



AIAA-2000-3828

NASA's Integrated Space Transportation Plan

David M. Anderson
NASA Marshall Space Flight Center
Huntsville, AL

**36th AIAA/ASME/SAE/ASEE Joint Propulsion
Conference and Exhibit**

The Von Braun Center
Huntsville, Alabama
16-19 July 2000

For permission to copy or to republish, contact the American Institute of Aeronautics and Astronautics,
1801 Alexander Bell Drive, Suite 500, Reston, VA, 20191-4344

NASA's Integrated Space Transportation Plan

David M. Anderson^{*}
 NASA Marshall Space Flight Center
 Huntsville, AL

Abstract

NASA's Integrated Space Transportation Plan (ISTP) is the basis of the agency's new Space Launch Initiative (SLI). ISTP was developed to provide a structured methodology and framework to enable the next generation of reusable launch systems which will operate at orders of magnitude lower operating costs and higher levels of reliability and safety. Created in the fall of 1999, ISTP is the culmination of a series of Space Transportation Architecture Studies (STAS I, II, and III) which identified requirements, developed candidate architectures, and identified sets of technologies required to enable those architectures. The studies were conducted as a partnership between NASA and industry. Both new designs and shuttle-derived concepts were examined. Architectures were identified for 2nd Generation Reusable Launch Vehicles (RLV), which would reach first operational capability in 2010, and 3rd Generation RLV, which will become operational in the 2025 timeframe. Second Generation RLV's have a goal of placing payloads in low earth orbit (LEO) at a cost of \$1,000/lbm, and a safety goal of 1/10,000 probability of loss of crew. The Third Generation RLV launch system will deliver payloads to LEO at \$100/lbm and approach airline-like reliability and safety, with a 1/10⁶ probability of loss of crew.

Introduction

Reducing the cost of going into and working in space and improving the reliability of future launch systems are the cornerstones for the effective utilization and exploitation of space to be realized. NASA, in partnership with private industry, has embarked on a new effort, the Space Launch Initiative, which is chartered to develop the technologies and capabilities

that will make future generations of fully reusable launch vehicles possible. SLI is comprised of several parts, each seeking to advance the state of access to space toward more routine, and cost-effective operations to, on-orbit, and from low earth orbit.

The intent and focus of SLI is to provide the foundation that enables future launch systems, not to develop the system itself. Future launch systems will not be developed and operated by the government, as the Shuttle is today, but will be owned and operated by private industry, with the government taking the role of a customer of launch services. The vision of SLI is that of the government working in partnership with emerging and established launch service providers to field systems that will cater to commercial customers as well as NASA and the Department of Defense (DOD).

ISTP has identified several distinct, but coordinated efforts to achieve this goal. The Second Generation Reusable Launch Vehicle Program is tasked to provide a knowledge and technology base to facilitate an open competition for reusable launch system in 2005. The main goals of the 2nd Gen RLV is to provide launch services to LEO for \$1,000/lbm with a 1 in 10,000 probability of loss of crew. The initial operating date of the 2nd Gen RLV system is 2010. Efforts to develop specialized capabilities for NASA-unique missions are also included. The 3rd Gen RLV program looks beyond 2nd Gen RLV, with the focus on launch systems to be fielded about 2025 and will provide payload services to LEO for \$100/lbm with a 1 in 10⁶ probability of loss of crew. Considerable effort is included in the 3rd Gen RLV effort to develop advanced on-orbit capabilities and conduct research into more exotic "4th generation" technologies. Finally, the Alternative Access effort seeks to provide a near-term alternative means of providing payload delivery to the International Space Station (ISS) distinct from the primary current means of the Space Shuttle. Alternate Access is focused on smaller payload classes than

^{*}Aerospace Engineer, 2nd Generation Program Office, Senior Member, AIAA

Shuttle, in the range of several hundred to a few thousand pounds, and is uncrewed.

Second Generation Reusable Launch Vehicle Program

In order to achieve the goals of the 2nd Gen RLV Program, NASA has chartered a program office at Marshall Space Flight Center, in partnership with other NASA centers. The program is focused in two areas- Systems Engineering/ Requirements Definition and Goals Management. The program also includes projects for the various technology/ advanced development areas to be examined in the 2nd Gen RLV effort.

The intent of Systems Engineering/Requirements Definition is to provide a consistent, coordinated set of program requirements that outline clear objectives for the technology/advanced development activities. Systems Engineering/Requirements Definition is also tasked to develop systems engineering processes for program use that lay out coordinated activities and products which support timely program decision points and culminate in a competitive procurement for 2nd Gen RLV launch services in 2005. Systems Engineering/ Requirements Definition also leads systems analysis efforts that provide the foundation for technology identification and assessment.

Goals Management includes those activities which manages the technology/advanced development efforts and provides means to mitigate the risks associated with those activities to assure that an effective set of technologies will be available in the 2005 time frame to support the 2nd Gen RLV competition. Risk Management, Data Management, and Risk Management activities are administered through Goals Management. The 2nd Gen RLV projects will report progress through the Goals Management activity. The project areas currently identified for the 2nd Gen RLV effort are:

- Airframe/TPS
- Propulsion
- Vehicle Subsystems
- Systems Engineering
- Operations
- Integrated Vehicle Health Management
- Crew Systems
- Flight Mechanics
- Flight Demonstrators

The focus of the technology/advanced development efforts will be on those items which can be brought to a technology readiness level of 6 or 7 by 2005 and

contribute to the cost and safety goals identified for 2nd Gen RLV.

No specific launch system architecture has been identified or will be selected by NASA for the 2nd Gen RLV. Architecture development is the responsibility of the prospective bidders for the 2005 competition. Both new designs and configurations derived from the current Space Shuttle will be considered. For the 2nd Gen RLV to accomplish the design reference missions (DRM's) identified for it, a set of functional capabilities have been identified and are presented in Table 1. The Design Reference Missions are found in Reference 1.

1. Service the International Space Station (ISS)
2. Accomplish crew rotation for the ISS
3. Deliver, deploy, activate, and checkout spacecraft and/or payloads
4. Provide services to cargo:
 - + Power
 - + Command and telemetry
 - + Fault detection, annunciation, and safing
 - + Heating and cooling
 - + Vehicle attitude and pointing services
5. Accomplish rendezvous and docking/berthing
6. Retrieve, repair, or service on orbit spacecraft; including refueling capability
7. Assemble, service, and checkout space platforms
8. Reboost on orbit spacecraft and platforms
9. Deorbit space debris or inactive spacecraft
10. Stationkeep with other spacecraft
11. Provide remote manipulator services for deployment and assembly tasks
12. Accomplish extravehicular activities for assembly, repair, and servicing functions

Table 1
Second Generation RLV Functional Capabilities

Alternative Access

The Alternative Access activity is being conducted as a coordinated effort with the 2nd Generation RLV program. The goal of alternative access is to provide a near-term capability to deliver smaller payloads to the ISS in an uncrewed vehicle. Initial capability is targeted for 2003. Payloads of a few hundred pounds to a mini-Pressurized Logistics Module are under consideration for alternative access. The candidate launch architectures for this effort will depend on present or near-term technologies which can be readied in time to support the initial capability date. Expendable, partially reusable, and fully reusable architectures will be considered for alternative access.

Third Generation Reusable Launch Vehicle

The 3rd Generation RLV effort, known as Spaceliner 100, is managed through the Advanced Space Transportation Program office at Marshall Space Flight Center, in partnership with other NASA centers. The focus of Spaceliner 100 is to conduct a long range technology effort directed toward making sound investments in the identification and development of technologies envisioned to hold the highest potential of enabling an advanced reusable launch system beyond the expected operational life of the 2nd Generation RLV. The goals of the 3rd Generation RLV are to provide payload delivery to LEO at a cost of 100/lbm, with a 1 in 10⁶ probability of loss of crew. A 3rd Gen system would need to conduct missions with near airline-like operational efficiency to reach these goals.

Spaceliner 100 is divided into five project areas as shown:

- Propulsion Technology
- Airframe/TPS Technology
- Launch Technology
- Integrated Vehicle Health Management
- Operations and Range Technology

Propulsion Technology is concerned with advanced airbreathing and rocket technologies which will provide levels of performance which far exceed the current state of the art. Current efforts are focused on rocket-based combined cycle (RBCC), which functions as a rocket during the initial phases of flight, converts to a high efficiency ramjet during the ascent through the sensible atmosphere, and converts back to rocket in exo-atmospheric flight to orbit. Initial efforts are underway to conduct flight tests of this technology in the latter half of the decade. Advanced rocket technology, particularly pulse-detonation, are being investigated for use in advanced upper stages and rocket-powered boosters.

Airframe/TPS Technology explores advanced structural materials and techniques which will add design margin and reduce weight, which contributes to higher performance and vehicle efficiency. This effort also investigates structural design concepts such as highly integrated structures and advanced cryogenic tank design which will allow for highly advanced vehicle shapes and are capable of higher cross-range on reentry, which adds to operational efficiency, and thus lower costs. Thermal Protection System efforts focus on those candidate technologies that provide highly reusability,

are operationally efficient, and exhibit higher thermal performance.

Launch Technology investigates technologies associated with advanced guidance, navigation, and control; onboard power systems, integrated design and analysis tools, and crew systems technologies. Advanced, adaptive autopilot designs will be required to enable vehicles with multicycle propulsion systems and increased operating margins. To achieve high launch rates, guidance and control systems for 3rd Gen RLV's must be able to provide operating margin in far more varied atmospheric conditions than is possible today. Launch technology is concerned also with the development of advanced integrated design and analysis tools which will provide more efficient, highly integrated design cycles than today. Advanced power systems and crew system technology efforts are also included.

Integrated Vehicle Health Management includes those technologies which monitor, sense, and report the state of the vehicle while being prepared for flight, in flight, and during post flight inspections. A variety of efforts are being considered which will allow real-time monitoring of structural, thermal, propulsion and other major system performance and functionality. IVHM will allow for enhanced operational efficiency by providing high fidelity diagnostic data quickly for maintenance and repair.

Operations and Range Technology develops those technologies which will transform today's highly labor intensive launch and recovery operations into a more streamlined "Spaceport" type of operation. Future RLV's will be most efficient if they can operate at high flight rates from a variety of locations, including inland sites, and are not limited to a small number (sometimes 1) of launch sites. Advanced range technologies will help to enable this capability, as will highly efficient operational methodologies.

ISTP recognizes that there are technology areas which cross over between the 2nd and 3rd Gen RLV efforts. For example, some technologies identified for 2nd Gen RLV will not progress as originally intended, and will be evaluated for applicability for 3rd Gen RLV. Likewise, the potential exists for some 3rd Gen RLV technologies to progress faster than anticipated, and will be evaluated for use in 2nd Gen RLV. To facilitate this process ASTP has provided a mechanism through its RLV Focused Project to set up a "clearinghouse" for such technologies.

ASTP has initiated a systems analysis activity which is tasked to provide the analytical efforts and

trade studies which will generate the technical rationale from which management decisions can be made concerning the correct areas of technology investment. Concept studies, technology assessments and prioritizations, economic, and safety/reliability analyses will be conducted to determine the best directions to go in technology investment.

Summary

NASA's Space Launch Initiative is intended to enable the development of 2nd and 3rd generation reusable launch systems by identifying and developing key technologies essential to meeting the cost and safety/reliability goals set forth for future launch systems. In the fall of 1999, NASA, in partnership with industry, developed the Integrated Space Transportation Plan as a framework for Space Launch Initiative activities. The 2nd Generation RLV program is focused on enabling a near-term competition for RLV launch services planned for 2005. The 3rd generation effort,

named Spaceliner 100, is structured to provide a technology base for RLV's envisioned for the 2025 time frame.

Acknowledgement

Assistance provided in the preparation of this paper by Steve Cook, Dan Dumbacher, Dr. Chuck Smith, and Bruce Shelton of Computer Sciences Corporation is gratefully acknowledged.

References

Second Generation RLV Reusable Launch Vehicle
Level 1 Requirements Document, August 1999

Advanced Space Transportation Program Plan,

Second Generation Reusable Launch Vehicle Program
Plan,