TRANSFORMATIONAL SPACEPORT AND RANGE CONCEPT OF OPERATIONS

A VISION TO TRANSFORM GROUND AND LAUNCH OPERATIONS

FUTURE INTERAGENCY RANGE AND SPACEPORT TECHNOLOGIES

FIRST

Reducing the Cost of Sustained Operations Through Technology Infusion

TRANSFORMATIONAL SPACEPORT AND RANGE CONCEPT OF OPERATIONS

A Vision to Transform Ground and Launch Operations for Future Space Transportation Systems

Future Interagency Range and Spaceport Technologies

June 2005

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, Office of the Secretary of Defense, and the Air Force Research Laboratory), 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 coordinating individual agency interests in addressing the national space transportation 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.

June 2005

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EXECUTIVE SUMMARY

The FIRST Transformational Spaceport and Range Concept of Operations (CONOPS) presents a long-term, sustainable vision for future U.S. space transportation infrastructure and operations, developed cooperatively by the Department of Defense (DoD), the Federal Aviation Administration (FAA), and the National Aeronautics and Space Administration (NASA). The interagency vision described in the Transformational CONOPS would transform today's space launch infrastructure into a shared system that supports worldwide operations for a variety of users while also supporting new types of missions for exploration, commercial enterprise, and national security, and eventually routine public space travel as part of the global transportation system.

The set of four FIRST CONOPS (Figure ES-1 below) describes the common vision for shared future space transportation system (FSTS) infrastructure from a variety of perspectives.

The FIRST program concept is defined in a set of four Concept of Operations documents. The high level "Transformational" CONOPS articulates the FIRST vision, while the three more detailed CONOPS describe systems and operations from varying perspectives.

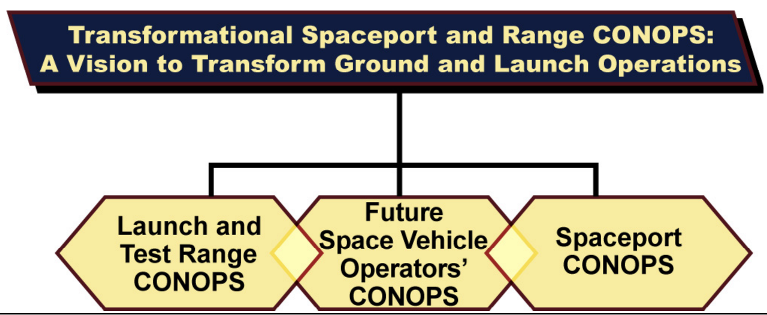

Figure ES-1– Structure of the FIRST Concept of Operations documents.

The FIRST vision—inspired by the worldwide air transport system—integrates spaceports with a global range that supports simultaneous flights within hours of notification and flight operations patterned after the air transport system. The FIRST vision describes a single integrated "system" of space transportation systems that replaces today's proliferation of program-unique facilities to enable lower-cost, routine access to space for a variety of applications and markets.

Government and commercial space access stakeholders have increasingly overlapping goals in the areas of responsive operations, reduced operations costs, and increased safety and reliability. The FIRST vision addresses these shared goals with the common system-of-systems solution for anticipated missions and markets. The resulting concept, referred to here as the Future Space Transportation System, or FSTS, could achieve key advantages for the nation by improving infrastructure adaptability, reducing duplicative systems and facilities, and increasing interagency synergy in related research and development.

The transformation of space transportation operations toward this vision would be based on a set of guiding principles, including:

- *Common, Shared-Use Infrastructure. A variety of vehicle and payload architectures integrate into flexible spaceport and range infrastructure*

- *Responsiveness. Space flights are rapidly planned and executed to respond to unfolding world events and opportunities that demand quick reaction*
- *Adaptable. Technology is designed for evolutionary reuse on future programs*
- *Ease of use. Standardized interfaces streamline operations*
- *Concurrency. The global system supports multiple simultaneous flights*
- *Minimization. Infrastructure is reduced to control sustained operations and maintenance costs by implementing automation and other streamlining technologies*
- *Test and evaluation flight activities are isolated from other flight operations.*

Conceptual Architecture. The top-level FSTS conceptual architecture is synthesized from the four major space launch and range infrastructure functions derived from the FIRST vision. As illustrated in Figure ES-2, the first two of these major functions (*Managing the System* and *Communicating Information*) support the other two (*Preparing for Flight* and *Managing Movement*).

The FSTS concept addresses four major launch infrastructure functions: "Managing the System" and "Communicating Information" provide underlying and enabling capabilities to support the direct functions of "Preparing for Flight" and "Managing Movement."

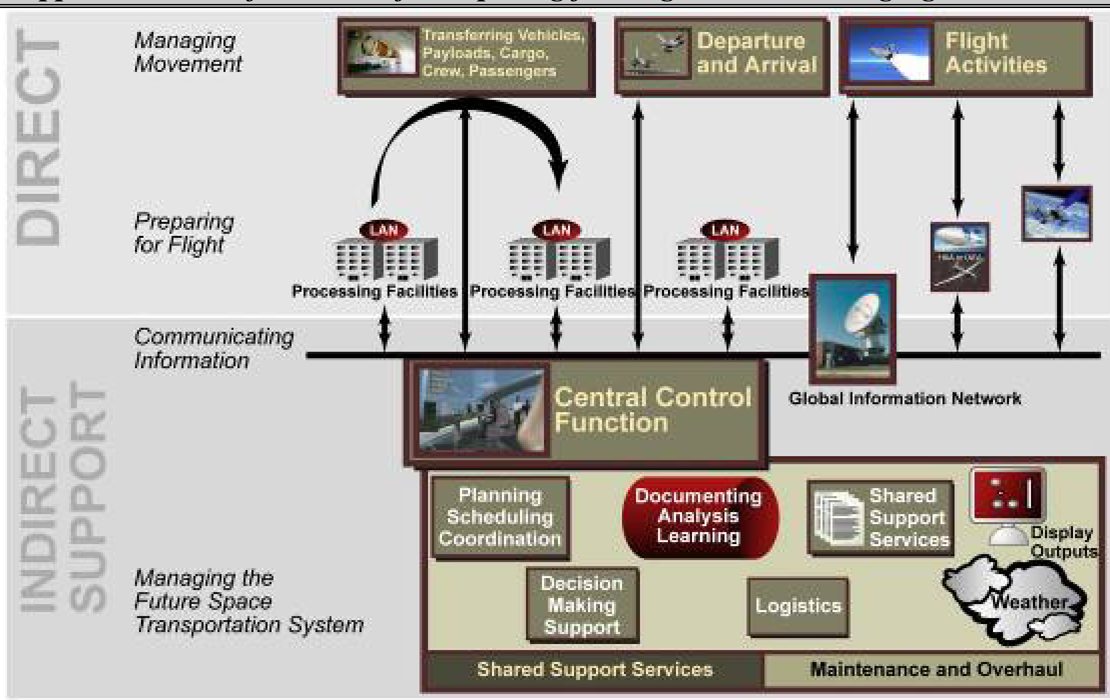

Figure ES-2. Relationships of Top-Level FSTS Functions.

The conceptual architecture for *Managing the Future Space Transportation System* includes a network-centric Central Control Function, an integrated suite of automated analysis and decision support tools, basic shared support infrastructure (including roads, utilities, medical, security, etc), and industrial and laboratory facilities to support maintenance and overhaul activities.

The envisioned FSTS conceptual architecture for *Communicating Information* includes ground-based, space-based, and airborne mobile assets operating worldwide, ground-based networks to distribute and archive information, close proximity wireless interfaces to acquire data from vehicles, support systems, and shared-use systems tied to the Global Information Network.

The FSTS architecture to support *Preparing for Flight* includes shared-use spaceport facilities, systems, equipment, and infrastructure with standard interfaces. It also includes a local area network that connects the vehicle and payload elements, control centers, ground systems and support equipment to the Central Control Function through the Global Information Network.

Managing Movement is analogous to runway and other surface operations and traffic control functions at airports. The FSTS architecture for managing movement consists of radars and optical systems at departure/arrival sites and aboard airborne platforms. Over time, this architecture will evolve toward a primarily space-centric capability, supplemented by airborne assets, and with low-cost, modernized, ground-based instrumentation as needed to support particular requirements.

Evolution of System Elements. One of the key components of the FSTS is a global system of transportation nodes, or “spaceports”—multi-modal nodes connecting land, sea, air and space transportation systems. Over time, range functions assimilate with spaceport functions, leading to the overall FSTS concept illustrated in Figure ES-3.

The long-term FSTS vision is to manage space transportation assets using a variety of control centers and user facilities connected through a global network.

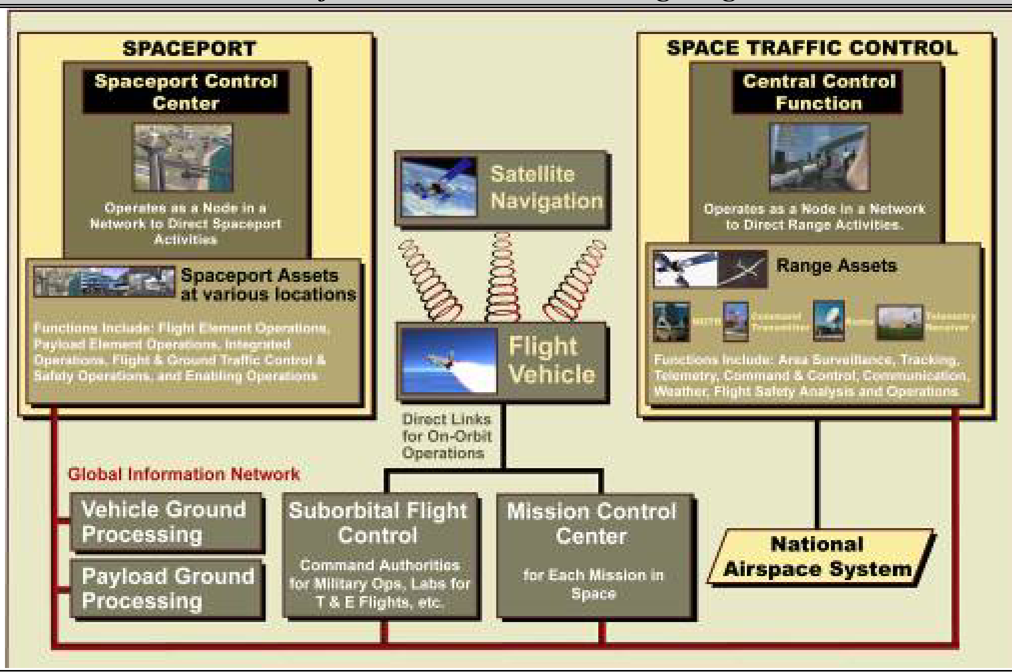

Figure ES-3 – Conceptual FSTS Architecture.

FSTS Operations. To support any particular space flight operation, FSTS operations are typically conducted to align with six sequential phases:

1. Planning begins when a user generates an initial flight profile and requests FSTS support. Flight profiles facilitate coordination of operations and determination of which infrastructure assets are required to support each operation.

2. Processing includes vehicle and payload integration and steps to ensure proper interaction between flight systems and the FSTS.

3. Departure Operations include the countdown or final checkout, actual takeoff/launch, and initial flight.

4. During Flight Operations, once a vehicle is in Earth orbit or beyond, the various control centers monitor the flight. These centers re-engage only if the flight is cut short and requires support for an unscheduled reentry and landing/recovery.

5. Return and Landing operations include the return flight and landing (or recovery) of reusable vehicles and vehicle elements. This phase begins prior to deorbit, with coordination through the Central Control Function to ensure all required support is scheduled and available.

6. Refurbishment and Turnaround includes deactivating, safing, and de-servicing flight vehicle and support systems. Integrated health management systems report information for routine post-flight reports on asset usage and performance for billing and maintenance orders.

Mass Public Space Transportation. Looking further into the future, evolving FSTS operations enable and support safe, affordable, routine mass public space transportation. This long-anticipated but still visionary image of the future is based on a series of assumed developments over the next several decades. Technology and operational advancements as well as market demand have proven notoriously difficult to predict into the distant future because unanticipated breakthroughs and unforeseen events set in motion substantial departures from the expected course of development. Despite these potential uncertainties, operations associated with the FSTS functions in this long-term view enable a revolutionary streamlined approach to "global space transportation traffic control" for operational space launch activities. 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.

Operations far in the future could involve the "range" function transforming to a global "space traffic control" function. A "global space transportation traffic control" capability like the Space and Air Traffic Management System (SATMS) would logically evolve from the Central Control Function to manage operations. This is similar to the way the air traffic control system is used today to manage use of the National Airspace System (NAS).

Enabling Capabilities. Several broad technology areas require advancement to support the envisioned ways of operating in the future. Some technology areas and standardization approaches that address the technical challenges include the following:

- Self-diagnostic integrated health management and healing technologies
- Autonomous vehicle and payload servicing systems
- Space-based and unmanned airborne mobile range system platforms
- Compressed data streams providing more efficient use of bandwidth
- Close proximity IR and spread spectrum wireless interfaces
- Integrated, system-wide software planning and scheduling technologies
- High-density, precision weather instrumentation and forecasting
- Flexible, automated vehicle and payload handling, assembly, and integration systems
- Designing vehicles to standards to reduce infrastructure needs & enhance interoperability
- Leveraging standards and techniques developed initially for terrestrial applications to support in-space infrastructure for implementing the U.S. vision for space exploration.

1 PURPOSE

The Transformational Concept of Operations (CONOPS) provides a long-term, sustainable vision for future U.S. space transportation infrastructure and operations. This vision presents an interagency concept, developed cooperatively by the Department of Defense (DoD), the Federal Aviation Administration (FAA), and the National Aeronautics and Space Administration (NASA) for the upgrade, integration, and improved operation of major infrastructure elements of the nation's space access systems. The interagency vision described in the Transformational CONOPS would transform today's space launch infrastructure into a shared system that supports worldwide operations for a variety of users. The system concept is sufficiently flexible and adaptable to support new types of missions for exploration, commercial enterprise, and national security, as well as to endure further into the future when space transportation technology may be sufficiently advanced to enable routine public space travel as part of the global transportation system.

The vision for future space transportation operations is based on a system-of-systems architecture that integrates the major elements of the future space transportation system – transportation nodes (spaceports), flight vehicles and payloads, tracking and communications assets, and flight traffic coordination centers – into a transportation network that concurrently accommodates multiple types of mission operators, payloads, and vehicle fleets.

This system concept also establishes a common framework for defining a detailed CONOPS for the major elements of the future space transportation system. The resulting set of four CONOPS (see Figure 1 below) describes the common vision for a shared future space transportation system (FSTS) infrastructure from a variety of perspectives.

The FIRST program concept is defined in a set of four Concept of Operations documents. The high level "Transformational" CONOPS articulates the FIRST vision, while the three more detailed CONOPS describe systems and operations from the perspectives of future range operators, vehicle operators and spaceport operators.

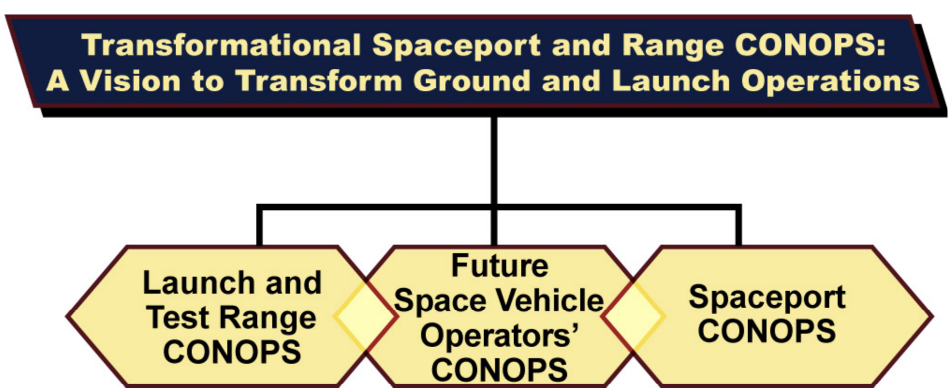

Figure 1 – Structure of the FIRST Concept of Operations documents.

2 ASSUMPTIONS

The future concepts presented in this CONOPS are based on several key assumptions:

- *A variety of new space vehicles will be deployed concurrently in the future.*

At a minimum, some of the development programs now underway in the civil, national security, and commercial space sectors will result in new operational space transportation vehicles. Added to the existing space transportation fleet, these deployments will lead to concurrent operation of different types of vehicles, even if one or more of the existing vehicle types are retired in the future.

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

As space travel and access to space become more available, they will also become more routine, enabling increases in traffic and capacity, and leading to standardization for pre-flight preparation, departure, and return much like that found at airports. Pre-approved flight paths will become mandatory to ensure orderly, safe transportation to, through, and from space, resembling today's air transport system.

- *Traditional functions provided by today's ranges, spaceports, and operators will merge into an integrated system of space transportation systems.*

Functions that are today strictly assigned to ranges, spaceports, or space flight operations will integrate to provide a global space transportation capability. Infrastructure systems will integrate with vehicle systems to form the system-of-systems referred to herein as the Future Space Transportation System (FSTS).

- *In the later portion of the period of time covered by this CONOPS, launch vehicle reliability will approach that of current airline reliability.*

Future sub-orbital and orbital Reusable Launch Vehicles (RLVs) will be reliable enough to fly over populated areas without increasing risk to public safety above the currently acceptable levels associated with commercial air traffic.

3 A VISION OF FUTURE SPACE TRANSPORTATION OPERATIONS

An integrated network of shared infrastructure is essential to implement U.S. innovations in space access that promise to deliver benefits of commonplace space transportation. The FIRST vision establishes guiding principles, necessary capabilities, and concepts for integrating operational resources into a single integrated "system" of space transportation systems that replaces today's proliferation of expensive program-unique facilities to enable low-cost, responsive, routine, and safe access to space for a variety of applications and markets.

The transformation of America's space transportation operations and infrastructure starts with a vision inspired by the tremendously successful worldwide air transport system. Supported by decades of experience and lessons-learned in space transportation operations, the FIRST vision integrates spaceports – which host an array of users and missions with common resources – with a global range that supports simultaneous flights within hours of notification and flight operations patterned after the air transport system. The following sections discuss establishment of the vision of program-independent infrastructure, its significance to the country, and the outlook for its implementation.

3.1 TRANSFORMATION – ESTABLISHING INDEPENDENT INFRASTRUCTURE

Many of today's U.S. space launch facilities and systems trace their legacy back decades. Much of the existing U.S. launch infrastructure has evolved over the past 50 years through repeated adaptation to new launch vehicles and space programs. The cycles of renovation, reconstruction, and tailoring by individual programs have led to many systems that are unique, labor-intensive, expensive to maintain, difficult to adapt to new requirements, and often duplicative. This situation leaves many budget-strapped program managers with little choice other than to upgrade and tailor outdated systems to their unique vehicle requirements. Federal agencies are realizing that such an approach cannot be affordably sustained much longer; indeed, much of the launch infrastructure for the U.S. Air Force evolved expendable launch program was built anew. A new concept is needed to establish a sustainable approach to developing and operating space launch infrastructure for a variety of users.

The fundamental goal of the new space transportation operations concept envisioned by FIRST is to transform today's space launch infrastructure into an affordable and responsive system-of-systems independent of vehicle architecture. The long-term vision is to advance and apply operations technology that enables operations similar to that of airlines and tactical air campaigns, enabling space flights to be repeatedly planned and conducted according to a consistent set of steps regardless of vehicle and payload. In this vision, launch vehicles are designed to work within existing infrastructure rather than requiring adaptation of legacy systems or creation of unique systems. This transformation is needed to affordably and responsively accommodate high flight rates and multiple vehicle architectures without maintaining duplicative infrastructure or reconfiguring systems to support each flight.

This new concept relies on a broad definition of infrastructure that includes all facilities, systems, services, and processes for operating flight vehicles and payloads. In this sense, infrastructure is more than just buildings, roads, and utilities; it includes systems and operations for performing all major space transportation support functions. In this context, infrastructure is the essential and persistent foundation of any transportation mode, independent of vehicle. This holistic perspective is critical in formulating a vision and implementation plan for advancing U.S. space transportation infrastructure beyond today's isolated program-unique assets toward common, shared-use global systems that meet the needs of tomorrow's missions.

For example, as the FSTS concept is implemented, the primary purpose of flight safety and control systems currently associated with range facilities transforms from a focus on flight termination and redundant tracking sources to a common space traffic control service concentrating on space surveillance, debris mitigation, and traffic deconfliction that parallels air traffic control functions of today. The systems and processes initially put in place enable this shift to take place by introducing the automatic decision-making support systems necessary to operationalize space for civil exploration, commercial operations, and military users. New global capabilities emerge through a series of spirals to provide worldwide communications among ground-based, mobile, and space-based assets that will serve as the backbone of the global network for all FSTS users.

This transformation of space transportation operations and resources is governed by a set of guiding principles that form the foundation of the FSTS concept as described in the box below.

Guiding Principles for the FSTS

Common, Shared-Use Infrastructure. A variety of vehicle and payload architectures integrate into flexible spaceport and range infrastructure

Much of the current US space launch infrastructure is unique because it was designed around specific vehicle architectures. This situation precludes affordable sharing of facilities and systems for new architectures without significant modifications. The FSTS concept is based on the premise that shared infrastructure designed to accommodate a variety of interoperable missions and vehicle architectures will provide the optimal cost/benefit balance for space access. The historic approach of building or recycling infrastructure for a specific vehicle family is replaced with sustainable systems designed to support future vehicles. The new vehicle-independent systems and processes reduce or eliminate the infrastructure duplication often found across programs, and provide advanced capabilities to users that may not otherwise afford them while enabling concurrent flights of various types of vehicles to and from different locations.

Responsiveness. Space flights are rapidly planned and executed to respond to unfolding world events and opportunities that demand quick reaction

The FSTS dramatically shortens flight call-up times, enabling the rapid launch capability needed to support emerging national security needs, orbital rescue, and some anticipated commercial markets.

Adaptable. Infrastructure technology developed today is designed for evolutionary reuse on future programs

The FSTS is intended to enable a low-risk spiral development approach to incrementally add capabilities and improve operations, transforming the nation's spaceport and range capabilities over time to support and enable new missions.

Ease of use. Standardized interfaces streamline operations

Consistent standardization reduces the need for specialty skills and equipment, thereby reducing processing times, lowering support costs, and improving productivity, leading to the potential of higher flight rates and lower operations costs.

Concurrency. The global system supports multiple simultaneous flights in all mission areas

Many future missions require concurrent flights. For shared infrastructure to be effective, all elements of the FSTS support multiple simultaneous flights.

Minimization. Infrastructure is reduced to control sustained operations and maintenance costs by implementing automation and other streamlining technologies

Program- or vehicle-unique assets tend to become legacy assets because cash-strapped programs can generally only afford operations and maintenance of existing assets rather than replacement or large-scale modernization. Technological obsolescence increases as the pool of legacy assets grows, resulting in proliferation of assets that are expensive to operate and maintain because they cannot employ new technology. The FSTS concept relies on interoperability to divorce infrastructure from individual programs, helping to break the legacy asset cycle and control the proliferation of aging infrastructure. Interoperability leads to minimization, which leads to lower costs.

Test and evaluation flight activities are isolated from other flight operations.

The FSTS concept recognizes the basic incompatibility between test flight operations and operational missions. While some assets, such as the global space-based range, can be used for both classes of activities, provisions for preventing one class from interfering with the other are embedded in the concept.

The future launch and test range infrastructure includes space-based and ground-based assets for managing and deconflicting global space traffic. A "Central Control Function" manages worldwide assets; coordinating the range, flight, and spaceport operations conducted from a network of FSTS control centers. The Central Control Function, conceptually illustrated in Figure 2 provides a variety of services using automated, intelligent decision support systems directed toward safely and efficiently managing the use and condition of spaceport and range assets, while also serving users' information needs. New processes, central coordination, and global access to flight-planning systems allow flights to be planned, cleared, and executed within hours of identification of the need.

An integrated national "system" of space transportation systems that enables low-cost, responsive, routine, safe access to space for a variety of applications and markets lies at the heart of the FIRST vision.

Figure 2 – The FIRST Vision for the Future of Space Transportation.

Space flight operations (a term referring to all activities involved in operating a space transportation system) rely on an integrated, centrally managed, global network-based capability to coordinate space transportation assets and activities during en-route operations. A hierarchy of control centers manages different operational aspects of space flights and links multiple operators to maintain seamless, consistent, and safe flight operations. The routine efficiency that results from this hierarchy helps to achieve airline-like operations, accommodate increased flight rates, and allow for multiple vehicle architectures that do not require a uniquely configured infrastructure.

Most space flight vehicles no longer require dedicated or unique facilities or ground support equipment. For those designs, routine scheduled turnaround is limited to consumable replenishment. Vehicle health management and self-test capabilities inform operators of corrective actions needed before the next flight. In some cases, aircraft-like certification of vehicle fleets opens the door to repetitive commercial flight operations. Vehicle performance margins facilitate simple and rapid ground processing by increasing test tolerances and equipment change out intervals, and reducing unscheduled work. Dedicated flight software design and testing is not required for every flight.

Spaceports rely on simplified operations and standardized interfaces with flight vehicles. A global system of Commercial Transportation Centers evolves from airports to support hypersonic air and space travel through common facilities and systems. The centers are scaled to address passenger and cargo volumes resulting from ever-changing market logistics and new technology-enabled vehicle capabilities. Competition and standardization fuels sustained advances in support infrastructure capability and performance, paving the way for support of large-scale public space travel.

3.2 SIGNIFICANCE TO AMERICA

The U.S. space sector faces several fundamental challenges – and opportunities – in space transportation. Today's space transportation systems support various mission types with program-unique systems and procedures. Existing ground processing operations are often manpower-intensive and many of the facilities and systems that support ground processing and space flights are aging and near the end of their design life. Collectively, these facilities and systems are capable of supporting a diverse set of vehicles and missions, but each type of mission relies on its own unique set of ground systems and facilities and flight support assets that are tremendously expensive to operate, maintain, and modernize. Further, many of the existing systems were not designed to support concurrent flights, support launches on short notice, be used over such a protracted lifetime, nor easily accommodate updates for newer technology and systems.

However, future missions will impose substantially increased support needs in terms of concurrent flights, responsiveness, and geographic coverage to protect adjacent facilities, transportation corridors and population centers, and to enable these missions to defend the country and open new frontiers for exploration and business enterprise. At the same time, one of the most significant and continuous challenges faced by the federal government and private enterprise is an increasing need to expand services within existing budget levels.

For instance, NASA is facing an unprecedented opportunity to expand the footprint of mankind to other worlds. Such a bold mission would be enormously expensive using current systems and technology. In addition, the International Space Station offers the scientific community an opportunity to find new solutions to endemic problems. Science platforms for studying our planet, its fate, and its place in the universe also offer untold opportunity to expand our understanding of nature. However, accessing space safely, routinely, and affordably remains the critical roadblock to capitalizing on these opportunities. To enable new missions such as these, NASA is seeking substantial improvements in safety and turnaround time, cost reductions, and reduced risk to its workforce.

At the same time, our national security is being challenged in new and devious ways. The Department of Defense (DoD) and the Department of Homeland Security (DHS) need highly responsive space access to support pop-up maneuvers and rapid global surveillance to quickly monitor or react to an evolving crisis, national security threats, and targets of interest. Our national security also relies on the development and deployment of new defensive technologies that require extensive flight test and evaluation, which relies on adaptable, flexible support systems with expanded capabilities compared to today's systems.

In addition, potentially viable business cases are emerging for commercial space transportation enterprises. These business cases remain tremendously sensitive to improvements in transportation costs and safety. Growth of *today's* established commercial space market, which is dominated by the launch and operation of communications satellites, is also highly sensitive to cost and safety.

As described in detail in the FIRST Needs Assessment[1] and summarized in a set of "design reference missions" (detailed later in this document), all of these space access stakeholders have common goals of responsive operations, reduction of operations costs, and increased safety and reliability. The FIRST vision is crafted to seamlessly address these shared goals with a common solution for anticipated missions and markets in the three sectors that utilize space systems: commercial, civil, and national security. As a result, key advantages of common solutions are attainable for the nation, including reduced costs through shared investment and operations support, improved adaptability to new missions through shared-use infrastructure, reduction of duplicative systems and facilities, and increased synergy in related research, development, and on-going modernization.

The first major step toward achieving this concept of independent infrastructure that supports concurrent and affordable operations is to seek common solutions and technological needs for next generation systems and programs such as the Air Force Global Launch & Test Range[2] and Operationally Responsive Spacelift initiative, NASA's Constellation program to develop new launch vehicles,[3] and the Space and Air Traffic Management System proposed by the FAA. These initiatives share many goals and technical challenges. With such natural synergy, shared technology investment could lead to common architectural solutions that avoid unique spaceport and range systems in favor of common, shared-use systems. While a single shared solution for all functions of all programs is unlikely to appear, many functions could be addressed with common solutions and technology developed over the timeframes outlined in the next section. As described in Appendix 1, FIRST provides a platform for identifying appropriate common stakeholder interests.

3.3 TIME FRAMES – A ROADMAP FOR THE 21ST CENTURY

The FIRST vision spans a timeframe beginning with today's Space Shuttle and Evolved Expendable Launch Vehicle systems and reaching to the realization of the dream of mass public space travel. As a result, the FSTS concept charts a path from the current state of relying almost exclusively on vehicle-unique, ground-based assets for U.S. space transportation operations through a series of spiral development steps to eventually effectuate routine and responsive space access for national security, exploration, commercial operations, and a variety of other space access applications. The path spans three conceptual timeframes, depicted as "eras" in Figure 3.

Three eras are addressed in formulating and planning the FIRST concept.

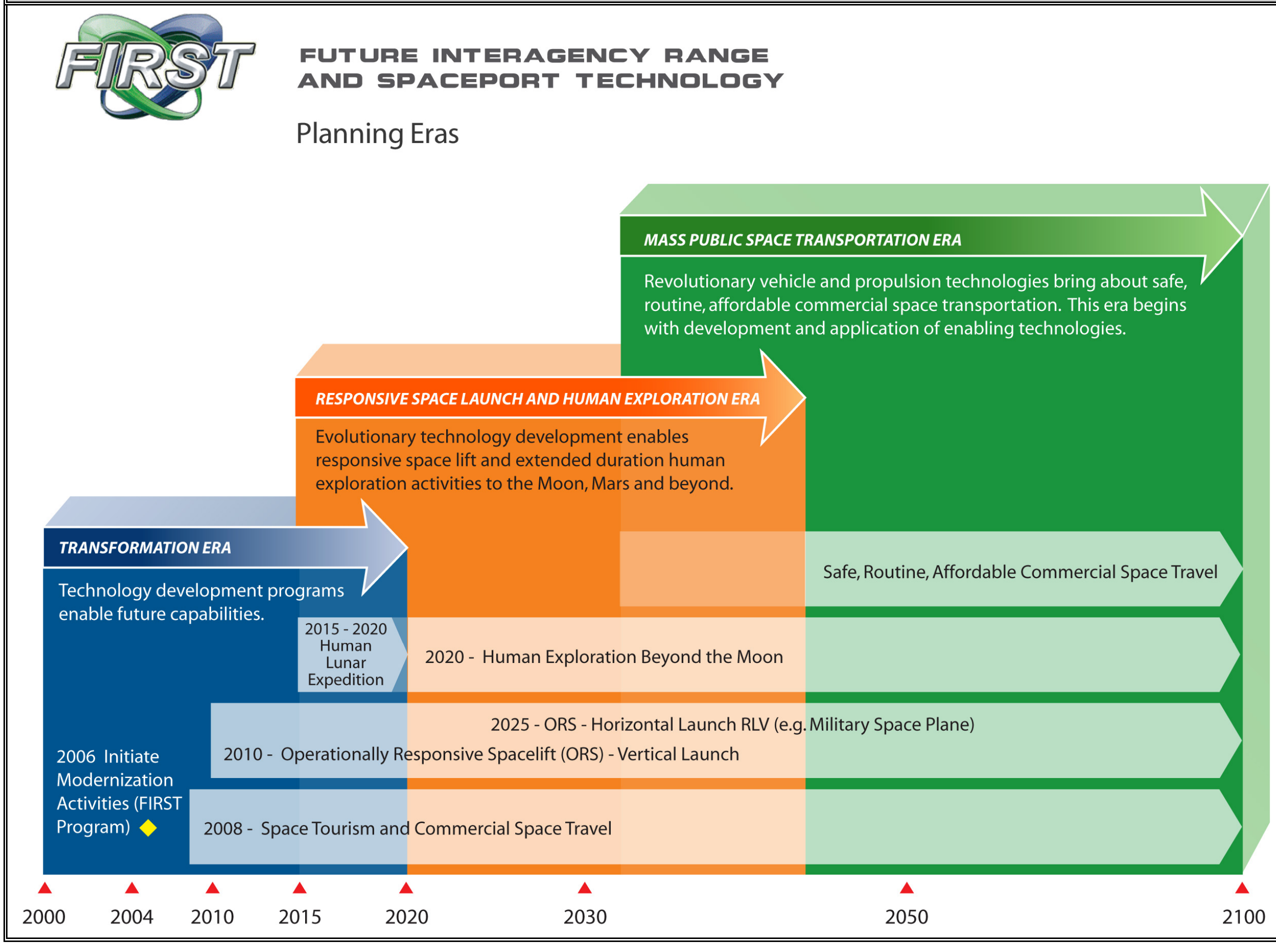

Figure 3 - FIRST Program Planning Eras.

The first, or current, era is characterized by transformation. Transformation refers to fundamental change involving advanced technologies that enable new concepts of operation. The technologies developed in this era are implemented and institutionalized through new policies, organizations, architectures, and economic and business models. This era also ushers in a new type of space operator: with the formation of “Virgin Galactic” in 2004, the FAA expects that the world’s first commercial tourism suborbital space flights will begin in 2008. These changes will initiate a fundamental shift away from vehicle-unique infrastructure, establishing the spiral development path for technology advances that is needed to support future missions and space transportation businesses.

The Responsive Space Launch and Human Exploration Era is poised to begin within the next decade, with activities ramping up in an overlap with the current era. Highlighting this overlap, these future missions are enabled by the Crew Exploration Vehicle (CEV) and operationally responsive spacelift (ORS) development efforts being pursued during the Transformation Era. New sustainable space transportation businesses emerge to serve a growing market for adventure travel and specialty transport services. During this era, space transportation business models could further stratify if market demand is strong enough to support separation of vehicle operators (“spacelines”) from vehicle manufacturers. Examples of the missions enabled by these capabilities include prompt global strike in support of military objectives and human space exploration missions to the moon, Mars, and beyond, with growing opportunities for privatization and outsourcing to commercial providers.

The Mass Public Space Transportation era will emerge when the economics and technology of space travel align with the demands of a mass market. The third era is characterized 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. 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 needed anywhere in the world and into space. Recent achievements spurred by the ANSARI X-Prize® initiative – including repeated suborbital flights of a multicrew vehicle – offer a glimpse at what could someday be a common method of transportation and tourism.

Throughout these eras, the FSTS will continue to evolve and expand through a series of spiral development cycles. New technologies that build upon previous cycles will be devised, developed, and implemented for the common benefit of all users. Through this, the system will ensure that current needs are always met while staying ahead of the emerging needs of new system customers.

X-PRIZE is a registered trademark of the X-Prize Foundation.

4 FUTURE SPACE TRANSPORTATION SYSTEM CONCEPT

The Future Space Transportation System is structured as an integrated system-of-systems that provides the capabilities required to address the major functions derived from the FIRST vision. These major functions form the framework for establishing the top-level FSTS architecture according to key architectural principles. The following paragraphs describe these principles, functions, and top-level architecture.

4.1 ARCHITECTURAL PRINCIPLES

In establishing the FSTS architecture, several characteristics and features must be adopted universally to achieve the FIRST vision and guiding principles. The key characteristics, or "architectural principles," include:

- The FSTS system-of-systems architecture integrates:
    - A central control function that controls access to and operation of the system, makes information available to authenticated users, and provides access to automated analysis tools to support planning, scheduling, coordination, and decisions
    - Spaceports (terrestrial, orbital, lunar, and other non-terrestrial locations) with interfaces to inter-modal ground, air and/or water transportation networks
    - Operations control centers, including air and space traffic management hubs
    - Data collection systems (for area surveillance, tracking, telemetry, and weather)
    - Communication relay nodes (ground- and space-based)
    - Flight vehicles and payloads.

  This concept addresses all elements of a total space transportation system.[4]
- Open architecture with plug-and-play interfaces enable the FSTS to accommodate new systems and vehicle types with minimal "patching"
- Standardized interfaces between host systems and user systems, as well as standardized processes, procedures, and protocols accommodate a wide variety of vehicle types by using a variety of launch, landing, and customer facilities
- A global network provides secure information to authenticated users and operators
- Continuously-available data collection assets and sensors provide real-time data from vehicle, spaceport, and range systems to support responsive and concurrent flight operations

4.2 CONCEPTUAL ARCHITECTURES FOR MAJOR FUNCTIONS

The top-level FSTS architecture is synthesized from four major functions derived from the FIRST vision. This top-level system-of-systems architecture is comprised of conceptual architectures for each major function illustrated in Figure 4 and the necessary capabilities to implement each function. The first two of these major functions (*Managing the System* and *Communicating Information*) support the other two (*Preparing for Flight* and *Managing Movement*). In turn, *Managing the System* relies on *Communicating Information* as the means of maintaining connectivity within the Global Information Network. Both of these major functions are essential to coordinating and directing the functions involved in *Preparing for Flight* and *Managing Movement*.

The system-of-systems FSTS concept addresses four major launch infrastructure functions: "Managing the System" and "Communicating Information" provide underlying and enabling capabilities to support the direct functions of "Preparing for Flight" and "Managing Movement."

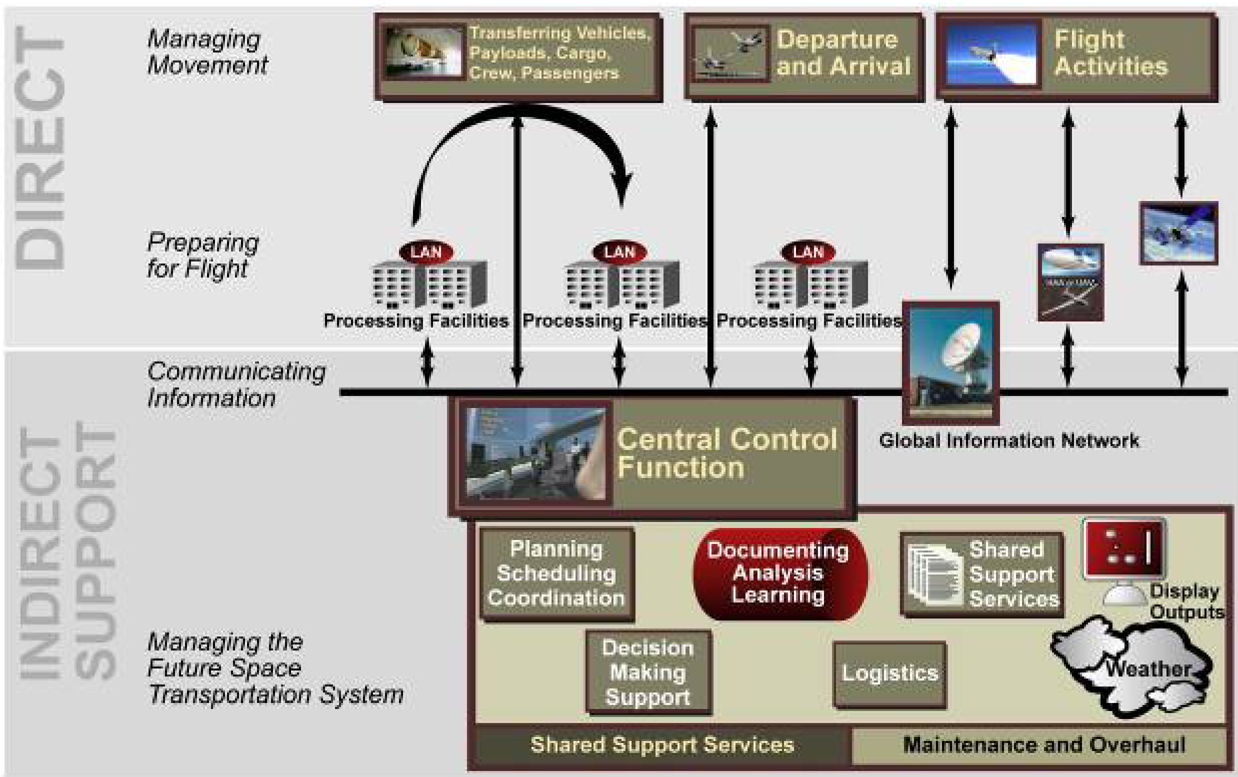

Figure 4. Relationships of Top-Level FSTS Functions.

The following subsections describe the conceptual architectures for the major functions of the FSTS at the system level. More specific descriptions of the capabilities necessary to implement these functions are provided in Appendix 2. Detailed descriptions of some architecture elements and conceptual architectures for each capability are provided in the detailed FIRST CONOPS documents.

4.2.1 Managing the Future Space Transportation System

The envisioned architecture for managing the FSTS is depicted in Figure 5. The conceptual architecture includes:

- A network-centric Central Control Function to manage, direct, and coordinate FSTS operations and assets, providing the information necessary for the FSTS users and operators at various control centers to maintain situational awareness during ground and flight operations
- An integrated suite of automated analysis and decision support tools to autonomously evaluate and recommend alternative courses of action

- Basic shared support infrastructure (including roads, utilities, medical, security, and concessions) similar to a town
- Industrial and laboratory facilities to support maintenance and overhaul activities.

The Future Space Transportation System architecture for managing the network-centric system relies on an integrated suite of software tools, user interfaces, and displays.

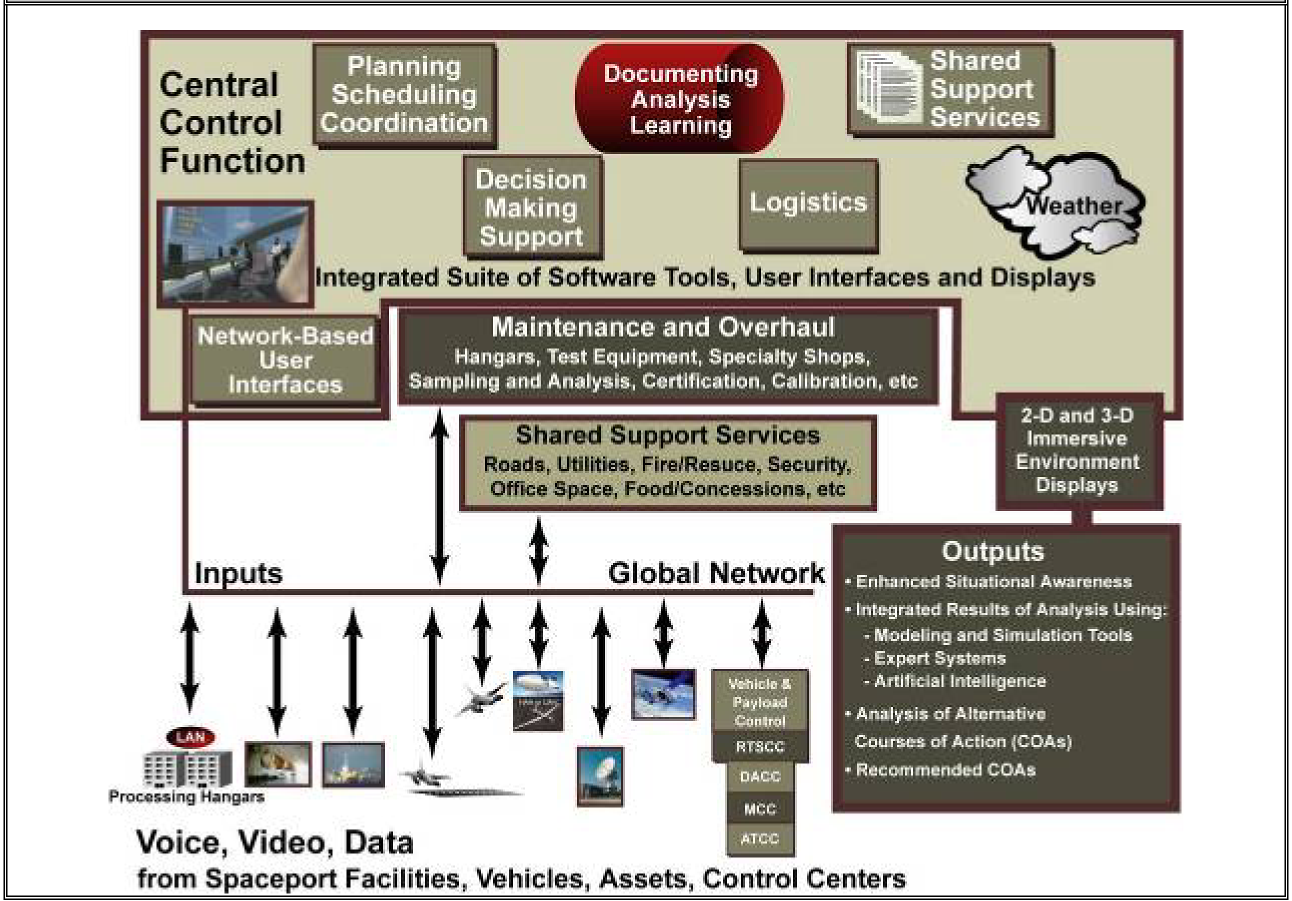

Figure 5 – FSTS Architecture to Manage the Network-Centric System.

From an FSTS architecture perspective, the specific capabilities addressed in this major function all rely on an integrated suite of software tools, user interfaces, and displays. Over time, through the first and second eras, elements of this integrated suite of automated capabilities are developed and added while some functions are still performed with people in the loop. The main focus of the spiral development during these two eras is on qualifying and certifying these automated capabilities. In the third era, the integrated suite of automated capabilities is fully functional and in use as the primary means of managing the network-centric FSTS.

The architecture for managing the network-centric system of spaceports, range assets, and control centers that will enable future space transportation can be described in three main parts.

- First, inputs are gathered from system users and operators, and from automated systems monitoring the health and status of spaceport, range, and control center assets. These inputs are communicated to the Central Control Function through the Global Information Network.

- Second, the Central Control Function uses an integrated suite of sophisticated software analysis tools, user interfaces, and displays to facilitate processing of these voice, video, and data inputs and convert them to usable knowledge.
- Third, display systems communicate the outputs of these processes to system users and operators, flight crews, and control centers.

The heart of the architecture for managing the future space transportation system resides within the Central Control Function. The Central Control Function is an integrated, centrally managed, network-centric capability that will coordinate and monitor the condition of all required FSTS elements around the world to support space transportation and flight test and evaluation operations, both on the ground and in flight. It consists of an integrated suite of sophisticated software tools that use expert systems and artificial intelligence capabilities to convert input information into knowledge to support situational awareness and recommended courses of action. For example, this integrated suite of software tools includes the following:

- Planning, scheduling, and coordination software to interactively evaluate inputs from a variety of users and operators, as well as from automated status reporting systems, to automatically optimize plans and schedules based on requests and constraints. This software also automatically considers inputs from sensors and systems that monitor air and space traffic conditions, and coordinates mission profile requests with control authorities responsible for approving them, communicating constraints and routing instructions to ensure safety and separation during flight operations.
- Decision-making support systems to analyze inputs based on vehicle and mission profile parameters, local geography, population, weather conditions, and traffic constraints (among other situational awareness parameters) to formulate and analyze alternative courses of action. These systems also automatically evaluate these alternatives along with real-time situational awareness information to formulate recommendations to support decisions regarding primary and contingency courses of action.
- Weather systems, consisting of a centralized hub function to analyze and display data from weather radars, satellite imagery, and a variety of sensors. This analysis will help to provide situational awareness, forecasts and hazardous earth and space weather watches, advisories, and warnings for the many spaceport and range operations that are dependent on weather conditions.
- Logistics systems that autonomously monitor and process input information using expert systems and artificial intelligence to automatically plan and schedule shipping and receiving, storage, cleaning, sampling and analysis, certification, calibration, maintenance, and modification actions, including placing orders for commodities, supplies, spare parts, ground systems, tools, protective clothing/equipment/systems, and precision measuring equipment to support space transportation activities.

As depicted in Figure 6, the architecture elements associated with Shared Support Services support and enable the ground processing phases of a space flight operation or test and evaluation mission. These include the most basic underlying physical spaceport infrastructure elements. Examples include roads for transporting workers, logistics elements, and flight vehicles and payloads (as well as flight crews and passengers) among facilities; utility systems to distribute power, water, and other consumables; office space; security, fire/rescue, and medical support facilities, systems, and equipment; and food service/concessions for the convenience of spaceport workers.

The architecture for managing the FSTS also includes basic elements like those found in a small town.

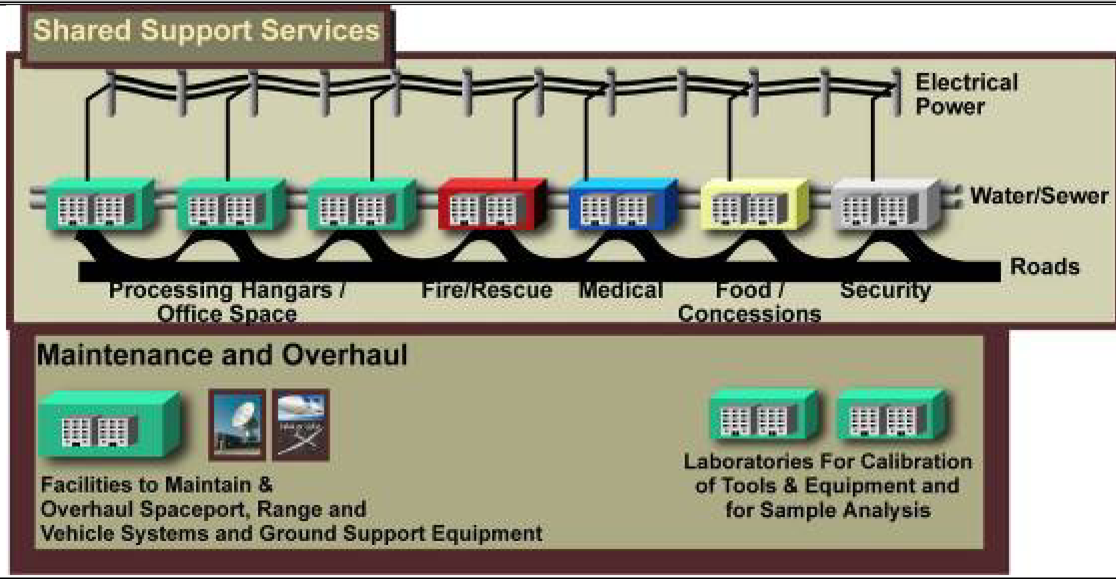

Figure 6 – Architecture Elements for Shared Support, Maintenance, and Overhaul.

The architecture for managing the FSTS also includes facilities, systems, and equipment to support maintenance and overhaul activities for flight vehicles, payloads, and support equipment. Examples of architecture elements in this category include hangars for vehicle and payload processing, maintenance, and modifications, as well as for maintenance and modification of range and spaceport systems and equipment; the ground support equipment that is used in these facilities; specialty shops for fabricating parts; laboratories for analyzing samples of commodities used aboard flight vehicles; and, labs for calibrating tools and equipment.

4.2.2 Communicating Information

The envisioned FSTS conceptual architecture for communicating information includes:

- Ground-based, space-based, and airborne mobile assets using wireless connections to provide continuous, redundant capabilities to acquire and relay voice, video, and data to and from control centers, flight vehicles, spaceports, and range assets operating worldwide
- Ground-based networks to distribute and archive voice, video, data and timing information among ground-based locations
- Close proximity wireless interfaces to acquire and input information to and from facility systems, ground support equipment, processing and handling systems, and flight vehicle/payload elements during processing operations
- Shared-use systems tied to the Global Information Network to support any authorized and authenticated user/customer/operator, regardless of location, to command, control, and monitor pre- and post-flight processing activities, as well as flight operations
- The network-centric Central Control Function to provide the information necessary for FSTS users and operators at control centers to maintain situational awareness during ground and flight operations using three-dimensional immersive displays and other intuitive user interface approaches.

The Future Space Transportation System architecture for command, control, monitoring, data relay (telemetry), and communications is arranged in three layers.

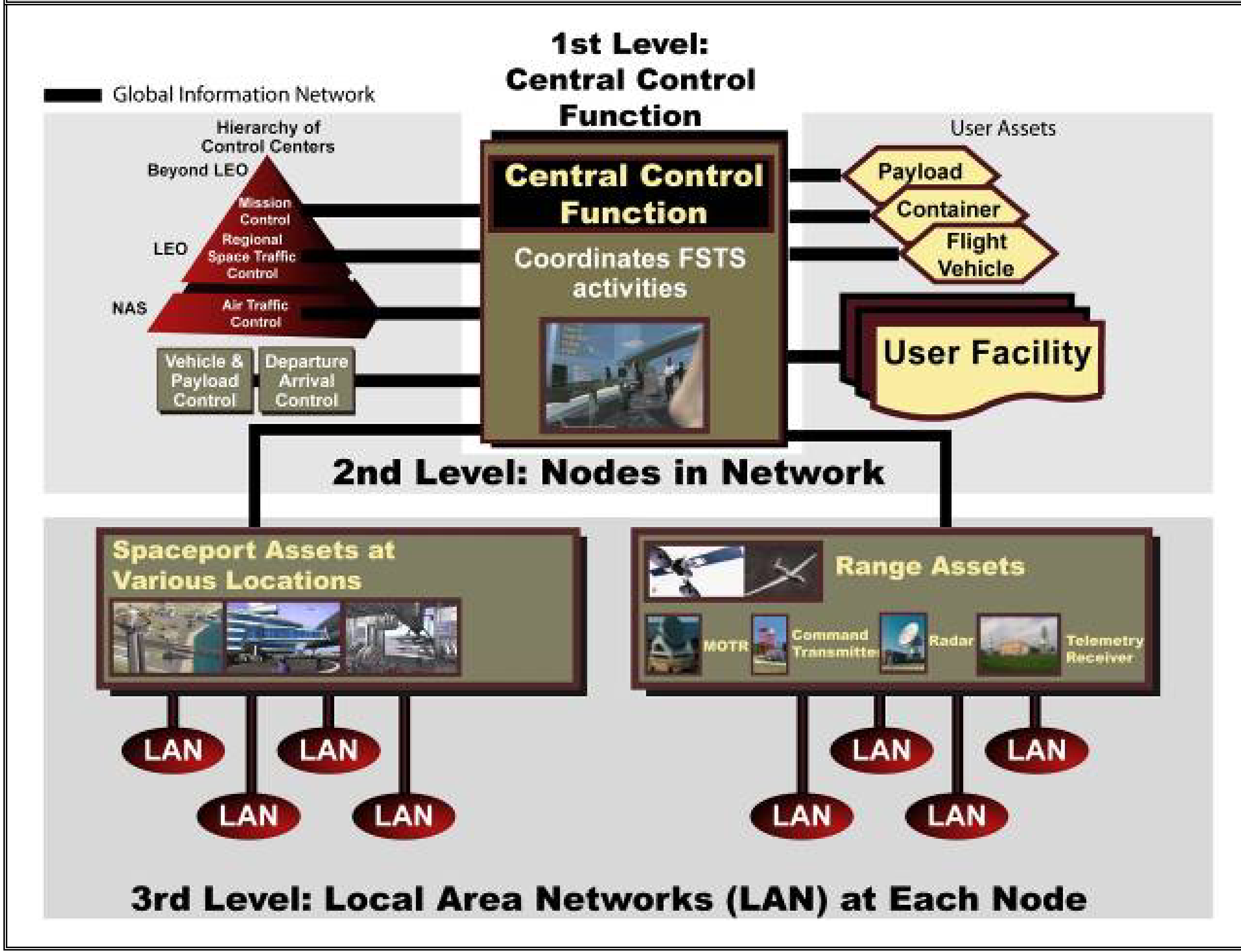

Figure 7 – Three-Tiered FSTS Architecture to Communicate Information.

As shown in Figure 7, the elements of the future space transportation system communication architecture are arranged in three main levels: (1) the Global Information Network interfacing with the Central Control Function to direct operations, (2) the separately functioning major nodes in this network, and (3) the local area networks (LANs) within each node, using wireless proximity technologies along with wire, cable, and fiber optics to maintain connectivity.

Over time, this capability evolves to include increasing network-centric connectivity, autonomous self-configuring capabilities, and redundancy for improved reliability, capacity, and information assurance/security. The focus during the current era is to develop network connectivity throughout individual spaceports and ranges using service-oriented technology, which allows automated systems to independently provide information and services to each other on demand. The focus during the second era is to expand the connectivity and central control capability to multiple spaceports and ranges across regions within the U.S., while also developing and qualifying autonomous self-configuring capabilities to enable more flexible use of bandwidth on demand. In the third era, the system has evolved to become one high-capacity, global, redundant, secure, self-configuring network with a Central Control Function supporting operations worldwide using an integrated communication architecture.

To support the planning, scheduling, and preparation associated with a space flight or test and evaluation mission, the FSTS architecture includes a secure distributed network that is accessible to all authenticated users and operators of the FSTS in accordance with information assurance principles and practices. This Global Information Network allows FSTS users to plan and test their systems regardless of location.

To support initialization, calibration, and verification, the FSTS architecture includes both hard-wired and wireless connectivity to the secure Global Information Network. This enables the Central Control Function to collect health and status information from FSTS assets along with voice, video, and data via telemetry from flight vehicles. This connectivity also enables the Central Control Function to distribute command, control, and communication information to FSTS assets and flight vehicles.

During the deployment, configuration, and verification activities that are part of the planning process, and during the ground processing of flight vehicles and payloads (including pre-launch and post-flight refurbishment and turnaround), the FSTS architecture provides robust, two-way connectivity with the FSTS assets at distributed fixed locations, aboard airborne platforms, and aboard satellites.

As shown in Figure 8, the FSTS architecture elements required to provide this connectivity include ground-based networks and wireless connections to mobile and space-based platforms. The wireless portions of this architecture use a combination of radio frequency, infrared, spread-spectrum, free space optics, and laser communication connections.

Supporting departure, flight, return, and landing operations requires RF connectivity with flight vehicles for two-way telemetry/command/communication links with FSTS assets. This is particularly important to ensure that missions requiring short-notice support from the FSTS assets (e.g., to support an intact abort and emergency landing after a flight vehicle malfunction) are aware of the emergency and able to respond by stopping other activities, coordinating clearances for use of airspace, and configuring FSTS assets to support the emergency reentry, descent, landing, and post-landing or recovery operations.

The future space launch and test range uses ground-based, space-based, and mobile assets to provide data relay (telemetry), command, control, and communication functions worldwide.

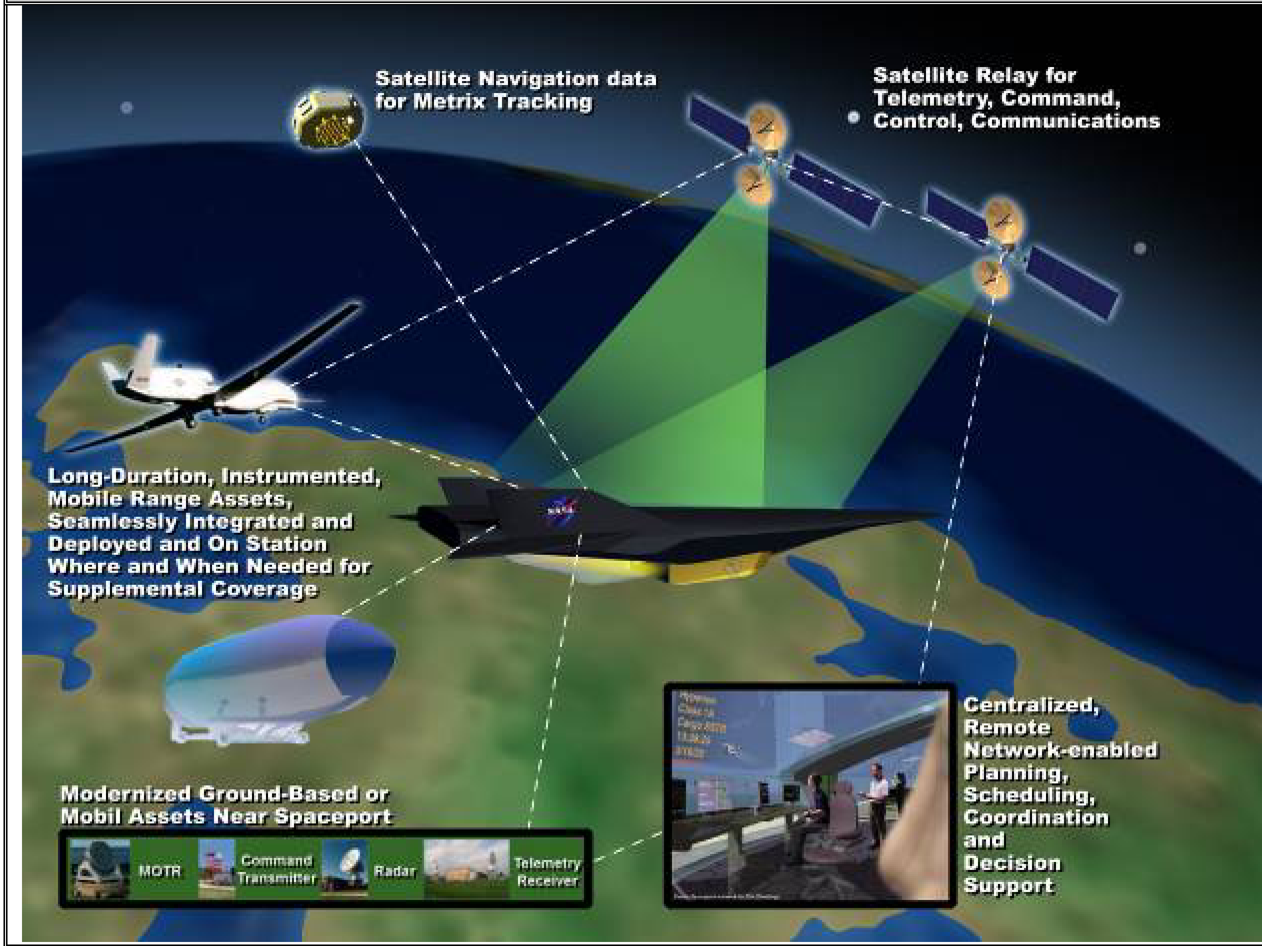

Figure 8 – Mobile and Space-based Architecture for Communicating with Vehicles.

4.2.3 Preparing for Flight

To support ground processing of flight vehicles, payloads, and crew (including passengers), the FSTS architecture includes an integrated set of spaceport facilities, systems, equipment, and infrastructure for vehicle and payload pre-flight and post-flight processing, flight system integration, and ground systems turnaround and servicing. As depicted in Figure 9, ground processing activities are supported and enabled by systems that are not specific to any vehicle, payload, or mission. Rather, these systems are shared and available for use and reuse to support any vehicle, user, mission, or payload with standard interfaces. These shared-use systems are available through and make use of the Global Information Network to ensure that any authorized and authenticated user/customer/operator—regardless of location—can access relevant information during preparation activities and flight operations. User control centers coordinate with a spaceport control center to control, checkout, move, and maintain vehicle and payload elements. Standardization allows widespread automation of ground servicing and processing that further reduces costs and flight preparation time.

The FSTS architecture for preparing vehicles, payloads, crew, and passengers for flight consists of facilities and ground equipment that support multiple types of vehicles and standard interfaces.

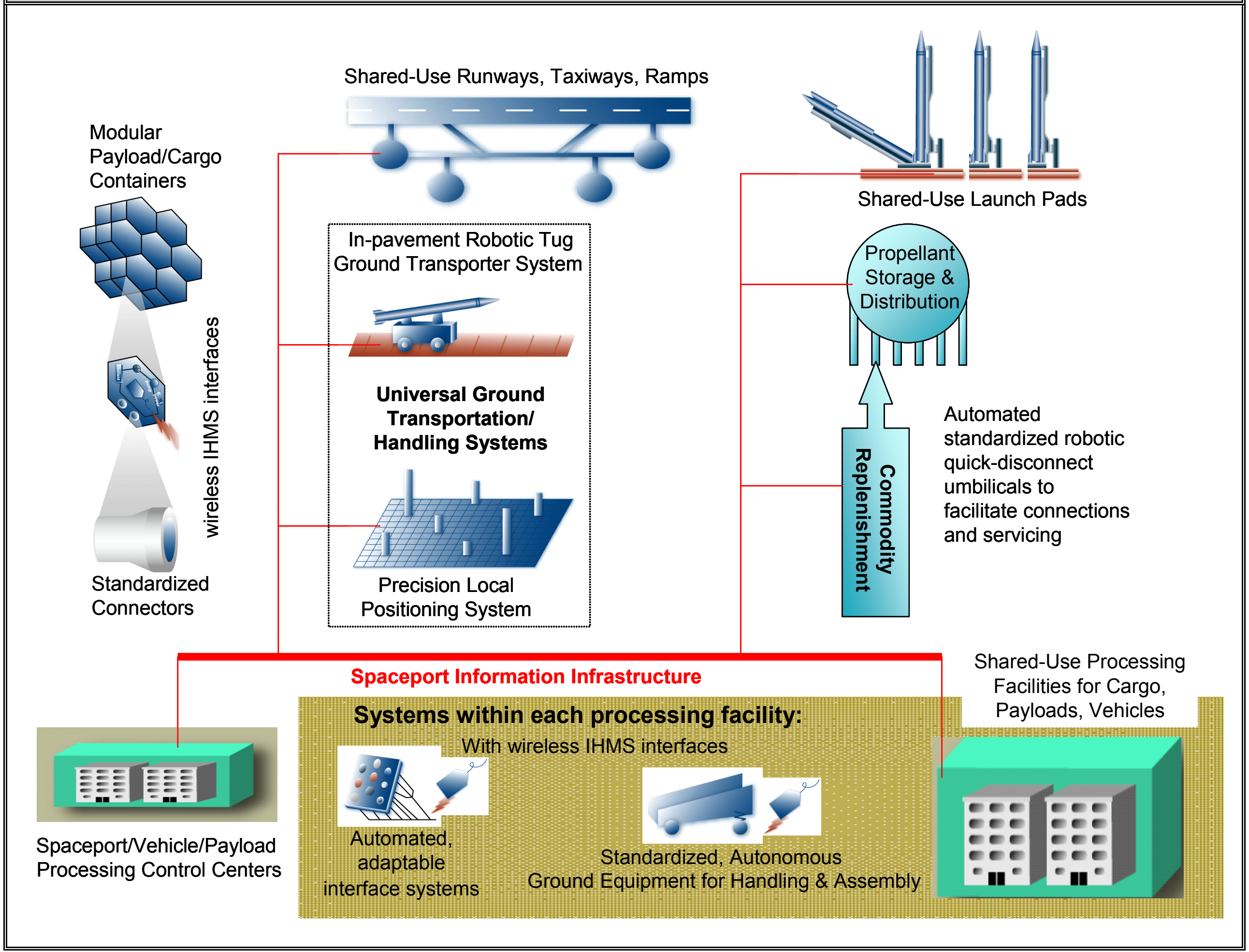

Figure 9 – FSTS Architecture for Preparing for Flight.

To carry out ground processing operations within any facility, the FSTS architecture includes a local area network that connects the vehicle and payload elements, spaceport control center, ground systems and support equipment to the Global Information Network. These local area networks rely on wire, cable, fiber optic, and wireless connectivity to exchange data between flight preparation operations and control centers to support integrated health management, wireless data exchange and flight element tracking, and integrated scheduling. In some cases, technicians use handheld devices to conduct operations involving ground support equipment, vehicle and payload elements, and to assist with and track the progress of crew members and passengers in preparing for flight.

Standardization is an important element of the architecture for conducting these operations. To enable point-to-point flight operations, nearly all vehicle and payload interfaces, facility dimensions (e.g., door sizes, floor weight capacity, high bay areas), ground support equipment (e.g., crane capacity, hook height, electrical interfaces, fluid interfaces), and handheld devices (e.g., bar code readers to track parts usage and logistics, check tool calibration, communicate status from built-in test equipment) must be standardized across all spaceports. Standardized payload containers ease payload/vehicle integration and reduce environmental and physical constraints on integration operations.

Over time, the architecture that supports flight preparation evolves to include more integrated and standardized support capabilities. The focus during the current era is to develop standards and implement them at individual spaceports and ranges. The focus during the second era is to expand the standardization to regions within the U.S., encompassing multiple spaceports and ranges, as well as emergence of rapid turnaround capability for some new reusable launch vehicles. Finally, in the third era, the FSTS has evolved into a globally standardized system that supports point-to-point operations worldwide with a variety of vehicle types.

4.2.4 Managing Movement

Managing Movement refers to transferring vehicles, payloads, cargo, crew, and passengers between processing facilities during ground processing activities, and during departure, arrival, and the portions of space flight operations that are monitored and controlled as part of the FSTS. This function is closely analogous to runway operations and air and ground traffic control functions at large airports.

Departure operations – including the final servicing known today as the countdown and launching the vehicle into space – and arrival operations for returning vehicles and elements are controlled from Departure/Arrival control centers. These centers are part of a global network of control centers with tiered levels of responsibility manage regional jurisdictions of airspace and low earth orbit. Space transition corridors are established through these regions to manage departing and returning space flights with aviation operations. Consistent with the planned FAA Space and Air Traffic Management System, this concept merges air traffic control and space traffic control with a global system to manage in-flight movement of space launch vehicles.

The main architecture elements for area surveillance and metric tracking to support departure/arrival operations include satellite navigation capabilities aboard flight vehicles, and tracking and imaging radars and a variety of optical systems at or near spaceports to detect, image, identify, and track objects in the local area to contribute to situational awareness, control risks to the public (for safety), and identify potential threats (for security). These elements are illustrated in Figure 10.

Each spaceport that supports frequent operations includes or has access to a multiple-object tracking radar (MOTR) and modernized, low-cost radars, including single-object tracking radars to accurately measure distance, azimuth and elevation data; imaging radars to augment tracking radars, measure vehicle attitude, miss distance, object deployment, and the extent of damage during intercept tests; and, continuous wave (CW) radars to image, identify, and characterize what happened when during a launch or test flight.

In addition, optical instrumentation is employed to address the recommendation of the October 2003 Columbia Accident Investigation Board (CAIB)[5] to provide at least three different views during launch and ascent of flight vehicles. Some instruments are placed at points where they can track the vehicle from the side as it proceeds along its intended path. To ensure optimal positioning of these instruments, some are mounted aboard mobile airborne platforms, including unmanned aerial vehicles (UAVs) and high altitude airships (HAAs) that can be re-located to provide coverage when and where needed. Each airborne mobile platform remains on station for up to a year at a time, flying above the weather.

The FSTS architecture for managing movement consists of various types of radars and optical systems at fixed ground-based departure/arrival sites and aboard airborne mobile platforms that can be located to provide supplemental support where and when needed.

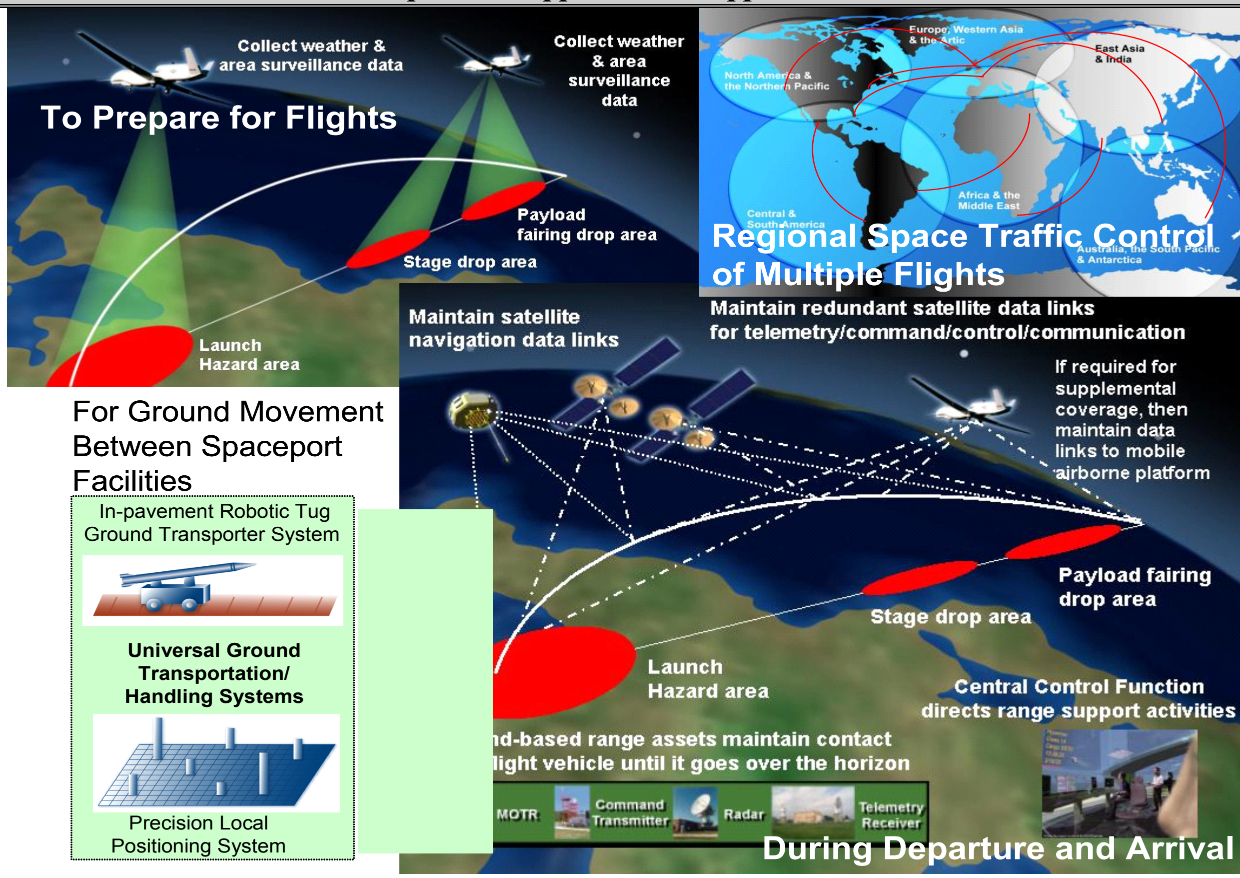

Figure 10 – FSTS Architecture for Managing Movement.

Over time, the architecture that is used to manage movement will evolve toward a primarily space-centric capability, supplemented by airborne mobile assets, and with low-cost, modernized, fixed-location ground-based instrumentation as needed to support particular requirements. The focus during the current era is to transition to GPS metric tracking, while developing and deploying low-cost radar systems at a few individual spaceports and ranges. The focus during the second era is to expand the shared use of space-based and airborne mobile assets to provide these functions across regions within the U.S., encompassing multiple spaceports and ranges. In the third era, the FSTS evolves into the envisioned space-centric system supporting operations worldwide, while using airborne mobile assets and low-cost ground-based instrumentation to support particular user needs.

4.3 External Interface Concepts

As common use of the FSTS expands, the system will increasingly interact with other aerospace transportation management systems, ground-based transportation nodes, and user resources. The following subsections describe interfaces to key external systems.

4.3.1 FAA Space and Air Traffic Management System

Today, interfaces with the FAA is normally limited to ensuring clear zones around launch and recovery operations by imposing restrictions on airspace use. Launch vehicles spend very little time at altitudes of concern to the FAA: there is normally plenty of time to issue Notices to Airmen (NOTAMs) to clear airspace before a launch, and restrictions can be lifted almost immediately after a launch. Shuttle reentries and landings are slightly more complex, as a long air corridor needs to be cleared for entry.

The scenario for future spaceports and mission operations will require a much more integrated approach. RLVs, depending on the type developed, may spend much more time in the atmosphere at launch and/or on recovery than existing launchers. Suborbital RLVs and hypersonic craft that will operate inside, outside, and through the boundaries of existing launch ranges and restricted airspace will require new procedures. Not only will such craft be operating on flight paths not used by any current vehicles, but their speeds will mean that reaction times to deconflict with potential hazards will be much shorter than those encountered with current air traffic.

Accordingly, the proposed SATMS[6] will need to be tightly integrated with spaceports, ranges, and mission operations, and many functions will need to be automated to ensure adequate reaction speed. Launch vehicles launched from two-hour alert, as the Air Force envisions, will not permit the usual 48-hour NOTAMs to be issued, and such vehicles may need corridors through the atmosphere too large to be permanently restricted without affecting commercial air traffic. RLV recoveries will also need clearing of considerable airspace at shorter notice, and sometimes at nearly no notice in the event of emergency recoveries.

The effective control system of the future will likely include joint spaceport/FAA operations centers, tightly coupled and possibly physically co-located, in which automated control systems overseen by human controllers will be constantly monitoring both air and space traffic. Situations requiring rapid response (urgent launches from alert status, an emergency RLV landing, etc.) will need to be instantly recognized, alternatives analyzed, and options presented to controllers by the system’s computers. When a decision is input, the system will need to instantly notify all affected traffic and monitor rerouting. In addition, collision avoidance technology will be needed to integrate with user-requested preferred route or “free flight” operation of the National Airspace System.

The capabilities described for future spaceports and mission operations will require considerable changes in the capability to integrate air and space control and surveillance. Orbital and suborbital RLVs and hypersonic craft will require new capabilities and procedures, particularly if their use results in significantly increased flight rates. Accordingly, an integrated capability that tightly integrates the SATMS with spaceports, ranges, and mission operations will be needed, as will procedures to clear airspace quickly for responsive launch and contingency operations. Highly responsive control systems that use both automation and human operators overseen by human controllers will need to constantly monitor air and space traffic and the areas in which these may conflict with future vehicles.

4.3.2 Inter-Modal Interfaces

As space transportation becomes more routine, commercial and government opportunities to transport goods and people via space can be expected to grow. Efficient and economical transport requires effective interfaces with ground, air and water transportation networks. In fact, efficient inter-modal interfaces may become an increasingly critical feature of future spaceport and range infrastructure as users opt for the advantageous economics and logistics of accessible space transportation sites over remote and hard-to-reach launch bases.

4.3.3 Space Flight Operators

Space flight operators – analogous to today's airlines – are the customers of the FSTS. These customers manage and operate their transportation system using the shared infrastructure provided by the FSTS, which supports common planning, scheduling and coordination; weather, traffic, and system health situational awareness; global data access and management; and system command and control as needed. These infrastructure elements and associated user interfaces are described in detail in the FIRST Space Vehicle Operator's Concept of Operations.[7]

4.4 CONCEPTUAL EVOLUTION OF SYSTEM ELEMENTS

The FSTS infrastructure is a national capability serving an increasing field of stakeholders. Future vehicles, some of them privately owned, and new civil, commercial, national security, and commercial transportation center spaceports will take on new missions and increase traffic. The growing complexity of the nation's – and the world's – space transport operation demand closer integration of all FSTS components with clearly defined roles and responsibilities.

One of the key components of the FSTS is a global system of transportation nodes, or "spaceports" that supports national defense missions, government research and exploration missions, commercial and private ventures, and mass public air and space transportation. Spaceports are multi-modal nodes connecting land, sea, air and space transportation systems together. Where security and safety allow, commercial, government and military operations will share spaceport facilities and services to increase efficiency and realize cost savings. Some spaceports will be dedicated to national security missions for security and safety reasons while other spaceports will be dedicated to commercial activities like space tourism.

The Spaceport Base Operational Model, Figure 11, illustrates the interrelationships and component flow patterns between the operations required to prepare, launch, recover and service flight vehicles and related spaceport infrastructure. It demonstrates how a future spaceport can address national defense missions, government research and exploration missions, commercial and private ventures, and mass public air and space transportation in a way that maximizes commonality of activities and the benefits of applied technology enhancements over time.

The basic spaceport operational model outlines a concept for accommodating a variety of future mission types with common operations and new technology.

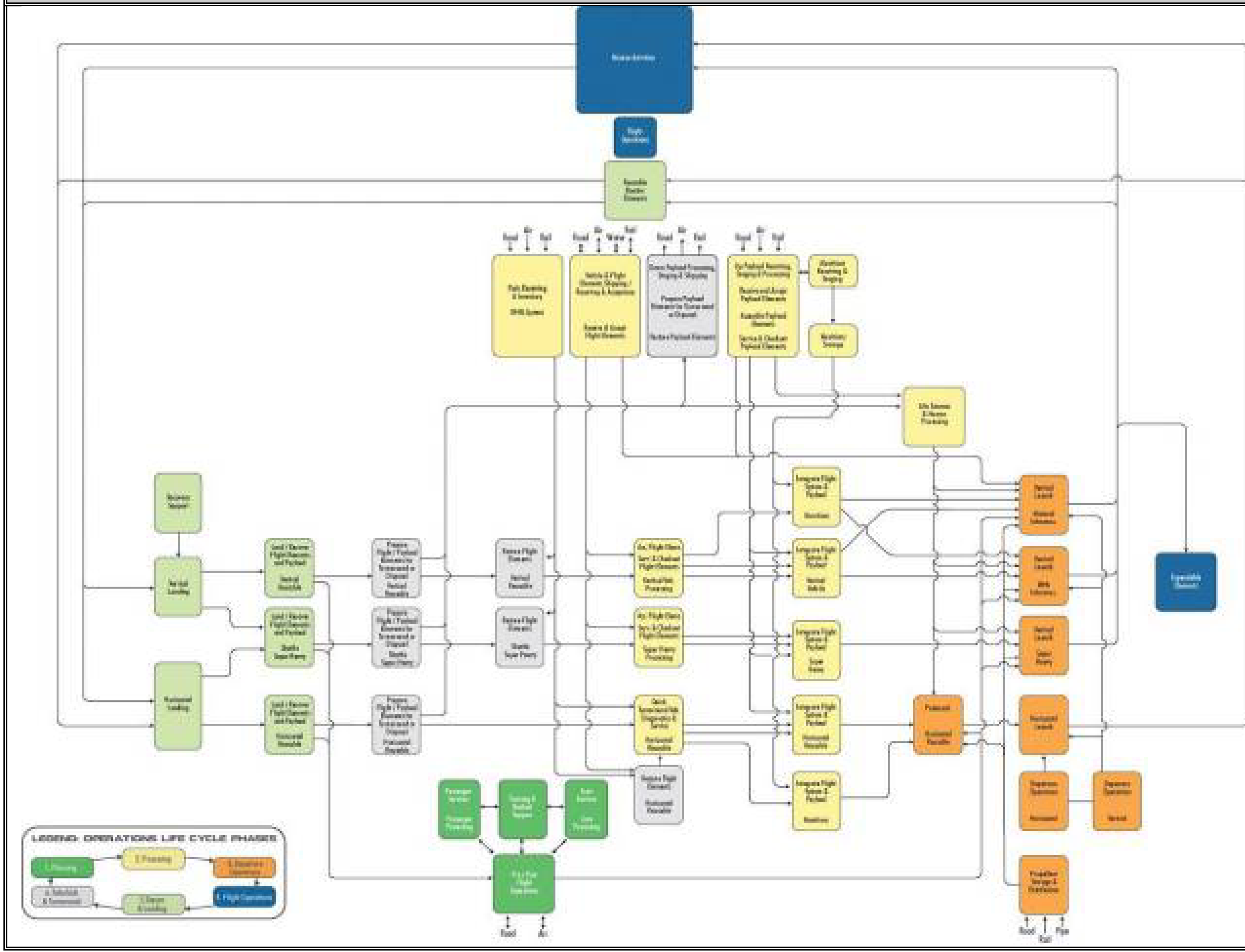

Figure 11 – Spaceport Base Operational Model.
(See FIRST Spaceport CONOPS[8] for detailed view.)

The global spaceport system includes Commercial Transportation Center (CTC) spaceports that evolve from airports. As hypersonic suborbital space travel becomes more reliable through technology innovation and consistent vehicle performance, suborbital service will debut between major world economic capitals effectively shrinking global distances and opening up further global trade. Various markets are served by CTCs that are scaled in size or tiered to address passenger and cargo volumes resulting from ever-changing market logistics and new vehicle capabilities. At many sites, the distinction between airport and spaceport is largely eliminated as the two previously unique facilities are integrated into a global FSTS that is safe and affordable, efficient and reliable, and meets the needs of all users through consistent and responsive levels of service.

With this shift, a new "plug & play" operational concept emerges which envisions spaceports that use common and standardized interfaces to vehicles, payloads, and related flight hardware (Figure 12). Simplifying and standardizing the interfaces between the spaceport and flight hardware and eliminating the need for extensive reconfiguration between missions can achieve significant schedule and cost savings. In this concept, spaceports function much like an airport does today, supporting higher flight rates and the ability to accommodate concurrent operations.

Shared infrastructure and standard interfaces lead to a new operational concept that eliminates vehicle-unique infrastructure and extensive reconfiguration between missions.

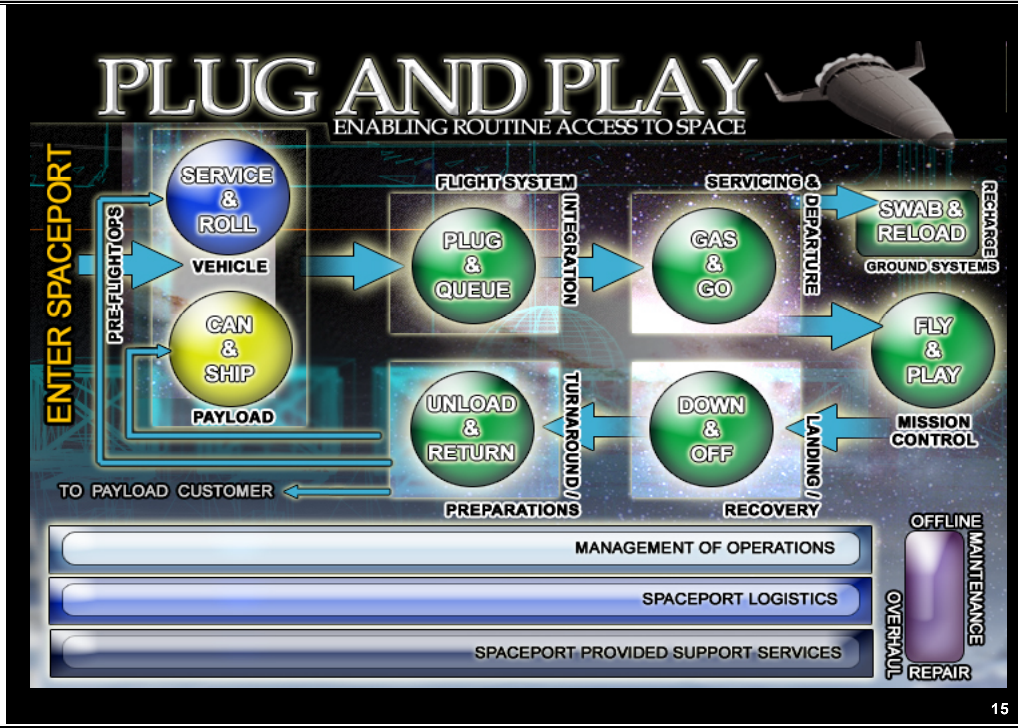

Figure 12. Plug & Play Vision of Spaceport Operations. [Source: ASTWG[4]]

New vehicle architectures pose a special challenge to spaceports because significant unique infrastructure has always been required for each vehicle type. Ensuring spaceport standards are incorporated in the system architecture of new vehicles and payloads from the beginning of the development process will limit the need for constant upgrades, new facilities, and highly expensive program-specific maintenance to accommodate new vehicles. As a result, the spaceport must be evolvable to accommodate next generation vehicle and payload architecture without impacting spaceport operations or requiring new facilities and extensive costs. The spaceport must also provide safety and environmental protection at a low cost and with minimum difficulty through enhanced vehicle and spaceport design while supporting concurrent operations within user-driven schedules. Technological advancement will be a key component to achieving these requirements.

Advances in ground processing and launch technologies improve flight safety and modernize infrastructure to reduce turnaround times and operations costs. Management of the spaceport will be improved with the addition of an automated and paperless logistics system and automatic interactive scheduling and spaceport data management and training systems. Vehicle turnaround times of hours with intelligent inspection technologies and smart nonintrusive sensors, autonomous vehicle and GSE health management systems, rapid handling and assembly techniques, and advanced fluid servicing technologies will be the standard of these spaceports. Specific operational capabilities enabled by these technologies include coordination among a network of spaceports, on-demand propellant loading, autonomous, reconfigurable ground systems, and automated inspections all working towards ensuring flight safety and sustaining multiple flights per day.

The common national vision of an architecture and operation of a future next-generation U.S. space launch and test range concept is another key component of the FSTS. This global "range" concept is based on a primarily space-centric future space launch and test range capability, supplemented by modernized ground-based systems and mobile platforms to carry instrumentation. The concept enables and supports a variety of civil, commercial and national security space launch operations and flight test activities when and where needed around the world.

To accommodate future missions, the range capability transforms to provide automated planning, scheduling, coordination, and decision support systems; weather sensors, models, and data archive capabilities; and ground-based assets near spaceports for surveillance, tracking, data relay (telemetry), and command and control capabilities for high-density traffic areas. Space-based assets relay telemetry, command and control data, and communications to and from flight vehicles as needed throughout flight profiles.

A central control function manages the entire suite of range assets as well as interactions among the range assets, spaceports, and during space flight missions. The central control function also manages range systems and functions through a central planning and control capability to coordinate operations among all users of range services throughout all mission phases. During flight planning, range systems are configured and verified by establishing, coordinating, and verifying interfaces with mission and operations control centers, user networks and facilities, external agencies (e.g., to coordinate use of the national airspace system), and communication networks to support the mission.

The central control function coordinates use of required airspace by interfacing with appropriate national airspace management authorities operating the SATMS. The central control function also interfaces with proper authorities to ensure it has all necessary data with regard to collision-avoidance constraints associated with objects in Earth orbit. The central control function coordinates operations and missions to be sure the organizations responsible for assigning airspace and collecting and analyzing data to avoid orbital collisions are aware of the flight plans for scheduled range-

National Spaceport Testbed

To bridge the gap between laboratory R&D and technology deployment, a test and evaluation capability is developed to test and demonstrate emerging operations technologies in a simulated environment. The capability also supports certification of critical operations technologies and provide a means of controlling technical risk for future programs and businesses.

Examples of potential ground demonstrations include testing of autonomous umbilicals, rapid propellant loading techniques, launch exhaust management validation, launch environment vibro-acoustic evaluation, as well as smaller subsystem designs such as advanced hazardous gas and leak detection methods. In addition, range technology demonstrations for space-based, mobile, and deployable range systems are pursued. Integration of command, tracking, and surveillance technologies are demonstrated during launch events in "shadow" mode. Other areas of focus for test and evaluation of transformational spaceport and range technologies could include:

- *Self healing and situational awareness technologies and demos*
- *Advanced command and control techniques, networks, and architectures*
- *Autonomous, adaptive self-training, planning, and schedule systems for flight vehicle and support infrastructure operations*
- *Advanced modeling and simulations*
- *Autonomous safing/reconfiguration after landing technologies*
- *Advanced cryogenic systems for standardized propellant loading operations*
- *Common-use ground handling equipment*
- *Self-diagnosis and autonomous repair technologies*
- *Rapid reconfiguration of infrastructure assets*
- *Operational planning and training*

supported activities and missions that could pose airspace and/or in-orbit collision avoidance hazards or issues. Enabling the airspace and collision avoidance authorities to effectively deal with potential space flight events requires continuous communication and coordination between them and the range function.

Interactions with spaceports also include pre-flight assembly, checkout and verification to ensure the proper operation of the flight vehicle's telemetry, command, control, and communication systems and support of the countdown or final checkout, actual takeoff/launch, and initial flight of a vehicle. During flight operations the central control function reassigns primary communication connectivity from ground-based assets to space-based and mobile assets. This critical connectivity is used for space flight operations throughout the flight. Transforming data into information for real-time situational awareness and decision support is critical to ensuring safe operations. Integrated data systems with standard protocols and formats reduce the costs associated with data processing and information management.

As public space travel becomes common, range capabilities evolve toward a global aerospace traffic control capability responsible, in part, for maintaining air and space situational awareness of missions transiting to, through, or from space as part of the global transportation system. Over this period, evolving range capabilities enable a streamlined approach to "global space transportation traffic control" for operational space launch activities.

The FSTS is based on a network-centric capability to coordinate space transportation assets using a variety of control centers and user facilities connected through a Central Control Function and global network.

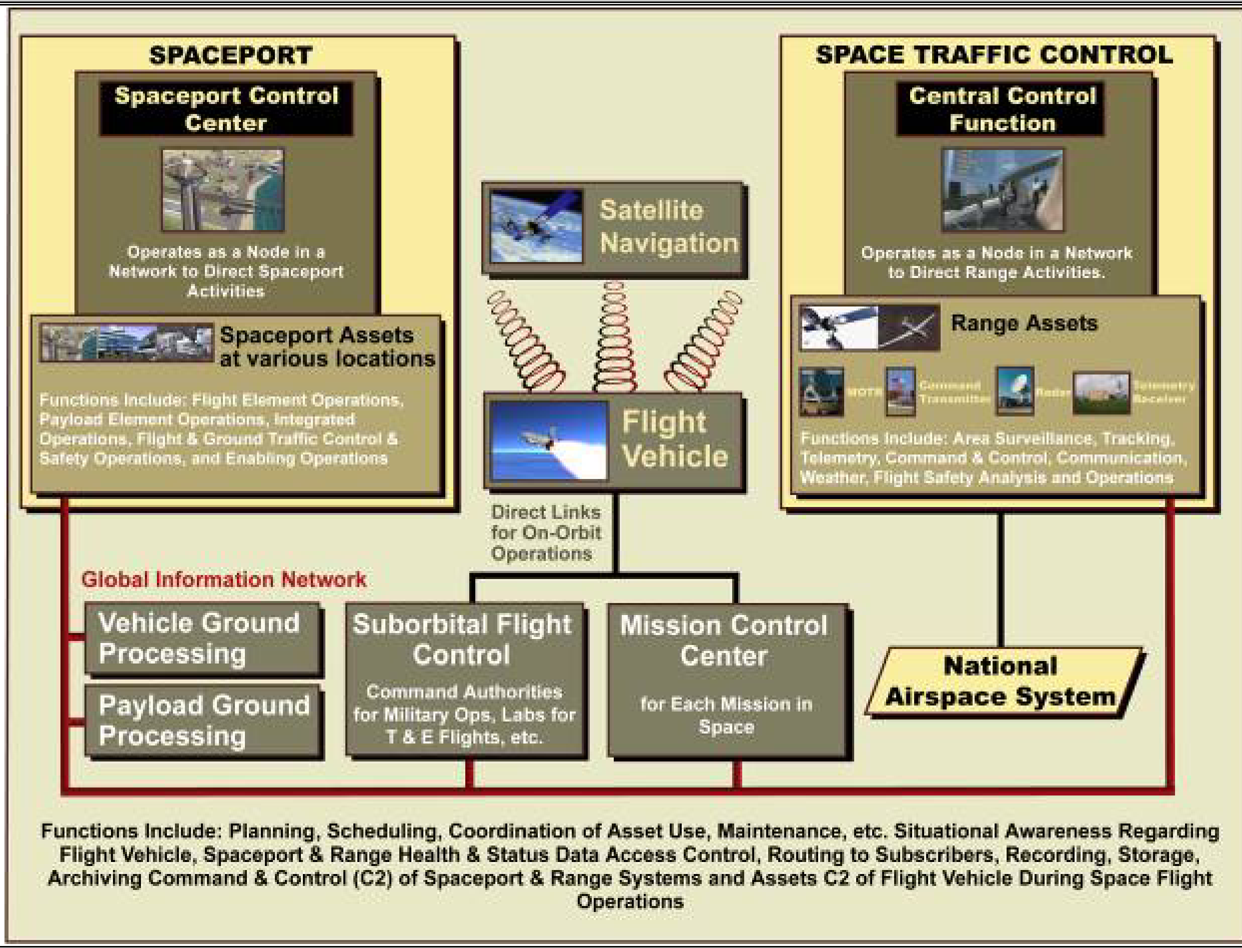

Figure 13 – Conceptual FSTS Architecture.

During this era, the range functions are gradually assimilated with spaceport functions, leading to the overall FSTS conceptual architecture illustrated in Figure 13. The range functions provided to users remain the same, but the range function is available continuously, and the method of providing services makes it transparent as to whether they are range or spaceport functions. The central control function is provided by a global space traffic control capability based on the SATMS concept to manage operations. In addition, standardization and interoperability enable a variety of commercial space transportation missions and point-to-point operations between interoperable spaceports. Flight termination commands are no longer required for flight vehicles with autonomous intact abort and emergency landing capabilities—though the need for continuous communication around the world persists. Only minimal ground-based and supplemental mobile airborne assets owned and primarily operated for non-range-related purposes are needed to support space transportation.

5 FUTURE SPACE TRANSPORTATION SYSTEM OPERATIONS

While the previous section described the conceptual architecture elements that provide the major functions of the future space transportation system (FSTS), this section describes FSTS operations. This section is divided into two parts. The first part describes the operation of the FSTS during the first and second eras, characterized by transformation and responsive space launch/human exploration, respectively. The second part describes how the FSTS supports routine space flights as part of the global transportation system in the third era, characterized by mass public space travel.

The FSTS operations described in this section distinguish between infrastructure providers, or "hosts," and infrastructure users—a model that is analogous to today's commercial air transportation system. Infrastructure hosts (i.e., spaceport, range, and control center operators) support space flight operations by providing the systems, facilities, and processes required to support national security, civil, and commercial space transportation operations. (Some hosts may limit their support to national security activities while others may limit their support to suborbital commercial flights, and still others may support all types of missions on a shared-use basis.) The FSTS connects these hosts through a Global Information Network so they can coordinate plans, schedules, and operations among themselves and with users. Users include space flight vehicle operators and payload owners.

Users conduct vehicle-specific operations including processing, launch and return (involving spaceports) and en-route flight operations (involving range support) along flight paths. Hosts support users' operations by providing vehicle-independent, common-use spaceport infrastructure along with range and traffic control assets and functions.

Distinguishing between infrastructure hosts and users provides the framework for assessing vehicle-specific infrastructure, identifying standards to enable more shared use of infrastructure, eliminating unnecessary duplication of functions, and maintaining independent safety oversight.

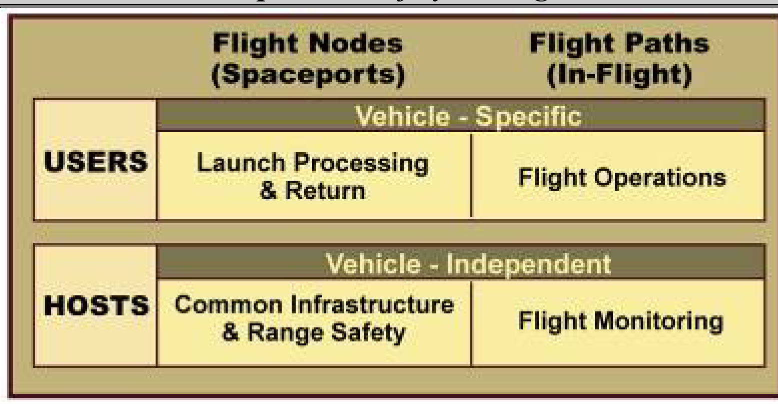

Figure 14 – FSTS Infrastructure Host and User Distinctions

The top row in Figure 14 refers to vehicle-specific operations conducted by users. The lower row depicts the common or shared-use infrastructure that is independent of any particular user or vehicle. This is the arena of the spaceport and range hosts who support user operations.

To support any particular space flight operation, FSTS operations are typically conducted to align with the six sequential phases depicted in Figure 15.

FSTS operations are typically conducted in six sequential phases.

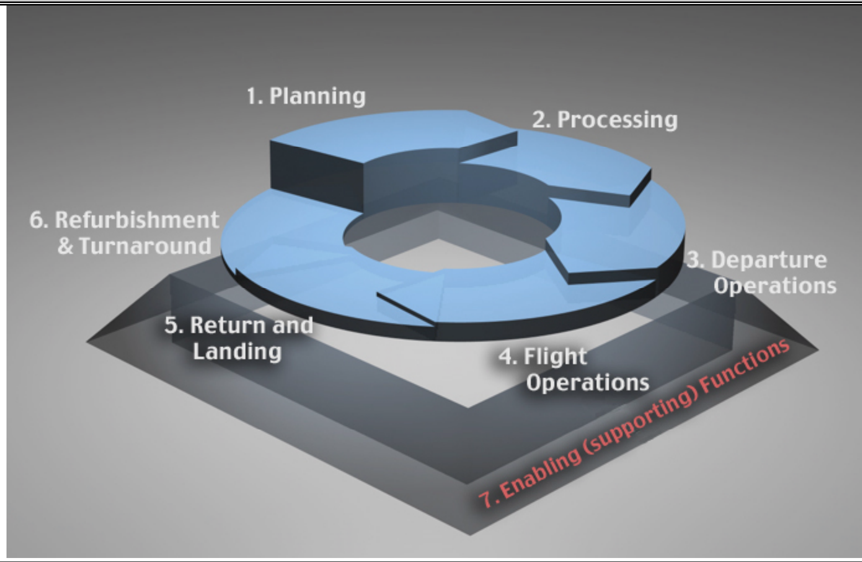

Figure 15 – The Six Phases of a Space Flight Operation

The functions provided by the major FSTS elements in each phase are listed in Table 1.

	Spaceport	Range	Mission Operations
Planning	• Planning, scheduling, preparation, & coordination • Receive and accept flight and payload elements	• Planning & scheduling • Initialization, calibration, verification • Deployment, configuration & verification	• Scheduling & Coordination • Training and certification • Development, Test and Evaluation • Mission planning
Processing	• Assemble flight elements • Assemble payload elements • Service and checkout flight and payload elements • Integrate flight system and payload	• Pre-flight processing • Checkout and verification of vehicle and flight safety • Weather monitoring and planning	• Pre-launch processing • Flight readiness and certification processes
Departure Operations	• Execute departure operations	• Final operations (holds, scrubs) • Support launch/take off • Safety of flight • Communications and telemetry	• Countdown and final launch commit • Launch and flight to space
Flight Operations	• Monitor and manage flight • Traffic Control and Safety	• Support flight • Telemetry and tracking	• Monitoring and situational awareness of on-orbit ops
Return & Landing	• Land/recover flight elements and payload	• Support return flight preparation • Support re-entry, landing, recovery • Telemetry and tracking	• Deorbit and re-entry • Return flight through NAS • Landing and Recovery
Refurbishment & Turnaround	• Prepare flight /payload element turnaround • Restore flight/payload elements for reuse • Restore ground systems for reuse	• Shutdown of tracking/telemetry systems • Routing/archival of data • Range performance analysis • Report range usage • Scheduled maintenance, repairs, modifications	• Post-flight processing

Table 1. Functions Provided by FSTS Elements

The remainder of this section explains the operation of the FSTS through the six sequential phases. The first section describes the operations envisioned during the first two eras; the second section offers a vision of the third era.

5.1 Transformation, Responsive Space Launch, and Human Exploration

To support pre-launch processing and flight activities for space transportation operations during the first two eras, typical FSTS operations begin in the planning phase and transition from one phase to the next in sequence, as depicted in Figure 15.

5.1.1 Planning

Planning begins when a user generates an initial flight profile and requests FSTS support for a space flight operation. In this request, the user defines the scope, objectives and requirements for the space flight operation, along with strategies for accomplishing them. 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.

Based on the flight profile, the Central Control Function determines which infrastructure assets are required to support the space flight operation. Plans for using these assets are integrated into the automated master schedule along with all other planned flights and activities, with updates generated as events impact requirements, availability, and plans. Planning steps may also include establishing interconnectivity among various takeoff/launch/landing/ recovery sites and control centers.

5.1.2 Processing

The processing phase includes pre-flight assembly, checkout and verification processes that precede a space flight operation. The processing phase typically includes vehicle and payload integration, checkout and verification to ensure proper interaction between flight systems and the FSTS. Processing also includes movement of vehicles, payloads, crew, and passengers between facilities, as required, to prepare for departure operations. Operators at the Vehicle and Payload Control Centers maintain situational awareness and retain primary control of integration, checkout, and ground transportation operations during processing. 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.

Processing also includes flight readiness verification to ensure all flight hardware, software, and operations organizations are ready for flight. Flight readiness verification uses the Global Information Network to initiate and analyze results from automated processes. It also relies on standardization and intelligent computing systems to assess readiness in real-time. The process phase typically concludes with an FSTS-enabled formal process of surveying all flight organizations, functions and elements to certify readiness for flight.

5.1.3 Departure Operations

The departure operations phase includes the countdown or final checkout, actual takeoff/launch, and initial flight. This phase typically includes FSTS support through all of the countdown processes, including loading and verifying vehicle commodities and mission parameters, final range/airspace interface checks, collision avoidance verifications, and management of holds, scrubs, or aborts. The Departure/Arrival Control Center retains primary responsibility for these operations. Systems and facilities are monitored by integrated health monitoring equipment to control operations and automatically identify and isolate failures and reconfigure or repair themselves autonomously. Operators in the Departure/Arrival Control Centers ensure the proper flight profile approvals and flight route clearances have been obtained and monitor space vehicle departures and arrivals in the general vicinity of the spaceport.

Launch/takeoff and initial flight include departure of a space vehicle from a launch site and flight through a NAS space transition corridor into a desired orbit or along a sub-orbital trajectory. Operators in the Departure/Arrival Control Center monitor the initial flight to ensure it is in accordance with its planned and approved flight profile. Operators in applicable Air Traffic Control Centers and Regional Space Traffic Control Centers also monitor the flight as it ascends within their regions of jurisdiction.

Once a vehicle is in Earth orbit or beyond, the Departure/Arrival Control Center, Air Traffic Control Centers, and Regional Space Traffic Control Centers monitor thje flight. These centers re-engage only if the flight is cut short and requires support for an unscheduled reentry and landing/recovery.

5.1.4 Flight Operations

As the flight vehicle proceeds through the space transition corridor, primary connectivity is reassigned to space-based and mobile assets supporting the flight over the horizon from the spaceport. This connectivity allows Air Traffic Control Centers and Regional Space Traffic Control Centers to monitor and issue routing instructions to suborbital hypersonic point-to-point flights as they fly en route between spaceports.

For space flight operations in LEO or beyond, the vehicle operator is responsible for mission operations. In the event of in-flight anomalies, onboard vehicle and payload diagnostic systems and the user's Mission Control Center transmit relevant data to the Central Control Function, where it is distributed on the Global Information Network throughout the FSTS. This system allows all other FSTS control centers to be notified immediately when an unscheduled return is requested.

5.1.5 Return and Landing

Return and landing operations include the return flight and landing (or recovery) of reusable vehicles and vehicle elements. This phase begins prior to deorbit, when the Mission Control Center coordinates through the Central Control Function to ensure all required support is scheduled and available as originally planned. Regional Space Traffic Control Centers monitor the flight during deorbit and reentry maneuvers. Once the vehicle enters the National Airspace System, the 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 maintains responsibility for issuing routing instructions to the flight crew (when applicable) and/or to the ground control center responsible for the flight, throughout terminal flight and landing/recovery at the applicable spaceport or recovery location.

5.1.6 Refurbishment and Turnaround

The refurbishment and turnaround phase includes deactivating flight vehicle and support systems, safing and de-servicing the flight vehicle and payload to eliminate potential hazards, and transition range assets to continue support for other flights. Automated health management systems report information needed for routine post-flight reports on asset usage and performance for billing and generation of maintenance and repair orders. Post-flight processing is tracked in real-time through the Global Information Network, allowing data to be analyzed to provide more complete understanding and insight into vehicle performance, trends, system anomalies, and maintenance or repair actions.

5.2 MASS PUBLIC SPACE TRANSPORTATION

This section addresses FSTS operations in the third era enabling and supporting safe, affordable, routine mass public space transportation. This long-anticipated but still visionary image of the future is based on a series of assumed developments over the next several decades. Technology and operational advancements as well as market demand have proven notoriously difficult to predict into the distant future because unanticipated breakthroughs and unforeseen events set in motion substantial departures from the expected course of development. Despite these potential uncertainties, operations associated with the FSTS functions in the third era are envisioned to enable a revolutionary streamlined approach to “global space transportation traffic control” for operational space launch activities.

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 public transportation using a variety of spaceports around the world, as illustrated in Figure 16. 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.

In the third era, spaceport and vehicle standards lead to 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 system of spaceports enables routine hypersonic point-to-point flights to destinations around the world.

Figure 16 – Spaceports around the World[8]

Operations in the third era differ from those in the interim period because the third era involves highly-reliable suborbital and orbital reusable launch vehicles to carry cargo and passengers to, through, and from space, as part of the global transportation system. In this period, the “range” function transforms to a global “space traffic control” function. Other differences include:

- Broad acceptance of standardization and interoperability to enable a variety of commercial space transportation missions and point-to-point operations.
- A variety of geographically dispersed spaceports used regularly to fully integrate space transportation missions into the global transportation system.
- Flight vehicles that include autonomous intact abort and emergency landing capabilities requiring continuous communication around the world, both for traffic control instructions and to accommodate contingency and emergency situations.

A “global space transportation traffic control” capability like the SATMS evolves from the Central Control Function to manage operations. This is similar to the way the air traffic control system is used today to manage use of the NAS. The new capability interacts with the NAS to coordinate space transportation operations with the air transportation. In other words, the central control function is provided by a global space transportation traffic control capability like SATMS to manage operations.

5.2.1 Planning

In the third era, flight profiles for suborbital point-to-point flights between major destinations are well defined for routine flights. When necessary, autonomous systems analyze alternative courses of action and automatically develop solutions with minimal human intervention. The Central Control Function manages dozens of spaceports and hundreds of flights each day, with heavy reliance on automation. The FSTS control center architecture remains analogous to today's air traffic management system, with Departure/Arrival Control Centers managing traffic in and out of spaceports and Regional Space Traffic Control managing en route traffic through pre-defined and well-established corridors.

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 conduct dozens of flights per day 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.

The increased flight rate in the third era drives the need for processing, refurbishment, and turnaround of reusable space flight vehicles between flights in ways that resemble today's aircraft-processing operations at airports. 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 to accommodate tight turnaround schedules. 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.

5.2.3 Departure and Arrival, Return and Landing Operations

As automation and flight rates increase in the third era, Departure/Arrival Control Centers at each spaceport coordinate departing and arriving flights with Air Traffic Control Centers and Regional Space Traffic Control Centers similar to today's air traffic control systems. As is the case in the first two eras, departure is supported with an onboard satellite navigation system and an inertial guidance system providing independent sources of metric tracking and time-space position information (TSPI). This data is included with the vehicle telemetry stream for transmission to ground-based and space-based controllers.

5.2.4 Flight Operations

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. 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. Consequently, operators in control centers are able to support more flights simultaneously.

5.2.5 Refurbishment and Turnaround

In the first two eras, FSTS assets enter the refurbishment and turnaround phase between operations. In contrast, in the third era, such frequent operations are envisioned that the spaceport, range, and control center assets operate virtually continuously, and are rarely directed to enter this phase except when a particular asset requires off-line maintenance.

At the conclusion of a scheduled operation (or after official release of assets following an anomaly), FSTS assets typically remain active and are immediately reassigned to support the next operation. Automated health management systems aboard each asset continuously report status to the Central Control Function, where it is used to generate and distribute routine post-operation reports on system usage and performance.

6 A DAY IN THE LIFE

The "day in the life" story in this section describes how future space flight operations and activities are conducted using the envisioned future space transportation system to support multiple types of operational space transportation missions and flight test activities. These examples were chosen from the three Design Reference Missions (DRM) categories associated with this CONOPS to highlight how the future space transportation system operates as an integrated system. As shown in Figure 17, the DRM categories associated with this CONOPS are:

1. Routine Space Flight Operations
2. Responsive Space Flight Operations
3. Flight Test & Evaluation Activities

Each DRM illustrates the scope of activities the future space transportation system supports, and highlights which types of missions stress its capabilities.

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

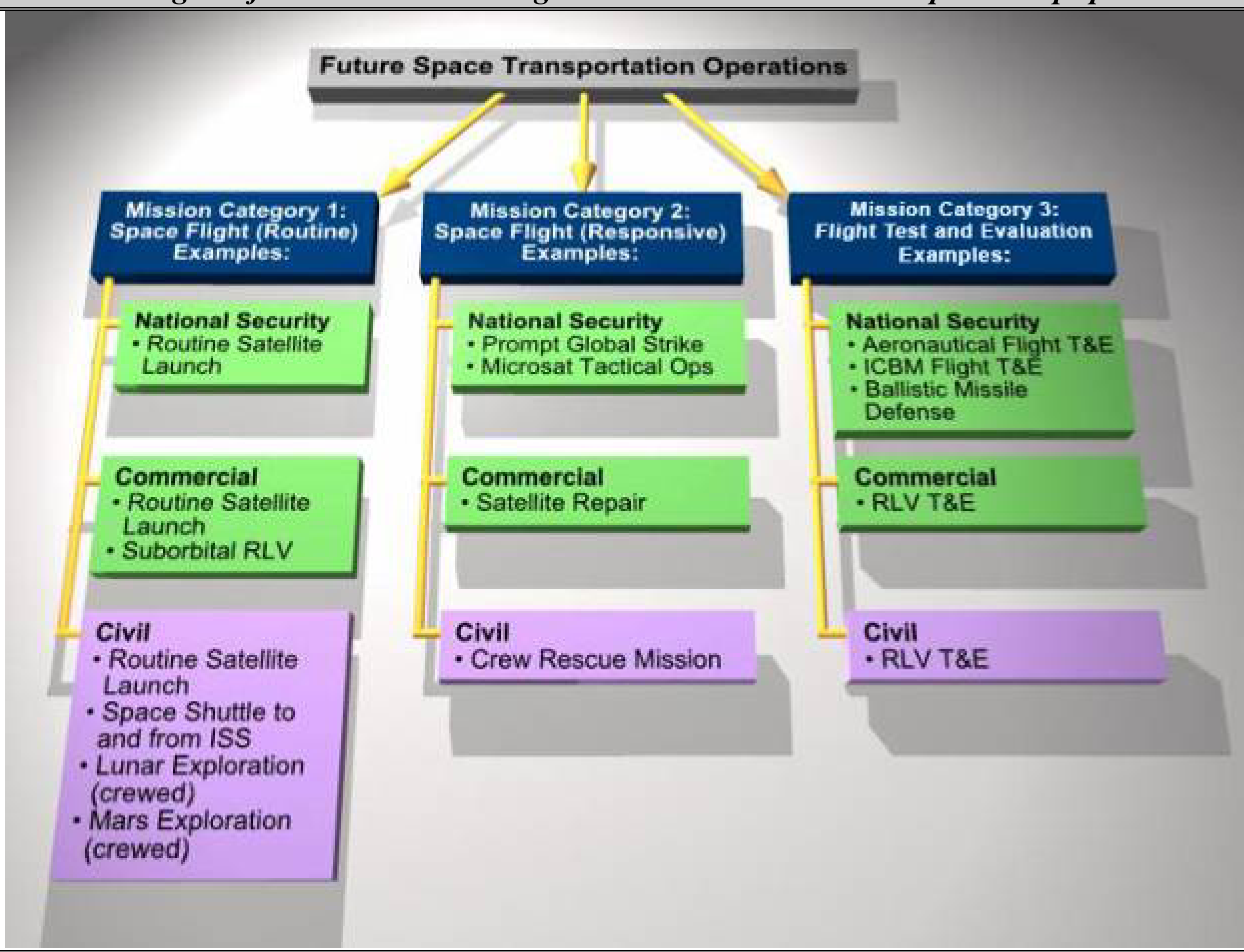

Figure 17 – Design Reference Missions and Example Scenarios

The scenario described in this section highlights several examples of missions derived from the DRMs, but it only depicts one day's operations. The context for that day's operations is shown in the yearlong schedule of activities in Figure 18, which highlights the importance of the future range's ability to support frequent and multiple concurrent operations.

A typical future year, as envisioned, will include many routine, responsive, and test missions, with frequent overlapping and concurrent operations.

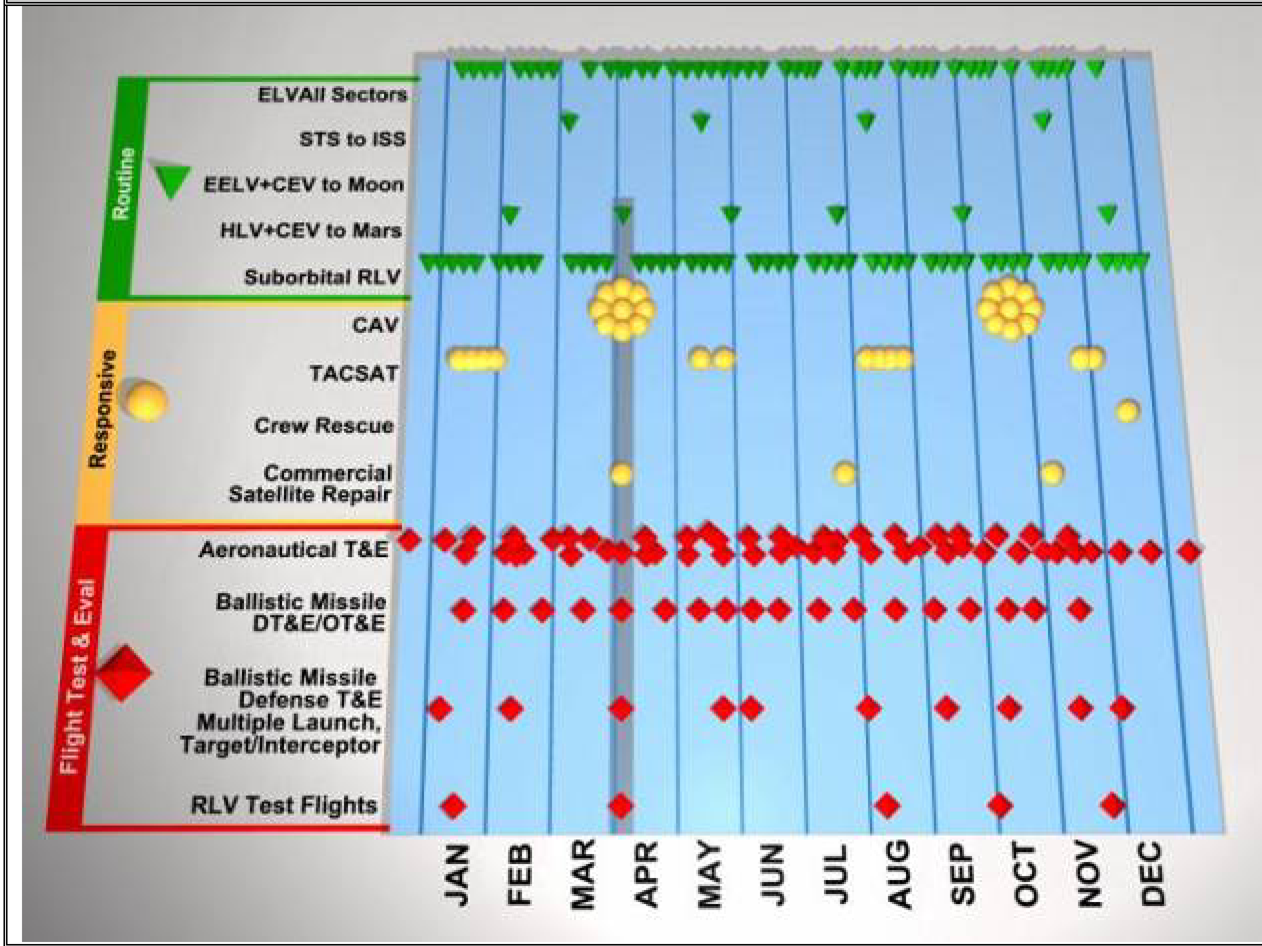

Figure 18 – Example Mission Scenario for a Future Year

Each mission described in this section was chosen to illustrate specific characteristics of future space flight operations, how particular functions and capabilities are employed in support of each of the DRMs, and how the network-centric future space transportation system provides responsive, flexible, adaptable capabilities to support a variety of missions and activities, when needed anywhere in the world. The six specific examples are:

1. Routine commercial suborbital RLV flight
2. Routine scheduled NASA launch to support a crewed mission to the Moon
3. Routine scheduled NASA launch to support a crewed mission to Mars
4. Operationally Responsive Space (ORS) Prompt Global Strike (PGS) missions
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

These examples were chosen from among the many possible example missions for each DRM to illustrate the specific ways that each DRM stresses the future space transportation system capabilities in terms of each of the performance characteristics identified in the Needs Assessment. Specifically:

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

Flight Rate	Dozens of suborbital 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
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	To enable development of commercial tourism, package delivery, and other markets

Flight #2 Routine NASA launch supporting a crewed mission 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 mission to the Moon illustrates the need for:

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 missions
Minimize Cost	To enable an affordable human exploration program

Flight # 3 Routine NASA launch supporting a crewed mission 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 mission 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
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 missions
Minimize Cost	To enable an affordable human exploration program

Flight # 4 Operationally Responsive Space (ORS) Prompt Global Strike (PGS) missions – Operationally Responsive Spacelift (ORS) missions 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 suborbital flights per week in the responsive space launch and human exploration era, and dozens per week in the mass public space travel era
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
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	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
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 accommodate frequent, repeatable flight test operations using multiple locations
Safety	To enable launches and complex intercepts in multiple locations, in support of realistic and representative threat scenarios
Flexibility & Adaptability	To enable target and interceptor test launches from multiple locations, to support realistic test scenarios that are representative of actual threat scenarios
Concurrent Operations	Provide range support for multiple simultaneous operations

The combined scenario described in this section includes examples to illustrate the operations associated with each of these missions, including interactions among them when operations overlap and require concurrent support.

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

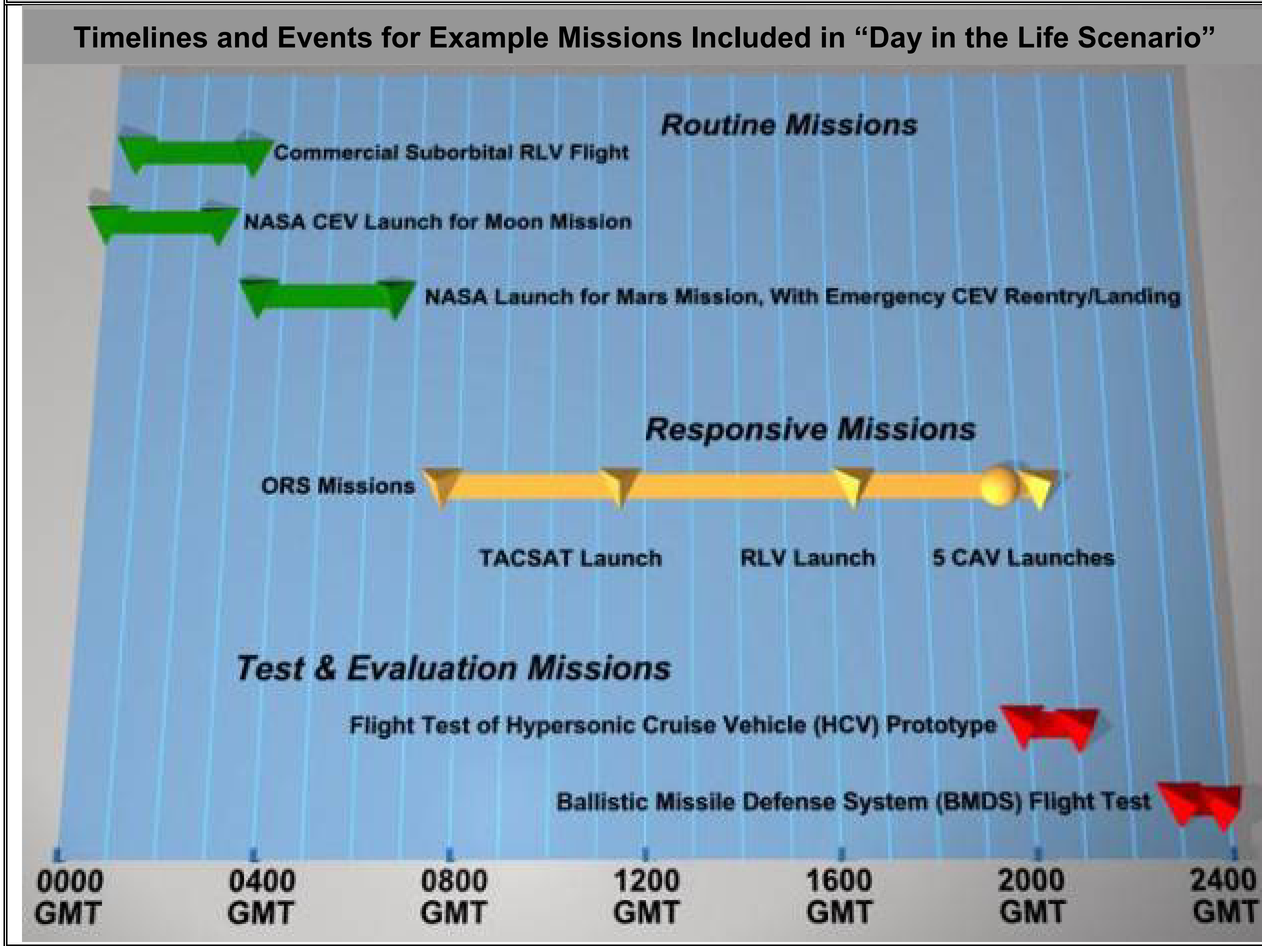

Figure 19 – Overview of Day in the Life Scenario

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 future spaceports and a network-centric range with global connectivity are able to responsively support various types of concurrent missions and activities, using inherent flexibility and adaptability to transition from one operation to another.

The following "day in the life" story is told from the perspective of the vehicle operator in each case, whether the vehicle operator is a member of the flight crew (e.g., a commercial "spaceline" operator or a crew member on a NASA exploration mission) or a ground controller operating a space flight vehicle without a crew on board (e.g., a military flight test or operational mission).

Based on the assumptions described in Section 2, as well as the description of the capabilities of the FSTS architecture in Section 4, 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 approach to space flight operations
- Able to accommodate frequent flights with short lead times
- Able to manage multiple flights and activities simultaneously
- Automated and less manpower-intensive
- Seamlessly integrated with the NAS via the planned SATMS.

In addition, it is intended to illustrate:

- The effects of reliability and mean time to repair on overall system availability.
- How overlapping satellite coverage and automated hand-offs provide global communications connectivity for voice, video, telemetry data, and positive command and control.
- How the future system avoids telemetry, command, and communication interference during concurrent operations.
- Conditions when multi-function airborne assets are employed.
- How each type of ground instrumentation element is employed, and why it's important.
- How accurate, timely weather measurement, forecast and warning information is gathered, distributed, and used.

This scenario illustrates how operations are conducted in the third era characterized by mass public space transportation. FSTS functions are provided to commercial space transportation providers in a manner that makes it transparent as to whether they are range or spaceport functions. The scenario emphasizes the actions of space flight vehicle operators (whether on-board flight vehicles, or in control centers on the ground). It builds on the integrated architecture description and operating models described above, to conduct current, emerging, and future national security, civil, and commercial missions 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 spaceport and range support 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 20 – Support for Commercial Suborbital RLV Flight

Time	Scenario Description	Vehicle Operator Actions
0001 GMT	Government and commercial vehicle operators planning operations in the coming 24-hour period are monitoring normal air and space traffic data at various mission operations centers.	Members of the flight crew that will be flying aboard ***Spacequest Spacelines*** flight 6402 depart from their Oklahoma homes to commute to the Oklahoma Spaceport using ground transportation. The Spacequest operations center has reviewed weather conditions and updated the on-line flight plan on the centralized FSTS database with manifest information specific for this flight. There are no major changes to the standing flight plan and mission profile for today's excursion.
0050 GMT	A commercial suborbital flight from Oklahoma to California is scheduled for takeoff at 0230 GMT. This	The flight crew arrives at the Oklahoma Spaceport, goes through the mandatory security screening process on the way to the departure gate, and arrives at the gate where the passengers are waiting.

	is a routinely scheduled monthly flight that's 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.	waiting. The crew boards the spaceliner and takes their positions on board. All activated range assets and integrated health monitoring systems report nominal status after verifying calibration certifications are current. Status of the preflight processing in Oklahoma is monitored over the Global Information Network at the California Spaceport where preparations for the flight's arrival are underway.
0100 GMT	Begin suborbital RLV propellant loading.	A ground crew employed by the Oklahoma Spaceport initiates the propellant loading operation using the spaceport's adjustable ground support equipment to connect the vehicle's propellant loading ports to the spaceport's propellant distribution systems. The flight crew aboard the vehicle monitors the automated propellant loading operation taking place with the vehicle parked at the gate. The passengers in the gate area hear an announcement letting them know that the boarding process will begin in about 30 minutes.
0130 GMT	Continue pre-flight checkout processes. Passengers begin to board the suborbital RLV at the Oklahoma Spaceport.	The flight crew aboard the vehicle continues to monitor the automated checkout process that continues to take place with the vehicle parked at the gate. The flight crew monitors their displays as indicators change from red (indicating checkout steps yet to be completed) to yellow (indicating steps in process) to green (indicating steps complete). The flight vehicle's system status display indicates the current state of readiness for each vehicle system (according to the vehicle's on-board integrated health monitoring system) as the automated pre-flight processing activities continue. The crew's displays indicate that range connectivity has been established as the vehicle begins to relay two-way voice, video, and data communications through two satellites, an airborne mobile range asset over the Great Plains, and the ground antennas located near the spaceport. The dynamic situational awareness display in the cockpit shows the planned mission profile with local weather and air traffic information overlaid along the portions of the flight path within the Earth's atmosphere. It dynamically displays the orbital tracks of flight vehicles, orbiting satellites, and debris in the region near the flight path through space. It also indicates which range assets will be used to maintain connectivity during ascent, suborbital flight, and reentry/return flight/and landing at the California Spaceport.
0230 GMT	Suborbital RLV takes off from Oklahoma for a 20-minute flight to California.	The flight crew sees on its cockpit displays that the Oklahoma Spaceport Departure/Arrival Control Center has cleared Spacequest Flight 6402 for taxi to the active runway, and for an on-time takeoff. An operator in the Departure/Arrival Control Center makes voice contact with the flight crew to confirm that it has received and understands the instructions for taxi and takeoff. The flight crew manually controls the spaceliner as it taxis to the runway, and then (after verifying once again that all systems are "go" according to the integrated health monitoring system), they

		initiate the automatic flight sequence. The vehicle accelerates down the runway, lifts off, and begins its rapid, near-vertical ascent.
0240 GMT	Suborbital vehicle ascends along planned flight path and reaches apogee, beginning descent and reentry.	The cockpit display continuously indicates the robustness of the two-way communication link between the flight vehicle and each range asset it is in contact with. The display indicates the handoff of the primary communication relay path from one range asset to another as the vehicle flies along its planned trajectory. Space-based range assets also continue to provide redundant connectivity throughout the flight. The Departure/Arrival Control Center makes a voice call to the flight crew to indicate it has handed off responsibility to the North American Regional Space Traffic Control Center for the short-duration flight through its region of responsibility. The crew responds, acknowledging that it has received the information and understands. An operator at the North American Regional Space Traffic Control Center makes a voice call to the crew to confirm what it sees on its situational awareness display—that no conjunctions are expected between its flight path and any orbiting objects—and to confirm that Spacequest 6402 is cleared for reentry as planned. Again, the crew responds, acknowledging that it has received the information and understands. The vehicle automatically begins reentry as planned.
0250 GMT	Suborbital RLV descends through the atmosphere, approaches the California Spaceport and lands on the runway.	As the flight crew continues to monitor its situational awareness display showing the tracks of air traffic in the region, an operator from the California Spaceport Departure/Arrival Control Center makes voice contact with the flight crew to confirm that it is cleared for approach and landing. The cockpit display now indicates that ground-based radars, imaging systems, and telemetry receivers at the California Spaceport have acquired the vehicle and are maintaining contact with it as it descends and lands on the runway. As the vehicle touches down, the flight crew disengages the automatic flight system, controls the vehicle's deceleration, and pulls off of the runway and taxis to the arrival gate, as instructed by the California Spaceport Departure/Arrival Control Center. The situational awareness display shows the termination of the communication relay links with each range asset as the umbilical connector is mated to the vehicle at the gate. The crew initiates the vehicle's automatic power-down sequence and monitors its displays as the vehicle systems go off line in sequence.
0300 GMT	California Spaceport reports mission complete to central control system.	The operator from the California Spaceport Departure/Arrival Control Center thanks the crew for its business and tells them the spaceport and range support usage and billing data has been sent to the headquarters for Spacequest Spacelines.
0302 GMT		The passengers and crew from Spacequest Flight 6402 egress the vehicle and go to their connecting flights or final destinations. Spacequest Spacelines ground crew at California Spaceport begins post-flight processing activity on the vehicle to prepare it for its return flight to Oklahoma next week.

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

A scheduled 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.

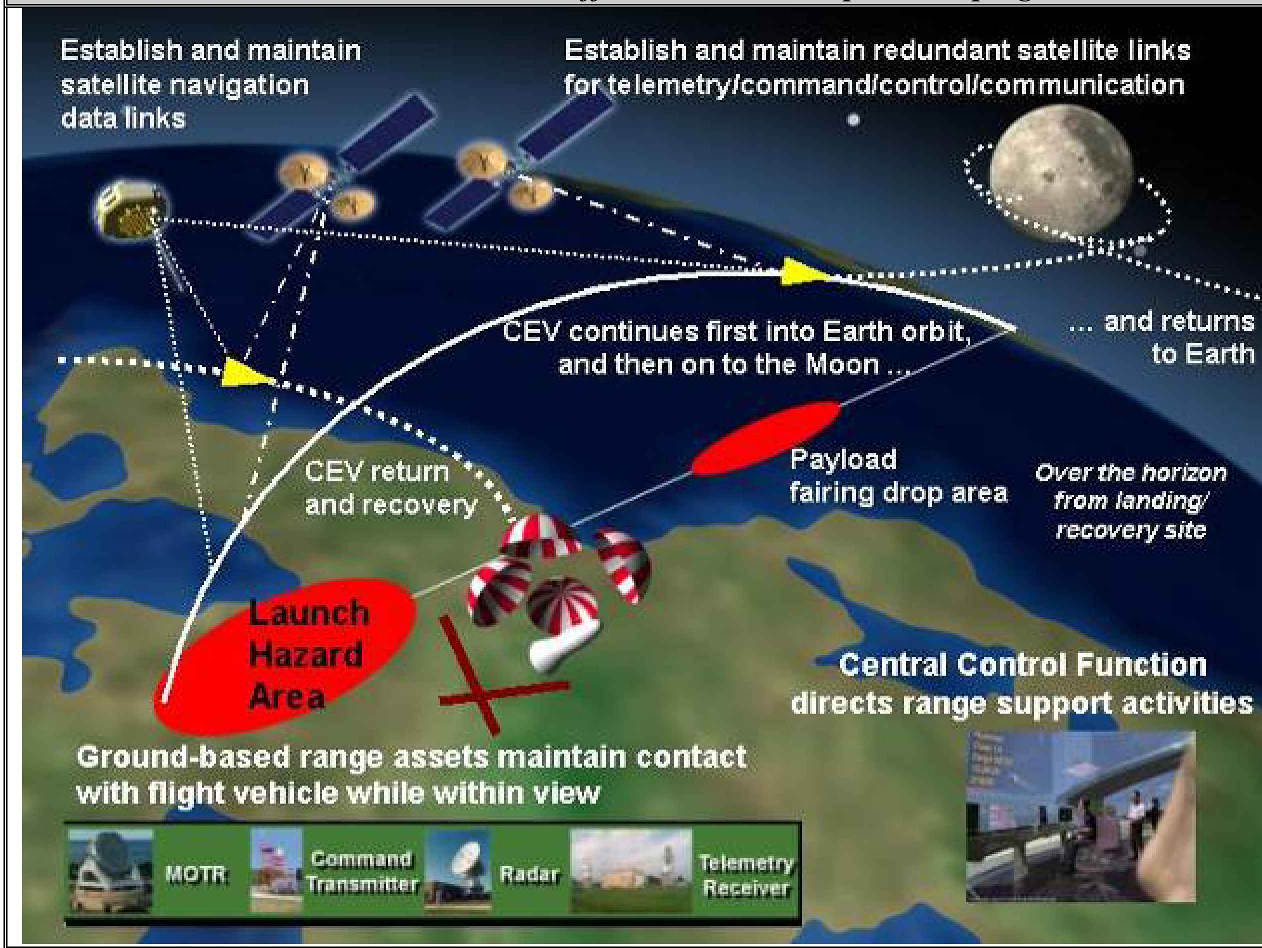

Figure 21 – NASA Launch of Crewed Mission to the Moon

Time	Scenario Description	Vehicle Operator Actions
0010 GMT	An evolved expendable launch vehicle (EELV) is scheduled for liftoff from Cape Canaveral Spaceport, Florida at 0140 GMT. This is the fifth of six Lunar Exploration missions planned within a six-month cycle.	For the past year, the flight crew for this lunar expedition has been in training at a variety of locations to ensure it is prepared to conduct all aspects of the mission and that it is familiar with emergency procedures in case of anomalies or contingencies. Finally, the scheduled launch date has arrived and the crew is suiting up with the help of technicians at the crew preparation facility on Kennedy Space Center. The Vehicle Processing Control Center officially handed off primary responsibility to the Mission Control Center yesterday, and operators in the Mission Control Center have been monitoring the progress of the automated EELV and Crew Exploration Vehicle pre-launch checkout processes for the past 12 hours.

0050 GMT		The flight crew arrives at the EELV launch pad and (again with the help of technicians) straps into the CEV. Meanwhile, operators in the Mission Control Center (through the Global Information Network) monitor their displays as information flows in to indicate that all network connectivity has been verified among all of the range assets and control centers that will be supporting the scheduled launch. Displays indicate that the range configuration is now complete, and voice calls on the network indicate that the Cape Canaveral Spaceport Departure/Arrival Center is in the process of confirming with the local Air Traffic Control Center that airspace has been assigned and cleared for the EELV ascent, and for all contingency abort landing and recovery options for the CEV.
0100 GMT	Pre-launch checkout process begins.	The flight crew is now in place in the CEV and observing its situational awareness and vehicle health monitoring displays as they indicate progress through the automated checkout processes for the EELV and the CEV. Operators in the Mission Control Center observe on their situational awareness displays that the range assets scheduled to support the launch have started to actively engage ground- and space-based sensors and transceivers to support countdown activities, verifying robust two-way data link with the vehicle on the launch pad. Both the flight crew and the Mission Control Center receive voice callouts from the Cape Canaveral Spaceport Departure/Arrival Center as their situational awareness displays indicate that the airspace has been assigned and cleared for the ascent and contingency landing options. The Mission Control Center and the flight crew participate in the final commit for launch polling process, each providing a “go” response. Both continue to monitor their displays, watching as indicators turn from red to yellow to green, indicating the completion of each sequential step in the countdown procedure.
0140 GMT	EELV with CEV ignition and lift-off from Cape Canaveral Spaceport, Florida.	Operators in the Mission Control Center and the flight crew aboard the CEV continue to monitor their situational awareness and vehicle system status displays during ascent, keeping an eye out for any anomalies being flagged by the automated systems. The situational awareness displays in the Mission Control Center and aboard the CEV show the vehicle’s ascent trajectory, current weather conditions along the ascent path, and all air and space traffic in the region, while also indicating which ground- and space-based range assets are being used to collect and relay tracking, imaging, telemetry, command, control, and communication information during ascent.
0145 GMT	CEV proceeds over the horizon from the launch site.	The Mission Control Center (and flight crew) receives a voice call from the Cape Canaveral Spaceport Departure/Arrival Control Center indicating that it has handed over responsibility for issuing routing instructions for the flight vehicle to the Regional Space Traffic Control Center that’s responsible for the region over Africa and the Middle East. A controller in the African Regional Space Traffic Control Center contacts the Mission Control Center to confirm its active role, reporting that no conjunctions are expected during ascent and injection into Earth orbit.

		The situational awareness displays in the Mission Control Center and aboard the CEV change to indicate that the primary connectivity for tracking, telemetry, command, control, and communication is now being routed through space-based range assets, which continue to provide connectivity until CEV reaches Earth orbit.
0150 GMT	CEV separates and moves toward the location where it will maneuver to rendezvous and dock with other elements in orbit (delivered by previous launches) that together will then be launched out of Earth orbit onto a lunar trajectory.	The Mission Control Center and flight crew continue to monitor system status and situational awareness displays as the vehicle proceeds through the automated sequence of events, including separation of the CEV from the launch vehicle and maneuvers in orbit to rendezvous with other exploration elements in orbit. All planned maneuver burns, course corrections, and attitude adjustments proceed as planned and calculated in real-time by the navigation system aboard the CEV.
0200 GMT	CEV executes rendezvous and docking maneuvers to link up with other elements in orbit.	Operators in the Mission Control Center and the flight crew aboard the CEV receive periodic voice calls from Regional Space Traffic Control Centers as they actively hand off responsibility from one to another during these initial orbits and in-space maneuvers—from the Africa/Middle East Center to the East Asia/India Center, to the Central and South America Center, to the Center that's responsible for the space traffic over Europe/Western Asia/Arctic, and so on. Each Regional Space Traffic Control Center in turn makes voice calls over the network to indicate when there may be conjunctions with other orbiting elements, providing maneuvering instructions to avoid them, to reiterate the information that appears on the situational awareness displays which also include instructions on recommended courses of action based on the results of automated expert system analysis of situational awareness information.
0215 GMT	Docking complete. Lunar exploration vehicle is configured for launch out of Earth orbit onto a lunar trajectory.	The Mission Control Center acknowledges that the transportation-related portion of the mission is now complete and the operators and flight crew make voice calls over the net to thank the supporting Regional Space Traffic Control Centers for their support. Operators in the Regional Space Traffic Control Centers acknowledge the call over the network and bid the crew farewell on their mission as they go back to monitoring other in-space transportation activities.
0232 GMT		The Mission Control Center is now the only ground control center that is still actively engaged in monitoring and controlling the CEV/lunar exploration mission. As long as the CEV and other lunar exploration elements are in low Earth orbit, the Mission Control Center maintains a continuous link with the Central Control Function to ensure that it can immediately notify all other control centers around the world if a contingency arises that requires an emergency reentry, return flight, and landing/recovery. The Mission Control Center receives one last active voice call from the Central Control Function to thank them for their business, wish them well on their mission to the Moon, to let them know that the range assets that have supported the space flight operations up to this point are now shut down, and that the bill for spaceport and range usage has been sent to NASA.

6.3 NASA Shuttle-Derived Super Heavy Lift Vehicle for Mission to Mars

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

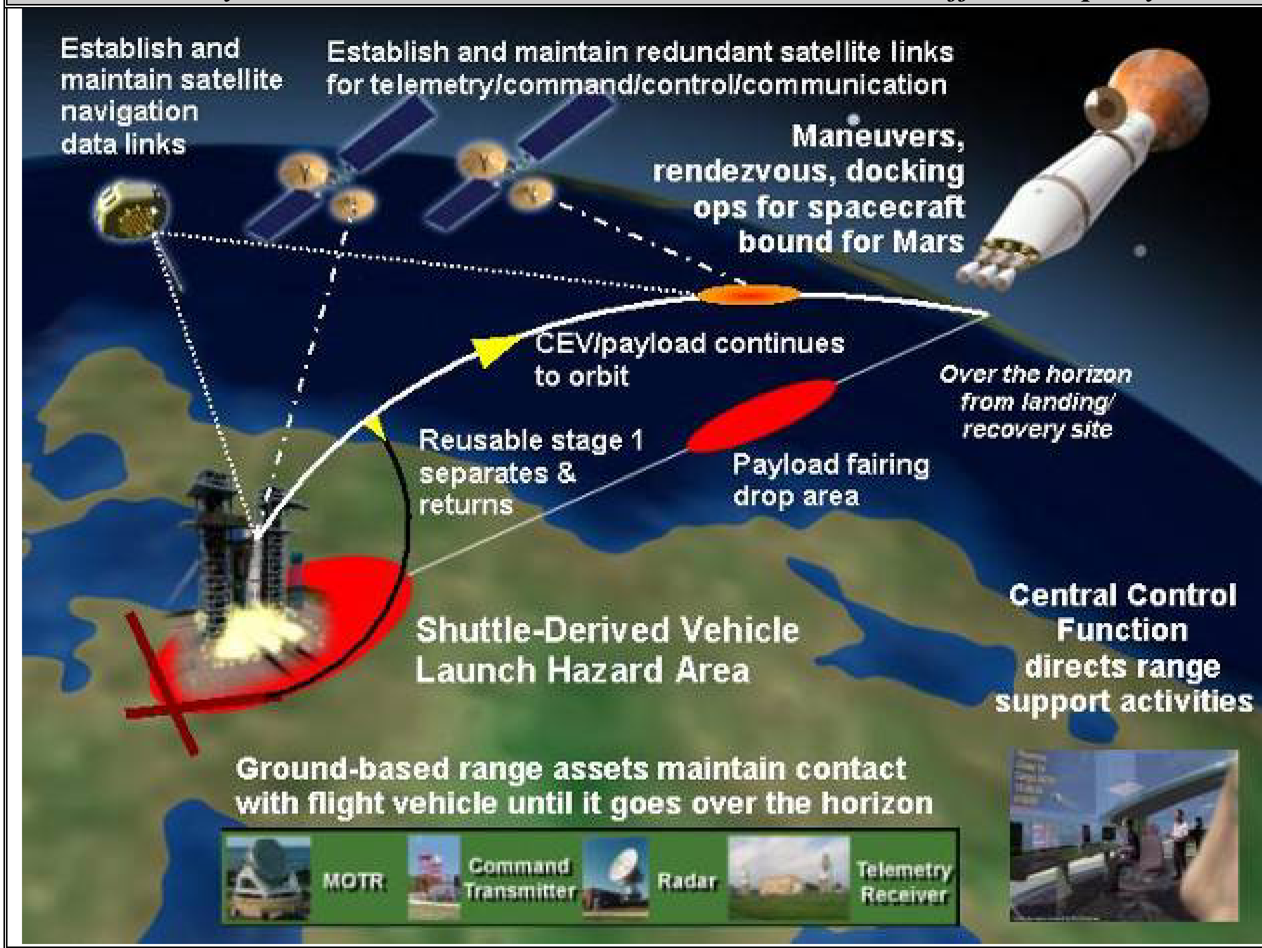

Figure 22 – NASA Launch of Crewed Mission to Mars

Time	Scenario Description	Vehicle Operator Actions
0440 GMT	A Shuttle-derived super heavy lift launch vehicle (with a reusable first stage) is scheduled for liftoff from Cape Canaveral Spaceport, Florida at 0610. This is the fourth of six missions that will be launched over a six-month span to assemble large spacecraft in orbit and conduct a crewed mission to Mars.	For the past two years, the flight crew for this Mars exploration mission has been in training at a variety of locations to ensure it is prepared to conduct all aspects of the mission and that it is familiar with emergency procedures in case of anomalies or contingencies. Finally, the scheduled launch date has arrived and the crew is suiting up with the help of technicians at the crew preparation facility at Cape Canaveral Spaceport. The Vehicle Processing Control Center officially handed off primary responsibility to the Mission Control Center two days ago, and operators in the Mission Control Center have been monitoring the progress of the Shuttle-derived heavy lift launch vehicle and Crew Exploration Vehicle (CEV) pre-launch checkout processes for the past 36 hours.

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. 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.	The Mission Control Center contacts the Vehicle Processing Control Center and requests that a technician deliver a spare telemetry transmitter to the CEV on the launch pad. An operator in the Vehicle Processing Control Center checks the automated logistics system (through the Central Control Function) to locate the spare part. The operator contacts and instructs a technician to pick up the spare part and deliver it to the launch pad. At the direction of the operator in the Vehicle Processing Control Center, the technician stows the spare part in a locker aboard the CEV that has been reserved for contingencies.
0500 GMT		The flight crew arrives at the Shuttle-derived vehicle launch pad and, with the help of technicians, straps into the CEV. Meanwhile, operators in the Mission Control Center (Global Information Network) monitor their displays as information flows in to indicate that all network connectivity has been verified among all of the range assets and control centers that will be supporting the scheduled launch. Displays indicate that the range configuration is now complete, and voice calls on the network indicate that the Cape Canaveral Spaceport Departure/Arrival Center is in the process of confirming with the local Air Traffic Control Center that airspace has been assigned and cleared for the Shuttle-derived vehicle's ascent, for the return flight of the reusable flyback first stage booster, and for all contingency abort landing and recovery options for the CEV.
0510 GMT	Pre-launch checkout process begins.	The flight crew is now in place in the CEV and observing its situational awareness and vehicle health monitoring displays as they indicate progress through the automated checkout processes for the Shuttle-derived vehicle and the CEV. Operators in the Mission Control Center observe on their situational awareness displays that the range assets scheduled to support the launch have started to actively engage ground- and space-based sensors and transceivers to support countdown activities, verifying robust two-way data link with the launch vehicle, flyback booster, and CEV on the launch pad. Both the flight crew and the Mission Control Center receive voice calls on the network as their situational awareness displays indicate that the airspace has been assigned and cleared for the ascent, flyback booster return flight, and contingency landing options for the CEV. The Mission Control Center and the flight crew participate in the final commit for launch polling process, each providing a "go" response. Both continue to monitor their displays, watching as indicators turn from red to yellow to green, indicating the completion of each sequential step in the countdown procedure.

0610 GMT	NASA Shuttle-derived super heavy lift launch vehicle lifts off from Kennedy Space Center, Florida.	Operators in the Mission Control Center and the flight crew aboard the CEV continue to monitor their situational awareness and vehicle system status displays during ascent, keeping an eye out for any anomalies being flagged by the automated systems. The situational awareness displays in the Mission Control Center and aboard the CEV show the vehicle's ascent trajectory, the flight path for the flyback booster, current weather conditions along the ascent and return flight paths, and all air and space traffic in the region, while also indicating which ground- and space-based range assets are being used to collect and relay tracking, imaging, telemetry, command, control, and communication information during ascent and return flight of the flyback first stage booster.
0612 GMT	Reusable first stage separates and begins flight back toward runway near launch location.	Operators in the Cape Canaveral Spaceport Departure/Arrival Control Center monitor the return flight of the reusable first stage booster. They have the authority to send routing instructions or emergency abort commands (through the Central Control Function) to be uplinked to the flyback booster during its return flight. Today there are no problems, and the flyback booster autonomously flies itself back to the runway and safely lands. Upon landing, the Departure/Arrival Control Center hands off responsibility for the flyback booster to the Vehicle Processing Control Center. The booster is towed back to a processing hangar and prepared for its next flight.
0615 GMT	Crew exploration vehicle (CEV) and payload proceed over the horizon from the launch site.	The Mission Control Center (and flight crew) receives a voice call from the Cape Canaveral Spaceport Departure/Arrival Control Center indicating that it has handed over responsibility for issuing routing instructions for the flight vehicle to the Regional Space Traffic Control Center that's responsible for the region over Africa and the Middle East. A controller in the African Regional Space Traffic Control Center contacts the Mission Control Center to confirm its active role, reporting that no conjunctions are expected during ascent and injection into Earth orbit. The situational awareness displays in the Mission Control Center and aboard the CEV change to indicate that the primary connectivity for tracking, telemetry, command, control, and communication is now being routed through space-based range assets, which continue to provide connectivity until CEV reaches Earth orbit.
0630 GMT	CEV and payload separate in orbit and begin maneuvers toward rendezvous and docking with other elements in space.	The Mission Control Center and flight crew continue to monitor system status and situational awareness displays as the vehicle proceeds through the automated sequence of events, including separation of the CEV from the launch vehicle and maneuvers in orbit to rendezvous with other exploration elements in orbit. All planned maneuver burns, course corrections, and attitude adjustments proceed as planned and calculated in real-time by the navigation system aboard the CEV.
0700 GMT	CEV and payload reach the proximity of the other elements in orbit and begin rendezvous and docking maneuvers.	Operators in the Mission Control Center and the CEV flight crew receive periodic voice calls from Regional Space Traffic Control Centers as they hand off responsibility from one to another during the initial orbits and in-space maneuvers—from the Africa/Middle East Center to the East Asia/India Center, to the Central and South America Center, to the Center that's responsible for the space traffic over Europe/Western Asia/Arctic, and so on.

		Each Regional Space Traffic Control Center in turn makes voice calls over the network to indicate when there may be conjunctions with other orbiting elements, providing maneuvering instructions to avoid them, to reiterate the information that appears on the situational awareness displays which also include instructions on recommended courses of action based on the results of automated expert system analysis of situational awareness information.
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 Mission Control Center and flight crew continue to monitor system status and situational awareness displays as the vehicle proceeds through the automated sequence of events to maneuver in orbit to rendezvous with other exploration elements in orbit. The flight crew aboard the CEV and the Mission Control Center displays light up with flashing anomaly indications and audible alarms sound aboard the vehicle and in the Mission Control Center. The vehicle status displays indicate that two of the CEV's three redundant power buses have failed. The flight crew implements the recommended recovery procedure and attempts to reset the circuit breakers. Unfortunately, that doesn't work and the alarms continue to sound. The CEV crew declares an emergency and begins preparations for reentry and landing. The Mission Control Center requests emergency reentry, return flight, and landing/recovery support through the Central Control Function. The Central Control Function coordinates actions to activate range assets to provide coverage for potential return flight paths aligned with the orbital plane of the CEV. Weather forecast information for each location is displayed for abort site selection. Weather concerns over Texas prompt the Mission Director to select Oklahoma Spaceport as primary abort site. In parallel, the Central Control Function issues a warning to the Pacific and Western America Regional Space Traffic Control Centers, the Air Traffic Control Centers, and the Oklahoma Spaceport Departure/Arrival Control Center where the CEV is planning to reenter, descend, and land.
0712 GMT	CEV maneuvers away from other spacecraft and begins emergency reentry procedures.	Situational awareness displays in the CEV and the Mission Control Center show the reentry and flight profile along with the space-based, airborne mobile, and ground-based range assets along the flight path and at the intended emergency landing site that are being activated to support the contingency. The status indicators for each range asset begin turning from red to yellow one by one, to indicate that they're entering the execution state and being prepared to support the emergency return flight of the CEV. The indicators turn green as each range asset actively engages sensors and transceivers and verifies its robust two-way data link with the CEV. Oklahoma Spaceport acknowledges the emergency and clears local and ground traffic from the landing zone. Spaceport emergency services and recovery teams are mobilized to support recovery. The situational awareness displays aboard the CEV and at the Mission Control Center indicate that airspace is assigned and cleared for the emergency landing.

0718 GMT	CEV begins reentry.	The situational awareness displays automatically update in real time to indicate which space-based and airborne mobile range assets are providing tracking, imaging, telemetry, command, control, and communication connectivity with vehicle during its descent. Operators in the Regional Space Traffic Control Center are in voice contact with the Mission Control Center and the flight crew.
0723 GMT	CEV enters atmospheric flight toward emergency landing.	Operators in the Regional Space Traffic Control Center hand off primary authority for routing flight vehicle traffic to the Oklahoma Spaceport Departure/Arrival Control Center as the designated emergency-landing site. The flight crew and Mission Control Center maintain voice contact with the Departure/Arrival Control Center and local Air Traffic Control Center through the descent. The situational awareness displays automatically update in real time to indicate that ground-based range assets are now in contact with the descending flight vehicle. Space-based and airborne mobile assets also continue to provide redundant connectivity until the CEV safely lands.
0740 GMT	CEV lands safely and recovery operations begin.	Operators in the Oklahoma Spaceport Departure/Arrival Control Center and Air Traffic Control Center make voice calls over the network to inform the Mission Control Center and the flight crew that their participation is completed and that they're dropping off the net, but not before congratulating the team on a successful trip home. The situational awareness displays automatically update to show each space-based and mobile airborne range asset dropping its connectivity with the CEV, while the ground-based assets maintain connectivity until the ground umbilical connector is mated.
0745 GMT		Recovery crews approach the flight vehicle, verify active systems are secured in conjunction with the flight crew, and assist the flight crew with egress. IVHM diagnostic data from the vehicle is relayed to the Mission Control Center and Vehicle Processing Center at Cape Canaveral Spaceport to begin the anomaly resolution process for the next mission. The Mission Control Center hands off authority for servicing and repairing the recovered CEV to the Vehicle Processing Control Center at the Oklahoma Spaceport. The flight crew is transported to the local spaceport medical facilities for checkouts and the vehicle is transported to a spaceport hangar for post-flight assessment. No one mentions it over the network, but the Central Control Function has already sent the bill to NASA for spaceport and range support.

6.4 Operationally Responsive Space (ORS) Missions

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

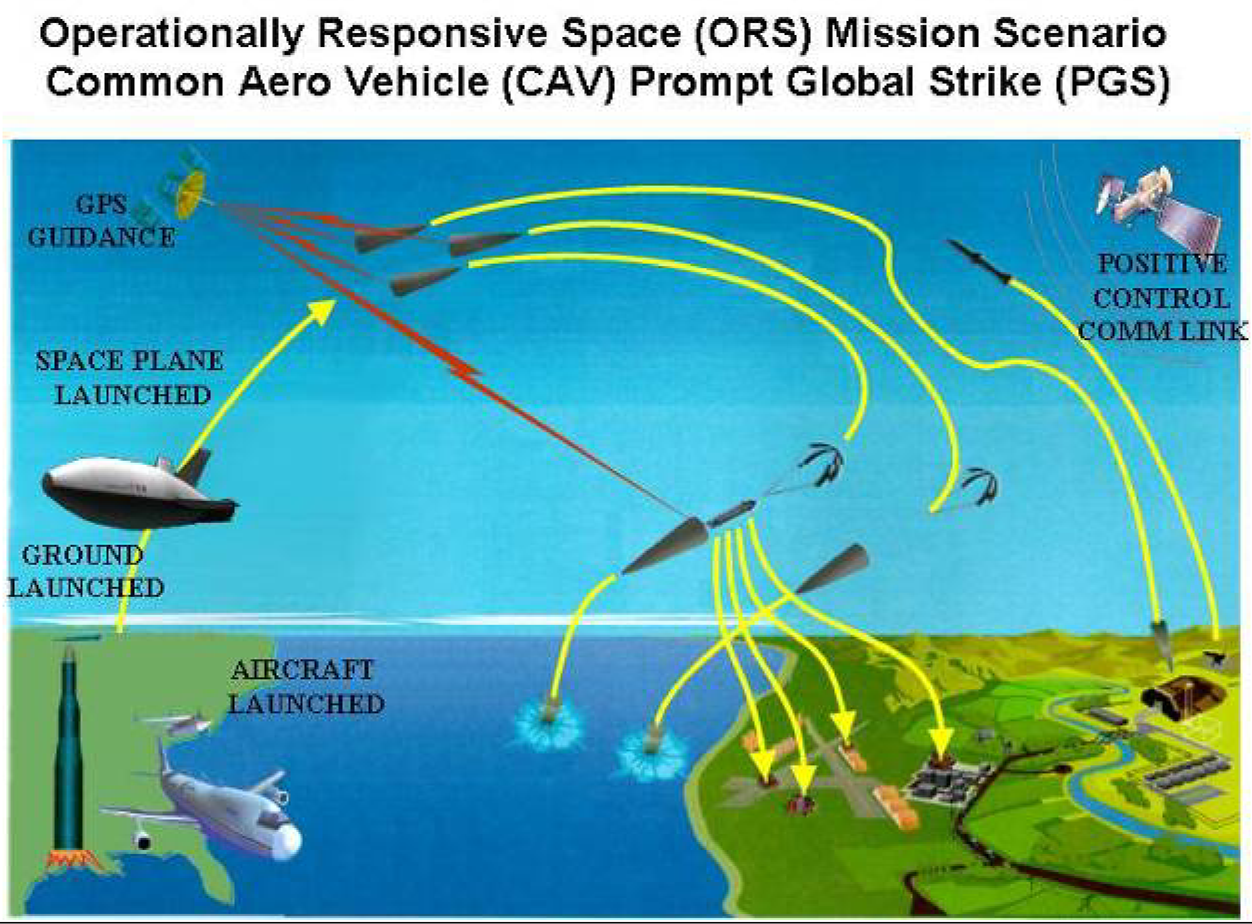

Figure 23 – Operationally Responsive Space Prompt Global Strike Missions

Time	Scenario Description	Vehicle Operator 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.	All the world's Regional Space Traffic Control Centers receive real-time updates on the trajectory of the new object as it ascends. Each Regional Space Traffic Control Center takes actions to notify Mission Control Centers responsible for satellite and spacecraft operations in space if their automated decision support tools calculate that there could be a conjunction with this new object. Similarly, Departure/Arrival Control Centers are notified if any of the scheduled space flight operations for their spaceport would result in a conjunction with this new object.

0732 – 0750 GMT	Ground controllers lose contact with a U.S. commercial imaging satellite. Space surveillance sensors not related to the range detect debris, emanating from the imaging satellite's anticipated orbital position.	The Regional Space Traffic Control Center that's responsible for the region above North America notifies the NASA Mission Control Center that a crew exploration vehicle (CEV) already in orbit should adjust its course to ensure a greater vertical separation when its orbital path crosses that of the damaged imaging satellite. The Mission Control Center relays that information to the flight crew, and the crew executes a burn to avoid the debris field. Similarly, based on the same information that's now being distributed by the Central Control Function over the Global Information Network, NASA, Air Force, and commercial spacecraft operators in Mission Control Centers that are responsible for 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 operation center that controls ORS missions submits a high-priority schedule request through the automated range scheduling system to delay other scheduled range activities to initiate planning for two ORS missions later in the day. Both are to be conducted in response to the unanticipated foreign launch because DoD suspects it 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 microsatellite at 1147 GMT so it can go into an orbit that will enable it 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.	Operators in the DoD ORS mission operation center (a user facility that is not co-located with any spaceport) consider alternative courses of action and recommend that Air Force Space Command approve its plan to launch an inspection satellite from Vandenberg Air Force Base (VAFB) to check the damage on the imaging satellite, and a reconnaissance mission to learn more about the antagonistic nation's intentions. AFSPC/CC approves the recommendation. Operators in the DoD ORS mission operation center submit a high-priority schedule request through the Central Control Function. The automated scheduling software take in this new information from the Central Control Function and re-calculate support plans and schedule changes, notifying all affected users and operators of the changes through the Global Information Network.
0930 GMT		Operators in the Vandenberg AFB ORS Vehicle Processing Control Center initiate automated procedures to prepare the vehicle for flight.

		Meanwhile, operators in the DoD ORS mission operation center monitor their displays as information flows via the Global Information Network in to verify status of network connectivity among all of the range assets and control centers that will be supporting the scheduled launch. Displays indicate that the range configuration is now complete, and voice calls on the network indicate that the Vandenberg Spaceport Departure/Arrival Center is in the process of confirming with the local Air Traffic Control Center that airspace has been assigned and cleared on an emergency basis for the ORS launch.
1147 GMT	ORS launch 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 DoD ORS mission operation center continue to monitor their situational awareness and vehicle system status displays during ascent. The situational awareness displays in the DoD ORS mission operation center show the vehicle's ascent trajectory, current weather conditions along the ascent path, and all air and space traffic in the region, while also indicating which ground- and space-based range assets are being used to collect and relay tracking, imaging, telemetry, command, control, and communication information during ascent.
1149 GMT	ORS vehicle passes over the horizon from the launch location	The DoD ORS mission operation center receive a voice call from the Vandenberg Departure/Arrival Control Center indicating that it has handed over responsibility for issuing routing instructions for space flight vehicles (but not the high-priority ORS mission) to the Regional Space Traffic Control Center. A controller in the Regional Space Traffic Control Center relays over the network through the Central Control Function that no conjunctions are expected during ascent or in-space operations. The situational awareness displays in the DoD ORS mission operation center change to indicate that the primary connectivity for tracking, telemetry, command, control, and communication is now being routed through space-based range assets, which continue to provide connectivity through the duration of the mission.
1349 GMT	ORS mission to inspect satellite is now complete	The DoD ORS mission operation center sends commands (through the Central Control Function and space-based range assets) to maneuver the ORS vehicle and relay imagery back to Earth for processing and display. The Regional Space Traffic Control Center continues to monitor the position of the ORS vehicle so it can issue warnings to other spacecraft and satellite operators in case of a potential conjunction with the ORS vehicle.
1425 GMT		Operators in the DoD ORS mission operation center inform the Central Control Function that this mission is now complete and that the ORS inspection vehicle is being de-orbited for destruction in the Earth's atmosphere. The Regional Space Traffic Control Center continues to monitor the trajectory of the ORS vehicle and will issue warnings to other spacecraft and satellite operators in case the ORS vehicle trajectory deviates from the planned reentry path creating of a potential conjunction with other operations. The situational awareness displays automatically update to show

		each space-based and mobile airborne range asset dropping its connectivity with the ORS vehicle.
1510 GMT	An ORS launch from Cape Canaveral AFS is ordered for 1620 GMT.	Operators in the Cape Canaveral ORS Vehicle Processing Control Center initiate automated procedures to prepare the vehicle for flight. Meanwhile, operators in the DoD ORS mission operation center (through the Global Information Network) monitor their displays as information flows in to indicate that all network connectivity has been verified among all of the range assets and control centers that will be supporting the scheduled launch.
1520 GMT		Displays indicate that the range configuration is now complete, and voice calls on the network indicate that the Cape Canaveral Spaceport Departure/Arrival Center is in the process of confirming with the local Air Traffic Control Center that airspace has been assigned and cleared on an emergency basis for the ORS launch.
1620 GMT	Takeoff of reusable launch vehicle from Cape Canaveral AFS.	Operators in the DoD ORS mission operation center continue to monitor their situational awareness and vehicle system status displays during ascent. The situational awareness displays in the DoD ORS mission operation center show the vehicle's ascent trajectory, current weather conditions along the ascent path, and all air and space traffic in the region, while also indicating which ground- and space-based range assets are being used to collect and relay tracking, imaging, telemetry, command, control, and communication information during ascent.
1624 GMT	Flight vehicle proceeds over the horizon from the launch site.	The DoD ORS mission operation center receive a voice call from the Cape Canaveral Spaceport Departure/Arrival Control Center indicating that it has handed over responsibility for issuing routing instructions for space flight vehicles (but not the high-priority ORS mission) to the Regional Space Traffic Control Center. A controller in the Regional Space Traffic Control Center relays over the network through the Central Control Function that no conjunctions are expected during ascent or in-space operations. The situational awareness displays in the DoD ORS mission operation center change to indicate that the primary connectivity for tracking, telemetry, command, control, and communication is now being routed through space-based range assets, which continue to provide connectivity through the duration of the mission.
1705 GMT	RLV passes over the foreign launch site and conducts its reconnaissance mission.	The DoD ORS mission operation center sends commands (through the Central Control Function and space-based range assets) to maneuver the ORS vehicle and relay imagery back to Earth for processing and display. The Regional Space Traffic Control Center continues to monitor the position of the ORS vehicle so it can issue warnings to other spacecraft and satellite operators in case of a potential conjunction with the ORS vehicle.
1750 GMT	RLV reenters and flies toward the planned landing site.	Operators in the Regional Space Traffic Control Center hand off primary authority for routing flight vehicle traffic to the Departure/Arrival Control Center at the landing site. The situational awareness displays in the DoD ORS mission

		operation center automatically update in real time to indicate that ground-based range assets are now in contact with the descending flight vehicle. Space-based and airborne mobile assets also continue to provide redundant connectivity until the CEV safely lands.
1755 GMT	RLV lands and DoD ORS mission control center reports mission complete.	Operators in the Departure/Arrival Control Center and Air Traffic Control Center make voice calls over the network to inform the DoD ORS mission operation center that their participation is completed and that they're dropping off the net. The situational awareness displays in the DoD ORS mission operation center automatically update to show each space-based and mobile airborne range asset dropping its connectivity with the ORS vehicle, while the ground-based assets maintain connectivity until the ground umbilical connector is mated.
1830 GMT		The DoD ORS mission operation center (through the Central Control Function) hands off authority for servicing and repairing the recovered ORS vehicle to the Vehicle Processing Control Center at the spaceport where it landed. No one mentions it over the network, but the Central Control Function has already sent the bill to DoD for spaceport and range support.
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 in 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 DoD ORS mission operation center submit a high-priority schedule request through the Central Control Function for these five CAV launches. The automated scheduling software takes in this new information from the Central Control Function and re-calculates support plans and schedule changes, notifying all affected users and operators of the changes through the Global Information Network.
1900-1930 GMT	Preparation 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 coast. CAVs with munitions are loaded onto two ground-based launch vehicles at one launch site, and onto another ground-based	Operators in the Vandenberg AFB and Cape Canaveral ORS Vehicle and Payload Processing Control Centers initiate procedures to prepare the ORS and CAV vehicles for flight—loading the appropriate munitions and payloads aboard the CAVs and integrating them with the ORS launch vehicles. Meanwhile, operators in the DoD ORS mission operation center monitor their Global Information Network displays as information flows in to indicate that all network connectivity is being verified among all of the range assets and control centers that will be supporting the scheduled launches. Displays indicate that the range configuration is now complete, and voice calls on the network indicate that the Vandenberg Spaceport Departure/Arrival Center is in the process of

1900- 1930 GMT	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.	confirming with the local Air Traffic Control Center that airspace has been assigned and cleared on an emergency basis for the ORS launch.
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 DoD ORS mission operation center (through the Global Information Network) communicate targeting data for the CAVs and launch vehicles. Ground-based range assets provide primary telemetry/command/control/communication interfaces with the flight vehicles, while space-based assets provide back-up capability while they're on the ground. Targeting data is sent through the range assets to each launch vehicle and CAV to program the proper trajectory parameters into the guidance systems.
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.	Situational awareness displays in the DoD ORS mission operation center, the Cape Canaveral Spaceport Departure/Arrival Control Center, Air Traffic Control Center, Regional Space Traffic Control Center depict the destruction of one of the ORS/CAV launches. As the others proceed along their intended trajectories, the Departure/Arrival Control Center for each launch site reports that it has handed over responsibility for issuing routing instructions for space flight vehicles (but not the high-priority ORS mission) to the appropriate Regional Space Traffic Control Center. A controller in the Regional Space Traffic Control Center relays over the network through the Central Control Function that no conjunctions are expected during ascent or flight through space. The situational awareness displays in the DoD ORS mission operation center change to indicate that the primary connectivity for tracking, telemetry, command, control, and communication is now being routed through space-based range assets, which continue to provide connectivity through the duration of the mission.
1942 GMT	DoD issues a re-targeting command for one of the CAVs carrying munitions, and now flying along a ballistic trajectory through space.	The DoD ORS mission operation center generates a target change order and communicates it through the Central Control Function. The range command and control system relays the re-targeting data to the CAV using the space-based assets that are maintaining a robust two-way telemetry/command/control/communication link with the CAVs in flight.

1944 GMT	All four CAVs begin reentry.	DoD ORS mission operation center and the Regional Space Traffic Control Center in the area where the reentries occur continue to monitor the flight. The space-based range assets continue to maintain a telemetry link with the CAVs during reentry by automatically engaging sensors designed to detect variations in the plasma field being induced by the CAV telemetry system to continue providing low-rate data during reentry.
1950 GMT	All four CAVs complete reentry and begin atmospheric glide maneuvers toward their designated targets.	The space-based range assets continue to maintain a telemetry link with the CAVs during glide maneuvers by automatically switching back to their primary radio frequency links. The Regional Space Traffic Control Center notifies the local Air Traffic Control Center of the CAV trajectories.
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.	The space-based range assets relay the CAV telemetry data back to the DoD ORS mission control center. Separate space-based assets establish a robust two-way telemetry/command/control link with the UAV in flight to relay its imaging data back to the DoD ORS mission control center as well.
2002 GMT	The three CAVs carrying munitions reach their dispensing altitude and speed, and deploy their munitions payloads.	The space-based range assets relay the CAV telemetry data back to the DoD ORS mission control center.
2003 GMT	Munitions explode on their targets. UAV collects and transmits real-time video.	The space-based range assets relay the UAV telemetry data back to the DoD ORS mission control center. Operators in the DoD ORS mission control center observe the real-time video from the UAV.
2006 GMT	CAV aeroshells autonomously destruct.	The space-based range assets relay the CAV telemetry data back to the DoD ORS mission control center.
2010 GMT	CAV mission complete.	Operators in the DoD ORS mission operation center inform the Central Control Function that this mission is now complete. The Central Control Function issues commands to deactivate range support assets. No one mentions it over the network, but the Central Control Function has already sent the bill to DoD for spaceport and range support.

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 system responsiveness and flexibility to support multiple concurrent aeronautical flight tests, 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 .

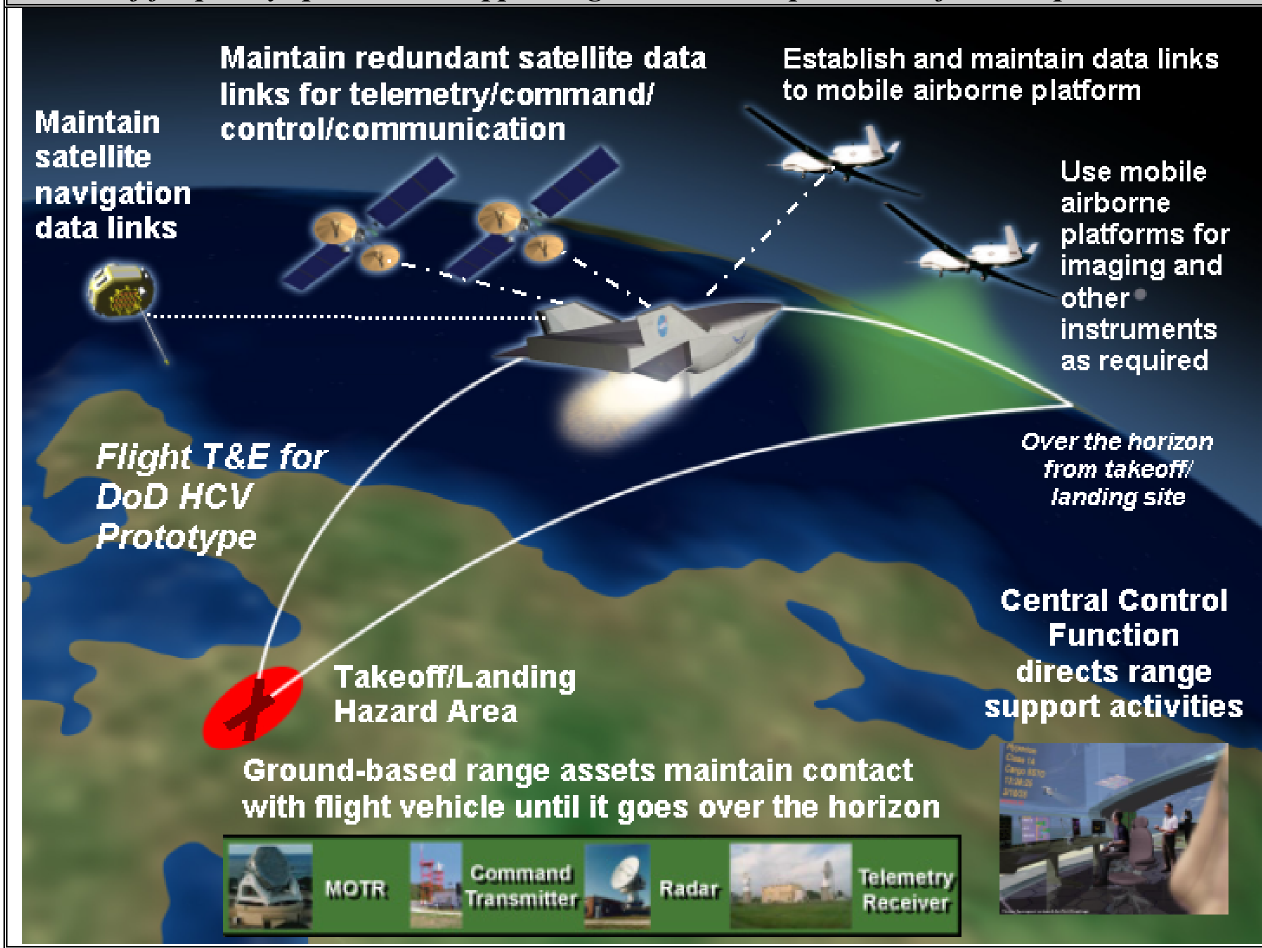

Figure 24 – Flight Test & Evaluation Mission for New Prototype DoD HCV

Time	Scenario Description	Vehicle Operator 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. CAVs are now well over the horizon from the continental U.S., conducting their operational missions.	The HCV mission operations center at the DoD lab that manages this test program (i.e., a user facility) has been monitoring the Global Information Network to keep track of the schedule changes that have affected this mission throughout the day.

	HCV mission operations center begins running a simulation program to be integrated with the flight test of the actual HCV hardware. This particular simulation program generates threats and provides simulated reconnaissance information. It also adds elements of training for HCV operators by imposing a virtual hostile threat environment and simulated reconnaissance mission objectives on the HCV flight test.	The HCV mission operations center receives a voice call from the Departure/Arrival Control Center at the flight test site where the takeoff will occur, notifying them that the range assets are ready to support the flight. The HCV mission operations center is running the simulation as an integral part of this hardware-in-the-loop test of the HCV that also provides a training opportunity for HCV operators flying a simulated reconnaissance mission that includes virtual hostile threats. The situational awareness display in the HCV mission operations center indicates that airspace is assigned and cleared for the flight test mission.
1955-2005 GMT	DoD HCV undergoes its final pre-flight checkouts on the runway.	The HCV mission operations center monitors the automated checkout process that takes place with the vehicle on the runway. Status indicators change from red (indicating checkout steps yet to be completed) to yellow (indicating steps in process) to green (indicating steps complete). The flight vehicle's system status display indicates the current state of readiness for each vehicle system (according to the vehicle's on-board integrated health monitoring system) as the automated pre-flight processing activities continue. The situational awareness displays indicate that range connectivity has been established as the vehicle begins to relay two-way data through two satellites, an airborne mobile range asset over the West Coast, and the ground antennas located near the takeoff site. The display also shows the planned mission profile with local weather and air traffic information overlaid along the portions of the flight path within the Earth's atmosphere. It dynamically displays the orbital tracks of flight vehicles, orbiting satellites, and debris in the region near the flight path through space. It also indicates which range assets will be used to maintain connectivity during ascent, suborbital flight, and reentry/return flight/and landing at the California site.
2005 GMT	Takeoff of DoD HCV from a DoD site inland in California.	The situational awareness display in the HCV mission operations center indicates that the Departure/Arrival Control Center has cleared the flight for takeoff. An operator in the Departure/Arrival Control Center makes voice contact with the HCV mission operations center to confirm that it has received and understands the instructions for takeoff. An operator in the HCV mission operations center controls the HCV as the vehicle accelerates down the runway, lifts off, and begins its ascent.
2010 GMT	HCV proceeds over the horizon from the takeoff site.	The situational awareness display continuously indicates the robustness of the two-way communication link between the flight vehicle and each range asset it is in contact with. The display indicates the handoff of the primary communication relay path from ground-based range assets to the airborne mobile platform

		over the Pacific Ocean as the vehicle flies along its planned trajectory. Space-based range assets also continue to provide redundant connectivity throughout the flight. The Departure/Arrival Control Center makes a voice call to the HCV mission operations center to indicate it has handed off responsibility for routing instructions to the North American Regional Space Traffic Control Center for the short-duration flight through its region of responsibility. An operator in the HCV mission operations center acknowledges the information.
2015-2045 GMT	HCV accelerates to hypersonic speeds over Pacific Ocean, then decelerates and turns to fly the simulated reconnaissance mission profile. As simulated threats are displayed on the operator's console, command inputs are relayed to the flight vehicle. It responds to each input well within the test requirements. Engineering data from the vehicle is down linked to mission ops center indicating a successful test. Following completion of this segment of the mission, the HCV proceeds back toward the landing site.	An operator at the North American Regional Space Traffic Control Center makes a voice call to the HCV mission operations center to confirm the information on its situational awareness display—that no conjunctions are expected between its flight path and any orbiting objects—and to confirm that the HCV flight is cleared for reentry as planned. Again, the operator in the HCV mission operations center responds, acknowledging the information. The operator flying the vehicle from the HCV mission operations center sends control inputs through the Central Control Function, where they are routed to the vehicle. A the same time, the range command and control system directs hand-off of primary responsibilities from mobile asset over west coast of U.S. to mobile asset over the Northern Pacific Ocean, while space-based assets continue to provide backup coverage. Range assets relay command and control inputs to the HCV in flight, from HCV operators being trained to operate the system. HCV operators in the HCV mission control center generate flight vehicle and payload commands as they execute a simulated reconnaissance mission that requires reacting to simulated threats in the virtual environment.
2045-2055 GMT	HCV appears over the horizon and approaches the landing site. HCV successfully lands, rolls out, and completes its flight test mission.	As the HCV mission control center continues to monitor its situational awareness display showing the tracks of air traffic in the region, an operator from the Departure/Arrival Control Center makes voice contact with to confirm that the HCV is cleared for approach and landing. The situational awareness display now indicates that ground-based radars, imaging systems, and telemetry receivers at the landing site have acquired the vehicle and are maintaining contact with it as it descends and lands on the runway. As the vehicle touches down, the HCV operator on the ground controls the vehicle's deceleration, and guides it safely off of the runway and taxis it toward the vehicle processing facility. The situational awareness display shows the termination of the communication relay links with each range asset as the umbilical connector is mated to the vehicle on the ground. The HCV operator initiates the vehicle's automatic power-down sequence and monitors its displays as the vehicle systems go off line in sequence.
2100 GMT		Operators in the HCV mission operations center inform the Central Control Function that this mission is now complete. The Central Control Function issues commands to deactivate test range support assets and sends DoD the bill for system support.

6.6 Ballistic Missile Defense System (BMDS) Flight Test

Scenario for 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 range 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 25 – Two-on-Two Ballistic Missile Defense System Flight Test

Time	Scenario Description	Vehicle Operator Actions
2310 GMT		BMDS mission operations center begins running a simulation program as part of a wargame exercise to depict and provide context for the threat scenario that will be addressed by the two-on-two BMDS flight test. The flight test will provide a hardware-in-the-loop element for this wargame, which will also include live, virtual and constructive elements as part of the integrated test and training exercise being conducted today. The test plans have been posted to the Global Information Network and all regional space, departure/arrival control and air traffic control centers in the test range area have been coordinated with for the impacts to the airspace and flight corridors that will occur during the exercise.

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 interceptors will be launched from Vandenberg AFB, CA to engage the targets.	The BMDS mission operations center receives voice calls over the network from all three of the Departure/Arrival Control Centers at the flight test sites where the launches will occur, notifying them that the system assets are ready to support the flight. The situational awareness display indicates that space-based and mobile range assets covering the northern and southern Pacific Ocean are activated to prepare for pre-launch countdown support. Mobile range assets over the ocean also show active indications as their sensors perform area surveillance and weather data collection activities along the planned flight path and near the planned intercept locations. All activated range assets and integrated health monitoring systems are indicating nominal status on the situational awareness display. The situational awareness display in the BMDS mission operations center also indicates that airspace is assigned and cleared for the entire flight test mission.
2320 GMT	Begin pre-flight checkout process for target and interceptor vehicles at Kwajalein, Alaska and California.	The BMDS mission operations center monitors the automated checkout process for each target and interceptor vehicle. Status indicators change from red (indicating checkout steps yet to be completed) to yellow (indicating steps in process) to green (indicating steps complete). The flight vehicle system status display indicates the current state of readiness for each vehicle system (according to each vehicle's on-board integrated health monitoring system) as the automated pre-flight processing activities continue. The situational awareness displays indicate that range connectivity has been established as the vehicles begin to relay two-way data through satellites and airborne mobile range assets over the Pacific Ocean, and the ground antennas located near the launch sites. The display also shows the planned mission profile with local weather and air traffic information overlaid along the portions of the flight path within the Earth's atmosphere. It dynamically displays the orbital tracks of flight vehicles, orbiting satellites, and debris in the region near the flight paths through space. It also indicates which range assets will be used to maintain connectivity throughout the mission, including the intercepts and debris tracking.
2335 GMT	Target vehicles take off from Alaska and Kwajalein for a 16-minute flight toward California.	The situational awareness display in the BMDS mission operations center indicates that the Departure/Arrival Control Centers at Alaska and Kwajalein have polled all participating control centers as part of the final countdown for the target launches. Air traffic control centers are notified of the launches. The vehicle status displays indicate liftoff and display performance parameters along with vehicle health and status information. The situational awareness displays automatically update in real-time to indicate where the vehicles are relative to their intended flight paths, along with other information on weather, traffic in the region, etc.

2340 GMT	Two interceptor vehicles are launched from Vandenberg.	The wargame simulation program being run in the BMDS mission operations center has indicated that it has detected the incoming target vehicles and issues a launch order for the interceptors at Vandenberg. Air traffic control centers are notified of the launches. As part of the test, virtual decoy data and other background data simulating a salvo of ten threat missiles are inserted by command uplink into the data stream that feeds the interceptor vehicle's guidance and targeting systems. The command is initiated through the BMDS mission operations center as part of the wargame, but it is sent through the Central Control Function and routed to the interceptors through the range command and control system.
2344 GMT	Interceptors approach and engage the target vehicles.	The situational awareness display in the BMDS mission operations center depicts the interceptors approaching the targets along the planned trajectories, along with the simulated (color-coded) wargame data regarding decoys and other missiles in the area. The display also includes another color-coded overlay to depict the space-based and mobile range assets maintaining connectivity with all four vehicles, now operating in relatively close proximity to each other. The display also includes the ground-based radars, imaging systems, and telemetry receivers in Hawaii collect information as the interceptor vehicles approach and engage the targets. A real-time video feed (routed through the range telemetry and communication paths) shows the view from airborne mobile assets in the area to observe and collect information on the engagements and as the resulting debris descends toward the Ocean. The HCV mission operators celebrate the successful engagement, but only briefly as the simulated portion of the wargame scenario continues without the hardware in the loop.
2350 GMT	BMDS mission complete reported to central control system.	Operators in the BMDS mission operations center inform the Central Control Function that the hardware-in-the-loop portion of this mission is now complete. The Central Control Function issues commands to deactivate range support assets. The situational awareness display in the BMDS mission operations center changes in real time as each range assets powers down its sensors and transceivers.
2355 GMT		The Central Control Function sends the bill to the BMDS operator for the spaceport and range support.

7 ENABLING CAPABILITIES

This section summarizes some of the key 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 systems as envisioned.

7.1 TECHNOLOGY NEEDS

A variety of enabling capabilities will be necessary to develop the FSTS architecture and operations. The integrated system of vehicles, payloads, ground infrastructure, flight safety management and operations control and coordination will require significant advances to shift away from vehicle-unique infrastructure toward common-use assets that provide greater flexibility and responsiveness. For range operations, ground-based assets focused primarily on ascent are expected to give way to space-based and mobile resources with global reach interacting with spaceports to meet mission needs throughout the flight profile of future missions. Spaceport technology will evolve from one-of-a-kind, vehicle unique systems to common, standardized systems lowering overall system development and acquisition costs for operators and hosts.

Specific technology development and demonstration needs are detailed in the Spaceport, Range and Spaceflight Operations CONOPS. The broad technology areas needing development include but are not limited to the following:

- Self-diagnostic integrated health management and healing technologies for both ground and flight systems
- Autonomous vehicle and payload servicing systems
- Space-based and unmanned airborne mobile range system platforms
- Advanced network and data-handling and security technologies
- Compressed data streams providing more efficient use of bandwidth
- Close proximity IR and spread spectrum wireless interfaces
- Low-maintenance, low-cost sensor technologies
- Integrated, system-wide software planning and scheduling technologies
- Rapid-prototyping, autonomous operations modeling and simulation
- High-density, precision weather instrumentation and forecasting
- Flexible, automated vehicle and payload handling, assembly, and integration systems
- Two-dimensional and three-dimensional immersive environment displays

7.2 STANDARDIZATION

Standardization is an important element of any strategy to increase availability of shared resources and boost interoperability among space flight 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 through an integrated architecture, improve safety (especially under emergency conditions), and reduce total costs.

Adopting standards will also lead to benefits in operating future in-space infrastructure in and beyond Earth orbit to support the U.S. vision for space exploration. Standardization would limit proliferation of proprietary and vehicle-unique interfaces in the in-space navigation and communication infrastructure required to support these operations. Such a strategy could leverage standards and techniques developed initially for terrestrial applications.

APPENDIX 1. FIRST – THE PLATFORM FOR CHANGE

The Future Interagency Range and Spaceport Technology (FIRST) program is being formulated to focus and coordinate multiple agency efforts to advance the nation's space launch infrastructure systems. FIRST is intended to provide the platform for a low-risk spiral development approach to incrementally add capabilities and improve operations, transforming the nation's spaceport and range capabilities over time to support and enable new missions for a variety of users with common needs.

On February 8, 2000, the White House released a report titled *The Future Management and Use of the U.S. Space Launch Bases and Ranges*. The report found that "Today, no Air Force–NASA program focuses on next-generation range technology in support of the missions of both the Air Force and NASA. Such a program would address capabilities beyond modernization activities the agencies are currently executing… Space-based or other advanced alternatives need to be examined to create revolutionary improvements in such areas as range safety, flexibility, capacity, and cost. Next generation technologies could benefit future operational expendable and reusable launch systems, as well as test and evaluation activities." Consequently, the report recommended "the Air Force and NASA should develop a plan to examine, explore, and proceed with next-generation range technology development and demonstration, with a focused charter to improve safety, increase flexibility and capacity, and lower costs for reusable and expendable launch vehicles." In response to this recommendation, NASA and the Air Force established the Advanced Range Technology Working Group (ARTWG).

The purpose of the ARTWG is to provide both a forum and a framework for discussion of future possibilities for range technology development. Membership includes NASA Centers/Programs, Private Industry, Current and Future Spaceport and Range Customers, Operators and Developers (including existing and emerging launch services providers), Commercial and emerging Spaceports, Academia, States, the FAA, Department of Defense, and Department of Commerce. The ARTWG was chartered to:

- Identify space launch and test range technology needs for a broad spectrum of ranges.
- Develop a roadmap (plan) that contains project options for the development and demonstration of range technologies that will meet the needs of the existing and future ranges established by federal policy or by other U.S. entities.
- Develop plan approaches and options for reaching the next-generation advanced ranges of the future.

In parallel with the formation of the ARTWG, NASA Kennedy Space Center formed the Advanced Spaceport Technology Working Group (ASTWG). ASTWG has continued to refine and build on efforts that have been underway since 1994 to identify ways to improve the efficiency of ground operations at launch sites. From 1995 through 1997, as part of NASA's Highly Reusable Space Transportation Study, an informal NASA-led government/industry team produced a "catalog" of generic functions that would have to be provided by spaceport infrastructure regardless of the specific vehicle types supported. In 1998, under NASA KSC leadership, the "Vision Spaceport" research project was undertaken to identify how drivers of launch infrastructure and operations are related to the cost and flight rate capability of a spaceport. NASA Headquarters asked the team to also confront the technology challenges associated with revolutionary improvements in ground system performance. Since then, the ASTWG has been building on this body of work to refine the vision for future spaceport capabilities and to develop technology roadmaps to enable the development of advanced spaceport capabilities.

The initial focus of the FIRST program is analysis and implementation of the spaceport and range technology roadmaps that were developed over the past two years by the ARTWG and the ASTWG. The FIRST program is intended to be managed and conducted as a collaborative multi-agency partnership involving NASA, Air Force Space Command, the Air Force Research Laboratory, the Office of the Secretary of Defense, and the Federal Aviation Administration, with each participating organization retaining control over its own resources. The purpose of the FIRST program is to implement the technology development and demonstration recommendations from the ARTWG and ASTWG. One of the initial steps in formulating this program is to establish the concept of operations for future spaceports, ranges, mission management, and interactions with the FAA as space launch vehicles for spaceports and vehicles undergoing flight testing supported by the future next-generation global space launch and test range traverse the National Airspace System.

The FIRST program will focus on conducting range and spaceport technology development and demonstration activities, as recommended by the February 2000 White House report on The Future Management and Use of the U.S. Space Launch Bases and Ranges. The purpose of these activities will be to enable the achievement of an overarching far-term vision for future next-generation space launch and test range and spaceport capabilities. The FIRST program will contribute toward achieving this vision by establishing and implementing a detailed strategy to enable the transformation of spaceport and range capabilities through an incremental spiral development process. In implementing this strategy, FIRST will identify and pursue specific, directed technology efforts. It will also include efforts to identify and leverage opportunities for synergy among the technology areas already being addressed by participating organizations, commercial industry and academia, as further contributors toward modernizing and improving the nation's spaceport and range capabilities.

APPENDIX 2. SPACE TRANSPORTATION SYSTEM CAPABILITIES

The nation's space community continues to establish independent initiatives to evaluate plans and approaches for future space transportation system architectures. Some of these initiatives are considering specific missions and vehicle architectures while others are evaluating the value of developing shared resources, assets and infrastructure to support proposed concepts. Much of the analysis is based on a detailed definition of a space transportation system and its components: working definitions range from work breakdown structures to functional breakdowns, from capabilities to technology areas, from frameworks to catalogs. Many of these initiatives recognize the value of establishing a common definition framework to facilitate strategic technology, management, and cost analysis, facilitate comparisons between initiatives, and serve as a basis for discovering opportunities for synergy such as technology investment sharing.

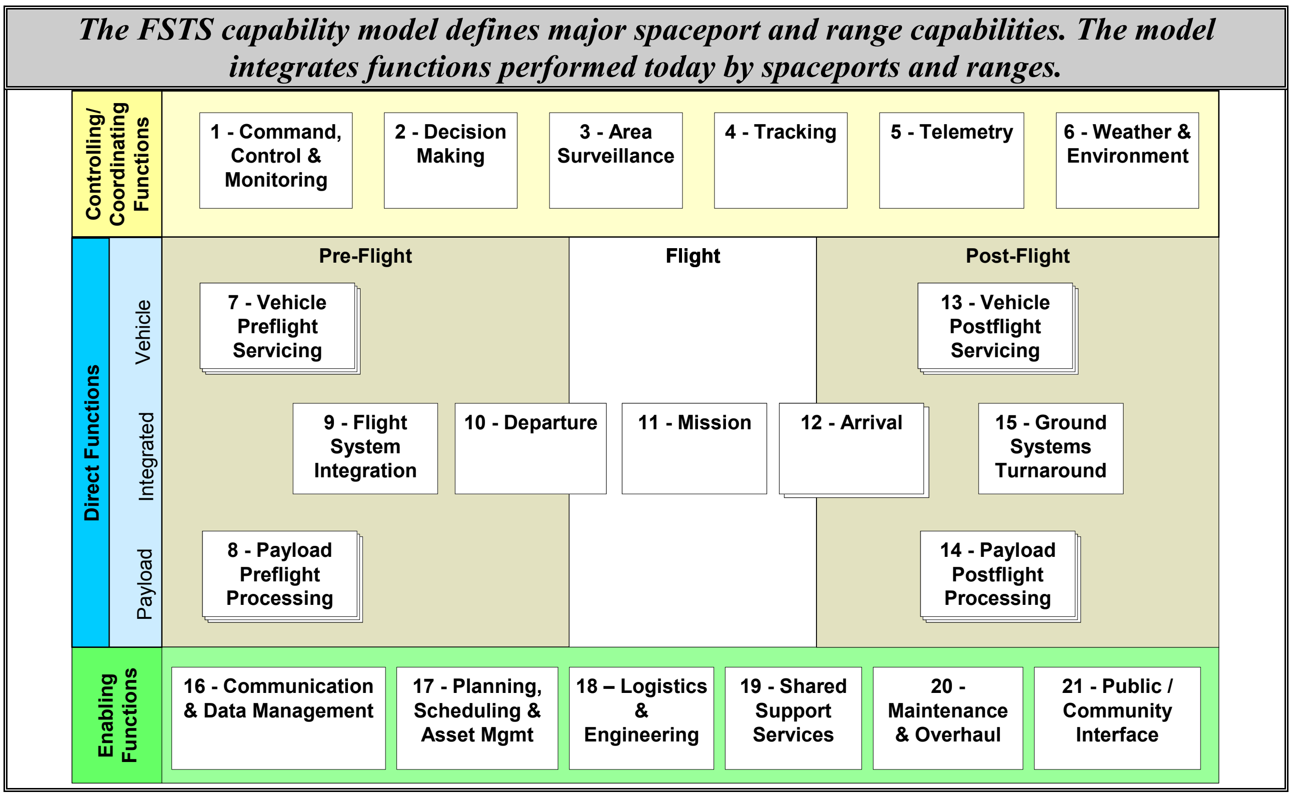

Figure 26. Integrated FSTS Capability Model

The FIRST concepts of operations are based on an integrated FSTS capability model, shown in Figure 26 that was derived from models established by the Advanced Spaceport Technology Working Group and the Advanced Range Technology Working Group. This detailed model is designed to provide a basis for a common definition framework for use by other initiatives.

These capabilities map to the four major FSTS functions as shown in Table 2 below. These four higher-level functions form the basis for the Transformational Spaceport and Range CONOPS by grouping areas of similar functionality to support the top-level conceptual architectures presented in Section 4. Detailed conceptual architectures for each capability item in the Capability Model above are presented in the detailed FIRST CONOPS.

Major FSTS Functions	Specific Capabilities of the FSTS
Managing the System	◆ Planning, Scheduling, and Asset Management ◆ Decision-making ◆ Weather and Environment Analysis ◆ Logistics and Engineering ◆ Shared Support Services ◆ Maintenance and Overhaul
Communicating Information	◆ Data Relay (telemetry) ◆ Communications and Data Management ◆ Public/Community Interface ◆ Command, Control, and Monitoring
Preparing for Flight	◆ Vehicle Pre-Flight Servicing ◆ Payload Pre-Flight Processing ◆ Flight System Integration ◆ Vehicle Post-Flight Servicing ◆ Payload Post-Flight Processing ◆ Ground Systems Turnaround and Servicing
Managing Movement*	◆ Area Surveillance ◆ Tracking ◆ Departure ◆ Mission ◆ Arrival

Table 2. Four major functions must be integrated into a system-of-systems FSTS architecture to achieve the FIRST vision. Specific capabilities are needed to implement each major function.

The following sections describe the individual capabilities defined in the integrated capability model.

Command, Control and Monitoring

Command, Control and Monitoring relies on vehicle and ground system hardware, software, wiring/cable, fiber optics, and wireless transmission capabilities to monitor, command, and control flight vehicle, spaceport, and range systems to support ground processing and flight operations. This includes central control and monitoring of spaceport and range facilities and systems to ensure proper configuration, current calibration, proper operation, maintenance needs, etc to ensure readiness to support scheduled ground and flight operations. It also includes the systems required to manually, automatically or autonomously abort the flight of crew-carrying vehicles for emergency landings, or to terminate the flight of expendable launch vehicles when an errant vehicle poses unacceptable risk to people or property. It also provides for remote guidance, attitude or payload control and other uplink communications functions for select launch vehicles. For human-rated vehicles, this includes the monitoring, command, and control of spaceport and range systems required to support the safe return of the crew to Earth, and preferably, the vehicle as well during intact abort and emergency landing operations.

* *Managing Movement* refers to transferring vehicles, payloads, cargo, crew, and passengers between processing facilities during ground processing activities, and during departure, arrival, and the portions of space flight operations that are monitored and controlled as part of the FSTS.

Decision Making

Decision making refers to the automated expertise and supporting hardware/software systems used to evaluate and ensure "readiness" of flight preparations and real-time flight safety for pre-flight operations, launch, flight, reentry, return, and landing. Flight preparations include flight plan analysis and approval and generation of instrumentation coverage plans. Real-time flight safety operations use inputs from weather, tracking, telemetry, area surveillance, catalogs of in-space objects, and FAA Air Traffic Control systems to generate situational awareness with regard to the flight vehicle's intended path, with particular attention to other objects within the hazardous areas, and to ascertain the acceptability of the in-flight vehicle's path based on safety and mission success criteria.

Area Surveillance

Area surveillance relies on hardware and software system to detect people and vehicles in those land, sea, and air areas where toxic and/or debris hazards may exist as a result of range- or spaceport-supported operations, including both ground-based activities and flights. Such areas may have to be cleared to ensure that the presence of people, ships, aircrafts, or other vehicles does not increase risk levels beyond acceptable limits during range-supported operations, or to ensure security.

Tracking

Tracking relies on hardware, software, and equipment to transmit, receive, process and display TSPI as required for range safety purposes, engineering flight analysis, and debris recovery and failure analysis in the event of a mishap. This includes real-time TSPI on flight vehicles and/or debris from on-board, ground-based, or space based assets through all phases of flight where a vehicle can pose a hazard to property or people.

Data Relay (Telemetry)

The telemetry function relies on hardware, software, wiring/cable, fiber optics, and wireless transmission capabilities to receive, process, archive, and display data received from flight vehicles, payloads, and other remote assets during ground processing, flight, and recovery or landing. This information is also used as a source of data for the reconstruction of events in the case of a mishap.

Weather & Environment

Weather measurement, forecasting, and display systems rapidly detect, evaluate, and communicate to vehicles, crews, and decision makers, in near real time, those weather parameters, forecasts and warnings which are key to safe, efficient operations. Operations include ground processing, ascent, flight, and recovery. Weather parameters include upper level winds for vehicle loads and trajectory shaping; surface winds, thermal structure and natural lightning for ground processing and toxic hazard decisions; triggered lightning potential to protect sensitive electronics; cloud thickness, coverage and height, and precipitation for visibility and thermal protection systems; and electron, proton, and x-ray flux to assess flight hazards to vehicle, crew, and payload systems. All weather data must be archived to permit accurate assessments of system design and operational issues. Consultation with weather personnel while designing operational systems or processes, to ensure weather impacts and capabilities are properly considered, is essential to reducing the impact of atmospheric phenomena on Range and Spaceport customers. To cost effectively develop and implement new technologies, customers must be directly involved in setting goals and priorities through a process similar to that currently exemplified by the NASA/USAF/NWS Applied Meteorology Unit. Environmental issues of spaceflight including infrastructure, acoustics, ground water / runoff, contamination control, nature protection, and conservation / resource management are also included within this functional definition.

Vehicle Preflight Servicing

Vehicle preflight servicing includes initial vehicle element receipt at the spaceport, element system/subsystem/component assembly (if required), element servicing and pre-integration checkout of systems and vehicle functionality. This is enabled by the hardware, software, operations and ground support systems to support ground processing of flight vehicle elements.

Preflight Payload Processing

Facilities and hardware/software systems used to receive, prepare, process, pack/load, encapsulate/containerize, checkout, and generally accommodate payloads before integration with the launch/flight vehicle.

Flight System Integration

Flight system integration includes joining and mating of hardware elements (e.g., flight vehicle stages, payloads with a launch vehicle, etc). This function also includes infrastructure and systems for lifting/cranes, positioning and alignment, access, interface support and functional verification of integrated systems integrity.

Departure

Departure infrastructure and systems support final propellant servicing (including the hardware, software, and operations involved in fueling, purging, and loading/replenishing other consumables as required by vehicle systems, payload systems, and ground support systems to support flight operations) and launch/takeoff of flight vehicles. This function includes technologies for structural/physical support (launch pads, umbilical towers, and launch rails), sound suppression, runways, access/environmental concerns, launch assist systems (catapults, rail-guns, maglev launchers, etc) and any other systems directly involved with vehicle flight origination. This culminates with Countdown and Final Launch Commit through Launch/Takeoff and Initial Flight phases.

Mission

Mission encompasses the active performance of flight operations. Systems actively monitor independent vehicle & payload flight and mission operations for their demands for support from the FSTS operational infrastructure, such as off-nominal return from flight. Operations centers coordinate support in real-time as mission status changes. Control centers coordinate flight activities and ensure safe and successful mission operations are achievable.

Arrival

Arrival infrastructure and systems support landing/recovery of flight vehicle elements. Technologies for runways/landing aids, access/environmental concerns, landing assist systems and any other systems directly involved with vehicle flight recovery are relevant to this function. The function also includes vehicle Reentry, Terminal Flight phases, through landing/recovery of individual flight elements.

Vehicle Postflight Servicing

Post-Flight servicing is enabled by the hardware, software, and operations involved in draining, purging, and inerting other consumables as required by vehicle systems. This also includes post flight inspection, system repairs and restoration of flight vehicle elements. Also includes ground support systems that support turnaround ground processing and preparation for pre-flight operations.

Postflight Payload Processing

Post-Flight payload operations are enabled by the hardware, software, and operations involved in safing, extraction/removal of cargo and passengers from returning flight vehicle elements. This also includes post flight inspection, system repairs and restoration of flight payload system elements. Also includes ground support systems that support turnaround ground processing and preparation for pre-flight payload operations. These operations may also need to accommodate passengers and crew and the equipment uniquely associated with human space flight.

Ground Systems Turnaround

Ground systems turnaround encompasses post-departure/arrival recycling and servicing of ground-based systems supporting flight operations. This includes active safing systems, wash downs, replenishment of volatile commodities, reloading of imaging support systems, etc. These are the routine, scheduled activities involved in the normal cycle of operations.

Communications & Data Management

Planning, scheduling, coordination, and management of spaceport, range and mission ops assets relies on hardware and software to provide de-confliction and scheduling of all internal/external spaceport and range assets, as well as coordination for use of airspace and frequencies, necessary to meet flight mission requirements. This includes interactions with local or regional frequency managers for frequency spectrum allocation, monitoring, local or regional airspace managers for special use/restricted airspace, and coordination and FAA officials for coordinating use of the National Airspace System. Documenting, analysis and learning are enabled by the data processing and information management hardware and software systems that are used to make recorded/archived and real-time status and planning information available rapidly, efficiently, and effectively. These functions depend on data collection (e.g., telemetry, monitoring) and distribution (through communication systems), and they support planning, scheduling, coordination, command, control, and decision-making. These systems can be used to draw conclusions and modify processes as a result of comparing actual versus scheduled and tasks, situational awareness information leading up to decision points, resource availability, and safety constraints. Analysis and learning functions also include assessing trends based on schedules and work performance and providing recommendations to generate new or modified work instructions to incorporate lessons learned as well as Data Archival, Mission Analysis and Reporting

Planning, Scheduling and Asset Management

Planning, scheduling, and coordination of spaceport and range assets relies on hardware and software to provide de-confliction and scheduling of all internal/external spaceport and range assets, as well as coordination for use of airspace and frequencies, necessary to meet flight mission requirements identified by operator's Flight Planning and Scheduling activities. This includes interactions with local or regional frequency managers for frequency spectrum allocation, monitoring, local or regional airspace managers for special use/restricted airspace, and coordination and FAA officials for coordinating use of the National Airspace System.

Logistics & Engineering

Logistics & Engineering function provides the facilities and hardware/software systems that support daily spaceport and range operations as well as sustaining engineering support. This includes storage, cleaning, for commodities, supplies, spare parts, ground systems, tools, protective clothing/equipment/systems, precision measuring equipment, and other support equipment required to enable the safe and efficient conduct of ground processing activities. It also includes the engineering systems for sustained operations of the FSTS such as mission planning systems, office space, documentation preparation, training & certification development, configuration management and other related aspects of sustaining engineering.

Shared Support Services

Shared support services are provided to operators and customers through facilities, equipment and infrastructure. These services provide general, commonly used capabilities for FSTS users/customers, including roads, plumbing, power, fire/rescue, security, office space, food/concessions, etc.

Maintenance and Overhaul

Maintenance and Overhaul is provided by infrastructure and equipment for off-line maintenance of FSTS equipment as well as flight hardware elements, including hangars, test equipment, specialty shops, sampling and analysis, certification, calibration, maintenance, modification, etc, as required.

Public/Community Interface

The FSTS nodes interact with other transportation types (air, sea, overland) and their surrounding community. Additional interfaces include utilities, communications, economics, public relations, health & safety, and employment and economics.

APPENDIX 3. REFERENCE MATERIAL

Many organizations have studied the challenges and opportunities associated with spaceport and range operations and technology. The results of many of these studies are directly relevant to – and in many cases contribute to – the concepts envisioned in this CONOPS.

The tables below list public documents and other reference material describing the results of these studies and associated operations and initiatives. The background documents provide a basis for considering the problems and challenges associated with today's ranges and spaceports. The projection documents provide various perspectives and ideas concerning the outlook for the future of the U.S. space launch infrastructure. The endnote references following the tables refer to source documents cited in the CONOPS. Some of these source documents are also included in the reference material listed in the tables below.

Background Documents

	Title	Dated
1	AFSPC Planning for Future Launch & Test Range Capabilities, AFSPC/XPP	May 2003
2	Next-Generation Launch & Test Range Concepts, briefing to ARTWG	Sep 2002
3	Grand Strategy Steering Group Update to RUCB	Feb 2002
4	Launch & Test Range System (LTRS) Vision, AFSPC/XPX	Feb 2002
5	Spaceport and Range Technology Roadmaps, NASA KSC-YA	Feb 2002
6	Report of the Defense Science Board Task Force on Air Force Space Launch Facilities, Aldridge	Jun 2000
7	The Future Management and Use of the U.S. Space Launch Bases and Ranges, White House	Feb 2000
8	NASA Space Network Support for Range Safety, GSFC	2000
9	Streamlining Space Launch Range Safety, National Academy of Sciences	2000
10	Range IPT Report, Lt Gen Henry	1999
11	Eastern and Western Range Safety Requirements (EWR 127-1)	Oct 1997
12	Columbia Accident Investigation Board, Final Report	Aug 2003
13	Commission on the Future of the U.S. Aerospace Industry (Walker Report)	Nov 2002

Spaceport, Vehicle, and Range Projections

	Title	Dated
	Current & Future Ranges	
1	ITT Loses Western Range Ops Contract to InDyne Inc, Santa Maria Times	14 July 2003
2	Wallops Flight Facility Range User's Handbook	23 June 2003
3	Western Range Users Handbook	May 2002
4	U.S. Launch Range Modernization Programs, FAA/AST Special Report	3Q 1999
5	The Next Generation Space Launch Range, Command and Control Technologies Corp. (CCT)	2000
6	Eastern Range Customers' Handbook	Sep 2003
	Current & Future Spaceports & Interfaces with FAA	
7	Advanced Spaceport Technology Working Group (ASTWG) Baseline Report	Nov 2003
8	Advanced Range Technology Working Group (ARTWG) Report	March 2004
9	National Airspace Redesign, Booz Allen briefing	July 2003
10	FAA Blueprint for NAS Modernization	2002
11	Cape Canaveral Spaceport Master Plan (Executive Summary and 246 MB report on CD)	July 2002
12	Potential Impacts of Space Transportation Operations on NAS Architecture	Sep 2001
13	Spaceport Scenario Planning: Envisioning Future Technology Needs	Apr 2002
14	VISION SPACEPORT 2nd & 3rd Gen Range & Space Traffic Management	Aug 2002
15	Canaveral National Spaceport, by CCT for Spaceport Florida Authority	Jun 2001
16	Renewing America's Space Launch Infrastructure & Operations, VISION SPACEPORT TEAM	Apr 2001
17	Spaceport Concept and Technology Roadmapping, VISION SPACEPORT TEAM	Nov 2000
18	VISION SPACEPORT Module Definition Document	Sep 2000
19	Catalog of Spaceport Architectural Elements with Functional Definition	Oct 1997
20	FAA Fact Sheet: National Airspace Redesign	23 Jan 2003
21	FAA National Airspace Redesign Milestones	Jun 2002
22	A Brief History of FAA and Its Predecessor Agencies	Sep 2003
23	Space and Air Traffic Management System (SATMS)	Sep 2003
24	FIRST Concept of Operations for Space Launch and Test Ranges	April 2004
25	FIRST Spaceport Concept of Operations	Nov 2004
26	FIRST Space Vehicle Operators Concept of Operations	Oct 2004
27	National Spaceport Testbed, 37th Space Congress, CCT and NASA-KSC	May 2000
	Current & Future Vehicles	
28	Articles on revising Shuttle flight path for landing	July 2003
29	Planned Delta IV and Atlas V Launch Manifest	July 2003
30	2003 Commercial Space Transportation Forecasts, COMSTAC and FAA/AST	May 2003
31	National Launch Forecast, AFSPC/XO	May 2003
32	Space Launch Vehicles: Government Activities, Commercial Capabilities, and Satellite Exports, Congressional Research Service	April 2003
33	U.S. Space Programs: Civilian, Military, and Commercial, Congressional Research Service	April 2003
34	2005 U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports	January 2005
35	NASA ASCENT Study Final Report (Futron)	Jan 2003
36	Market Opportunities in Space: The Near-Term Roadmap	Dec 2002
37	Suborbital Reusable Launch Vehicles and Applicable Markets, Aerospace Corp	October 2002
38	2002 U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports	January 2002
39	Describing a National Space Enterprise Model, ASTWG	
40	Operationally Responsive Spacelift (ORS) Mission Needs Statement	Dec 2001
41	Notes from Meeting with AFSPC/DRSR on ORS and AF Task Force CONOPS Missions	16 Sep 2003

Endnote References

[1] Future Interagency Range and Spaceport Technology Program (formulation), "Needs Assessment – Enabling New Markets and Missions for Spaceports and Space Launch Ranges." NASA-KSC, June 2004.
[2] The Air Force is planning to rename GLTR to "Responsive Launch and Test Range" (RLTR)
[3] http://exploration.nasa.gov/constellation/
[4] Advanced Spaceport Technology Working Group Baseline Report
[5] Columbia Accident Investigation Board Report, See http://www.caib.us/news/report/default.html. August 2003.
[6] FAA Commercial Space Transportation Concept of Operations, May 2001
[7] Future Interagency Range and Spaceport Technology Program (formulation), "Space Vehicle Operators Concept of Operations." October 2004.
[8] Future Interagency Range and Spaceport Technology Program (formulation), "Spaceport Concept of Operations." November 2004.