

The Next Generation Space Launch Range

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Abstract. Today's launch ranges rely on a vast network of manual activities to plan missions, schedule launches, configure instrumentation, preserve safety, and support mission analysis. Efforts are underway to replace currently-used 1960's technology with 1980's-era systems at the major U.S. launch ranges, but these efforts are insufficient to support the high flight rates and dramatic cost reductions needed to enable revolutionary long-term missions such as space solar power and public space access (McCleskey, Zapata, 1998). This paper describes a plan to evolve the existing U.S. launch ranges toward spaceports that accommodate frequent and routine flights by a variety of vehicle types and mission profiles. Known as *NextRange*,TM the plan is a comprehensive approach to solving key technical, business, and regulatory challenges associated with creating *commercial* launch ranges in the U.S. These challenges are a major obstacle to the emerging commercial spaceport industry, so economical solutions are urgently needed.

The NextRange program and its time-phased infrastructure architecture provide a framework for forging these solutions over the next 50 years. Integrated with the air traffic control system, the evolving spaceport infrastructure would progress through a series of "generations," eventually supporting space transportation operations to and from the earth's surface, in earth orbit, and among planetary bodies. This paper provides a brief review of the current range infrastructure and recent related studies. The main part of the paper focuses on the NextRange concept framework, including its long-term strategic plan and a technology roadmap.

INTRODUCTION

Virtually all U.S. orbital launches occur from one of two coastal "test ranges" in Florida and California. The legacy of these military test ranges and their continued reliance on launch methods designed for experimental missiles and rockets is extensively documented (U.S. Air Force, 1998, National Academy of Sciences, 2000). However, as the reliability and safety of launchers increase, a new era of routine space transportation is dawning. Powerful market forces are the engine of this new phenomenon, so commercial space enterprises are quickly overtaking military applications in terms of launches and economic impact. If this new trend is to grow and flourish, the "test ranges" must be replaced with spaceports that operate more like airports in support of routine commercial space transportation.

CURRENT LAUNCH RANGE INFRASTRUCTURE AND MODERNIZATION EFFORTS – "FIRST GENERATION"

For the test ranges, today's range safety begins with implementation of the procedures spelled out in the Eastern/Western Range standard EWR 127-1 (U.S. Air Force, 2000). This 500-page document contains on the order of 10,000 individual documentation, systems, personnel, administrative, and operations requirements that must be met or waived for every launch from these ranges. It is not uncommon for a team of engineers and technicians to work for up to a year or more on satisfying these requirements prior to a single launch. The team can swell to hundreds of personnel to manually ensure that the thousands of documented procedures and operations occur as planned for range configuration and safety. Range systems must be configured, tested, corrected, adjusted, and re-

tested repeatedly for every launch, making turnaround time between missions long and expensive, particularly between missions involving different types of launch vehicles.

Several efforts are underway to upgrade and modernize the existing test ranges. As the range owners and operators, the U.S. Air Force (USAF) has embarked upon a major two-phase initiative to standardize and automate the two ranges. Called Range Standardization and Automation (RSA), this program has addressed Y2K problems at the range, obsolete communication infrastructure, and is currently working on an automated planning and scheduling system for range facilities as well as automation of certain weather systems. The RSA phase II completion has slipped from 2003 to 2006, largely as a result of internal funding problems (Defense Science Board, 2000). Consequently, there is widespread belief that the program will eventually deliver obsolete technology.

Substantial research has been conducted on replacing or augmenting existing flight tracking radars with on-board GPS units that telemeter position data to ground controllers (Huff, 2000). Radar equipment is one of the most expensive and time-consuming elements of the existing range, so reducing or eliminating dependence on them should lead to reduced costs and cycle times between flights. In addition, NASA has conducted experiments to show how the Tracking and Data Relay Satellite System (TDRSS) could augment in-flight communications (Space.com, 2000, NASA, 1998). It is important to note that these efforts, while very promising, have focused on solving isolated issues at the ranges with little consideration paid to how the resulting technology would fit into an overall spaceport or space traffic management and operations architecture.

While the USAF progresses with test range modernization, other groups have initiated efforts to create launch sites at new locations. The most notable of these is perhaps the Kodiak Launch Complex (KLC) in southern Alaska, the only licensed U.S. launch site not co-located on a federal launch range (Ladner, 1997). KLC's unique situation allowed its developer to create a launch range "from scratch" subject only to requirements imposed by potential users and the Federal Aviation Administration (FAA) as licensing authority. Over \$20 million has been invested in creating the new launch facility, which boasts commercial off the shelf control systems and communications. Much remains to be done at KLC, however, as funding shortfalls have so far precluded development of a completely self-contained spaceport.

Spaceports in other areas of the U.S. have also been proposed. Many of these were initiated in response to the proposed VentureStar™ program from Lockheed-Martin; most are now sufficiently advanced to recognize that many other potential spaceport users could make their enterprise successful. State-sponsored spaceports in Florida, California, and Virginia are now open for business in cooperation with the respective federal launch facilities in those states. Existing and proposed spaceports outside of the U.S. follow some of the same patterns; operational sites in Russia and South America (Dalmau, 1996) compete with the U.S. test ranges for commercial launch business; proposed spaceports in Brazil, South Africa, Australia, and elsewhere are at various stages of development.

Policy and Regulation

The regulatory picture remains cloudy for the U.S. commercial spaceports as the federal government grapples with the tremendously complex problem of determining how EWR 127-1 requirements and other safety procedures will apply to non-federal property with minimal economic burden on the industry. Furthermore, both NASA and the FAA have recognized the need to routinely accommodate space flight vehicles in and through the national airspace system (NAS). NASA has initiated research into the tools that will be required to integrate launch vehicles, including reusable vehicles that will return to earth from orbit, into the nation's air traffic control system (Horn, 2000). This research has yielded a prototype architecture for integrating RLV mission planning with flight operations.

The FAA has also taken a substantial first step in defining a draft concept of operations for space launch activities within the NAS (FAA, 1999). The FAA draft concept of operations proposes a space and air traffic management system that will address the unique characteristics of vehicles moving between the earth's surface and orbit. This work has led to considerable research into how air traffic control methods and airline/airport operations could be applied to future space transportation operations. This research is emerging as one of the key technological and regulatory challenges facing the space transportation industry and lies at the core of the NextRange concept.

Recent Studies

After 50 years of safely supporting the nation's space launch needs, the national test ranges are confronting a challenge to rapidly change to accommodate the growing commercial launch industry or face obsolescence. This challenge has led to the commission of several studies in the past two years to investigate how the ranges have evolved and what they can do to strengthen the U.S. space industry without risking their strong safety record or core military mission. Several of these studies capture the problem from differing perspectives; taken collectively, they offer substantial insight into the complexity and enormity of the challenge:

Earlier this year, a National Research Council committee on space launch range safety supported the re-evaluation of the 50-year legacy of the ranges in light of new technologies, lessons-learned, and the growing demand for commercial launch services. Over 100 individuals participated in public proceedings of the committee, and the final report notes the 15 recently completed or on-going studies examining space launch activities. The committee explored the need for new telemetry and tracking technologies in particular (National Academy of Sciences, 2000).

Also this year, a federal interagency working group headed by the White House Office of Science and Technology Policy and the National Research Council completed a study dealing with future management and use of the national launch ranges. Their final report succinctly captured the need for launch range technology development:

“While the Air Force is pursuing substantial range upgrades through the range standardization and automation program, currently no focused, funded effort exists within the federal government to develop and demonstrate long-term next-generation technologies for range capabilities. Next generation range technologies will be essential to improve safety and reduce costs by orders of magnitude to enable high launch rate operations using next-generation highly reusable space transportation systems.” (White House, 1999)

The Air Force released a new report in June 2000 calling for definition of a “national space launch range vision” and enabling federal legislation to meet anticipated demands on the U.S. range infrastructure. The report summarizes several on-going modernization efforts and opportunities for several new technology applications (Defense Science Board, 2000).

Several other studies have been conducted in the past two years to probe the economic, political, and technological issues at the national launch ranges. In 1998, the U.S. Air Force Space Command initiated a “Range IPT” to address range turnaround times, scheduling systems, modernization programs, and other issues of concern to the space launch industry. Conclusions of the IPT stressed the importance of range modernization (U.S. Air Force, 1998).

A Commercial Space Transportation Advisory Committee (COMSTAC) working group recently prepared a report addressing high priority issues related to spaceports. The committee makes several recommendations, including improvements to the range reconfiguration process with available technology and procedures and initiation of an independent assessment to determine specific modernization needs to satisfy evolving commercial space launch infrastructure needs (Commercial Space Transportation Advisory Committee, 2000).

The Spaceport Florida Authority has commissioned a two-phase study to baseline operations at the Eastern Range and propose an “ideal” range configuration for future spaceport activities (Spaceport Florida, 2000).

THE NEXTRANGE™ CONCEPT

While completing an early-stage technical and economic analysis for the startup commercial spaceport group in Washington state, my firm recognized the value of establishing a more comprehensive spaceport development strategy. Such a strategy would allow spaceport analysts to paint a picture of the technical and economic potential of a proposed spaceport in the context of a national model. This approach would have the side benefit of applying a consistent, standardized development plan to multiple spaceports, somewhat simplifying the daunting task of creating operations standards for spaceports (which, in the airport industry, allow different types of aircraft to operate at all airports). The NextRange plan emerged from consideration of this strategy.

The NextRange plan is based on a long term strategy for migrating existing test ranges to commercial spaceports and products. One scenario begins with turning over a portion of an existing test range to a non-military spaceport operator. With this approach, one of the existing test ranges would be divided into two geographical areas: one dedicated to military and experimental launches that remain under the control of the USAF and subject to existing safety standards for test launches, and the second under the control of a spaceport operator subject to the FAA regulation associated with their launch site operators license. A third area could be dedicated to flight simulation and testing of new commercial vehicles and related technology (Brown, McCleskey, 2000) as shown in Figure 1. Operations and technology needed for the non-military spaceport will initially be similar to that used at the test ranges, but will evolve toward streamlined operations suitable for proven and certified launch vehicles. As the evolution unfolds, the range/spaceport systems and the air/space traffic control concept will converge, replacing the legacy range systems, procedures, and regulations with an aerospace traffic control and management systems. Once complete, orbital traffic management and eventually interplanetary traffic management will be added.

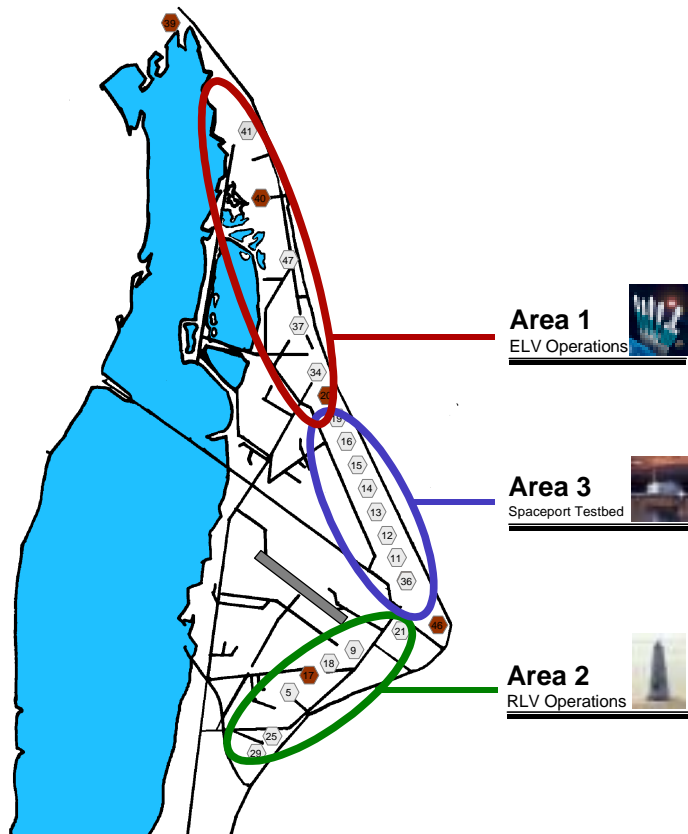


FIGURE 1. A notional concept for transforming the Cape Canaveral Spaceport shows how military, commercial, and flight test activities could be assigned to particular areas.

Since the future evolution of space launch ranges is intertwined with air traffic management, it is important to agree on a clear definition of “the range” and how it differs from envisioned “spaceports” and emerging notions of “space traffic control.” Many technologists today agree that it is desirable to eliminate “the range” altogether – these experts see the “range” as the current array of hard-to-maintain instrumentation, burdensome safety processes and requirements as embodied in EWR 127-1, and outdated communications and electronic infrastructure required to support these items for every U.S. orbital launch. However, when pressed, most also agree that many of the *functions* of the range (summarized in Figure 2) are necessary to conduct space flight – and always will be. It therefore seems reasonable to note that the term “range” refers to the functions, i.e., the responsibilities of today’s range operators, rather than today’s particular implementation of those functions. Also, “the range” is generally associated with the ascent phase of a space flight; today’s range functions are mostly unused during on-orbit and landing phases, largely due to the

What is the purpose of “the range”?

Primary range functions include:

- Mission Planning
- Scheduling
- Flight Tracking
- Flight Monitoring
- Flight Safety
- Range Surveillance
- Weather monitoring and prediction
- Telemetry and Communications
- Emergency Response
- Mission Analysis

Taken together, these functions make up the range infrastructure in place today. Other functions that will be required to realize next generation spaceports include:

- RLV support (launch and landing)
- Flight control
- Flight testing
- Multi-spaceport/airport infrastructure

FIGURE 2. Range functions.

expendable launch vehicle legacy of the launch sites.

The term “range” could therefore continue to serve a useful role in the spaceport vernacular as referring to the “spaceport-vicinity operations that require controlled air space.” This is similar to the region of restricted air space near airports. The more global notion of “space traffic control” refers to the worldwide operation of controlling all space-bound traffic, including the “ranges” as just defined, but focused on the inter-range and in-space traffic. In this definition, “space traffic control” is similar to regional en-route air traffic control centers that handle air traffic between airports.

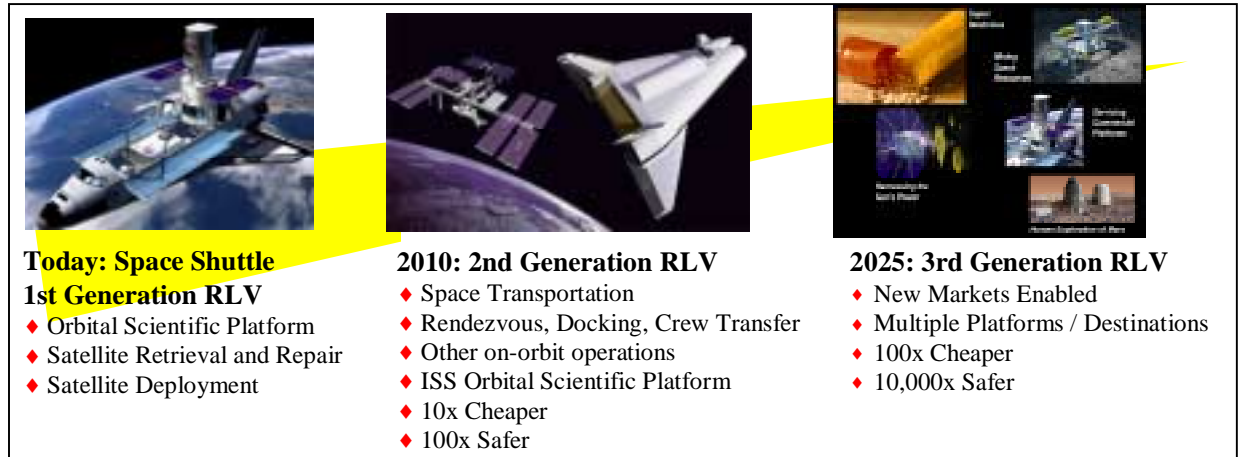


FIGURE 3. NASA Advanced Space Transportation Plan defines three generations of reusable launch vehicles.

Strategic Development Plan

The vision of existing test ranges dividing and then partially transforming to spaceports, then converging with air traffic management and expanding to in-space traffic sets the stage for designating multiple “generations” of spaceports consistent with NASA’s Advanced Space Transportation Plan (NASA, 1999) illustrated in Figure 3. Five generations of spaceports are suggested in Table 1, beginning with existing “first generation” spaceports that operate under EWR 127-1. A second generation spaceport would operate under FAA license and provide “flight safety” (as opposed to “range safety”) services throughout the entire flight – from launch to landing. Some of the facilities, systems, and procedures would resemble those of first generation spaceports such as vehicle-specific systems and instrumentation largely dedicated to space operations. A global spaceport infrastructure such as that suggested by the author in an earlier work (Brown, 1999) will be required to link second generation spaceports, laying the groundwork for the third generation aerospace traffic management system.

TABLE 1. “Generations” of Range and Space Traffic Control.

	Timeframe	Architecture	Concept of Operations	Regulation
Gen 1	Today	Focused on ascent phase of space flight	Flight by flight mission planning and execution	U.S. Air Force/EWR127-1
Gen 2	2005-2010	Space-based range allows control from launch to landing	Manages all phases of space flight	Joint military regulation and FAA licensing
Gen 3	2015-2025	Fully integrated space/air traffic control	Smaller crews in space traffic control “tower” ensure spaceliners comply with FAA rules	FAA licensing and oversight
Gen 4	2030-2040	Includes orbital transportation nodes	Space traffic controllers also manage flights to and from orbital nodes	FAA/International regulation
Gen 5	2040-2060	Includes nodes on the moon and other planets	Interplanetary traffic management	Interplanetary regulation

First Generation Spaceport: Today, Eastern and Western Ranges, based on missile test legacy and governed by EWR 127-1; responsible only for ascent phase of space flight.

Second Generation Spaceport: 2005-2010, 10x cost improvement, in transition from military to civil control. Spaceports operate under FAA license, but some facilities, systems, and procedures are similar to first generation, and many safety regulations are legacy 127-1; manages all phases of space flight.

Third Generation Spaceport: 2015-2025, 100x cost improvement, full civil control, similar to today's small airports. These new spaceports operate under FAA license with little resemblance to 1990's era launch sites.

Fourth Generation Spaceport: 2030-2040, Earth surface and earth orbit nodes, i.e., an orbital space station can serve as an integrated "spaceport" within the spaceline routing network; "orbit traffic control" is an integral part of the system, monitoring and controlling all objects in Earth orbit

Fifth Generation Spaceport: 2040-2060, A spaceport on the moon or other planet and the notion of interplanetary traffic control are introduced.

FIGURE 4. Spaceport generations can be defined that parallel the NASA space transportation plan.

A brief summary of the next generations of range and space traffic control is presented below.

Second Generation Overview

A second generation spaceport will have the capability to manage an entire space flight from departure to landing. Contrasted with today's first generation ranges that are responsible only for the ascent phase, these spaceports will expand beyond the launch-vicinity "range" to include the new global function of space traffic control. The second generation range is characterized by its transition from military to civilian control. Second generation spaceports will operate under FAA license, but some range-related facilities, systems, and procedures will be similar to first generation facilities, and many safety regulations will remain legacy EWR 127-1.

Architecture

Space-based assets for tracking, communications, and commanding will form the new core of the second generation range and space traffic control architecture. Global positioning satellites will provide the primary means for tracking space vehicles, while satellites such as NASA's Tracking, Data, and Relay Satellite System will handle communications. The second generation architecture will form the foundation for the third generation architecture, serving as a technological stepping stone to global space traffic control.

Concept of Operations

Launch, reentry, landing, and abort operations will eventually occur more frequently from several spaceports around the world. New, reusable launch vehicles (RLVs) will fly through the lower atmosphere and into orbit via space transition corridors (STC's) while other aircraft proceed on their routes in neighboring airspace. The second generation spaceport infrastructure, integrated with the NAS, will support launch, orbit and landing operations, as well as fueling, payload processing, and maintenance while maintaining required levels of safety, capacity, and efficiency.

Third Generation Overview

Third generation commercial spaceports will also operate under FAA license, but the operations would be completely integrated into a comprehensive air and space traffic control system with minimal instrumentation and systems unique to space flight operations (i.e., the infrastructure would be shared with airliner operations where feasible).

Architecture

The third generation architecture will consist of an extension to today's NAS and air traffic control (ATC) system. This architecture will support both mission planning and mission operations with a global integrated system. The planning process will require: initial mission profile information; a graphic depiction of the NAS configuration; a graphic depiction of user-preferred trajectories (both aircraft and space vehicle); resource demand under current, future, and alternative traffic situations; relevant environmental information; and 4-D trajectory modeling (X, Y, altitude, and time) and fast-time simulation capabilities. Upon completing the planning process, the ATCSCC spaceport operations coordination system disseminates the mission profile via the NAS-wide area information system (NAS-WIS) to notify airmen, mariners, the military, and other spaceports of the impending mission.

During a mission, flight status information will be continually updated and disseminated in real-time to the NAS users. This information will also be displayed on ATC-system and cockpit situational displays for tactical purposes. STC's and airspace sectors will be dynamically allocated and monitored to accommodate the mission and air traffic system demands. This integrated NAS/Spaceport infrastructure will provide all the necessary services and capabilities to accommodate space and air traffic operations. (VanSuetenael, 2000)

Concept of Operations

A third generation flight scenario would begin with an electronic filing of a flight plan. The flight plan contains the vehicle description, proposed flight, orbit, and trajectory data to be processed at the FAA Air Traffic Control System Command Center (ATCSCC). The mission profile is checked for conflicts, weather, and other possible constraints in a fast-time simulation, which is part of the launch, reentry, landing, and abort approval process. Once the flight is scheduled into the local and national daily operations, the automated command and control system issues clearances and uploads mission data directly to the vehicle operator, spaceport operator, the International Space Flight Organization (ISFO), the RLV's flight management system, and appropriate Airline Operations Centers. During flight, the range and tracking systems will monitor progress and disseminate flight status data to the ATCSCC and other system operators and users. For the final phase of flight, the orbiting or hypersonic vehicle receives a reentry clearance and returns to land at a spaceport where it is prepared for its next launch.

Fourth and Fifth Generation Concepts

A "fourth generation" spaceport would address orbital traffic management including transportation nodes in earth orbit, extending the space traffic management system to in-space platforms, debris, and natural objects. Such a system might be hosted on an in-orbit space station and implemented entirely through space-based assets, freeing the earth environment from related transportation infrastructure.

A "fifth generation" spaceport would also address interplanetary space traffic, which would require a communications and tracking infrastructure beyond earth orbit.

Technology Roadmap

Within this framework, technology challenges can be identified for each generation of spaceport. This arrangement directly leads to time-wise investment priorities and a comprehensive technology development. From a functional perspective, several range functions (refer to Figure 2) present serious technology challenges to achieving second generation status.

As mentioned earlier, technology work for first generation spaceports is already underway. This work is focused largely on advanced flight tracking techniques and development of commercial off the shelf products to support the listed functions. In general, the goal of this work is to reduce the range infrastructure and its associated maintenance cost. One of the goals of creating a second generation spaceport is to eliminate as much of the existing range infrastructure as possible. New technology is required to achieve this goal; key technology challenges and suggested research areas are listed in (Brown, Zapata, 2000).

One of the key facets in developing future spaceports is the strategic technology roadmap. The NextRange technology roadmap is based on four complementary research and technology elements that span technology readiness level (TRL) 2 to 9; proposed NRA-level work comprises the first element culminating in TRL 4 laboratory validation demonstrations. Subsequent elements include directed research (TRL 4-5) to refine the second generation launch range concept with an emphasis on defining system and component requirements for intelligent systems technology and decision support tools. The third element is a technology demonstration (TRL 6-7), and the fourth element is operations demonstration and commercialization (TRL 7-9).

CONCLUSION

Considerable time and effort has been expended on exploring and documenting the state of the national launch ranges in the U.S., with particular emphasis on the impediments to improving the range infrastructure. The next step in advancing the launch ranges is to define a vision and a strategy for implementing that vision of transforming the ranges into “spaceports” that overcome those impediments. The proposed NextRange™ plan is one such strategy that should be explored further.

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NextRange is a trademark of Command and Control Technologies Corporation.

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