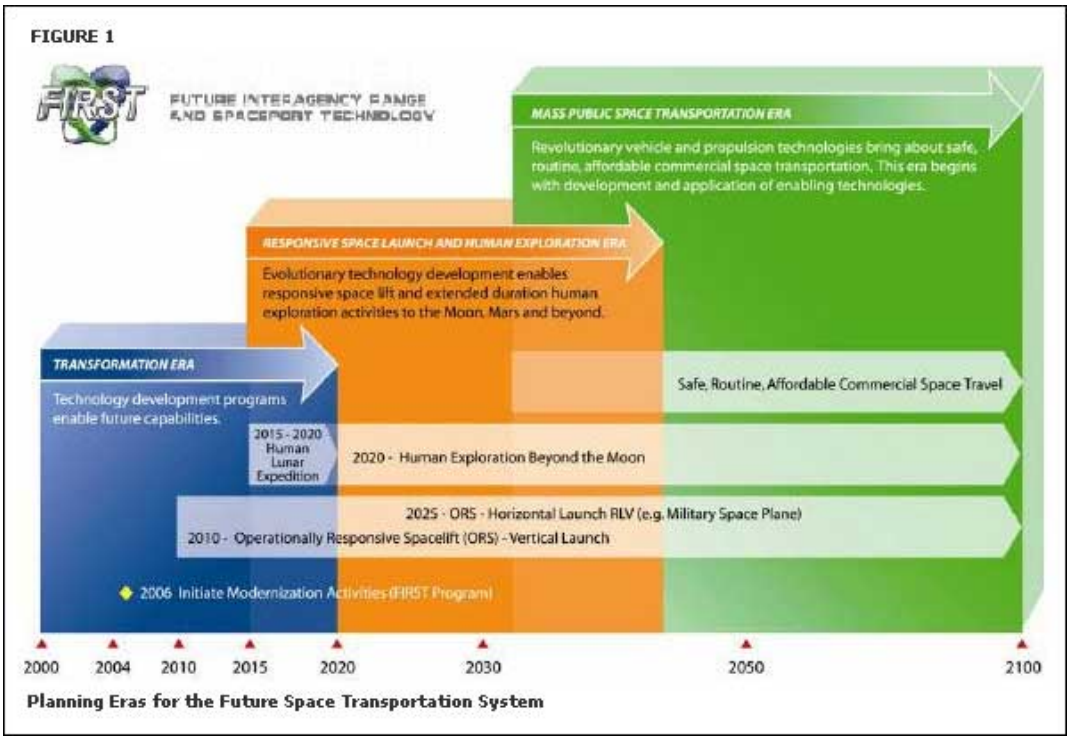
Developing the Future Air and Space Transportation System Through Interagency Partnerships

by Richard VanSuetendael, Ph.D., Shelia Helton-Ingram, Stewart Jackson, Cristina Guidi, and Darin Skelly

The first century of modern aviation produced the safe, highly efficient and reliable air transportation system of today. The end of the 20th Century saw air traffic control-towered airports totaling nearly 70 million operations. By 2014, forecasters predict that number will grow to almost 80 million operations. In the commercial space industry, a fairly constant average rate of around 20 launches per year is projected over the next 10 years. However, the President's vision for the nation' space exploration program, national defense, and a commercial space industry that is only in its infancy are factors that could greatly influence future launch rates.

Suborbital space flight and space tourism are two potential markets that could change the industry dramatically. Attracting space transportation pioneers, over two dozen teams from seven countries are competing for the $10,000,000 X-Prize. The prize goes to the first private company to build and launch a spacecraft that can carry three people to an altitude of 100 kilometers (62.5 miles), return them safely, and then repeat the operation within two weeks using the same spacecraft. As Charles Lindburgh won the $25,000 Orteig Prize with his historic transatlantic flight in 1927, over 100 incentive prizes were offered between 1905 and 1935 to advance aviation technologies that helped to create today's multibillion dollar air transportation industry. What impact will space transportation have as it becomes a multibillion dollar industry? As early aviation entrepreneurs could only speculate on the growth of air travel, we too can only imagine the markets that await this emerging industry.

In the future, it is envisioned that daily space launch and reentry flights will occur at "spaceports" throughout the United States and the world. Advances in vehicle design, avionics, range safety, and air traffic management are some of the technological areas that will make frequent space access a reality. Government and industry partners participating in the Advanced Range Technologies and Advanced Spaceport Technologies Working Groups (ARTWG & ASTWG) are defining a vision and needed capabilities for the future space transportation system. This vision calls for spaceports to someday operate like today's airports, and for ranges to be a seamless, integrated part of the National Airspace System (NAS). The needed capabilities are allocated across three spiral development eras: Transformational Technology Era (2004 - 2020); Responsive Space Launch and Human Exploration Era (2015 - 2045); and Mass Public Space Transportation Era (2035 and beyond), as shown in Figure 1.



Planning Eras for the Future Space Transportation System

There are currently 22 spaceports throughout the world and yet, unlike other transportation systems, most of these spaceports are unique and operations are conducted completely independent of one another. Each spaceport and range caters to the vehicle-specific designs and mission requirements. This lack of an integrated national system approach causes space transportation to be extremely expensive. Revolutionary advancements in the reduction of cost and time to access space will not be realized without significant technological breakthroughs in the ground processing, launch operations, and air traffic/range operations systems. As both the air and space transportation industries evolve through modernization, and through the introduction of new technologies, today's unique and mostly separate air and space transportation systems will converge into a common infrastructure.

Air and Space Traffic Operations

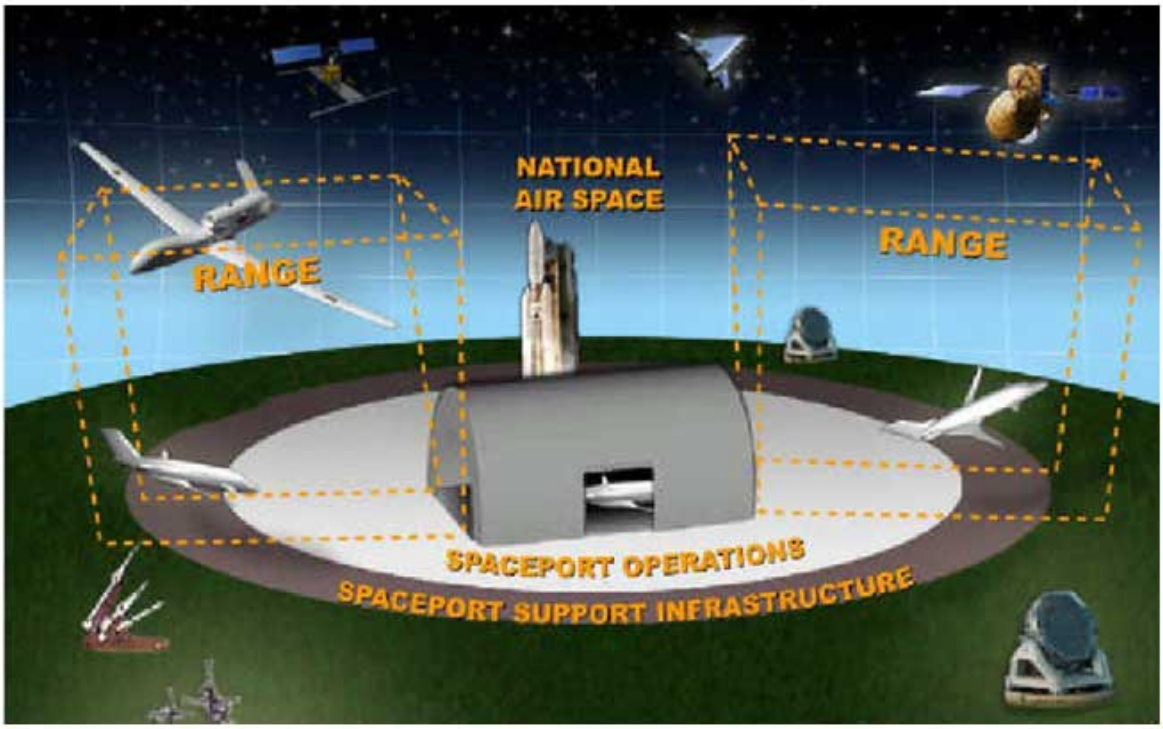
In today's air traffic system, a primary axiom for safe flight is to maintain adequate separation between an aircraft and other aircraft, obstructions, weather, and other hazards. This strategy also holds true for space launch/reentry vehicles, with some additional considerations for the higher-energy, greater velocities, and other characteristics of the vehicle. The current procedure for ensuring aircraft are safely distanced from the spacecraft during a launch is to restrict all air traffic from flying in a very large region of Special Use Airspace (SUA) and/or Altitude Reservations (ALTRVs) within the range. During a launch, aircraft that would normally fly through this airspace simply take a longer, alternate route to their destination. This procedure accommodates today's launch rates and launch sites. However, this approach may not be acceptable if launch rates significantly increase, or when there is greater demand for this airspace to accommodate growth in air travel and new spaceports. The NAS must accommodate this growth and future space operations with fair access to all users while maintaining the highest possible levels of safety, security, and efficiency.

During space launch and return flights, there are many potentially hazardous events that could occur. Range operators must analyze nominal and malfunction vehicle trajectories, weather conditions, debris and toxic plume dispersion, and blast overpressure models. Safety procedures also require that all the necessary launch range assets, such as

communications, flight termination, telemetry and various tracking systems be available with redundancy. The range and spaceport operators must ensure the surrounding airspace is clear of aircraft, ships are outside predicted debris impact areas, and other prescribed evacuation and coordination procedures are followed. For example, if a catastrophic failure were to occur during a launch, the resulting debris cloud would be extremely hazardous to any aircraft flying within the fallout zone. To avoid this hazard, an over-flight exclusion zone is defined for a downrange distance from the launch site based on a complex debris dispersion model. This type of analysis would, in part, be the basis for establishing SUA/ALTRV requirements for a proposed launch site. The FAA has established procedures for determining hazard zones for a proposed launch site in published rules for obtaining a commercial launch site license [DOT/FAA 14 CFR Parts 401, 417, and 420]. Many of the FAA's rules and safety requirements are based on the Air Force's experience in operating the Eastern and Western Ranges.

Future growth in both air and space transportation industries will place new capacity, efficiency, and safety demands on the NAS. Thus far, space launch and reentry operations have had minimal impact on the NAS. However, an increase in the frequency of commercial launches and reentries at both existing and new sites across the country, coupled with predicted increases in air traffic operations, will cause even greater competition for limited airspace. As the number of spaceports increases, new traffic management technologies and procedures will be needed to minimize the impact of space operations on the NAS. Figure 2 illustrates the future near-Earth space transportation environment.

FIGURE 2



Future Near-Earth Space Transportation Operating Environment

Needed Capabilities

The transition of a space vehicle through the NAS will need to be seamlessly integrated causing minimal disruption to air traffic. Future spaceports and ranges must eventually become a national network of systems that can support multiple vehicles' architectures concurrently. To accomplish this, 80-90% of range systems will need to be space-based platforms that can be augmented when and where needed, with mobile or deployable

elements and modernized ground components at departure and recovery locations. High accuracy weather prediction and advanced decision support tools (DSTs) will be essential to enhance situational awareness and to perform real-time, high-fidelity risk analyses needed for multiple space operations. Advances in ground processing and launch technologies are needed to improve processing safety, and to reduce turnaround times and operations costs. Specific examples include: automated real-time coordination among spaceports and air traffic control facilities; autonomous reconfigurable ground systems; automated vehicle, payload, and support system inspections and self-testing; and safe, on-demand propellant/fuel loading; all leading towards sustaining multiple space flights every day. Like today's airports, spaceport and range systems will need to become interoperable by employing standardized interfaces to reduce expensive dedicated infrastructure. As with aviation, space transportation system standards are needed to provide flexibility to accommodate various types of vehicles, while being able to adapt for new vehicles and payloads with minimal reconfiguration time and expense.

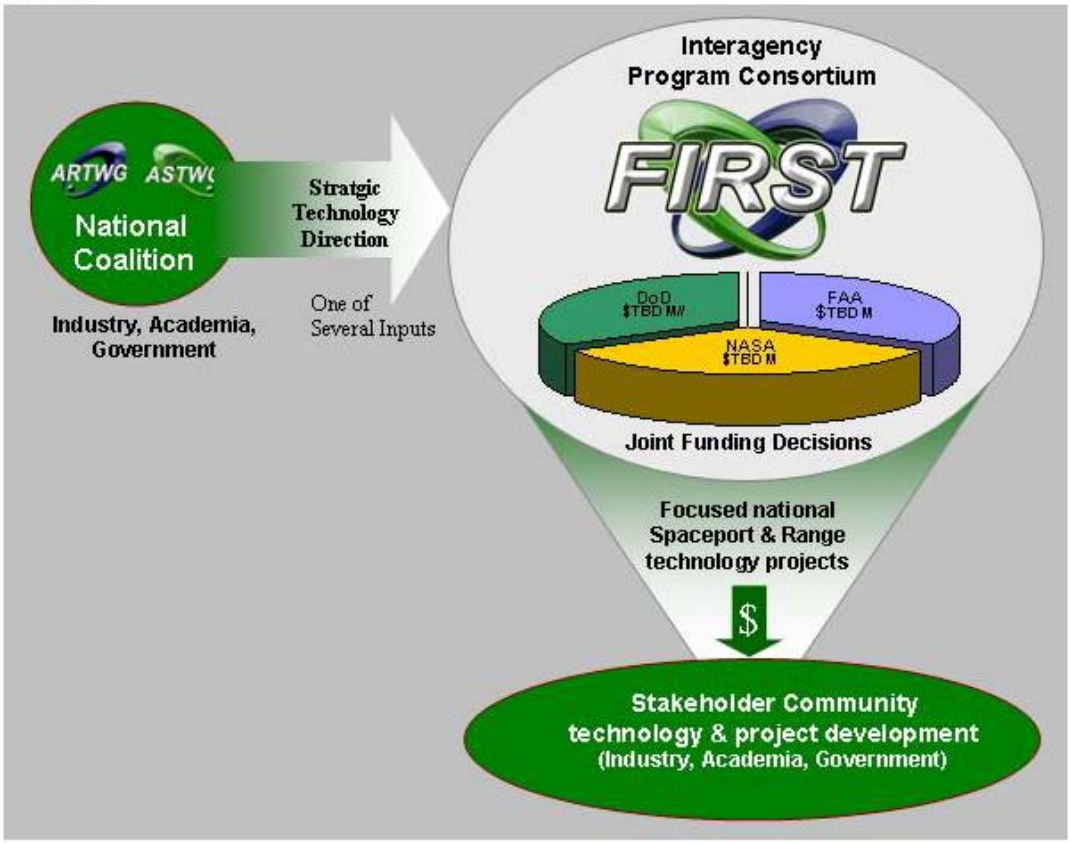
NASA and the FAA are studying several technological areas that have potential roles in the future Space and Air Traffic Management System (SATMS), which will need to accommodate new reusable, expendable, hybrid, and suborbital hypersonic space vehicles. Researchers are investigating the feasibility, requirements, and benefits for developing the next-generation DSTs for SATMS. These tools will integrate air and space flight planning and scheduling for collaborative decision-making among airlines, spaceport and range operators, and air traffic service providers. For example, current range safety models predict the trajectories and potential impact areas of falling debris. Air traffic management tools predict aircraft trajectories, identify potential conflicts, and determine alternate routes to avoid conflicts and severe weather. These ATM technologies (trajectory algorithms, conflict probe, etc.) could be integrated with range safety models (debris, toxic plume, overpressure shock, etc.) to develop SATMS tools that could be used by both controllers and range operators to more safely and efficiently control air traffic in close proximity of space launch and return operations.

Roadmaps to the Future

In response to several Congressional and White House reports, NASA has established the Advanced Range Technologies Working Group (ARTWG) and Advanced Spaceport Technologies Working Group (ASTWG), which are defining a vision and technology roadmaps for future ranges and spaceports. These working groups are co-chaired by NASA and the Air Force, and have a nationwide membership that includes the FAA and other federal and state government agencies and industry representatives.

The ARTWG is identifying future technology needs for a broad spectrum of range functions such as testing, research, and transport operations for government, commercial, and other customers flying various types of space and high-altitude vehicles. Similarly, the ASTWG addresses technology needs for ground systems that process payloads and prepare the vehicles for launch and, in the case of reusables, landing operations. Recognizing that a multi-agency consortium is needed to tackle this challenge, NASA created the Future Interagency Range and Spaceport Technologies (FIRST) Program. This unique program creates a NASA-DoD-FAA partnership for planning research and developing technologies identified in the ARTWG/ASTWG roadmaps. This interagency program consortium will jointly make funding decisions, allow for resource leveraging, as well as prevent effort duplication. Once the projects have been selected by the consortium, funding will be provided as a directed research and development effort, or by a request for proposal process. Figure 3 illustrates the relationship between ARTWG/ASTWG and the FIRST Program.

FIGURE 3



ARTWG/ASTWG and FIRST Program

The FIRST Program is currently in the formulation phase and several products are being produced to support a decision to start the program in FY06. An initial product being developed is the Needs Assessment, which identifies the key requirements for the future U.S. space transportation system. The assessment considers the needs of anticipated space applications by civil, national defense, and commercial users, including achieving routine commercial space travel, to help guide near-term investment decisions with a long-range perspective. The assessment incorporates design reference missions that cover a range of anticipated mission types. From these reference missions, a set of general requirements is derived that address the needs of all future anticipated missions, as well as specific target missions that are currently forecasted. No other programs currently exist to strategically develop an integrated space transportation infrastructure. By not utilizing this approach, a program-unique infrastructure that increases sustained operational costs will result, as we have today.

Another key program formulation product is the Concepts of Operations (ConOps) which provides a cohesive vision of how the future spaceports and ranges will operate. The ConOps will describe the operating characteristics of spaceports and ranges, as well as an overall integrated ConOps that describes an operational environment where all three partners' interests are addressed. This integrated ConOps will cover commercial (FAA), science and exploration (NASA), and national defense and security (DoD) space transportation operations.

Illustration by Pat Rawlings

Just as the airports and seaports of the world move massive amounts of cargo around the globe, spaceports will one day deliver goods and services necessary for ever increasing human activity beyond earth's confines.

Other deliverables include a Standardization Assessment, Technology Gap Assessment, Benefits Analysis, and a Return on Investment and Sensitivity Analysis. The program formulation phase is expected to be completed in early FY05, and the results from the data collection and analyses will be summarized in a final report, which is scheduled to be delivered in December 2005. Besides the program start-up decision, these products are valuable for coordinating programs internal to each agency, and to help identify potential technologies and infrastructure needed to accomplish each partner's mission.

Illustration by Pat Rawlings

An air traffic control tower cab shows how heads-up display technology could be used at future airports and spaceports.

In parallel to the ARTWG/ASTWG road mapping activities and the FIRST Program, the Joint Planning and Development Office (JPDO) is formulating the research strategy for aviation and aeronautics for the 2015-2025 timeframe. Through the JPDO, officials from the Department of Defense (DoD), Department of Commerce (DoC), Department of Home Land Security, NASA, FAA, and other organizations will use this forum to coordinate the vision and facilitate long-term transformation of the NAS.

Illustration by Pat Rawlings

A reusable aerospace vehicle may one day provide global express package service from Los Angeles to Tokyo in less than an hour.

The JPDO planning process considers improvements and goals set forth in the FAA's Operational Evolution Plan (OEP) and Strategic Plan, as well investigating and developing the more far-reaching technologies of the 21st Century. Members of the FIRST Program formulation team and the FAA Office of Commercial Space Transportation have been coordinating with the JPDO to fold future space transportation into their planning process.

Conclusions

Potential growth in both space and air transportation industries will place greater demands on the NAS. The introduction of more spaceports within the United States, coupled with predicted increases in air traffic operations, will cause even greater competition for limited airspace. As the transformation of the NAS occurs, and as a relatively new space commercial transportation industry emerges, air traffic service providers will need to allow all users fair access to limited airspace, while ensuring that the highest levels of safety, security, and efficiency are maintained.

The emerging space industry and growth in the NAS are driving toward the

development of an integrated
air and space transportation system. In the space arena, continued interagency collaboration and industry partnerships, like ARTWG/ASTWG and the FIRST Program, can identify new spaceport and range technologies that will be required to develop that system. ARTWG/ASTWG, the FIRST Program, and the JPDO are forums to coordinate the development and implementation of new air and space transportation technologies. These expanded government partnerships can formulate strategies and combine resources to tackle the many air and space transportation challenges that are ahead.

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Mrs. Shelia Helton-Ingram has over 20 years of experience in various facets of aviation development, training, testing and operations. She is currently working for the FAA, in the Office of Commercial Space Transportation as a Transportation Analyst. Her responsibilities include the safe integration of space vehicles operating within the National Airspace System.

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Mr. Stewart Jackson has over 26 years experience as an aerospace engineer, with 16 years experience in private industry before joining the FAA in 1994. Mr. Jackson is currently the Deputy Division Manager of System Engineering and Training in the Office of Commercial Space Transportation, and he has led teams that have granted the first FAA reentry operator's license and first launch site operator's license, and has developed the Reusable Launch Vehicle (RLV) regulations. Mr. Jackson holds a Bachelor of Engineering in Mechanical Engineering (BEME) from the City University of New York, a Master of Science in Business Administration (MBA) from Strayer University, and he is an Associate Fellow of the American Institute of Aeronautics and Astronautics (AIAA).

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Ms. Cristina Guidi has 16 years of experience in aerospace operations and technology development, and she is currently the NASA spaceport technologies program formulation manager for the Future Interagency Spaceport and Range Technology Program, the NASA Chair for the Advanced Spaceport Technologies Working Group, as well as the Acquisition Strategy Manager for Exploration Launch Vehicles. She was also the Lead Orbiter Project Engineer for the Space Shuttle Endeavour (OV-105). Ms. Guidi holds a B.S. in Electrical Engineering from Florida International University, and a Masters of Science degree in Space Systems from the Florida Institute of Technology.

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Mr. Darin Skelly has more than 10 years of experience in the aerospace industry, mostly in the areas of flight system safety, mechanical engineering, integration engineering, and launch processing. Mr. Skelly is currently the NASA range program formulation manager for the Future Interagency Spaceport and Range Technology Program, and he is the NASA Chair for the Advanced Range Technologies Working Group. Mr. Skelly was the Mission Manager the 2001 Mars Odyssey Launch, and has served on the Kennedy Space Center (KSC) executive staff, where he was involved with strategic planning and vision development for KSC. Mr. Skelly holds a Bachelor of Science in Aerospace Engineering from the University of Florida, and a Master of Science in Engineering Management from the University of Central Florida.

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