to monitor flight readiness and ensure final launch commit criteria are met. All requirements thus far are indicating "green." At 9 minutes before the launch, the system will automatically poll each manager and operator and indicate a go/no-go status based on each response. If there are no "yellow" or "red" status indications, the launch countdown will continue. If there any indicate "no-go," then the system will automatically initiate a voice connection for all relevant participants so a decision can be made in light of all available

		data. On this day, there are no problems. The countdown enters its final seconds on the way to T-0.
0130 GMT	EELV with CEV lifts off from the Cape Canaveral Spaceport.	As the vehicle ascends, the Mission Control Center monitors the flight of CEV-3 in anticipation of a handover of responsibility from the Departure/Arrival Control Center at Cape Canaveral Spaceport. The operators in the Departure/Arrival Control Center continue to monitor the vehicle ascent in the event an emergency return to the launch site is required. Operators and the crew receive an indication one of the engines on the EELV has developed a controller problem. Health monitoring systems on the EELV isolate the faulty controller and transfer authority to a redundant backup controller. Vehicle ascent performance is still nominal. Data regarding the controller anomaly are transmitted and recorded for later analysis.
0145 GMT	CEV proceeds over the horizon from the launch site.	The Departure/Arrival Control Center hands off control of CEV-3 to the Mission Control Center and notifies the crew with a voice call.
0230 GMT	CEV separates and moves toward the location where it will maneuver out of Earth orbit onto a lunar trajectory.	The Mission Control Center monitors the separation of the CEV from its launch vehicle. Displays show a visual depiction as well as telemetry data. The display also indicates the status of step–by-step automatic procedures being implemented aboard the vehicle in preparation for its engine firing which will propel it out of Earth orbit. The crew confirms agreement between the onboard burn solution and the solution calculated by ground-based systems in the Mission Control Center. After receiving confirmation, the crew enables the flight vehicle to automatically execute the burn. When the time arrives for the burn to take place, an orbital maneuvering system jet fails to ignite. Immediately, the vehicle health monitoring system diagnoses the problem, reconfigures to a backup jet and proceeds with the burn. The crew is now on the proper trajectory for its flight to the Moon. The crew and vehicle have successfully left Earth orbit. On the ground, the automated decision support system that supports the Mission Control Center explores potential courses of action within the pre-established flight rules to respond to the jet failure and its impact on planned future burns and events during the course of the space flight. Within a few minutes, the automated decision support system runs simulations of the various burns required by the space flight, modeling different approaches and outcomes, and exploring the probabilities and consequences associated with various other potential system failures. Within five minutes it generates 5 separate possible courses of action the crew can take for each possibility on the displays in the Mission Control Center, prioritizing them by safety of flight, crew health, vehicle health, and mission success criteria established prior to the launch.

6.3 NASA SHUTTLE-DERIVED SUPER HEAVY LIFT VEHICLE FOR SPACE FLIGHT TO MARS

A NASA launch of a Shuttle-derived, super heavy lift vehicle to support a crewed space flight to Mars highlights the need for more efficient use of frequency spectrum to provide telemetry, command, control, and communication links with sufficient capacity.

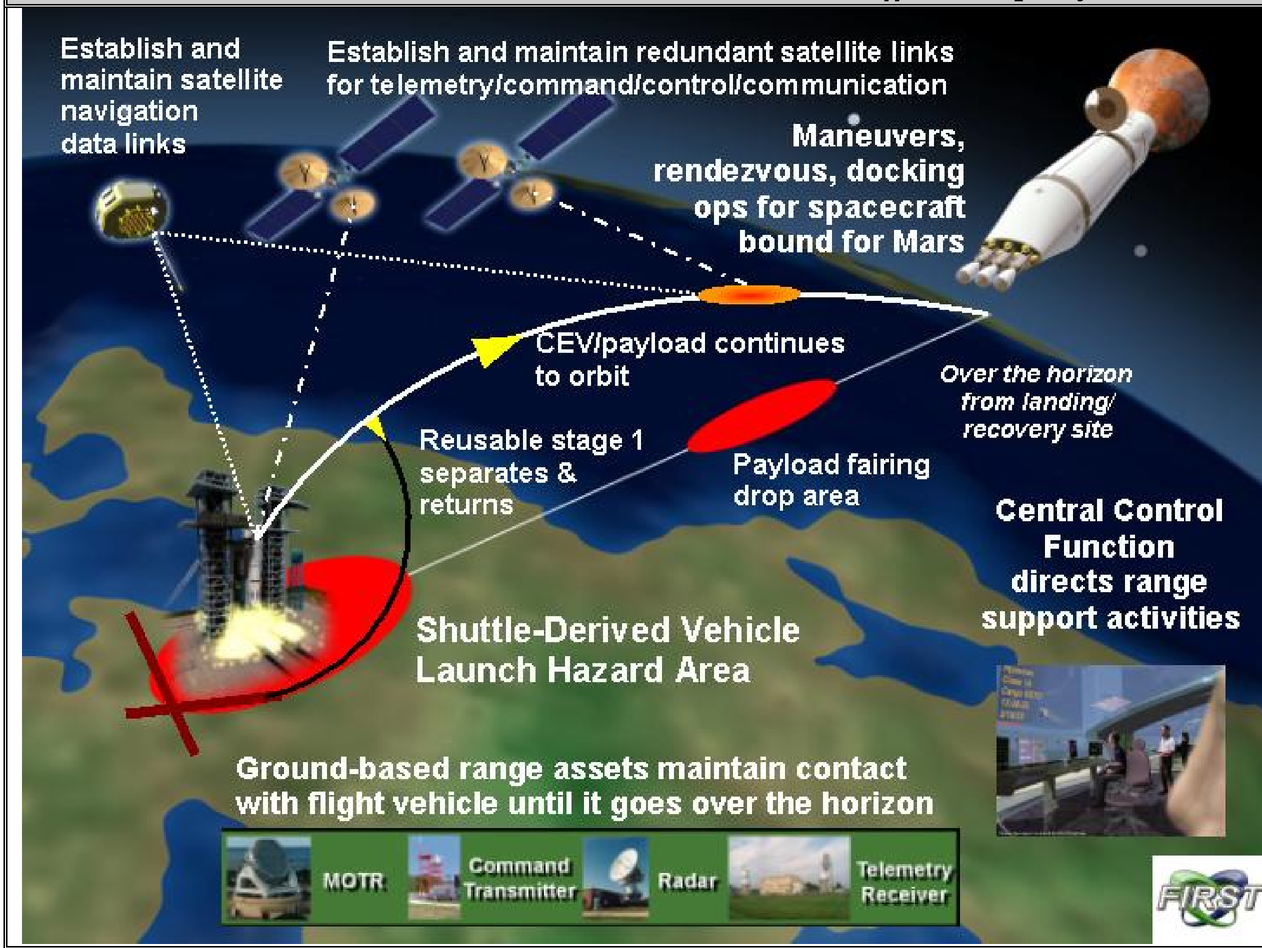


Figure 29. NASA Launch of Crewed Space Flight to Mars

Time	Scenario Description	Space Flight Operations Actions
0440 GMT	A Shuttle-derived, super heavy lift launch vehicle (with a reusable first stage) is scheduled for liftoff from Kennedy Space Center, Florida at 0610. This is the fourth of six missions that will be launched over a six-month span to assemble a large spacecraft in orbit in order to conduct a crewed mission to Mars.	The automated scheduling system issues an order through the Central Control Function to generate required support from all involved control centers that will be supporting this launch for a Mars exploration mission. Operators at the Cape Canaveral Spaceport Departure/Arrival Control Center who supported the previous EELV launch have remained on console to support the countdown for this launch. As soon as it became clear that the previous CEV flight would not be making an emergency return to the Cape Canaveral Spaceport, operators in the Departure/Arrival Control Center reconfigured their displays for Mars Exploration Mission 4 (MEM-4). From their displays, they see all flight vehicle and ground

		support integrated health monitoring systems are reporting nominal status.
0435-0455 GMT	As noted in the current space weather forecast, the effects of a recent solar flare are reaching the region between the Earth and Mars, where a previously launched CEV is already in transit as part of a mission designated MEM-3. The solar flare disrupts communications with the CEV in transit. When communication is re-established, the crew reports that one of the redundant CEV telemetry transmitters has been damaged by the storm and requests that a replacement unit be sent with the next crew.	Operators in the Mission Control Center send a request through the Central Control Function to the Vehicle Processing Control Center at the Cape Canaveral Spaceport to stow a spare telemetry transmitter on the MEM-4 vehicle on the launch pad. Operators in the Vehicle Processing Control Center request the spare part through the automated logistics system and instruct a technician to pick it up and deliver it to the vehicle on the pad, installing the late stowage item in an on-board locker reserved for contingencies. The flight crew and Vehicle Processing Control Center operator confirm that the spare transmitter is safely on board and notify the Mission Control Center through the Central Control Function. Automatically, the weight, location, description and bar code of the spare transmitter are entered into the stowage database. When the crew needs to know the exact location of this spare item, the database will point them to the right place. Just as importantly, when the automated on-board and ground-based decision support tools calculate thruster and engine firings, they will take into account the mass and placement of this stowage item.
0500 GMT		All data and network connectivity is verified among all control centers assigned by the Central Control Function to support the launch. Operators at Departure/Arrival Control Center request confirmation through the Central Control Function that the local Air Traffic Control Facility has assigned and cleared airspace as requested for the vertical ascent of the HLV and for all contingency abort landing sites for the Crew Exploration Vehicle (CEV). The Central Control Function receives verification from the Air Traffic Control Facility, and from the North American Regional Space Traffic Control Center that no conjunctions are expected with other objects in space.
0510 GMT	Pre-launch checkout process begins.	The Vehicle Processing Control Center generates a command to start the final countdown process. A notification is automatically issued by the Central Control Function to all users on the global network that the Cape Canaveral Spaceport has begun the final countdown for this flight. Upon receiving this notification, the local Air Traffic Control Facility issues routing instructions to aircraft operating along routes near the area to ensure the pre-defined airspace is clear along the EELV's intended flight path (plus safety margins). Pilots filing flight plans for airplane flight find NOTAMS describing the impending airspace restrictions. On operator displays at the Vehicle Processing Control Center and at the Departure/Arrival Control Center, the status indicators for the step-by-step procedures that make up the countdown change from red to green, one by one, as each is completed. The flight crew, already strapped into the vehicle, begins

		communications checks with the Departure/Arrival Control Center at the Cape Canaveral Spaceport and the Mission Control Center for this flight. While this is happening, the countdown reaches the step in the process for propellant loading. The automated ground and vehicle systems configure themselves and initiate loading of the propellants. All integrated health monitoring systems and built-in test equipment continue to indicate "go" for launch. From offices and user facilities in locations across the country and the world, NASA managers, flight and payload element managers, and operations support personnel have logged into the global system and requested access to the EELV launch designated CEV-3 to monitor flight readiness and ensure final launch commit criteria are met. All requirements thus far are indicating "green." At 9 minutes before the launch, the system will automatically poll each manager and operator and indicate a go/no-go status based on each response. If there are no "yellow" or "red" status indications, the launch countdown will continue. If there any indicate "no-go," then the system will automatically initiate a voice connection for all relevant participants so a decision can be made in light of all available data. On this day, there are no problems. The countdown enters its final seconds on the way to T-0.
0610 GMT	NASA Shuttle-derived, super heavy lift launch vehicle lifts off from Cape Canaveral Spaceport.	As the vehicle ascends, the Mission Control Center monitors the ascent of MEM-4 in anticipation of a handover of responsibility from the Departure/Arrival Control Center at Cape Canaveral Spaceport The operators in the Departure/Arrival Control Center continue to monitor the vehicle's ascent in the event an emergency return to the launch site is required. The flight goes smoothly through first stage burnout.
0611 GMT	Reusable first stage separates and begins flight back toward runway near launch location.	Controllers in the Departure/Arrival Control Center monitors the fly back stage through flight and landing.
0615 GMT	Crew exploration vehicle (CEV) and payload proceed over the horizon from the launch site.	The Departure/Arrival Control Center hands off control of MEM-4 to the Mission Control Center and notifies the crew with a voice call.
0630 GMT	CEV and payload separate in orbit and begin maneuvers toward rendezvous and docking with other elements in space.	The Mission Control Center monitors the separation of the CEV from its launch vehicle. Displays show a visual depiction as well as telemetry data. The display also indicates the status of step-by-step automatic procedures being implemented aboard the vehicle in preparation for its engine firing which will propel it out of Earth orbit. The crew confirms agreement between the onboard burn

		solution and the solution calculated by ground-based systems in the Mission Control Center. After receiving confirmation, the crew enables the flight vehicle to automatically execute the burn. When the time arrives for the burn to take place, an orbital maneuvering system jet fails to ignite. The burn takes place as planned.
0700 GMT	CEV and payload reach the proximity of the other elements in orbit and begin proximity operations in preparation for docking.	Operators in the Mission Control Center monitor streaming video, audio and procedural steps as the crew prepares to rendezvous with MEM-3. On-board systems and a laser trajectory control system assist the vehicle's navigation system in executing an automated gradual approach to MEM-3. Crewmembers can take manual control of the sequence at any time if safety is compromised or a system failure requires it.
0710 GMT	CEV experiences an anomaly that results in the loss of two of its three redundant power buses during rendezvous operations. After attempting to reset the circuit breakers, the CEV crew declares an emergency and begins preparations for reentry and landing.	The automated deorbit burn calculator determines from the vehicle's present orbital position, that it can make an emergency landing at Edwards in 3 hours or KSC in 4 ½ hours. The status being sent by the vehicle health monitoring system prompts controllers at the Mission Control Center to declare an emergency through the Central Control Function. The Central Control Function, in turn, notifies all involved control centers can clears their schedules to accommodate the emergency reentry, descent, return flight, and landing/recovery operations. Weather forecast data play heavily into the automated decision support system's consideration of options and its recommendation that the best opportunity for landing will be the first opportunity at Edwards. The crew and the Mission Control Center concur with that option and the crew enters a command that will automatically execute the burn at the appropriate time. The operators at the Edwards Departure/Arrival Control Center receive instant text messages on their handheld communication devices that a MEM emergency has been declared. They report to the Edwards Departure/Arrival Control Center and obtain and initiate contingency CEV landing procedures through the global network that's controlled by the Central Control Function. Meanwhile, the Central Control Function has also notified operators in the North American Regional Space Traffic Control Center and in the California Air Traffic Control Facility near Edwards of the emergency CEV landing plan. The Air Traffic Control Facility initiates procedures to re-route air traffic to clear the appropriate airspace for the vehicle's return and issues emergency notices to airmen for the vicinity surrounding the reentry and return flight path.
0712 GMT	CEV maneuvers away from other spacecraft and begins emergency reentry procedures.	The flight crew members strap into their seats and call up their onboard reentry procedures. As control center operators around the world and the flight crew watch their respective data displays, the deorbit burn takes place aboard MEM-4.

0718 GMT	CEV begins reentry.	The Regional Space Traffic Control Center monitors the reentry along with the Air Traffic Control Facilities and the Edwards Departure/Arrival Control Center.
0723 GMT	CEV enters atmospheric flight toward emergency landing at Edwards	The Regional Space Traffic Control Center hands off primary responsibility to the Departure/Arrival Control Center. The Mission Control Center maintains voice, video, and data contact with the flight crew until they land.
0740 GMT	CEV lands safely and recovery operations begin.	Operators at the Edwards Vehicle Processing Control Center work through emergency post-landing procedures to safe the vehicle for crew egress and crew and ground support personnel safety. The crew safely egresses the vehicle. The vehicle manufacturer test engineers at a user facility connected to the global network that's controlled by the Central Control Function request data on the power generation systems that failed that was archived during the flight. They receive it almost immediately on their desktop computers at their facility in Virginia. The data makes them suspect a circuit board problem in the electronic controller unit that controls the electrical distribution system. They forward the serial and lot numbers of the two boards to the manufacturer over the global network. An engineer at the manufacturer facility initiates inspections of stock circuit boards from the same lot. He finds indications of delamination on more than half. Immediate tests show a high failure rate of the boards in this lot. This information is transferred back to Vehicle Processing Control Centers at the Cape Canaveral Spaceport and at Edwards. The automated logistics system checks the lot and serial numbers for these parts aboard the next CEV being processed for launch and finds another board from the same lot. The automated planning and scheduling system adjusts the processing flow for that vehicle to remove and replace the board with another from a different lot. It also re-schedules the return of the CEV from Edwards to the Cape Canaveral Spaceport, and re-schedules the aborted flight. All control centers are notified by the Central Control Function of the new launch date and schedules required to meet it.

6.4 OPERATIONALLY RESPONSIVE SPACE (ORS) PROMPT GLOBAL STRIKE (PGS)

Operationally Responsive Space (ORS) launches of prompt global strikes highlight the need for responsive operations with the capacity to support frequent and concurrent flights, global communication connectivity for positive control throughout the flights, standardization & interoperability to support launches from multiple locations, safety approvals for responsive flights, flexibility and adaptability to accommodate frequent flights from multiple locations, efficient use of frequency spectrum for secure communication worldwide, and through plasma during reentry, and low-cost operations..

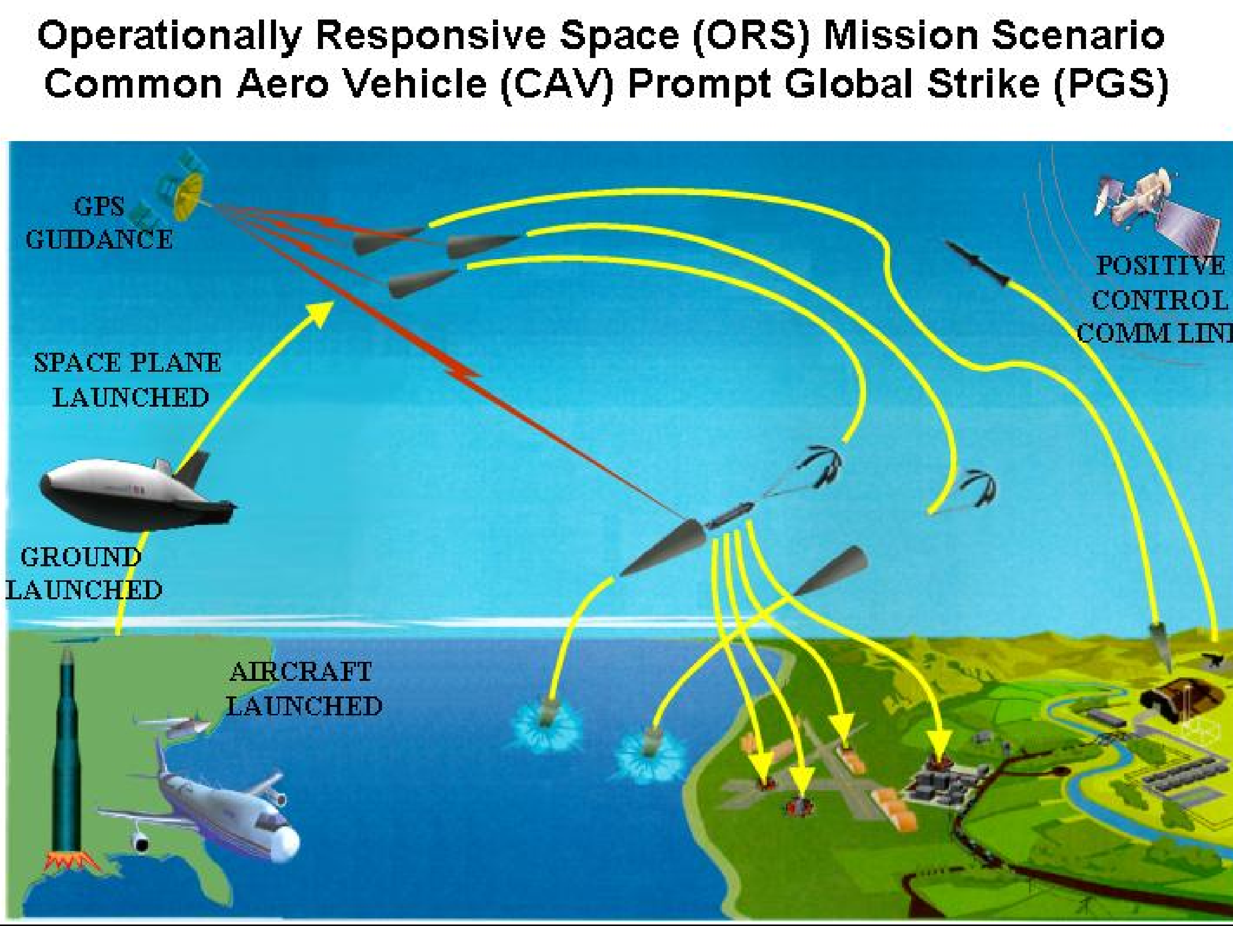


Figure 30. Operationally Responsive Space (ORS) Prompt Global Strike (PGS)

Time	Scenario Description	Space Flight Operations Actions
0646 GMT	U.S. early warning satellites detect a launch of an expendable rocket of unknown type from a nation currently antagonistic toward the United States. The trajectory appears to be toward high-inclination, low Earth orbit.	

0732 – 0750 GMT	Ground controllers lose contact with a U.S. commercial imaging satellite. Debris is detected by space surveillance sensors not related to the range, emanating from the imaging satellite's anticipated orbital position.	Range command and control system issues debris warning to all Mission Control Centers operating flight vehicles in low Earth orbit through the Central Control Function. Based on instructions from a Regional Space Traffic Control Center, a NASA crew exploration vehicle (CEV) already in orbit performs a collision avoidance (COLA) maneuver to adjust its course, providing greater vertical separation when its orbital path crosses that of the imaging satellite. Also based on instructions from Regional Space Traffic Control Centers, NASA, Air Force, and commercial spacecraft operators with satellites whose orbital paths cross the orbital path of the debris cloud maneuver their spacecraft to create greater separation and place their spacecraft in an attitude to minimize the chance of debris strikes.
0815 – 0830 GMT	The DoD mission operations center that controls ORS missions submits a high-priority schedule request through the automated scheduling system to delay other scheduled activities to initiate planning for two ORS missions later in the day. Both are to be conducted in response to the unanticipated foreign launch which the DoD suspects may have been carrying an anti-satellite weapon that attacked the commercial imaging satellite to mask preparations for regional aggression. DoD orders a rapid-response ORS mission from Vandenberg AFB to launch an inspection micro satellite at 1147 GMT so it will be able to maneuver and rendezvous with the remains of the commercial imaging satellite to inspect it for evidence of attack. DoD also orders preparations for an unpiloted reusable ORS vehicle at Cape Canaveral AFS to be prepared for launch a few hours later.	The automated scheduling system conducts its assessment of alternative courses of action and notifies DoD that its planned hypersonic cruise vehicle test flight will be delayed from its previously-scheduled launch time of 1630 to 2005 GMT to avoid any potential interference with these newly-identified operational ORS flights. The system sends a command to the Central Control Function which integrates the new military plan into the master schedule, notifying all users of the schedule impacts and revisions. At the request of the Vandenberg Departure/Arrival Control Center, the Central Control Function issues an order to ground-based and space-based range assets that will be supporting the ORS flight from Vandenberg AFB. Mobile airborne range assets begin active area surveillance and weather data reporting along the anticipated ORS flight path. Meanwhile, the Central Control Function coordinates with the North American Regional Space Traffic Control Center and uses automated decision support tools to calculate the required launch time to align the ORS vehicle's orbit with the failed imaging satellite. The Central Control Function also notifies the local Air Traffic Control Facility and the North American Regional Space Traffic Control Center to initiate procedures to clear the appropriate airspace for the vehicle's launch, issue notices to airmen for the surrounding vicinity, and notify the Departure/Arrival Control Center if the current flight profile results in any potential conjunctions with objects in space.
1147 GMT	ORS vehicle launches from Vandenberg AFB, timed to coincide with the passage of the orbital plane of the non-functioning commercial imaging satellite over the launch location.	Operators in the Vandenberg Departure/Arrival Control Center monitor the vehicle's flight path and system status during its ascent. All systems are functioning nominally. As the vehicle passes over the horizon, the local Air Traffic Control Facility lifts the airspace restrictions that had been established for the launch.

1149 GMT	ORS vehicle passes over the horizon from the launch location	The DoD mission operations center, through the Central Control Function, will retain primary control over this flight for the duration of its two-hour flight. Based on the results of automated decision support tool calculations, the Central Control Function sends a command to the vehicle to conduct a rendezvous burn that will bring the ORS vehicle within inspection distance of the commercial satellite. As the vehicle nears the satellite, the DoD mission operations center, through the Central Control Function, sends a command to activate on board still and video cameras. As onboard systems power up the cameras, operators in the DoD mission operations center, through the Central Control Function, begin to receive down-linked video images indicating that the satellite has indeed been severely damaged. Operators control the cameras' zoom lens in and out, to capture visual documentation of the damage. The pictures and video are forwarded to Pentagon officials immediately over the secure global information system.
1349 GMT	ORS mission to inspect satellite is now complete	The Central Control Function directs participating assets to go to post-operation state.
1510 GMT	An ORS launch from Cape Canaveral AFS is ordered for 1620 GMT.	At the request of DoD mission operations center controllers, the Central Control Function issues an activation order to ground-based and space-based range assets that will be supporting the ORS flight from Cape Canaveral AFS. At the request of the DoD mission operations center controllers, the Central Control Function issues an order to ground-based and space-based range assets that will be supporting the ORS flight from Cape Canaveral Spaceport. Mobile airborne range assets begin active area surveillance and weather data reporting along the anticipated ORS flight path. Meanwhile, the Central Control Function coordinates with the North American Regional Space Traffic Control Center and uses automated decision support tools to calculate the required launch time to align the ORS vehicle's orbit with the failed imaging satellite. The Central Control Function also notifies the local Air Traffic Control Facility and the North American Regional Space Traffic Control Center to initiate procedures to clear the appropriate airspace for the vehicle's launch, issue notices to airmen for the surrounding vicinity, and notify the Departure/Arrival Control Center if the current flight profile results in any potential conjunctions with objects in space. Uncrewed aerial platforms begin active area surveillance and weather reporting along planned flight path.
1550 GMT	Final checkout of ORS RLV begins.	Military operators at the Vehicle Processing Control Center monitor the automated pre-launch checkout sequence. All systems are go.

1620 GMT	Takeoff of ORS RLV from Cape Canaveral AFS.	Operators in the Cape Canaveral Spaceport Departure/Arrival Control Center monitor the vehicle's flight path and system status during its ascent. All systems are functioning nominally. As the vehicle passes over the horizon, the local Air Traffic Control Facility lifts the airspace restrictions that had been established for the launch.
1624 GMT	Flight vehicle proceeds over the horizon from the launch site.	The DoD mission operations center, through the Central Control Function, will retain primary control over this flight for the duration of its two-hour flight.
1705 GMT	RLV passes over the foreign launch site and conducts its reconnaissance mission.	All flight vehicle and payload/flight data is relayed through space-based range assets to and from the Central Control Function controlling the flight.
1750 GMT	RLV reenters and flies toward the planned landing site.	The Cape Canaveral Spaceport Departure/Arrival Control Center has primary control over the flight as it returns for landing, in coordination with the local Air Traffic Control Facility that has cleared the airspace for its return flight through the National Airspace System.
1755 GMT	RLV lands and DoD ORS mission operations center reports mission complete.	The local Air Traffic Control Facility lifts restrictions on the airspace that was restricted during the vehicle's descent. Data from the reconnaissance flight is forwarded immediately from the Departure/Arrival Control Center to Pentagon officials using the secure global information network.
1845 GMT	Based on results of the inspection and reconnaissance missions, DoD determines that the foreign launch did carry the ASAT weapon that destroyed the commercial imaging satellite. Additional intelligence reporting in the mean time has concluded that there are three more ASATs being prepared for launch from the antagonistic country. The President orders a prompt global strike mission to destroy the ASAT launchers before they can attack other U.S. satellites.	Operators in the Cape Canaveral Spaceport and Vandenberg Departure/Arrival Control Center are informed that the range command and control system (through the Central Control Function) has directed ground-based and space-based range assets to go to the generation state to prepare to support simultaneous ORS launches of five vehicles. The Central Control Function notifies the local Air Traffic Control Facilities near the launch sites to re-route air traffic around the local areas so it can use the airspace for these five ORS CAV launches. The central scheduling function notifies DoD (through the Central Control Function) that the hypersonic cruise vehicle flight test that had been scheduled for 1945 GMT will be delayed until at least 2005 GMT to avoid potential interference with operational launches.
1900-1930 GMT	Preparations orders are issued to conduct simultaneous ORS launches of five vehicles from two land-based locations in the continental United States and from one airborne platform flying off the west	Operators at the Vehicle Processing Control Centers, Departure/Arrival Control Centers and Air Traffic Control Facilities on the East and West Coasts monitor the preparation of all five vehicles and maintain voice communication with each other. Automated status indicators for all vehicles indicate green. All systems on all vehicles are go for launch.

	coast. Common Aero Vehicles (CAVs) with munitions are loaded onto two ground-based launch vehicles at one launch site, and onto another ground-based vehicle at another. A CAV with a UAV for battle damage assessment is loaded onto the other launch vehicle at the second launch site. The aircraft carrying the fifth CAV (already loaded with munitions) takes off from its alert position and establishes its racetrack pattern over the Pacific Ocean, awaiting specific targeting data and the launch order.	The Departure/Arrival Control Center coordinates with the local Air Traffic Control Facility for use of some West Coast airspace for the flight of the aircraft carrying the air-launched CAV to the launch location over the Pacific Ocean.
1930 GMT	Targeting data is uploaded to each CAV and the launch order is issued. All five launch vehicles begin their flights at the same time.	Operators in the Departure/Arrival Control Centers execute commands to upload targeting data to each launch vehicle and CAV to program the proper trajectory parameters into the guidance systems. After 1 minute, the vehicle onboard systems verify that the targets are loaded. The displays in the Departure/Arrival Control Centers show 5 green status indications—one for each vehicle.
1933-1940 GMT	One of the launch vehicles flying over the ocean from the eastern launch site malfunctions and its autonomous flight termination system destroys the launch vehicle, the CAV, and its munitions payload. The other four launch vehicles proceed over the horizon from their initial launch locations. The CAVs separate from their launch vehicles and begin traveling through space along ballistic trajectories toward the target area.	The automated decision support tools operated by the Central Control Function calculate the areas where the debris from the vehicle destruct action will fall. Operators in the Departure/Arrival Control Centers that will control these five flights from end to end continue to monitor the remaining four vehicles and separations from their launch vehicles. Regional Space Traffic Control Centers also continue to monitor the progress of each vehicle's flight through their respective regions of jurisdiction.
1942 GMT	DoD issues a re-targeting command for one of the CAVs carrying munitions, and now flying along a ballistic trajectory through space.	One of the Departure/Arrival Control Centers executes a re-targeting command for one of the vehicles it launches, and waits for confirmation from the command and control system that it has relayed the re-targeting data to the CAV and received confirmation from onboard systems that the re-targeting data is onboard. Within one minute, the operators receive a confirmation indication on their displays that the

		new target is on board the CAV.
1944 GMT	All four CAVs begin reentry.	Operators in the Departure/Arrival Control Centers monitor the vehicles descent through the atmosphere.
1950 GMT	All four CAVs complete reentry and begin atmospheric glide maneuvers toward their designated targets.	Operators in the Departure/Arrival Control Centers monitor the vehicles descent through the atmosphere.
1955 GMT	The CAV carrying the UAV reaches its dispensing altitude and speed, and deploys the UAV to begin its ISR mission to collect battle damage assessment data.	Operators in the Departure/Arrival Control Center controlling the CAV flight with the UAV on board see indications on their displays that the CAV with the UAV has reached its dispensing altitude. They wait for indications to change status as the UAV is deployed. They receive notification that the UAV is now being remotely flown by a pilot in the continental United States.
2002 GMT	The three CAVs carrying munitions reach their dispensing altitude and speed, and deploy their munitions payloads.	As the munitions from the remaining CAV's are deployed, operators in the Departure/Arrival Control Center operating this CAV flight monitor indications on their displays.
2003 GMT	Munitions explode on their targets. UAV collects and transmits real-time video.	Operators in the Departure/Arrival Control Centers see video relayed from cameras on board the UAV displayed on their workstations. Initial views indicate all targets were destroyed. The downlinked video is automatically archived and transmitted to Pentagon officials via the secure global information system.
2006 GMT	CAV aeroshells autonomously destruct.	Operators in the Departure/Arrival Control Centers see the destruct indications of the CAV aeroshells.
2010 GMT	CAV mission complete.	Flight data is automatically archived for retrieval and post analysis.

6.5 FLIGHT TEST OF A NEW PROTOTYPE DOD HYPERSONIC CRUISE VEHICLE (HCV)

Flight test & evaluation of a new prototype DoD hypersonic cruise vehicle highlights needs for responsiveness to support multiple concurrent aeronautical flight tests per day, standardization and interoperability to enable point-to-point flight operations, and efficient use of frequency spectrum to support high data-rate requirements for multiple vehicles .

Figure 31. Flight Test & Evaluation for New Prototype DoD HCV

Time	Scenario Description	Space Flight Operations Actions
1950 GMT	Test flight of a new prototype DoD hypersonic cruise vehicle (HCV) had originally been scheduled for 1945 GMT has been re-scheduled for 2005 GMT takeoff to avoid potential interference with multiple concurrent operational CAV launches. The CAVs have proceeded over the horizon from the continental U.S.; conducting their operational missions.	DoD requests support for its re-scheduled test flight of a new DoD hypersonic cruise vehicle. The Central Control Function orders ground-based assets at the takeoff site, airborne assets over western U.S. and northern Pacific Ocean, as well as space-based assets covering the region, to enter the generation state to support the re-scheduled test flight. The Departure/Arrival Control Center (through the Central Control Function) coordinates use of airspace for flight test activities. Operators in the Air Traffic Control Facility re-route air traffic to ensure safe separation.

1955-2005 GMT	DoD HCV undergoes its final pre-flight checkouts on the runway.	Operators in the Vehicle Processing Control Center, and in the Departure/Arrival Control Center, monitor the progress of the automated pre-flight checkout system as it indicates completion of required preparation tasks one by one.
2005 GMT	Takeoff of DoD HCV from a DoD site inland in California.	Operators in the local Departure/Arrival Control Center, Air Traffic Control Facility, and Regional Space Traffic Control Center monitor the initial flight of the vehicle.
2010 GMT	HCV proceeds over the horizon from the takeoff site.	Operators in the local Departure/Arrival Control Center, Air Traffic Control Facility, and Regional Space Traffic Control Center continue monitoring onboard systems and vehicle data.
2015-2045 GMT	HCV accelerates to hypersonic speeds over Pacific Ocean, then decelerates and turns to fly back toward the landing site.	Operators in the local Departure/Arrival Control Center, Air Traffic Control Facility, and Regional Space Traffic Control Center continue monitoring onboard systems and vehicle data.
2045-2055 GMT	HCV comes over the horizon and approaches the landing site. HCV lands successfully, rolls out, and completes its flight test mission.	Operators in the local Departure/Arrival Control Center, Air Traffic Control Facility, and Regional Space Traffic Control Center continue monitoring onboard systems and vehicle data. Automatic data archival of all flight test data is initiated and forwarded to the test conductor for analysis.

6.6 Ballistic Missile Defense System (BMDS) Flight Test

A scenario depicting a two-on-two ballistic missile defense system (BMDS) flight test involving two targets and two interceptors. Each launched from a different location highlights needs for global coverage to provide telemetry, optics, radar, and other support over broad ocean areas, standardization and interoperability to enable target and interceptor launches from multiple locations, evolved safety approval processes to enable complex intercept tests, and flexibility and adaptability to accommodate frequent flights and schedule changes.

Figure 32. Two-on-Two Ballistic Missile Defense System Flight Test

Time	Scenario Description	Space Flight Operations Actions
2315 GMT	A two-on-two BMDS intercept test scenario is scheduled to begin at 2335 GMT. Target vehicles will be launched simultaneously from the Reagan Test Site at Kwajalein Atoll in the Marshall Islands, and from the Kodiak Launch Center in Alaska. Both will proceed toward the west coast of the United States. Two	The automated scheduling system issues an order through the central command function to generate support for the BMDS test. Operators at Reagan and Kodiak configure there displays with BMDS displays.

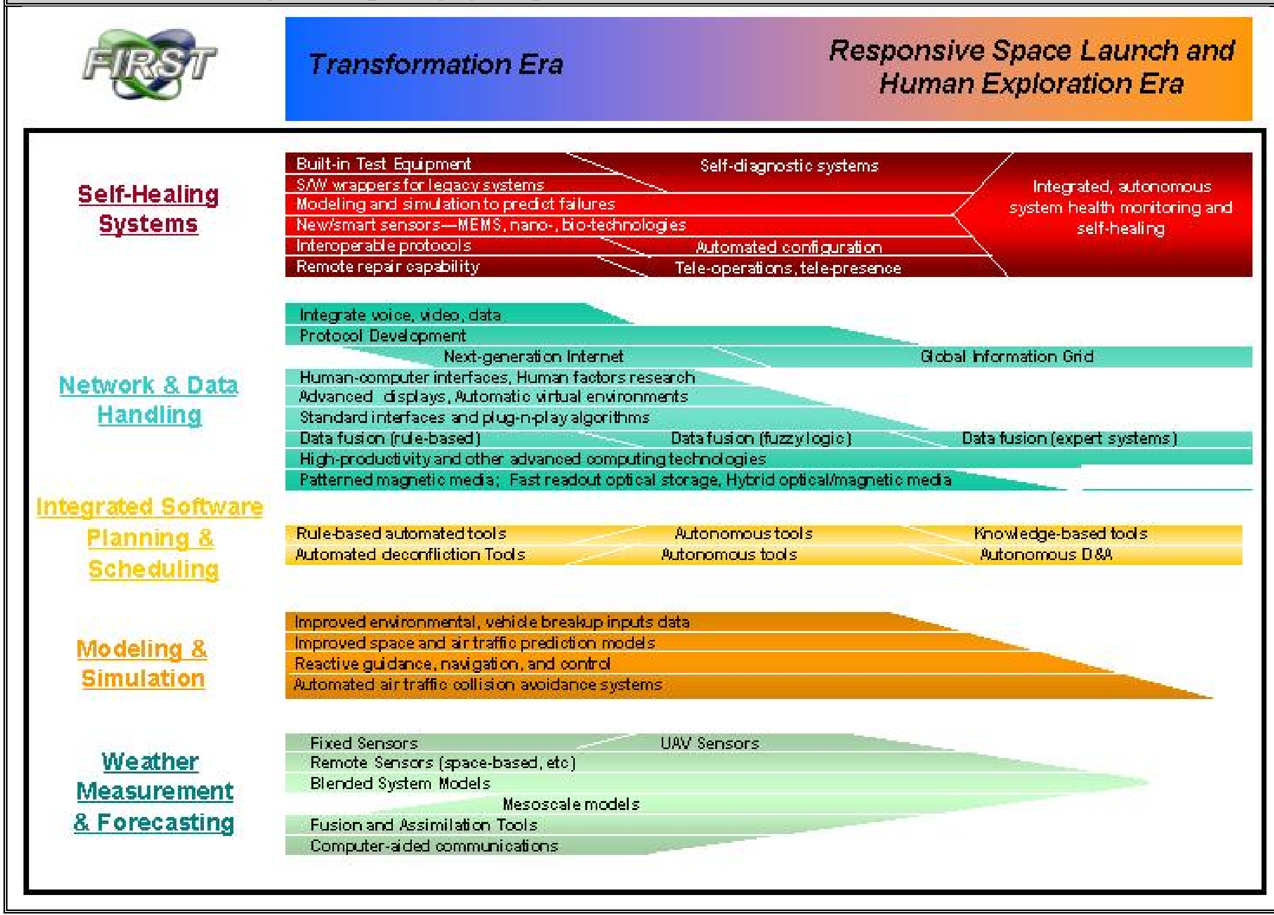
	interceptors will be launched from Vandenberg AFB, CA to engage the targets.	
2320 GMT	Begin pre-flight checkout process for target and interceptor vehicles at Kwajalein, Alaska and California.	Central control function verifies data and network connectivity among all assets and control centers that will be supporting the scheduled BMDS test. Operators see indications that all assets are ready to support the test.
2330 GMT	Continue pre-flight checkout processes.	Operators at Reagan converse with the operators at Kodiak about the test while each continues to monitor the vehicles that will be launching from their facility. All indications are good, all system are go.
2335 GMT	Target vehicles take off from Alaska and Kwajalein for a 16-minute flight toward California.	The operator at Reagan verifies the target vehicle has launched and notifies his Kodiak counterpart. He then continues to monitor a three-dimensional graphical display of the vehicle, its flight boundaries and its trajectory.
2340 GMT	Two interceptor vehicles are launched from Vandenberg.	The operator at Kodiak notifies the operator at Reagan that the interceptor vehicles have launched. On his display, the Reagan operator can see the two vehicles on trajectory toward the target vehicle launched minutes ago. He watches as relevant data from both vehicles and time to intercept is overlaid on the graphic.
2340 GMT	Interceptors approach and engage the target vehicles.	As video from mobile assets in the area begin streaming live video, the operators see the target destroyed by the interceptors. Airborne mobile assets also observe and collect information on the engagements and as the resulting debris descends toward the Ocean.
2350 GMT	BMDS mission complete reported to central control system.	Data from the test is automatically archival for retrieval during flight test analysis.

7.0 ENABLING CAPABILITIES

This section describes the enabling capabilities that will be necessary to enable future space flight operations as described in this CONOPS. While it is not the primary purpose of this CONOPS to envision new technologies or capabilities, this CONOPS is intended to describe new ways of operating with technologies or capabilities that are likely to exist in the future. Hence, this section describes a variety of technology areas and standardization approaches that address the technical challenges that stand in the way of achieving the necessary capabilities to enable future space flight operations as envisioned.

7.1 TECHNOLOGIES

This enabling technology roadmap presents a time-phased approach to addressing the technical challenges associated with achieving the necessary capabilities for the envisioned future space flight operations described in this CONOPS.



Source: ARTWG Baseline Report

Figure 33. Enabling Technology Roadmap

The enabling technology roadmap depicted in Figure 32 presents the recommended time-phased approach to pursuing these technology development and demonstration activities over time. The five technology areas addressed in this section are:

- Self-Healing Systems
- Network and Data-Handling

- Integrated Software Planning and Scheduling
- Modeling and Simulation
- Weather Measurement and Forecasting

The remainder of this section describes opportunities and recommendations regarding development and demonstration activities that should be pursued to address each of these areas and enable the future space flight operations capabilities envisioned in this CONOPS.

7.1.1 Self-Healing Systems

Technology development and demonstration activities to enable the incorporation of integrated health monitoring, auto-configuring and self-healing capabilities into future spaceport, range, and flight vehicle systems will:

- Enhance reliability and availability;
- Enable automated planning, scheduling, coordination and configuration of spaceport and range assets to support responsive and concurrent ground processing and space flight operations at a higher operations tempo;
- Support improved real-time situational awareness based on area surveillance and flight vehicle information; and
- Enable automated decision-making support capabilities.

This enabling technology area could be pursued in the near-term by adapting built-in test equipment from the automotive and aviation industries, along with use of software wrappers to enable continued use of some legacy spaceport and range systems in the new network-centric environment while individual new systems are incrementally brought on-line to improve future range operations. In the mid-term, these technologies could be combined to enable the development of self-diagnostic systems. The roadmap also recommends pursuing parallel near- and mid-term technology improvements in tiny sensors along with modeling and simulation to better predict component and system failures as means of enhancing the built-in diagnostic capabilities of range systems.

In parallel, near-term technology efforts to improve interoperability and remote repair capabilities could enable evolution in the mid-term to technologies for automated system configuration and tele-operations to accomplish repairs of remotely-located systems and components. All of these technologies could be combined in the far-term to enable systems with integrated and autonomous health monitoring, diagnostic, auto-reconfiguration, and ultimately, self-healing capabilities.

7.1.2 Network and Data Handling

Improving the data handling and network capabilities to distribute, record, store, archive, and retrieve voice, video, and data over the global network will:

- Improve interoperability among spaceports, ranges and control centers, with national airspace management systems, and with user networks and systems.
- Take advantage of common, standard interfaces, protocols, and formats for processing, transferring, displaying, and coordinating data and information so it can be fused and integrated more simply for information displays depicting situational awareness.

- Leverage use of commercial-off-the-shelf systems that incorporate standard, expandable, plug-and-play capabilities and network architectures to enable use of advanced data handling capabilities being developed for a variety of applications, as well as a variety of innovative digital data storage and display capabilities.

Technology efforts in this area focus on leveraging ground and wireless network development efforts being pursued for commercial applications. Technologies to improve ground-based networks include near-term integration of digital voice, video, and data streams along with development of new protocols and next-generation Internet research that's already being pursued for a variety of commercial applications. These technologies should be further refined, combined, and leveraged to ensure that future range data transport systems are compatible with the planned and emerging Global Information Grid.

Data handling technologies should focus in the near-term on standard interfaces and plug-and-play algorithms. In parallel, future technology development efforts should focus on enabling increasingly sophisticated levels of data fusion from a variety of disparate sources, starting with rule-based methods, then incorporating fuzzy logic, and expert systems later. Meanwhile, the development of standards and protocols to document data and network-based embedded software should be pursued in parallel to enhance the compatibility of data and simplify its combined use.

Commercial advances in computing technologies should also be leveraged and pursued in parallel to enhance data handling capabilities on ranges. Under the data processing heading, commercial technologies to improve the speed of processors, coding and embedded processors, including serializer/deserializer (SerDes) chips and associated protocols, should be leveraged to enhance global network capabilities.

With regard to digital data recording, storage, archiving, and retrieval, commercial off the shelf, expandable, modular, network-accessible, automated mixed media library systems are available today to enable access to more than a dozen types of storage media. A wide variety of research projects are currently underway for a variety of commercial and defense applications. Some explore new digital data recording, storage, archiving, and retrieval architectures concepts, techniques, and implementations that reduce data bandwidth and data access latency limitations. commercial efforts to improve data recording and archiving technologies (e.g., magnetic, optical, and hybrid arrays) should also be leveraged for use as part of the global network supporting space flight operations. Others are intended to simplify the design of complex embedded systems by focusing on ways to automate network controller design and systems integration. Still other projects are pursuing standards for high-density optical, magnetic, volumetric, hybrid, organic, cellular, and tissue-based memory systems that are less sensitive to losses induced from reading the data. All of these technology development activities could be leveraged to improve the ability of the FSTS and its global network to efficiently handle data.

Finally, display technologies should address improvements in human-machine interfaces, human factors, and various technologies to enhance the ability to display information in ways that are both intuitive and meaningful to system operators and users as well as flight crews.

7.1.3 Integrated Software Planning and Scheduling

Various integrated software planning and scheduling technologies should be leveraged from the commercial sector to:

- Improve the efficiency of planning, scheduling, and coordinating spaceport, range, and control center support, and
- Enable centralized control of more complex and frequent global operations.

These include commercial efforts to develop increasingly sophisticated, automated, and autonomous tools using rule- and knowledge-based algorithms, data mining techniques, and methods of standardization and integration to enable sharing of databases and automation of scheduling functions, including de-confliction of large numbers of operations using limited resources. Information assurance principles must be included and addressed in parallel to enable these capabilities to be applied in applications that could include safety and security risks associated with space flight operations.

7.1.4 Modeling and Simulation

Technologies to improve modeling and simulation apply to a variety of space flight operations functions, but focus in large part on:

- Safety, as enhanced by automated decision-making analysis and support, relating to toxic, debris, and collision hazards;
- Weather-related constraints, including modeling of atmospheric and environmental parameters in combination with the dispersal characteristics of leaking or exploding propellants and vehicle debris after breakup;
- Simulation of the reliability and failure modes of spaceport, range, and control center assets to support planning, scheduling, and coordination of assets for operational use and maintenance/repair; and
- Training, using sophisticated modeling and simulation capabilities.

Data handling technologies described above can contribute to modeling and simulation, but technologies to improve visualization and integration of modeling outputs should also be pursued to take full advantage of the increasingly capable models. Increasingly capable models also rely on more accurate input data and more complete understanding of physical processes, so improved sensor capabilities can also contribute to improvements in this area.

Three technology areas would have to be developed together to enable enhancements in collision avoidance: increasingly sophisticated predictive models for air and space traffic, adaptive guidance/navigation/control technologies that can respond correctly and in time to avoid impending collisions, and automated systems to assist in executing collision avoidance maneuvers within the structural limitations of vehicles in various phases of flight from launch through landing.

7.1.5 Weather Measurement and Forecasting

A variety of technologies should be pursued to enhance the ability of spaceports and ranges to measure and forecast weather conditions, including lightning, to enhance the safety and efficiency of ground processing and flight operations.

These include improved sensor technologies, first on the ground and later as instruments to be carried on space-based or mobile airborne platforms, improved models to take multiple conditions and phenomena into account in modeling and forecasting regional (or meso-scale) weather patterns. Communicating the inputs and results of these improved models also requires improvements in technologies for data assimilation and fusion, combined with computerized output generation and communication.

As a final note, many of the technology areas listed above and depicted on the enabling technology roadmap overlap with many other areas of applicability besides space flight operations. This overlap leads to possibilities for synergy and collaboration to advocate, develop, and demonstrate technologies with a variety of applications, both on and outside ranges.

7.2 STANDARDIZATION

Even today, the nation's spaceports, ranges, and control centers are the product of substantial investments to provide shared-use supporting infrastructure for flight test and operational space flights. For future space flight operations capabilities, standardization is an important element of any strategy to increase availability of shared resources and boost interoperability among vehicles operating to and from multiple locations—a key element of the vision for future civil, commercial and military space transportation that involves routine and frequent point-to-point flights.

Designing flight vehicles to be compatible with a standard set of spaceport, range, and control center interfaces would reduce the total amount of infrastructure required to support projected future missions, enhance interoperability by providing a common network-centric architecture for connecting assets, improve safety (especially under emergency conditions), and reduce total costs.

Standardization is most economical and operationally beneficial in cases—as envisioned for the third era—characterized by mass public space transportation and:

- High operations tempo (i.e., more traffic)
- Many different vehicle types interfacing with the same support infrastructure
- Multiple takeoff/launch/landing/recovery locations in use to support point-to-point flights.

Adopting standards will also lead to benefits in designing future in-space infrastructure in and beyond Earth orbit to support the U.S. vision for space exploration to pursue Moon and Mars exploration. The in-space navigation and communication infrastructure that will be required to support these operations could leverage advanced technologies developed initially for terrestrial applications.

Examples of areas where standardization will be both beneficial and practical for enhancing the nation's ability to conduct space flight operations include:

- Wireless communication protocols
- Schedule integration
- Shared common databases

Standardization of spaceport, range, and control center infrastructure is not a new concept, but it is essential to achieve the FIRST vision. Standards will only be accepted if they benefit users by providing economic advantages, improved capabilities, or more efficient operations. Any standards development activities for the future of space flight operations must be coordinated with and leverage established standardization organizations and processes.

8.0 SUMMARY

This CONOPS outlines a common national vision for conducting space flight operations. The vision described in this CONOPS offers an integrated, interoperable approach for conducting future civil, national security and commercial space transportation operations in ways that resemble today's management of the commercial air transportation system.

In contrast to today's vehicle-unique operations, this vision for the future is based on the shared use of spaceport and range support elements worldwide, to accommodate multiple simultaneous flights of different types of vehicles to, through, and from space. This worldwide transportation system is enabled by a centrally-managed, automated planning, scheduling, and coordination capability with network-based user interfaces. Future space flight operations are supported using a variety of control centers tied together through a network-centric Central Control Function to coordinate ground and flight operations and support worldwide.

Future space flight operations are enabled by:

- A centrally-managed, secure, global information network that is accessible to all users and operators on a subscriber service basis
- A hierarchy of control centers, each with its own clearly-defined authorities and roles, to support more frequent and routine space flight operations worldwide
- Automated planning, scheduling, coordination, and decision support systems
- Integrated health management systems to automatically identify and isolate system faults and automatically re-configure systems to continue supporting and conducting space flight operations, and continuously report status to enhance situational awareness
- Seamless coordination of space flight operations with use of the National Airspace System and to ensure safe separation among objects flying to, through, and from space

To achieve this vision, the nation's space flight operations capabilities evolve through a series of incremental spiral development steps over time, with progress being driven by increasing demands for improved support capabilities for future space flight operations, and by technology availability.

The primary focus during the Transformation Era is on technology development and incremental deployment of new capabilities to support emerging missions. In the Responsive Space Launch and Human Exploration Era, support for future space flight operations is coordinated through a Central Control Function. In the Mass Public Space Transportation Era, standardization across spaceports, vehicles and operations centers allow various types of space vehicles to operate at multiple locations worldwide.

In conclusion, pursuing opportunities for technology development and demonstration activities will enable the development of the future capabilities described in this CONOPS. Only by developing these capabilities will future space flight operations be able to satisfy the future demands for space transportation from the civil, commercial, and national security space sectors, including eventual mass public space travel to rapidly move people and cargo between points on the globe and into space.

APPENDIX 1 – SEQUENCED ACTIONS

Space flight operations are typically conducted to align with the following six sequential phases:

1. Planning
2. Processing
3. Departure Operations
4. Flight Operations
5. Return and Landing
6. Refurbishment and Turnaround

Range operations are typically conducted in six sequential phases.

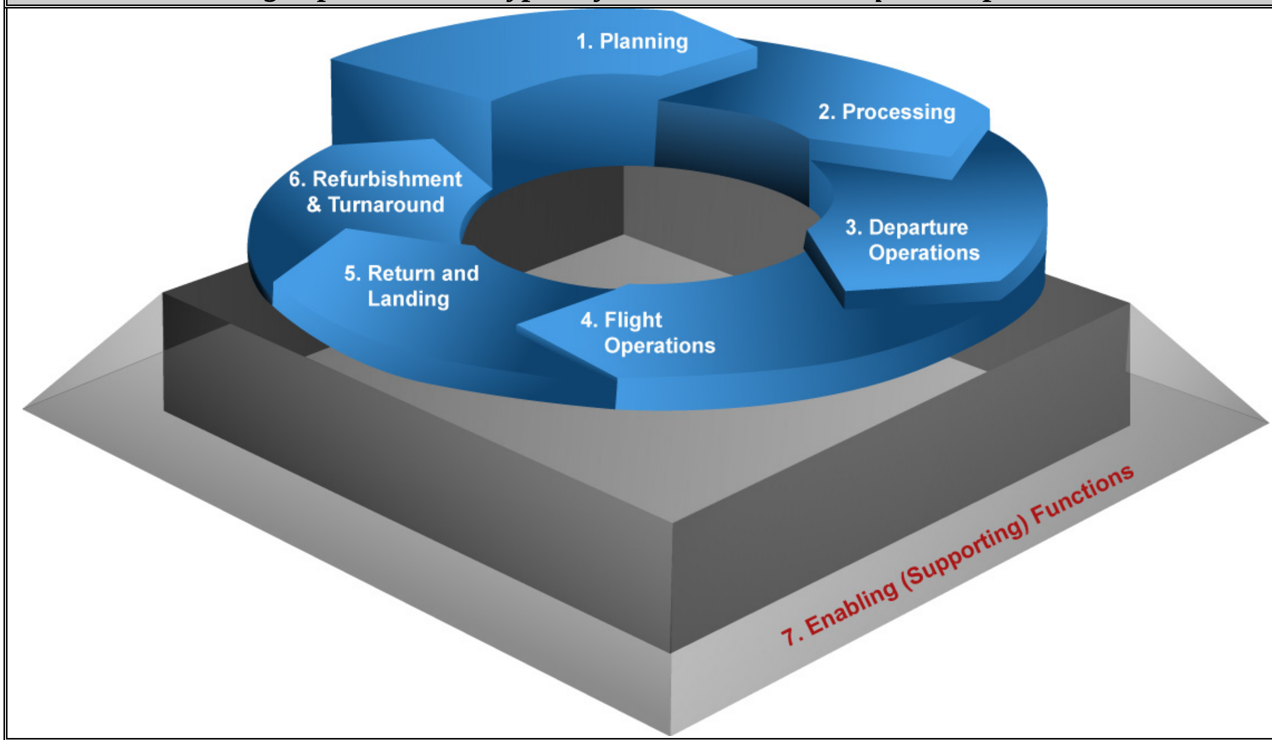


Figure A-1. Sequenced Actions

1. Planning

The planning phase includes all activities required before beginning to support processing activities, including:

- Analysis of vehicle and flight parameters by automated decision-making support tools to determine safety restrictions, flight trajectory limits, potentially hazardous areas.
- Planning, scheduling, and preparation activities, including weather measurement and reporting, area surveillance, and data fusion for decision-making support.
- Initialization, calibration, and verification of supporting assets and their connectivity to the communication network for distribution of command, control, voice, video, and data.

- Deployment, configuration and verification of supporting system readiness to support flight safety and user interfaces and requirements to support pre-flight and flight operations. The configuration and verification step also includes establishing, coordinating, and verifying interfaces with various control centers, user networks and facilities, and external agencies and networks.

2. Processing

The processing phase includes all activities required for to support the pre-flight processing, checkout and verification that precedes a space flight operation . This phase typically includes pre-flight processing, checkout, and verification processes to ensure proper installation and operation interfaces with the flight vehicle(s) and payloads/cargo, and crew and passengers (when applicable).

3. Departure Operations

The departure operations phase includes all activities required to support the countdown or final checkout, takeoff or launch. This phase typically includes:

- Countdown processes (e.g., loading and verifying vehicle commodities and flight parameters), including holds, scrubs, or aborts.
- Support for launch/takeoff of space launch or flight test vehicles until they pass over the horizon from the launch/takeoff site.

4. Flight Operations

The flight operations phase includes all activities required to support the near-Earth transportation aspects of space flight operations. This phase typically:

- Support for atmospheric flight, reentry, landing, and recovery operations; and
- Real-time data collection, recording, distribution, processing, and display during the space flight operations that involves near-Earth transportation.

5. Return and Landing

The return and landing phase includes all activities required to support the reentry, atmospheric flight, and landing of flight vehicles at landing/recovery sites.

6. Refurbishment and Turnaround

The refurbishment and turnaround phase includes all activities required to efficiently transition from the operations support phases back to a safe mode, and typically includes the following:

- Shutdown of range instrumentation systems from the active mode that was required to support an operation;
- Routing and archiving data to make it available for post-operational data reduction, analysis, and display, including re-construction and analysis of anomalous events;
- Performing analyses to assess system performance while it was in use to support the space flight operations;
- Report support asset usage to support the generation of billing data and to provide inputs data for the scheduling of periodic maintenance or repairs;
- Scheduled maintenance, repairs, and modifications; and
- Idle/standby.

APPENDIX 2 – GLOSSARY

Abort. A premature termination of an operation for any reason. The abort may occur at any point from initiation of an operation to expected completion.

Airspace. Space above the surface of the earth or a particular portion of such space; usually defined by the boundaries of an area on the surface, projected upward. Controlled airspace is the space within which some or all aircraft may be subject to air traffic control.

Analysis. The verification by quantitative/qualitative evaluation using system, subsystem, or component representation (e.g., mathematical and/or computer models, simulations, algorithms, equations), charts, graphs, circuit diagrams, and representative data or evaluation of previously qualified equipment.

Archive. This function stores data for subsequent retrieval.

Asset. Anything available to the range that can be scheduled. Examples of assets include instruments, facilities, vehicles and personnel. Consumables are not assets.

Automated. The application of methods for making processes, functions, algorithms, or equipment self-acting or self-moving; to make automatic.

Availability. A measure of the degree to which an item is in an operable and committable state at the start of a flight when the flight is called for at an unknown (random) time. Availability is dependent on reliability, maintainability, and logistics supportability.

Bent Pipe. A method of routing data or communication signals through a transponder without changing its content.

Centralized. A capability of assets, group of assets, components, functions, or processes anywhere in the LTRS such that they can be monitored, controlled, displayed, recorded, etc.

Collect. The acquisition of data from various sources including sensing, signal reception, generation, measurement, and observation.

Commercial-Off-The-Shelf (COTS). Commercial product/equipment designed for commercial use. It is procured exactly as found in the commercial market, and the product/equipment changes and upgrades are the same as vendor provides to his commercial customers.

Concept of Operations (CONOPS). An Air Force document which describes the sequenced actions and capabilities required to generate the desired effects needed to achieve military objectives.

Concurrent. The occurrence of separate activities or events during the same time interval, where the individual steps of the separate activities or events do not necessarily occur at precisely the same time.

Configuration. A collection of interfaced assets supporting a particular space flight operation.

Configure. The act of arranging components to operate in a defined state.

Countdown. See "launch countdown"

Data. Information that is used as a basis for mechanical or electronic computation, or a collection of facts, numbers, letters, symbols, etc., from which a conclusion can be drawn. Range data may be raw or processed, and in analog, digital, hard copy, and/or electronic formats. Types of data include but are not limited to; telemetry, space object, timing, weather, metric, imaging, range asset health and status, voice, hazard, vehicle uplink, and data products.

Debris. The parts of a launch vehicle, satellite, missile, or reentry vehicle that are either jettisoned, broken off, or a result of flight termination.

Deconflicted. Asset(s) or group of assets that have no higher priority required, and/or are not scheduled to be in use.

Display Data. Visual presentation of information (e.g., graphical, textual or discrete "image"). Display function determines not only the information to be shown, but the methods of presentation. Various purposes for displays are: 1) Continuous system control, 2) System status monitoring, 3) Briefing, 4) Search and identification, and 5) Decision making. Information can be presented on a surface, cathode ray tube (CRT) window, or screen.

Distribute Data. To prepare data for transmission, including: identification of the destination(s) for data, formatting data appropriate for the destination(s), and presentation of data to the transport media, either physical or electronic.

Failure. The loss of proper service that is suffered by the user interface to the asset.

Hold. A temporary interruption of a launch countdown script.

Image. The representation of an object by optical, microwave, chemical, or other processes**.**

Instrumentation. Devices or a system of devices used to collect and/or process data.

Interoperability. A measure of the ability to seamlessly share data and information with other sources, systems, agencies, etc.

Launch Commit Criteria. The implied decision tree which determines the go/no-go decision for the launch. Range safety and the range user will each have their own independent criteria.

Launch Countdown. The operation implementation of the scripted procedure that ends in the "commit to launch."

Maintenance. The technical process of keeping LTRS equipment in an operational state, or repairing a malfunctioning unit once the equipment is in use. The act of preserving LTRS (e.g., hardware, or software) from failure or decline. Maintenance is one element of sustainment that can begin before the system is deployed in the field.

Operation. Any procedure, function requiring the use of resources.

Operationally Responsive Spacelift (ORS).

Readiness. A measure of the ability to immediately execute an assigned activity or operation.

Reusable Launch Vehicle (RLV).

Reconfiguration Time. The time from final range release of an asset from one operation to asset ready to support a countdown or the next scheduled range operation. Reconfiguration is a known, pre-planned activity that includes asset deconfliction, configuration, calibration, and verification. Reconfiguration time excludes asset relocation.

Record. This function stores data, short term, for subsequent playback.

Reliability. Reliability is the probability that a system is operable and can perform its required function for the space flight operation's duration or a specified period of time. For the reliability requirements, this is represented by the probability that, under stated initial and operational conditions, the Range will be able to sustain specific functional capabilities over a designated period of time (t, defined below), without incurring a loss of those functional capabilities.

Retrieval. This function allows selective recovery of data from the storage media and provides it to the authorized requester.

Schedule [noun]. Published interdependencies of assets allocated to a particular activity or related sequence of activities, set for exact location(s), date(s), and time(s) that do not conflict with the use of assets allocated to other activities.

Standardization. The use of standard requirements to maintain performance over a wide range of common applications. Standardization applies to hardware, software, services, methods, and other processes.

Support. An activity which enables the fulfillment or accomplishment of a separate activity**.**

Telemetry (TLM). The process by which a measurement of a quantity is transmitted from a remote location to be recorded, displayed, or processed.

Test. The verification through systematic exercising of an item under appropriate conditions, with instrumentation and data collection and processing (followed by analysis and evaluation of quantitative data).

User. A Military organization, Government agency, civil, or commercial organization that makes use of range services and/or facilities.

Verification [by Demonstration]. The qualitative determination of properties or function of an end-item or component by observation. Demonstration will be used with and without special test equipment, simulators, recorded data and scenarios to verify requirement characteristics such as operational performance, human engineering features, service access features, transportability, display data and integration integrity.)

APPENDIX 3 – ACRONYM LIST

AFSPC	Air Force Space Command
ASAT	Anti-Satellite
ATC	Air Traffic Control
BMDS	Ballistic Missile Defense System
CAV	Common Aero Vehicle
CEV	Crew Exploration Vehicle
CONOPS	Concept of Operations
COTS	Commercial Off the Shelf
DoD	Department of Defense
DO T&E	Director of Operational Test and Evaluation
DRM	Design Reference Mission
ELV	Expendable Launch Vehicle
EELV	Evolved Expendable Launch Vehicle
FAA	Federal Aviation Administration
FAA/AST	Associate Administrator for Commercial Space Transportation
FIRST	Future Interagency Range and Spaceport Technologies
GMT	Greenwich Mean Time
HCV	Hypersonic Cruise Vehicle
IVHM	Integrated Vehicle Health Monitoring (System)
KSC	Kennedy Space Center
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
ORS	Operationally Responsive Space(lift)
PGS	Prompt Global Strike
RLV	Reusable Launch Vehicle
SATMS	Space and Air Traffic Management System
TACSAT	Tactical Satellite
TT&C	Telemetry, Tracking and Control
T&E	Test and Evaluation
UAV	Unmanned Aerial Vehicle

ENDNOTES

[1] "Needs Assessment, Enabling New Markets and Missions for Spaceports and Space Launch Ranges," Future Interagency Range and Spaceport Technologies, DRAFT as of May 2004

[2] "Serializer/Deserializer (SerDes) Chips. For transmitting and receiving data in Ethernet, storage and telecommunications networking equipment, Broadcom offers a family of serializer/deserializer chips … Broadcom's advanced SerDes chips support various data rates [from 3 to 10 Gbps] and incorporate many features, including advanced on-chip diagnostic intelligence that allows system designers to monitor, test and control high-speed serial links for signal integrity and bit error rate performance. ….", Broadcom products web page, http://www.broadcom.com/products/category.php?category_id=31&cookiecheck=1

[3] "Concept of Operations for Commercial Space Transportation in the National Airspace System," Version 2.0, Federal Aviation Administration, May 11, 2001

[4] "Concept of Operations for Spaceports," Future Interagency Range and Spaceport Technologies, DRAFT as of May 2004