

2nd Generation RLV: Program Goals and Acquisition Strategy

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Abstract: The risk to loss of life for Space Shuttle crewmembers is approximately one in 245 missions. U.S. launch service providers captured nearly 100% of the commercial launch market revenues in the mid 1980s. Today, the U.S. captures less than 50% of that market. A launch system architecture is needed that will dramatically increase the safety of space flight while significantly reducing the cost. NASA's Space Launch Initiative, which is implemented by the 2nd Generation RLV Program Office at Marshall Space Flight Center, seeks to develop technology and reusable launch vehicle concepts which satisfy the commercial launch market needs and the unique needs of NASA. Presented in this paper are the five primary elements of NASA's Integrated Space Transportation Plan along with the highest level goals and the acquisition strategy of the 2nd Generation RLV Program. Approval of the Space Launch Initiative FY01 budget of \$290M is seen as a major commitment by the Agency and the Nation to realize the commercial potential that space offers and to move forward in the exploration of space.

INTRODUCTION

While the market for satellite services has grown at an astounding rate, the U.S. share of the launch services market has declined to less than 50%. The U.S. commercial space industry grew 170% between 1993 and 1997. This figure is 10 times that of the commercial aircraft industry during the same 5 year period.¹⁰ In a recent survey conducted by the Satellite Industry Association (SIA), the SIA found overall satellite industry revenues were up by 15% [in 1998], to \$65.9 billion, with U.S. companies accounting for 46% of the total.¹¹

In the mid 1980s, the United States held virtually 100% of the commercial launch market. After rebounding from a low of 20% revenue capture in 1991, the market share of U.S. providers in 1999 was centered around 47%.¹⁰ The same SIA survey noted that "launch revenues declined 11% in 1998. Launch service providers had revenues of \$4.3 billion, while subcontractors engaged in vehicle construction took in another \$2.7 billion."¹¹

The United States has long held a significant advantage when it comes to trade balance within the aerospace industry. The export of military and commercial aircraft, the export of aircraft engines, the construction and launch of communication satellites, and the development and launch of scientific payloads have consistently resulted in the aerospace industry being afforded one of the highest positive trade balances of any U.S. industry. It is now necessary for the United States to take the next step in space transportation to both secure U.S. competitiveness in the launch industry and to enable new markets and new space business endeavors in the 21st Century.

THE MARKET

Despite reductions in Expendable Launch Vehicle (ELV) pricing in the last decade, the price paid by those who desire to place payloads into orbit is extremely high. The price is especially high for payloads greater than 10,000 lbs in mass. Current launch pricing for payloads in this class is around \$3,500/lb if launched on an expendable booster. Where markets can generate significant immediate revenues, this pricing can be recovered rather quickly.

However, to enable the expansion of current space industries beyond the traditional base will require considerable reductions in launch service pricing.

To enable the development of new markets outside of the traditional aerospace community, the cost of reaching earth orbit must be further reduced. Estimates tend to hover around \$1,000/lb as the upper threshold for triggering an expansion in what is known as the "elastic" market. The elastic market is that portion of the market which grows significantly in response to a reduction in launch pricing. Most predictors of the NASA and military launch markets view them as in-elastic or slightly elastic – meaning there is little relation to the number NASA or DoD space missions to the launch price. A conclusion of the Orbital Sciences Corporation (OSC) presented at the September 28, 2000, mid-term review of a study funded by NASA is that only commercial demand seems related to price.⁵

Preliminary findings by the Futron Corporation in a study also funded by NASA indicate that the mass requirements for payload launch are not trending dramatically to the micro-sized payloads as was predicted several years ago. Indeed, the testimony before the House Sub-Committee on Space and Aeronautics by the Director of Space Policy indicates that commercial GEO satellites will approach 15,000 lbs in mass with 150 transponders. Research by the Futron Corporation tends to hold the number of transponders per satellite at around 40 while advances in technology increase the capacity of those transponders.

While predictions may vary concerning the threshold for enabling of the elastic market, the mass requirements of payloads 15 years in the future, or the number of transponders, one thing is clear – to secure the future health of the space industry and to enable new entrepreneurial endeavors in the high tech industry -- the United States needs to be the first to market with a reusable space transportation system that is significantly safer than today's manned space flight systems and that is significantly cheaper than today's launch systems.

First to market is significant because analyses show that the flight rates required to close a commercial RLV business case depend upon majority capture of the available market. Splitting these revenues with a competing system will not allow recovery of commercial investment.

THE 2nd GENERATION RLV PROGRAM

In 1998 NASA awarded a number of contracts entitled the Space Transportation Architecture Studies or STAS. Through various phases from August of 1998 through May of 2000, these studies focused on definition of space transportation requirements, initial architecture options, technology prioritization, systems engineering and preliminary risk reduction. The results of these study efforts and other NASA independent analyses were incorporated into a single strategic planning and budgeting package for reusable space transportation in the new century. This integrated plan is known as the Integrated Space Transportation Plan or ISTP.

In August of 1999, the National Aeronautics and Space Administration delivered to the Office of Management and Budget the integrated plan for continuing space shuttle operations while improving safety, and beginning advanced development and technology research into the key areas which will allow achievement of the next major step in space transportation. The ISTP has five primary elements.

1. Ensure continued safe access to space through **Space Shuttle Safety Upgrades** until a replacement alternative has been demonstrated.
2. Invest in technical and programmatic **Risk Reduction Activities**, driven by industry needs, to enable full-scale development of commercially competitive, privately owned and operated Earth-to-Orbit reusable launch vehicles by 2005.
3. Develop an integrated architecture with systems that build on commercial ETO launch vehicles to meet **NASA Unique** requirements that cannot be economically served by commercial vehicles alone.
4. Enable procurements of near-term, launch services for select International Space Station needs on **Existing and Emergent Commercial Launch Vehicles**.
5. Secure safe, reliable and cost-effective access to space in the far-term through investments in **3rd-Generation RLV Technologies** for ETO and in-space applications.

It is items two, three, and four that make up the cornerstones of the Space Launch Initiative. This initiative is implemented by the 2nd Generation RLV Program led from the Marshall Space Flight Center (MSFC) in Huntsville, Alabama. The Program itself is made up of individual Projects which are managed by the corresponding NASA Center of Excellence in that field. The 2nd Generation RLV Program organization structure and its relation to other programs within the Space Transportation Directorate at the Marshall Space Flight Center are shown in Figure 1.

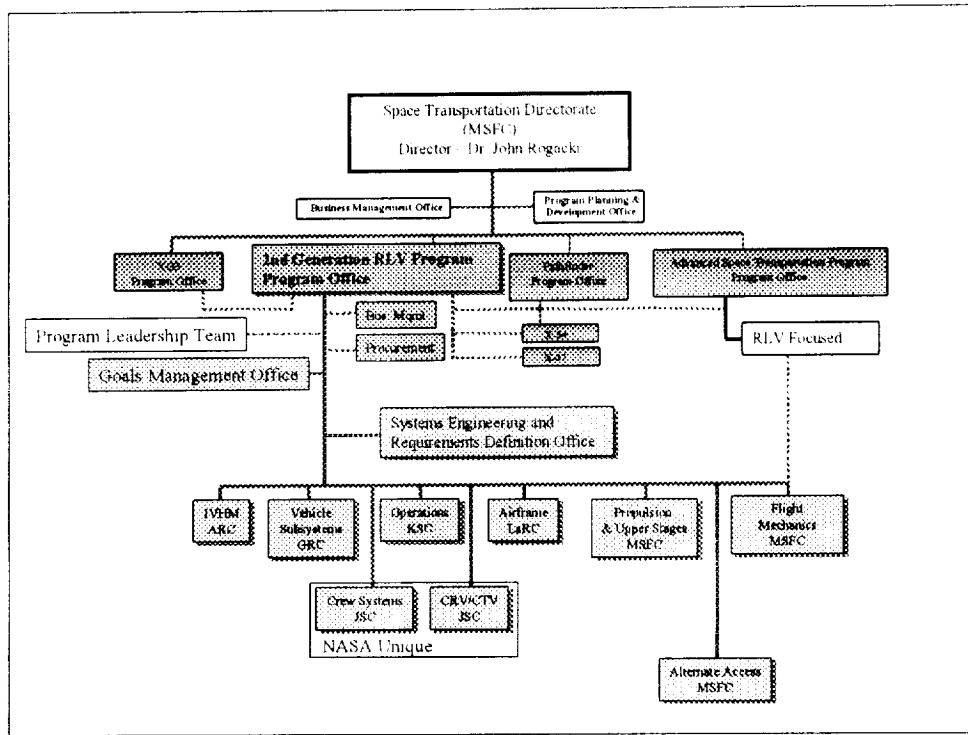


Figure 1

2nd GENERATION RLV PROGRAM GOALS

There are two Offices within the 2nd Generation RLV Program Office at Marshall Space Flight Center (MSFC). They are the Systems Engineering and Requirements Definition Office and the Goals Management Office. During the STAS studies, a high level requirements document was generated to guide the efforts of the participants. This document became known as the Mission Needs Document and is undergoing significant revision by the Systems Engineering Office. The Mission Needs Document not only documents the specific design reference missions, but it also serves as a repository of high level program goals. While not strictly "requirements", these goals serve to guide the 2nd Generation RLV architecture developers in determining the optimum design.

The 2nd Generation Goals Management Office is the day-to-day custodian of the program goals. The goals shown below have been developed in two phases. First, the Lockheed Martin Corporation facilitated a meeting at MSFC in which the specific goals and their definition were developed. These can be seen as derived from the goals written into the Mission Needs Document. The group attempted to prioritize the goals through an analytical hierarchy process, but found some of the goals were simply not comparable and also found that the Program Office itself did not have a consistent vision of itself as representative of the nation's reusable launch service needs.

That is, some in the group saw themselves as representatives of the NASA needs only, while others weighed commercial requirements more heavily, and still others felt they could not represent the needs of the military.

To resolve these inconsistencies and to develop a consistent understanding of the goals within the NASA Program Office, the program goals have been segregated into two distinct classes.

Strategic socioeconomic goals are those met by the implementation of specific policy, program structure, or acquisition strategy. Architecture Design Goals are those implemented directly within an architectural solution. Architecture Design Goals may in some cases be seen as having strategic aspects and vice versa. However, there is no effort to prioritize across these two classifications and NASA expects the Architectural Design Goals to flow directly to Level I requirements. The goals and the prioritization described below are still being developed and will be approved by NASA Headquarters before being considered baselined.

Strategic Socioeconomic Goals

1. **Commercially owned and operated 2GRLV:** Foster and support the commercial business viability for development, ownership, and operation of the 2GRLV system.
2. **Maintain and Nurture U.S. Industrial Base:** Foster and expand capabilities of the U.S. aerospace industry.
3. **Foster U.S. Industrial Competition:** Maintain multiple competitors through at least the decision for full scale development.
4. **Assured Access:** Provide an alternate means of meeting critical [NASA] mission objectives. The Near Term definition of Assured Access is to provide a means of access to the International Space Station on more than one U.S. Earth to Orbit launch vehicle.

Goal number one is seen as the most important of the strategic goals. The remaining three are viewed by the NASA Program Office to be of medium importance.

The team debated whether to place Assured Access in the Strategic Goals set or to place it in the set of Architectural Design Goals. Ultimately, the decision was made to place the goal of Assured Access with the strategic Goals. This decision was based principally on the opinion that it is not anticipated that solutions for alternative access would influence the 2nd Generation RLV architecture design. Assured Access, as implemented by the 2nd Gen Program Alternate Access Project addresses item four of the 2nd Gen program elements.

Architectural Design Goals

1. **Improve Safety:** Significantly control, reduce, or eliminate hazards over current systems for crew, processing personnel, public, and high value assets (including equipment, facilities, launch vehicles, flight hardware). Goal of 1 in 10,000 mission risk for loss of flight personnel.
2. **Lower Cost of Access to Space:** Significantly reduce the price of launch services to the customer. Goal of \$1000/lb customer pricing for Earth-to-Orbit transportation.
3. **Improve Probability of Mission Success:** Significantly increase the space transportation system's probability of achieving mission objectives.
4. **Be More Affordable:** Minimize nonrecurring costs for the 2GRLV architecture. This includes total development and production costs to IOC.
5. **Maintain current NASA space transportation functional capabilities and mission services:** As referenced in 2nd Generation Space Transportation Architecture Mission Needs Document [<http://www.hq.nasa.gov/office/codea/codeac/documentg.html>].
6. **Maximize Synergy between Commercial and NASA Requirements:** Leverage the 2nd Generation RLV capabilities driven by the commercial market to benefit overall launch needs.
7. **Improve Launch on Time Availability:** Increase the probability of launching during the specified opportunity.
8. **System Evolvability:** Provide a system that can adapt to changing needs and opportunities.

9. **Expand NASA's Human Space Flight Capabilities:** Expand functional capabilities and mission services as referenced in 2nd Generation Space Transportation Architecture Level 1 Requirements Document.
10. **Achieve 2nd Gen by 2010:** Achieve 2nd generation launch system's Initial Operational Capability by 2010.
11. **Provide Launch on Demand:** Minimize the time between the request for launch services and the actual launch.

Architectural Design Goals one through three are of the highest importance, goals four through six are of medium importance, and goals nine through 11 are the lowest in importance of the architectural design solution goals. For purposes of prioritization, *Achieve 2nd Gen IOC by 2010* was given a one year variance and *Provide launch on Demand* was interpreted as a two day turn around.

The Goal that receives the greatest amount of discussion is the 1 in 10,000 loss of crew goal. Current estimates of Space Shuttle reliability predict a loss of crew once in approximately every 245 missions. This reliability prediction considers the risk over the entire mission – not just ascent. Ascent risk estimates are 1 in 483. Setting the goal so high in relation to current safety predictions for the only operating reusable space transportation system always seems to draw criticism from those operating within the established aerospace community. The more aggressive entrepreneurial entries into the architecture development arena say the goal is too low, that something approaching the commercial aircraft standard is what will enable the expansion of space business.

Those participating in the 2nd Generation RLV architecture definition have been given the responsibility to determine the sensitivity of this goal to the application of technology and resources. In the end, the realistically achievable goal may be determined to be something less than 1 in 10,000. But until attainment of this goal is shown to be prohibitively expensive or limited by technology, it will remain at 1 in 10,000.

Discussion of the cost goal draws the next greatest amount of discussion. The development of architecture solutions center around meeting these two overriding goals – improve safety & lower the cost. While those who dream of tourist excursions to low earth orbit think the dollar value is too high others depending on the opening of expansion markets to close demanding business cases tend to think this value is on the upper threshold of market expansion. Perhaps not enabling the elastic market at all. This goal is a significant reduction in present ELV commercial launch market pricing, but not by orders of magnitude. The goal continues to appear reasonable and appropriate.

One of the keys to success of this program will be the analysis of market variables and determination of a commercial business scenario which has a high probability of success. The details of that scenario have not yet been determined, but will be developed over the next two years and indeed the next 5. No decision to commit the nation to development of a full scale vehicle system will be made before that time when the risks of successful development can be shown to be acceptably low.

ACQUISITION STRATEGY

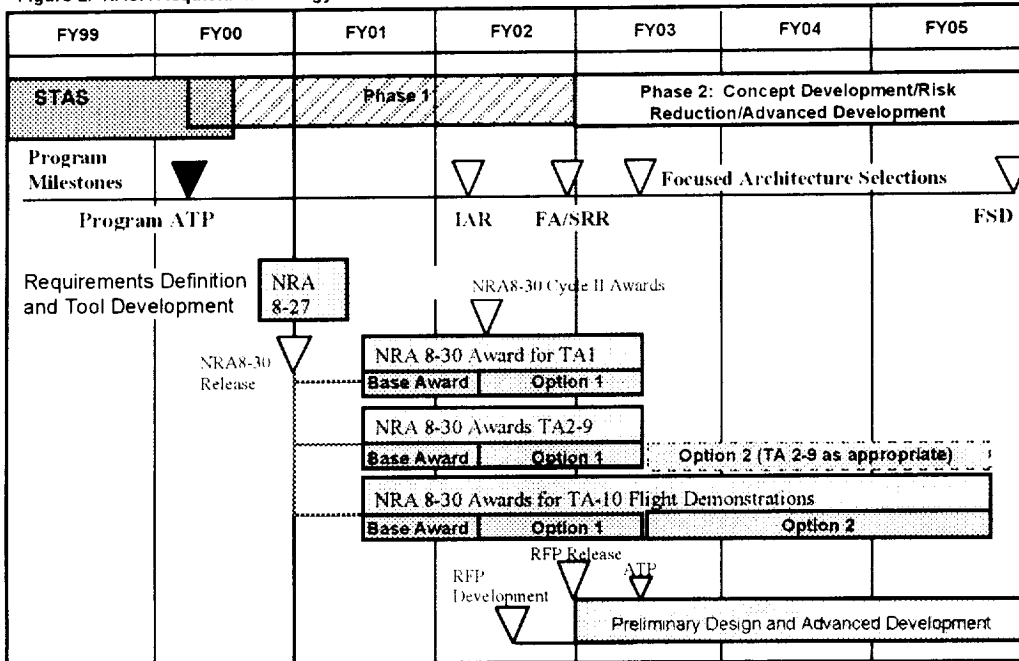
NASA's acquisition strategy for the 2nd Generation RLV Program is depicted in figure 2. NASA is currently evaluating proposals in response to the NASA Research Announcement NRA8-30. NRA8-30 technology Areas (TAs) generally breakdown along discipline lines with TA-1 being Systems Engineering and Architecture Development, TA-2 is Airframe, TA-3 is vehicle subsystems, and so on. For a full description of NRA8-30, view the Industry Briefing Charts at <http://procurement.nasa.gov/cgi-bin/EPs/bizops.cgi?gr=D&pin=62#NRA8-30>.

Awards from this solicitation will begin in earnest the architecture development and risk reduction activities necessary to enable the full scale development decision in 2005. The architecture development under NRA8-30 culminates in an Initial Architecture review at the end of the Base period of performance followed by the Final Architecture System Requirements Review (FA/SRR) at the end of the Option 1 period of performance. While many competitors have more than one concept under investigation, they are only allowed to bring one solution forward at the SRR.

NASA expects to further focus the development efforts following NRA8-30 by proceeding with a Request For Proposals (RFP) in FY2003. There are many competitors vying for the opportunity to build the next generation in

space transportation. Multiple awards are expected from NRA8-30. Contractual options will allow NASA to discontinue work that does not appear to be converging on the Program goals. A minimum of two awardees are expected from the RFP with a single offeror selected to build the final configuration if the decision in 2005 is favorable. The RFP would likely carry the competitors through a Preliminary Design Review, followed by a Critical Design Review in the late FY2005 timeframe.

Figure 2. NASA Acquisition Strategy



RISK

Sage advice demands that technology development be well in hand prior to the critical design review for any complex aerospace undertaking and certainly prior full-scale development^{1, 7, 8}. The purpose of the 2nd Generation RLV Program is not to begin construction of the next generation of space transportation system, but over the next five years seeks to buy down the risk of developing such a system.

There are many risks which must be mitigated over the next five years to enable the development of the system. Many of those risks are technical -- others are not. The single most significant risk to NASA is that it will invest \$4.4B over the next five years in risk reduction efforts only to have no commercial offeror prepared to take the next step in development of this commercially owned and operated reusable launch system. More specifically, the business case does not support the type of significant corporate investment that would be required to develop the system. NASA is left with a bag full of nifty technologies, but no vehicle.

It is imperative that NASA form partnerships with its commercial offerors in developing the strategies for achieving the program goals. And, that the Program strategies, as much as they represent the best interests of the American taxpayers, be those strategies which most enable the closure of the commercial business case.

A consistent set of technical risks continue to dominate the risk reduction efforts as competitors strive to meet the goals. They are:

- The development of crew escape systems which can be operated through-out the flight regime.
- The development of a highly reliable, high cycle life propulsion system.
- A long life (> 500 missions) light weight integrated airframe.
- The development of light weight low maintenance thermal protection systems, the development of a fully functional integrated vehicle health management system, and the design for and realization of low cost operations.

THE NEXT REVOLUTION IN SPACE TRANSPORTATION

If the 2nd Generation RLV Program is successful in achieving its goals, the landscape of business in space will be dramatically different than it is today. Lower launch costs will allow greater scientific achievement through increased budgets for basic research and payload development. non-traditional aerospace businesses will emerge to take advantage of the favorable environmental conditions of earth orbit such as micro-g, infinite vacuum, atomic oxygen, etc. Perhaps even adventure tourism in space will become a reality. NASA will no longer spend upwards of 21% of its budget on earth to orbit transportation. Dramatically reduced NASA spending for earth to orbit transportation will enable new investments in technology and space exploration. Approval of the SLI FY01 budget of \$290M is seen as a major commitment by the Agency and the Nation to move forward in the exploration of space and the realization of the commercial potential that space offers.

Safe and affordable access to space is the key to the next revolution in space travel.

References:

- 1 Mars Climate Orbiter Mishap Investigation Board, "Report on Project Management in NASA". March 13, 2000, pp. 9.
- 2 Lockheed Martin Corporation, "2nd Generation Reusable Launch Vehicle (RLV) Objectives, Characteristics, and User Needs", May 24, 2000.
- 3 Lockheed Martin Corporation, "2nd Generation Reusable Launch Vehicle Risk Reduction Definition Program Mid Term Report", September 26, 2000.
- 4 Boeing Space & Communications Group, "2nd Generation RLV Risk Reduction Program Mid Term Report", September 27, 2000.
- 5 Orbital Sciences Corporation, "2nd Generation RLV Risk Reduction Program Mid Term Review", September 28, 2000.
- 6 Futron Corporation, "Second Generation RLV Market Forecast Model Interim Review", September 18, 2000.
- 7 Rustan, Pete L., Space News Editorial adapted from May 11, 2000 testimony to the House Science Committee.
- 8 Stephenson, A. G., NASA Memorandum DA01, "Clarification of Cost Considerations in Project Management", March, 2000.
- 9 United States Air force Evolved expendable Launch Vehicle Fact Sheet. Current as of October 1998. http://www.laafb.af.mil/SMC/PA/Fact_Sheets/eelv_fs.htm
- 10 Mahone, Bruce L., "Prepared Testimony of Bruce L. Mahone, director Space Policy, Aerospace Industry Association of America, Inc. to the U.S. House of Representatives", March 11, 1999.
- 11 Anselmo, Joseph C. and Michael A. Taverna, "Satellite TV fuels Industry Growth", *Aviation Week and Space Technology*, April 12, 1999.