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Achieving Responsive Access to Space: Market, Money, Mechanics, and Management Lessons from X-33

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ACHIEVING RESPONSIVE ACCESS TO SPACE-- MARKET, MONEY, MECHANICS, AND MANAGEMENT LESSONS FROM X-33

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ABSTRACT

Achieving the goal of low cost access to space has eluded the country for decades. Several programs aimed at attaining this goal have fallen short. Multiple billions of dollars have been spent searching for low cost solutions to respond to perceived customer needs. However, our experience shows that customers for space transportation are not a monolithic entity. Different customers measure responsiveness to their requirements by different, sometimes opposing, values. Applying a one-size-fits-all approach to serving these different customer groups can lead to an inefficient expenditure of resources and a failure to respond to their needs. For example, some space lift users value low price above all else, while others value high reliability, and others high availability. Safety is the highest value of the human flight program. Each of these factors has an impact on the real and perceived risk by each party. And finally, excessively long vehicle development cycles create significant problems for all launch market customers and providers in a rapidly changing environment. To ensure true responsiveness, providers of space transportation systems must first identify the attributes that the different market segments value as being responsive. The investment required to achieve responsiveness must then be balanced against market prices and recurring cost to achieve an acceptable level of responsiveness while simultaneously creating a viable basis for a profitable business. The X-33/RLV program was not only designed to demonstrate technology, but to also try new business constructs enabling government and industry to move forward in developing the next generation low cost space transportation system. To fully reap the benefits of the lessons learned on X-33/RLV, one must look beyond the technology and the hardware that was built and assess the business and management premises on which the program was based.

INTRODUCTION

Achieving the goal of responsive access to space has eluded the country for decades. Several programs aimed at attaining this goal have fallen short, including the X-33/Reusable Launch Vehicle (RLV) program with which the authors were associated. While not successful in achieving a flight demonstration, the X-33/RLV program offers several lessons regarding appropriate approaches, strategies, and problems which may be encountered in the continuing pursuit of responsive space access.

Of the many important lessons learned while developing the X-33/RLV program, we have identified three key lessons which will bear significantly upon on-going and future programs attempting to meet the need for responsive space access. Those lessons are:

- The *users* and *suppliers* of space transportation (the “stakeholders”) are many and diverse. These stakeholders embrace, in most cases, significantly different definitions of “responsive space.” Consequently, they each prioritize the various system characteristics in a unique way. These priorities are rarely aligned and often countervailing. The first step in developing a truly responsive system is the thorough identification and understanding of the differing definitions.
- An effective space transportation system must either balance the competing requirements of the various stakeholders or respond to a selected subset of the total population of stakeholders.
- The one common attribute which is accepted by most stakeholders is the desire to drive risk to the lowest possible level. But here again, we

find different evaluations of risk and differing priorities associated with each. In fact, the one risk which was pivotal to the success of the full-scale RLV, market risk, was not addressable by the primary risk reduction tool, the X-33 technology demonstrator.

On the surface these lessons may appear somewhat self-evident. However, based on our experience, some of the stakeholders and their requirements are not immediately obvious and, more importantly, the ways in which their needs work against each other and the ramifications of such are very significant to the development of program strategies.

The balance of this paper will examine several countervailing stakeholder requirements and, where applicable, show how they came into play within the context of the X-33/RLV program. First, it will be explained how the X-33/RLV top-level program objectives were inextricably linked to the economic environment of the time and how the objectives were heavily influenced by non-economic factors of the major stakeholders. These top-level influences were conflicting under certain conditions. Unlike traditional advanced technology demonstration programs, the X-33/RLV top-level program objectives were not driven by performance. With few exceptions, all of the X-33/RLV advanced technology was driven by the top-level requirements of economics and reliability--not performance. And finally, based on the X-33/RLV lessons, some suggested strategic approaches to developing responsive systems will be offered.

X-33/RLV PROGRAM BACKGROUND

Governments around the world have been the traditional developer of launch systems. Developed after the highly successful Apollo program, NASA's Space Transportation System (STS) was originally envisioned as a low-cost alternative to expendable rockets. The Space Shuttle is truly a versatile heavy-lift space vehicle. However, as wondrous and capable as it is, the system failed to deliver the expected savings. Although most its major elements are reusable, its turnaround activities are labor intensive. Several top-level cost drivers are widely recognized. Significant costs are attributed to re-assembly operations which must be carefully performed to stage the Orbiter vehicle onto the Solid Rocket Boosters and External Tank. Similar to expendable vehicles, verifying the integrity of the assembled vehicle is a costly process that must be repeated prior to each flight. Furthermore, several STS subsystems were unexpectedly found to require extensive overhaul activities to ensure their reliability (e.g. the Space Shuttle Main Engines and Thermal Protection System, etc.).

Inevitably, questions began to circulate among the NASA planners. Could we build on the lessons of the Space Shuttle and develop an alternative vehicle? Could we design a reusable spacecraft to operate more like an airplane? High government budget deficits and a lower government priority on space transportation made the traditional prospect of a government developed new space transportation system highly improbable. As the U. S. economic environment grew at seemingly unstoppable rates, NASA began to construct a very different type of program that could justify commercial investment in developing a new launch system.

In the late 1980's, as a result of removing commercial payloads from the Space Shuttle, a concerted effort was made to develop a U.S. commercially owned and operated space transportation industry. This endeavor was substantially different than previous launch vehicle development programs because the additional development costs were not to be paid by the government and, therefore, needed to be considered in the pricing and market analysis. Additionally, each flight incurred high recurring costs associated with the expendable hardware and left limited room for cost reduction in the hopes of expanding market demand. It was postulated that one method to enhance pricing flexibility was to develop a totally reusable vehicle. Such a system, if flown frequently enough, had the potential to significantly bring down the recurring cost of getting payloads into space.

The goal of achieving dramatically reduced recurring costs was clearly a significant challenge from a technical perspective. Additionally, the potential developer faced significant questions, such as:

- Who would pay the development costs?
- What was the market for such a system?
- Would such a system gain back a significant portion of the commercial market share that was now dominated by competitors who were often subsidized by foreign governments?
- Could the costs be justified?

These unknowns, when combined with the goal of low cost access, presented many conflicting requirements that threatened success.

It was under these conditions that X-33/RLV was born. However, to build and fly the demonstrator within available funding, a novel management scheme and contracting mechanism would be required. Management had to be free to embrace only the value-added activities and eliminate those of marginal value. The government proposed to go forward with an industry-led partnership with the government acting as a major partner — not customer. So in the case of X-33, the X stood for more than just X-perimental technology. It became an X-periment in both business construct and management. Examining the lessons learned from this program must be conducted in this total context.

Management Structure

The management organization of the X-33/RLV program was established as a *partnership* between NASA and an industry team led by Lockheed Martin. The X-33 was to be the precursor to the first commercial reusable space vehicle. As previously stated, the government's top-level objective was to lower the cost of space access as compared to the current system (Space Shuttle.) Although Space Shuttle recurring costs were the main target of this effort, NASA realized they could not afford the non-recurring development costs required to bring a totally new design to fruition. NASA developed a procurement strategy that required only a small fraction of the development costs to be borne by the government — the remainder to be borne by industry utilizing a commercial development model. The government would fund 70% of a much smaller technology demonstrator (X-33) utilizing a fixed-funded Cooperative Agreement in lieu of a standard contract. The X-33 was planned to retire technical and political risks while increasing the confidence of private sector investors. After the successful flight of the X-33, it was envisioned, industry could approach Wall Street and acquire the financing to develop the much larger commercial launch vehicle. This vehicle would be able to serve multiple military and civilian customers including NASA, in addition to what was believed to be a greatly expanding commercial market. The plan called for industry to own and operate the vehicles as a commercial entity, with launch services purchased by NASA similar to purchasing a commercial airline ticket. If successful, the scheme would relieve NASA of its traditional role in developing and, more importantly, funding and operating a new vehicle.

Lockheed Martin was competitively awarded the $1.2B program and commenced work in July 1996. Use of a Cooperative Agreement on a major procurement was unprecedented. The partnership offered the government several advantages over traditional contracting methods, such as:

- Government and Industry shared risk;
- Government insight vs. oversight;
- Streamlined procurement and program management procedures;
- Small government program office;
- Shared government (+$950M) and Industry (+$250M) investment.

Lockheed Martin organized a diverse industry team, identified in Figure 1, capable of performing the technical and managerial tasks required to design, build and operate both the X vehicle (X-33) and the much larger Reusable Launch Vehicle (called VentureStar™). Each team member made a financial contribution to the X-33 development costs and waived any profit and General and Administrative costs. The government contributed 70% of the initial funding and industry made up the remainder. Team members were assigned tasks roughly according to their expertise. However, task assignments were sometimes modified and rearranged as the program progressed. Team members were treated as partners — not subcontractors. Normal protection inherent in the contractor/subcontractor relationship was not available within the team. If unexpected problems were encountered with a particular task (e.g. late delivery or costs overrun,) the task could be reassigned or additional investment provided as necessary. The original teaming arrangements called for each industry partner to invest an amount proportional to their work package. Although the partners were reluctant to increase their contribution, they were also anxious to see the program succeed. The government share was fixed and never increased.

Synchronizing, coordinating and motivating a large and diverse group of partners was a significant challenge. Each partner (either commercial or government) had its own idiosyncrasies, upper management perspective and business objectives that had to be accommodated when managing the

Partner	Function
Lockheed Martin	Overall lead, structure and system integrator, Launch Control System
Honeywell	Subsystems
Boeing Rocketdyne	Engine and Reaction Control System
BF Goodrich	Thermal Protection System
Jacobs-Sverdrup	Launch Facility
NASA	Guidance Navigation and Control, Trajectory design, Software, Engine Test Facilities

Figure 1. The X-33/RLV Team

program. In addition to management insight, NASA contributed expertise from its field centers. Many individual engineers of the highest caliber were assigned from NASA to the X-33 Integrated Product Teams (IPTs) and took assignments directly from the industry IPT leads.

Fundamental Principles

NASA articulated three initial goals which became the top level requirements of the program:

1. Significantly reduce the cost of access to space;
2. Leapfrog technology to regain market leadership in the global commercial launch services market;
3. Obtain private financing for the operational space transportation vehicle.

The financial community considered low risk, quick payback, and high returns attractive attributes for investments. In contrast, leapfrog technology implied high risk, and significantly lower pricing means lower revenues. Therefore, in assessing these top level goals, there were inherent conflicts in stakeholder objectives.

Multiple business plans were developed by the industry team to finance the multibillion-dollar development of a full-scale commercialized launch vehicle. Discussions were held with the industry partners, the investment community and the U.S. Government to ascertain the requirements for obtaining the participation of each of these stakeholders. A range of options were examined to mitigate the technical, market and business risks for each of the stakeholders. While it was believed the flight of the X-33 would go a long way to reduce technical risk, reducing the business risks to make the business plan acceptable to all parties was more challenging. Concern over policy issues (e.g. assured government use of a privately built system) made the investment community leery of the government commitment. Options such as government/private corporations, tax incentives, tax holidays, loan guarantees and anchor tenancy were all examined as the initial business plan was assembled. NASA's contention that lowest possible prices would create significant market growth — basically a "build it and they will come" philosophy — was not a comfortable market forecast approach for investment bankers. Consequently, a fairly conservative approach was formulated utilizing government loan guarantees as the fundamental financial instrument enabling third party investment. Loan guarantees, the anticipated use of the RLV to service the International Space Station (ISS), and a healthy commercial launch market provided the initial premises sufficient to close the preliminary business plan in 1996. However, collapse of the commercial launch market in 1999 increased the risk of the business plan to unacceptable levels. Profits from the reduced commercial launch revenues would no longer support the large non-recurring cost incurred from the early development years.

In hindsight, the inherent conflicts between stakeholders' goals can be identified within the initial principles of the X-33/RLV program. The next section identifies in general terms the primary stakeholders in the achievement of responsive space access and describes their primary goals and motivations.

STAKEHOLDERS AND RESPONSIVENESS

An important first step in formulating strategic plans is to identify the interested parties and how they measure responsiveness. In essence, who cares about, or has a stake in, responsive space transportation? Understanding stakeholders' motivations and needs is fundamental in developing effective strategies to meet those needs.

The full range of stakeholders with interests in the quest for responsive space access extends to essentially all current and potential future demanders for and suppliers of space transportation. These stakeholders can be grouped as users who demand space transportation (both commercial and U.S. and foreign government users such as DOD, NASA, other U.S. Government agencies, European Space Agency, etc.), suppliers of space transportation (companies and government agencies,) and other potential investors.

Figure 2 summarizes the 1996 forecast of users who represented the source of demand for space transportation, representing both (then) current and longer-term potential users.

The suppliers of space transportation are many and growing even though current market demand has slumped. It is expected that space market will re-emerge as current users and new entrepreneurs find successful new uses of space. Exciting candidates offering affordable space transportation will most likely emerge from among the current and proposed systems.

Stakeholder Metrics

Achieving responsive access to space is a challenge which involves meeting both technical *and* financial needs of the disparate set of stakeholders. As stakeholders have a varied set of both financial and non-financial criteria for determining the relative merits of various alternatives. Understanding the metrics by which stakeholders measure responsiveness is a key to developing effective strategies for achievement.

Our experience shows that space transportation stakeholders are not a monolithic entity. Different stakeholders measure responsiveness to their requirements by different, sometimes opposing values.

DEMAND	STAKEHOLDERS	PRIMARY USES	1996 MARKET SUMMARY
Civil Government	NASA, ESA, NOAA, etc	Earth sciences, astrophysics, planetary and human exploration	Geostationary operational environmental satellites, earth observation system, Hubble telescope, Galileo, International Space Station
Military Government	U.S. Dept of Defense, Foreign Governments	Communications, intelligence, treaty verification	Global Positioning Satellite, Defense Satellite Communication System, other national technical means
Commercial –GSO	Communications & broadcast companies	Communication and direct broadcast satellites	Intelsate, Eutelsat, Direct TV
Commercial – LEO	Mobile communications & remote sensing companies	Communications constellations, remote earth sensing	Iridum, GobalStar, Teledesic, Landsat
Commercial – Other	New/current companies not currently involved with space	Space manufacturing, hazardous waste disposal, space tourism, solar power	Unknown

Figure 2. Summary of 1996 Market/Demand for Space Transportation

As shown in Figure 3, the needs and requirements which provide the motivations for these stakeholders are, in some cases, opposing forces. Meeting requirements can require a balance between suppliers and demanders. But, as illustrated in the figure, both sides naturally want to move up towards the 100% requirements level — a potentially unattainable proposition. Commercial space users require cheap, efficient, relatively standard services to common destinations. Defense users look for reliable transportation to various destinations in a secure environment. Civil governments' primary focus for human spaceflight is safety and, for scientific payloads, low cost plus high reliability to multiple destinations. Government suppliers wish to deliver payloads reliably at low cost while maintaining a viable engineering and industrial base. Commercial suppliers wish to achieve essentially the same thing while maximizing profits, and minimizing investment and risk.

From an economic perspective, many different metrics have been used to measure the responsiveness of space transportation in terms of cost (e.g. dollars per payload pound to orbit, cost per flight, life cycle cost, net present value/internal rate of return, and many others.) A general problem in employing these metrics has been a lack of specific definition and understanding of the terms, and, in particular, their dynamic interrelationships.

The X-33/RLV program emphasis was placed on reducing recurring cost. However, there are other non-cost metrics such as high reliability, quick call-up availability, etc. which are valued more highly by some stakeholders than lower recurring cost. Additionally, the different definitions of cost and other responsiveness metrics sometimes work against each other. The next section provides a discussion of some of these countervailing forces and their ramifications within the X-33/RLV program.

RECONCILING COMPETING FORCES

The X-33/RLV program provides valuable insight regarding the ways in which responsive space access may or may not be achieved. As discussed below, the RLV program focus on the single measure of 'cost per flight/payload pound to orbit' ("It's the OPS, Stupid"), and its direct corollary, rapid turnaround, worked in opposition to some of the key needs of the industry team who were developing the system. It also worked against the inclusion of the full range of users of space transportation, such as the DOD. The market, economic, management, and technical forces which bear on a program must be viewed as an integrated whole, with forces from each area impacting and being impacted by forces in other areas. This section provides a sampling of the types of market, economic, management, and technical forces that were at odds and the difficulty in achieving a converged solution. While presented in separate discussions here, strategies geared toward producing a responsive system must be developed and accommodate the integration of each of the forces.

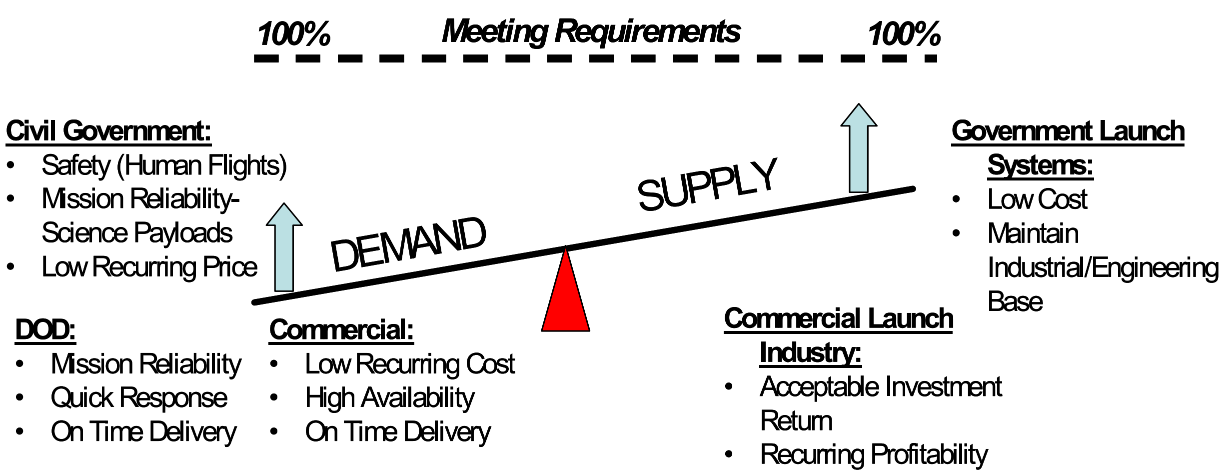

Figure 3. Stakeholders Responsiveness Definitions

Market Forces

The nature of a reusable launch system (where utilization, i.e. flight rate, is a key factor in recurring cost per flight) necessitated maximum capture of all accessible markets. In a traditional business case, the target number of flights per year would be derived by balancing market size, market share, turnaround time and number of flights needed to reach the price range. In this case, it had to be balanced with the flight rate or frequency of use needed to close the business plan, similar to commercial airplane usage.

Market forecasts were a driving force behind many of the strategic decisions made on the X-33/RLV program. Assessing the conflicting market forces, then developing a credible forecast and market capture had critical implications on the technical system design, operations concept, development costs, pricing strategies and, finally the overall credibility of the business plan. At the time of the X-33/RLV award in 1996, the total annual launch market was divided into four segments:

1) The global commercial satellite market (approximately 25-35 launches);
2) The civil government unmanned market (approximately 5 flights);
3) The government human spaceflight market (7 flights to supply the International Space Station); and
4) The DOD market (approximately 5-8 flights.)

While this represented a relatively small market from which to pursue a significant market share, optimism reigned with the prospect of new satellite concepts comprised of constellations numbering tens to hundreds of satellites. During the 1996-1998 timeframe multiple industry forecasts projected over 1200 commercial satellite launches within the next ten years. This growth scenario fed more optimistic projections that would be enabled if the price of launch could be dramatically reduced.

While the commercial market potential seemed more than enough to justify the business case assumptions, the investment community was very skeptical of the huge projected change in market activity. Consequently, to reduce market risk to an acceptable level, very conservative market growth assumptions were made which included a balance of commercial and government users. These assumptions, however, had their own set of conflicts as the scientific market was inconsequential and the DOD market would be largely served by the newly developed EELV's. That left the cargo and crew delivery missions to the ISS as the primary set of government target missions.

NASA's goal was to supply the International Space Station using a new vehicle that would reduce the operational transportation costs for the Agency. However, the ISS was still midway through its construction phase. NASA was reluctant to incur any additional costs to the ISS program to accommodate a new vehicle, despite the fact that it would eventually be cost effective when considering recurring costs. A new vehicle, for example, might require more frequent supply fights, new rendezvous equipment or procedures, etc. Even more critical, however, was the resolution of safety requirements to accommodate human spaceflight and identifying a funding source to cover the associated costs. It was also clear that simply mimicking the Space Shuttle procedures and capabilities would jeopardize the cost-effectiveness of the new system. Complicating the situation further, the investors' desire for the government to make an up-front commitment to utilize a new vehicle (before development had even been initiated) would represent a major change in government policy. The government was not willing to commit without a significant commitment by the investors, creating a classic "chicken and egg" situation.

Market Conclusion: Taken together, designing and operating a system which met the needs of the investment community while including all potential market segments proved unattainable. Ultimately, some tradeoffs among stakeholder requirements was necessary to formulate a viable program.

Economic Forces

Competing requirements surrounding two primary economic forces collided within the program. In summary they were:

- The definition of an economically "good business deal", and
- The definition and standardization of the measure of risk.

NASA's primary goal of the X-33/RLV program was to reduce their cost to $1,000 per payload pound to orbit. More specifically, the goal was to obtain a space transportation system which provided them a low recurring cost to orbit while utilizing substantial private investment to acquire the system from industry suppliers. In the longer term, lower recurring cost would free budget for other NASA activities, but restricted nearer term budgets made direct NASA investment difficult, if not impossible. The X-33 was intended to reduce the technical risk associated with developing the RLV system, and, to a lesser extent, reduce the investment risk by demonstrating the ability of the team to predict the development costs.

NASA's twin goals of low recurring cost and minimal direct U.S. Government investment ultimately worked in opposition to the goals of private industry. Private investors, regardless of any affiliation with the aerospace industry, generally required low investment risk from at least three primary perspectives — market, cost, and technical. In addition, based on the relative financial attractiveness of alternative uses for the investment monies, industry required discounted rates of return on cash flows at or above 20%.

NASA's economic return from a successful RLV system was primarily cost avoidance. They expected to save money by paying less for space transportation services provided by the new RLV as compared to the existing systems. Industry's return consisted of the net positive cash flow generated from operating revenue, less recurring costs. In short, the situation was such that NASA's low cost equated to industry's low revenue. NASA had conducted studies on future space market growth elasticity, and believed that $1,000/pound could be a level that would enable dramatic market growth. However, data credibility was brought into question — at least from the eyes of the private capital markets. Consequently, investors would only accept a revenue model consistent with gradual evolution of the current market forecasts.

An industry decision to provide the initial investment would only occur if the program showed an acceptable economic return for the investment. While not the only measure, private investors generally utilize Net Present Value (NPV) (or, alternatively, Internal Rate of Return (IRR)) as the primary investment metric for determining worthiness. NPV or IRR is obtained by performing a discounted cash flow (DCF) analysis of the cost and revenue streams for the program. By its nature, DCF highly values nearer term cash flows. The combination of the size of the RLV investment (more than $5B), the length of time from initial investment to the beginning of positive cash flow (at least 4 to 5 years), and industry's discount factor/hurdle rate (20% or more) drove a need for relatively high revenues early in the program to meet industry's NPV/IRR requirements. Figure 4 shows the net positive cash flow required to justify a $1 investment at 10% and 20% discount factors as a function of time. As the discount factor is larger, the required cash flow grows at an increasing rate over time. For example, at a discount rate of 20%, a dollar invested in the first year of the program would require a $3.00 net positive cash flow in 7 years (the second year of revenue generation), and net positive cash of over $5.00 in 10 years. Since net positive cash flow is essentially equal to revenue less operations cost and debt service, the effect put significant upward pressure on prices to meet industry's NPV/IRR requirements. Investors required higher revenue, which equated to higher recurring cost for NASA. The primary economic goals of the two stakeholders were working at cross purposes.

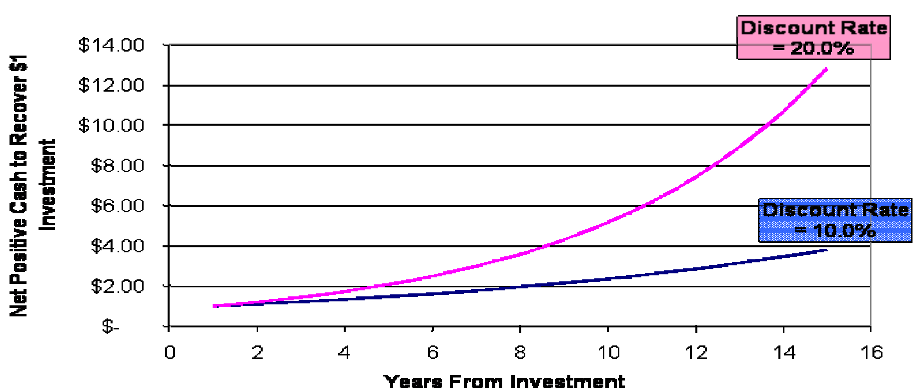

Figure 4. Net Positive Cash required to recoup investment of $1

Several mitigating alternatives were considered. Tax breaks for industry investors served to reduce cash-out during investment, but only to the extent that the investors had sufficient alternative income to take advantage of the reduced cash-out paid for income taxes. While potentially useful to larger corporations, this alternative offered little to startup entities. U.S. Government loan guarantees became a favored investment mechanism as a source of investment cash. The use of a government loan guarantee as an investment instrument (as opposed to a "bailout") was a difficult concept to convey. With the guarantee, private lending sources became available which would not have otherwise been so given the risk level of the program. Additionally, the government guarantee would make the funds available at relatively lower interest rates. However, this option also had difficulties. Specifically, this meant an interest rate of approximately 7% with loan guarantee (compared to a non-guaranteed rate of approximately 13% or more, if that money were even accessible.) For a $5 billion program this translated to almost $1B in interest that had to be added to the development costs of the program. Upon commencement of revenue-generating operations, the loan was due to be repaid by the RLV venture. The magnitude of the loan made its repayment (up to $1B per year) a significant drain on cash during the first several years of operations, even at the low interest rates. This served to substantially weaken the economic viability for investors utilizing DCF metrics to measure financial goodness. In addition, the presence of such a large loan on the balance sheet, coupled with recognition of the initial $5B+ development cost as losses, and the substantial dollar value of the reusable system's fixed assets (vehicles and infrastructure), left the company with negative net worth for up to 8 or more years of operations depending upon the scenario.

Another example of competing requirements was found in the evaluation and mitigation of risk. The X-33/RLV program faced substantial risk in three primary, inter-connected areas: technical, cost, and market. The X-33 program was designed to retire technical, and to a lesser extent, cost risk to a level acceptable for initiating development of the operational system. Although methods exist to quantify certain types of risk, perception of overall risk is generally qualitative. While helpful in reducing technical risk, the X-33 program could do nothing to mitigate market risk. Because of the high investment requirements, the reduction of cost risk was minimal relative to a level which would be acceptable to private investors. As the program progressed, the levels of technical traceability, scalability, and transferability from X-33 to VentureStar™ became less. Taken together, the projected levels of technical and cost risk at the end of the X-33 program were potentially high relative to the levels acceptable to most private investors, and market risk remained unaddressed.

Perhaps the most tangible evidence of the differing definitions of acceptable levels of risk was found in the pursuit of vehicle, or "hull" insurance. In exploring the cost to insure the operational RLV vehicles, it became clear that potential insurers viewed the overall combination of cost, technical, and market risk as high. The premium cost per flight to insure a vehicle was too high to accept and still close a business case. Insurability of assets became a reasonable way of objectively quantifying the overall system risk when viewed from the perspective of an important stakeholder, the insurance community. Insurers considered risk in its entirety, including not only technical, but non-recurring *and* recurring cost, and market. The primary concern was the system's ability to sustain sufficient revenue flows in the event of adverse circumstance, be they induced by technical, market, or cost forces.

Economic Conclusion: Program expenditures must be considered as an integrated whole, including both the non-recurring and recurring portions. Focusing on a single portion without consideration for the whole results in conflicting goals among stakeholders. In the future, the levels of investment and expected benefits for all stakeholders should be closely matched. Identifying a specific goal (e.g. $1,000 per pound) should be tempered by the investment return requirements of industry, or adjustments in the government to industry investment ratio. More specifically, given the differing goals of the stakeholders and the probable magnitude of levels of required investment (particularly for reusable systems), the development of a new space transportation system will most likely require significantly more direct U.S. Government investment than was postulated for the X-33/RLV. While tax breaks and loan guarantees can still play an important role, direct U.S.

Government investment as a greater percentage of the total investment will most probably be necessary to enable the development of a new space transportation system responsive to the needs of all stakeholders.

Technology demonstration programs can serve a useful purpose in mitigating some of these risks, but probably not all. Additionally, the definitions and levels of "acceptable" risk may vary between stakeholders. These differences should be understood, and as much as possible, quantified or defined in terms specific enough such that their reduction relative to all definitions can be measured.

Management Forces

Many intricate, interwoven management forces are at work in a large, complex undertaking such as X-33. Two forces, in particular, which came into conflict during the program were:

- The equal partnership nature of the Cooperative Agreement vs. unequal prioritization of the program among partners.
- The length of time required for system development vs. changing stakeholder requirements,

The practice of 'partnering' can have significant advantages over the traditional subcontractor relationship under certain conditions. In theory, it is expected that financial risk will be spread across multiple organizations thus easing the burden on any single organization. The reward for risk sharing is an equity position in the enterprise with a proportional return of enterprise profits. In reality, there is an additional criterion necessary to ensure success of this arrangement -- the risk to each parent organization must be about equal. The organization that is disproportionately invested in the enterprise will be much more motivated to see the project through to the end as compared to an organization with a small share…especially if the minority partner's share is also small compared to the minority partner's total business base.

Contraction in the aerospace industry during the 1990's aggravated the problem of the program's priority within each teammate's organization. All four of the teammates, Allied Signal, Rockwell/Rocketdyne, Rohr and Sverdrup were acquired by other companies during the course of the program. One of the acquiring companies, Boeing is a direct competitor to Lockheed Martin in the space launch business. If the enterprise is low risk and the development goes smoothly, there is no issue. On the other hand, if a high-risk development program experiences unanticipated overruns, it is generally the partner with the most to lose who ultimately finances the overrun of any partner. This situation can eventually negate the originally expected advantage of partnering. Rohr (now BF Goodrich) and Sverdrup (now Jacobs-Sverdrup) were both faced with their aerospace business becoming a much smaller part of a larger whole.

From a technical risk perspective, the use of a novel contracting mechanism such as a Cooperative Agreement might not have been the most suitable for the development of flying vehicles--particularly X vehicles. Industry and government alike have long viewed firm fixed price development efforts as too risky for industry to bear. Aircraft development typically extends into years. As project duration extends, overruns become more likely and more expensive. The government viewed the Cooperative Agreement as a fixed price investment with any additional funding to be provided by industry. While industry partners had minimal contractual termination liability under the Cooperative Agreement, high program visibility made termination an unattractive prospect for those members who assigned a high priority to successful project completion, while those for whom X-33 became a lower priority had less motivation to continue with the high risk, long term venture.

Despite the fact that NASA proposed an 'insight' rather than 'oversight' role, after several visible NASA failures on Mars missions and as the launch date neared, there was a definite cultural change that resulted in a much more risk-averse environment. The development of a new flying vehicle is a very high profile activity. Association with a failed launch would be embarrassing and potentially harmful to the space program. Some in the institution could not resist the temptation to revert to its traditional risk-reduction techniques — more oversight, many more reviews, and even late design changes to the system — a costly process.

Management Conclusion: In the business world, forging long term partnerships can be difficult indeed. They require new management processes, different chains of command and strong leadership to ensure that all involved in the partnership are moving in the same direction. The participation of the government made X-33/RLV more than a traditional business partnership in a variety of ways. The industry-led team inherited many unexpected stakeholders in the form of government agencies that are traditionally managed by the government program office. Luckily, most these offices were enthusiastic and helpful. The teammates experienced major industry consolidation, resulting in a change of management of all the industry partners between 1996 and 2000. In addition to the internal changes in priority and culture, the industry-led partnership required a change in behavior of a partner that was also a primary customer. Both sides were trying hard to adapt to new rules governing the program. To add to the pressure on sustaining the relationships, the external forces were rapidly evolving, creating major changes to the business environment around which the program was predicated. The satellite telecommunications industry went from its greatest growth forecasts to overcapacity, and the new satellite LEO constellation systems failed to attain their business objectives and declared bankruptcy. Long term partnerships are difficult to sustain in the best of times, but with so many parameters changing at the same time, it became difficult for all parties to maintain the level of commitment they had for the program in its inception.

Technical Forces

In conjunction with previously discussed premises of the program, the goal of the development team was to:

1. Establish a Concept of Operations (ConOps) that allowed for high flight rate with low recurring costs,
2. Design a vehicle that supported the operating concept,
3. Minimize development cost in accomplishing the first two goals.

In theory, minimum development costs could be achieved by designing a vehicle using only today's technology — in essence, developing nothing new. Ideally, the team could strive to obtain off-the-shelf components and arrange them into a vehicle that supports the ConOps, and expend no resources developing new technology. Unfortunately, the development of an aerospace vehicle is rarely accommodated by such serendipity. More likely, there exists a design-space continuum which combines the current technology with a series of newly developed technologies to produce optimal results.

The task of the X-33 program became an exercise in deciding which technologies deserve the attention of precious non-recurring development dollars. This took the form of a continuous reexamination of technologies and refocusing of resources as the designs of the X-33 and RLV matured. In this context the Cooperative Agreement was, for the most part, an excellent contracting tool that provided a relative high degree of flexibility in redirecting the program. However, stakeholders outside the program viewed the technical objectives and their relationship to the Cooperative Agreement very differently. The misunderstanding that technical objectives would only be adjusted if they were *unachievable* as compared to *unnecessary* was a major hurdle in capitalizing on this inherent advantage. Their differing perceptions directly conflicted with the incorporation of adjustments to the X-33 program goals. This section addresses some of the conflicts in requirements that inhibited the development process.

<u>The ConOps</u>

Low recurring costs could only be achieved by minimizing the pre-flight and post-flight processing activities. Taking a lesson from many years of aircraft flight experience, the processing activities were minimized by maximizing reusability while reducing vehicle stacking and reassembly tasks. Of course, vehicle losses due to airborne failures would also drive costs to unacceptable levels, so system and subsystem reliability became a paramount goal. The ConOps reflected the RLV approach to minimization of processing activities.

Using the principles defined in the ConOps, top level vehicle characteristics were derived and incorporated into the vehicle design. These were:

- Minimize the number of vehicle subsystems;

○ Servicing and repairing a variety of subsystems takes time, money and a labor force with numerous specialized skills.

- Maximize subsystem robustness;
  Fragile subsystems require substantial effort to maintain in a flight ready condition — numerous checks before flight and numerous repairs after flight. Furthermore, mission planning efforts are reduced by eliminating the multitude of variables associated with numerous subsystems and by taking advantage of the expanded flight envelope stemming from the robust designs.
- Minimize staging events;
  The reassembling of stages prior to flight is a delicate and crucial operation. Utmost care must be applied to ensure a high rate of success. Stacking usually requires significant infrastructure which in itself must be verified and maintained. All these activities are labor intensive and prone to human error.

Given the above list of vehicle characteristics, the program allocated appropriate resources to developing the technologies necessary for implementation into the design. A top-level abbreviated list follows:

- Metallic thermal protection system;
  Robust design utilized mechanical attachment, large degree of commonality, and tolerance to foreign object impact.
- Non-gimbaled robust engines utilizing differential thrust for directional control;
  The XRS-2200 linear aerospike engine was developed in record time and allowed access to components for relatively easy removal and replacement when need. Multiple reuses between overhauls and phased depot maintenance was the hallmark of this design.
- Electro-mechanical actuators;
  Electrically driven control surface actuators would allow the elimination of the maintenance prone hydraulic subsystem and its associated auxiliary power units.
- Simplified reaction control system;
  Non-toxic propellants significantly reduced ground servicing complications.
- Vehicle integration and dual-use structure;
  Composite structure and structure serving multiple purposes helped bring the mass fraction into the desired range.

In general, the above list was evaluated in light of the economic breakeven point or against other non-economic requirements e.g. safety. Many other technical advances have been documented elsewhere, and are outside the scope of this paper.

As the program progressed, conflicts surrounding stakeholder requirements began to emerge. This point is best illustrated by considering the circumstances surrounding the weight growth of the X-33. Weight is a fundamental parameter of all aerospace vehicles and under normal circumstances must be stringently controlled. The X-33 weight growth problem presents an opportunity to examine conflicting forces within the program. This point is best illustrated by examining interrelationship between weight and:

- The development of the composite tank,
- The top speed requirement specified in the Cooperative Agreement, and
- The flight-to-flight turnaround time specified in the Cooperative Agreement.

Composite Tank Development

Like most vehicle development efforts, the weight showed an upward trend as the vehicle matured. Generally, a weight control program would be instituted to keep weight from adversely affecting program performance or cost goals. However, a one-of-a-kind technology demonstrator program would realize little or no payoff expending recourses to reduce weight — except to mitigate a possible public perception problem.

The preliminary RLV design incorporated composite cryogenic tanks as a key enabling technology. Since the tanks comprise a major percentage of the total vehicle mass, it was originally thought that this technology would be necessary to provide the weight efficiency to meet the stringent mass fraction requirements. Thus, the original X-33 proposal included the development and use of composite cryogenic tanks. However, during the first three years of development, advances in aluminum metallurgy (e.g. friction stir welding and aluminum-lithium fabrication techniques) outpaced the composite tank developments. The individual composite tank (unit weight) came in slightly less than the weight of an equivalent aluminum tank. However, the total system weight was actually higher after integrating the composite tank into the vehicle as compared to an integrated aluminum tank. Other material advantages offered by composites failed to offset the inherent disadvantage of the higher risk technology. The RLV design team eventually abandoned the high risk composite tank (investors demand low risk) for the more familiar and predictable aluminum tank. It should be noted that the decision preceded the X-33 composite tank test failure by several months.

Although several technology development efforts were abandoned after their traceability to the RLV had eroded, the composite tank remained wedded to the X-33 for two reasons. First, some in the government technical community believed the composite tank development was justifiable on several levels — not merely as an X-33 component. Second, the development effort required a large expenditure of resources. When the composite tank eventually failed to pass its final acceptance test, funds were no longer available to design and build a metallic replacement.

Top Speed Requirement

During the development phase of any cutting edge aerospace vehicle, the vehicle characteristics and design requirements will change as the stakeholders learn more about the needs of the customer, state of the technology, resources available, and capability of the design and manufacturing team. This is a normal maturation process associated with all cutting edge development efforts. Recognizing this fact, the X-33 contracting agency fashioned the Cooperative Agreement to accommodate this need. The flexibility to readily modify the vehicle requirements/specifications was a benefit of the Cooperative Agreement. These changes could take place without the rigidity of a formal contract change process necessary to update a traditional contract.

The original purpose of the X-33 was to demonstrate the technologies that would be used to produce the follow-on operational system. Unlike most traditional contracts, the Cooperative Agreement dictated very few performance requirements. One exception was the minimum top-end speed requirement of Mach 15. Most aerospace procurements embark on a detailed operations analysis to determine the most suitable vehicle speed necessary to ensure successful operations. This requirement is usually governed by some operational need such as survivability, attaining low earth orbit, or economical ton-mile operations. The X-33 speed requirement, on the other hand, was not influenced by externally driven operational needs. The X-33 needed to reach a speed necessary to test the various subsystems such as thermal protection and main propulsion systems. But what speed was that? The speed specified in the RFP was used to compare different vehicle concepts during proposal evaluation. However, the speed necessary to validate the TPS is dependant upon the vehicle shape and TPS material properties. Nonetheless, the Cooperative Agreement specified the top speed at Mach 15 without full knowledge of the vehicle shape. For the most part, however, the design team maintained the ability to modify the vehicle characteristics in whatever manner necessary to achieve the ultimate objectives—proving and demonstrating various technologies for use in the RLV.

As the design matured and the vehicle weight climbed past the intended target, vehicle range and speed capability showed a corresponding decrease. Weight growth was mainly (but not solely) attributed to parallel design activities necessitated by the fast-track development process. The question under consideration was "can the X-33 meet the flight test objectives by flying at a slower speed?" The answer was "yes". The X-33 was only intended to validate the parameters matching the reentry environment – not an arbitrary Mach number. Together the partners agreed to replace the Mach 15 requirement dictated by the Cooperative Agreement with a more meaningful requirement. In short, the program simply could not justify implementing an expensive weight control program to reach a speed goal that was not absolutely mandated by the scientific or operational objectives.

However, some stakeholders viewed a Cooperative Agreement no differently than a traditional contract between a customer and supplier. Any change in the top end requirements was perceived as "the contractor failing to meet the objectives." X-33 weight growth was perceived by some outside the program as a 'predictor of doom' for the much larger RLV— as was the absence of a composite cryogenic tank.

Although scientific and programmatic justification can be found for modifying requirements, management must proceed with caution. What seems to be a perfectly logical decision when viewed from within the program can sometimes be perceived as a failure by stakeholders outside the program.

Turnaround Time

Another example of competing technical goals was the program goal of developing a vehicle capable of rapid flight-to-flight turnaround. A flight-to-flight turnaround time of 7 days (or less) was a primary goal of the X-33/RLV program. Quick turnaround would lead to a higher flight rate capability for the system, which would drive down recurring cost. Shrinking market forecasts coupled with the need to "self insure" by acquiring more vehicles than were required to fly the forecasts, reduced the need for such quick turnaround. While the system had the capacity to turnaround in seven days, the mission model did not require it. Other technical attributes, such as longer design life, became more useful to the economic viability of the program. While the promise of significant new markets emerging as a result of lower transportation costs was recognized, in fact investors would not risk large sums on an "if you build it they will come" market forecast. In addition, designs for quick response military systems were not readily adaptable or evolvable to commercial and NASA uses. The design decisions resulting from the turnaround goal added to the system weight and investment price tag. As a result, the X-33 program was pursuing a technical goal which drove design decisions that created a system which was ultimately in conflict with many of the attributes needed to meet stakeholder requirements.

Technical Conclusion: The initial challenge presented to the design team was the conceptualization of a Concept of Operations that satisfied the program economics. The fast paced development program required parallel activities that shortened the design period, reduced costs, and inevitably increased risk. The team predicted the technologies that could reasonably be expected to mature within the specified time and budget allocations. Most of these technologies were developed and integrated into the vehicle design (e.g. linear aerospike engines, metallic thermal protection system etc.) One technology originally predicted to be crucial to the success of the future RLV, the cryogenic composite fuel tank, was eventually found to be at a low Technology Readiness Level (TRL) and unnecessary for the RLV design. Unlike many previous development programs, the X-33 design team was able to quickly modify the vehicle requirements and characteristics as the technical justifications arose. However, this unusual flexibility could sometimes be misinterpreted by stakeholders outside the program resulting in significant damage to the program.

In summary, the market, economic, management, and technical forces which sometimes oppose one another must be resolved before a truly responsive space transportation system can be developed. The following section offers some strategic approaches for resolving these differences.

STRATEGIES FOR ACHIEVING RESPONSIVE SPACE ACCESS

Based on these lessons, effective strategies for achieving responsive space access must choose one of two paths, either make compromises in goals to satisfy at less than optimal levels the needs of disparate stakeholders, or identify a subset of stakeholders with like needs and attempt to focus on those needs at the expense of the wider stakeholder community.

Market Strategies

The market goal of the X-33/RLV program was two-fold: 1) to design a pricing strategy that achieved a high enough market share to attain the revenue required in the business plan, and 2) to set a price point low enough to enable new market growth. While industry was focused on the first goal, NASA had a strong interest in the second. However, both of these goals created conflict with the investors who wanted to maximize profit at the earliest possible time.

In order to balance both of these objectives, the recurring costs have to be low enough to achieve acceptable levels for each of these stakeholders.

As a precedent for this, one only needs to look at the current situation for expendable launch vehicles and even the Space Shuttle. In fact, when flying commercial payloads on the Space Shuttle was considered, the pricing to those customers was based on margin costs for that particular flight, rather that the true recurring costs of the flight. This can be accomplished by either focusing on particular market segments that enabled a much less costly vehicle to be developed, or as has been done with all launch vehicles in the past, some or all of the development costs would need to be forfeited and the pricing could then be based on recurring costs.

Economic Strategies

Pursuit of a single economic goal, in the case of RLV low recurring cost, may not, by itself be justified. In the X-33/RLV situation, the low recurring cost to users did not justify the high investment and risk. Viable future strategies will most likely involve a compromise of countervailing requirements, such as higher recurring for lower investment; higher turnaround times for lower investment; larger vehicle size for lower utilization factors, or different systems for different uses.

One promising strategy to meet the competing requirements is to utilize the potential difference between the relative value government and industry place on the time value of money. There is evidence to suggest that discount factors, or hurdle rates, acceptable to the U.S. Government and industry may be different. Based on our experience, a typical range of hurdle rates used in capital budget decision making by private industry is 20% to 25%. There is evidence that the government is willing to accept lower hurdle rates. As an example, in a General Accounting Office report on the EELV program, the GAO used "the real discount rate of 3.7 percent, adjusted for forecasted inflation, based on marketable Treasury debt with maturity comparable to that of the EELV program", (GAO/NSIAD-98-151, page 19). By our calculation, that equates to an effective discount rate of approximately 7%. OMB Circular A-94, "Guidelines and Discount Rates for Benefit-Cost Analysis of Government Programs" states that a 7% discount rate should be applied to constant year dollars.

This difference can be used to equalize economic "goodness" to both government and industry investors. Looking at the key variables of total non-recurring investment, investment share between government and industry, and recurring price and cost, ordered pairs of price per flight to the government (revenue for industry) and percent investment share from each can be calculated that result in each getting equal NPV at their respective discount rates. Then, taking into account other factors such as available investment funds, risk, etc., investment and pricing strategies can be developed which meet the needs of both stakeholders. The key is to avoid focusing on single parameters without consideration of countervailing requirements of other stakeholders.

The following simple example illustrates the idea. Assume a space transportation system with the estimated following parameters:

- Non-recurring cost = $5B
- 5 year development
- Recurring cost = $500M per year with capacity up to 20 flights per year (minimal variable cost)
- Alternative U.S. Government transportation cost = $2,500M per year
- 10 Flights per Year
- U.S. Government discount (hurdle) rate = 7%
- Industry/Investors discount (hurdle) rate = 20%
- Recurring price and investment share To Be Determined

(Note: These numbers are for illustrative purposes only and do not reflect any specific systems or scenarios.)

Figure 5 summarizes the scenario at an investment split of 75% government, 25% industry and a price per flight to the government of $165M.

Year	Total Investment	Revenue*	Recurring Cost*	Profit	Total Net Cash In (Out)	USG Alternative Cost	USG Net Cash In (Out)**	Industry Net Cash In (Out)**
1	$ 800				$ (800)		$ (600)	$ (200)
2	$ 1,100				$ (1,100)		$ (825)	$ (275)
3	$ 1,200				$ (1,200)		$ (900)	$ (300)
4	$ 1,100				$ (1,100)		$ (825)	$ (275)
5	$ 800				$ (800)		$ (600)	$ (200)
6		$ 1,650	$ 500	$ 1,150	$ 1,150	$ 2,500	$ 850	$ 1,150
7		$ 1,650	$ 500	$ 1,150	$ 1,150	$ 2,500	$ 850	$ 1,150
8		$ 1,650	$ 500	$ 1,150	$ 1,150	$ 2,500	$ 850	$ 1,150
9		$ 1,650	$ 500	$ 1,150	$ 1,150	$ 2,500	$ 850	$ 1,150
10		$ 1,650	$ 500	$ 1,150	$ 1,150	$ 2,500	$ 850	$ 1,150
11		$ 1,650	$ 500	$ 1,150	$ 1,150	$ 2,500	$ 850	$ 1,150
12		$ 1,650	$ 500	$ 1,150	$ 1,150	$ 2,500	$ 850	$ 1,150
13		$ 1,650	$ 500	$ 1,150	$ 1,150	$ 2,500	$ 850	$ 1,150
14		$ 1,650	$ 500	$ 1,150	$ 1,150	$ 2,500	$ 850	$ 1,150
15		$ 1,650	$ 500	$ 1,150	$ 1,150	$ 2,500	$ 850	$ 1,150

* 10 Flights per Year
** Investment Split = 75% USG / 25% Industry

Figure 5. Balance Economic Strategy Example

In this scenario, the overall program IRR is 12.4%, which is sufficient to satisfy the government stakeholder (with a hurdle rate of 7%,) but not industry (with a 20% hurdle rate.) Utilizing the differential between the stakeholders' hurdle rates, alternative solutions can be achieved which satisfy both parties while spreading the burdens of investment cost and risk. By varying these parameters, discounted cash flow analyses can be performed to determine the set of ordered pairs of recurring price and investment shares which result in positive NPV's for both government and industry. In essence, the ordered pairs represent program strategies which are "good" for both parties. Using the example, Figure 6 shows graphically sets of ordered pairs of percent investment and recurring price per flight at which the NPV for both parties is equal when discounted using their respective hurdle rates. In the example, if the government wishes to pursue a price per flight of approximately $150M, they should expect to invest 90% of the development cost. Alternatively, if the government has $3B available for non-recurring investment (60%), they should expect to pay a recurring price per. flight of about $180M if they hope to attract private investment.

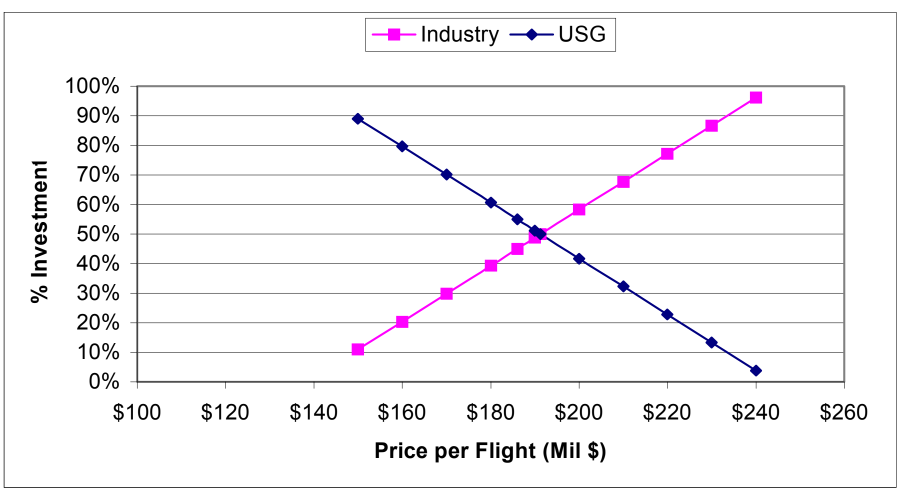

Figure 6. Price/Investment Pairs Resulting in Equivalent NPV

Admittedly there are several other factors which will affect strategic development. But the general concept of integrating the economic requirements of the stakeholders in a manner such as shown in this example will go further towards enabling development of responsive systems than focusing on single goals.

Management Strategies

While bold new ideas and initiatives do require new management approaches, this must be examined within the context of all the overall goals. It is likely that implementing large programs with multiple partnerships does necessitate cultural changes to be successful. The management structure needs to be reevaluated at different times in the program when significant changes occur, whether they are from the external environment, the technical aspects of the program or as a result of ensuring each of the stakeholders gets the best business deal possible. The aerospace community has a cultural heritage distinguished by a hierarchical relationship between government and industry and prime/subcontractors. If one were to examine the business/partner structures of the Information Technology industry, it would appear much more of a horizontal structure. In moving forward, the management organization and partnerships should be scrutinized and assessed as much as other elements of the program.

Technical Strategies

The overarching principles of low costs and reliability are the cornerstone to achieving responsive access to space. Appropriate attention to *requirements* is one of the most crucial and fundamental contributors to program success. Indeed, the last half century has witnessed many aerospace projects falling victim to the dreaded 'requirements creep' phenomena. However, when building toward responsive space access within a commercial model, the problem is more likely one of 'conflicting' requirements. Requirements must be thoroughly refined and consistent before beginning the design or development process in earnest. Use of high risk (i.e. low TRL) technology should obviously be kept to the absolute minimum. However, use of a low TRL technology is often the only answer to critical design issues. The use of a technology demonstrator can help raise the TRL and build stakeholder confidence. A prototype can also be used, but since it is intended to mimic or model the final vehicle to much higher fidelity, it often burdens the pathfinder vehicle with too much uncertainty. Furthermore, many stakeholders fail to understand the difference between these types of vehicles and therefore mistakenly interpret their results. And finally, in today's risk averse environment, the program should be funded and structured to complete the vehicle design and manufacturing in about 4 years. Programs that extend past this period of time are less likely to succeed due to the inevitable changes in the business, political and technical environment.

CONCLUSION

Over the course of the X-33/RLV program, it became clear that the singular focus on lowering recurring cost needed to be broadened to include other measures of responsiveness held by other stakeholders. The high investment, coupled with the high technical development risk, was not responsive to the requirements of potential investors, both public and private. The RLV suffered from a definition of responsiveness which was too narrow and did not include metrics necessary to satisfy all stakeholders. As the RLV program found, to be effective, the first step in developing responsive space access is to identify the definition of responsiveness held by all stakeholders. It appears unlikely that any new vehicle can be justified solely on the basis of economics alone. Some additional metrics must be valued highly enough to justify the costs.

As alternative strategies are developed for achieving responsive access to space, it will be imperative to their success that the strategies be founded in an understanding of the metrics by which responsiveness will be measured by all stakeholders involved. It will require choosing proper metrics to provide targets for focusing resources so that the strategies can be realized.

The X-33 /RLV program represented a bold initiative to create a sea change in the world of space transportation. It tried to leverage the compelling circumstances of technology readiness, a robust economy, industrial efficiencies, and a growing marketplace to transfer what had been a traditional government function to the private sector. In doing so, however, there were more stakeholders than would be the case if a product were to be developed solely by the government or solely by industry. This, coupled with the unanticipated environmental conditions that were changing rapidly impacted the basic premises of the program. Nonetheless, there were a number of lessons learned that are valuable to any decisions in moving forward. At least in the foreseeable future there will be a need for both government and industry to be involved in the development of the next generation space transportation systems and how we work together will be pivotal to the success of developing truly response systems for the 21st century.