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LEARNING FROM THE X-PRIZE EXPERIENCE

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Abstract

For several decades the space industry has dreamed of developing a reusable launch vehicle (RLV) to provide low cost access to space for human crews. Although governments traditionally sponsored these development initiatives, in 1995 a group of private investors decided to encourage development by private industry of a RLV by offering a monetary award. Aside from the obvious scientific and engineering challenges, these teams also face various non-technical challenges. Teams encountered their biggest initial non-technical challenge when seeking funding. Contest rules require competitors to secure non-governmental sponsors. To attract private investors and sponsors teams must convince them not only of the potential for success of their particular project but also that ultimately the vehicle will find a viable commercial market. Once able to develop prototypes for testing, teams must work with governmental regulatory agencies to obtain launch licenses for unproven vehicles that will ultimately carry crews. The new safety and liability issues raised by the presence of crews and the lack of governmental participation in the development raises a series of new challenges for licensing agencies. A quick review of the current experiences of participants and government officials involved reveals insights into the development of the commercial RLV industry.

Introduction

Since the inception of space programs governments and companies have envisioned the development of a completely reusable launch vehicle (RLV) that would enable frequent and reliable human space travel. Despite the recent high profile space adventures of a few private citizens, human space travel has not advanced significantly in the past few decades. Currently all human space flight occurs using the United States (US) Shuttle craft or Russian Soyez rockets; both vehicles entered into use several decades ago* and are only partially reusable. The extremely high cost per launch for these vehicles stagnated above the predicted price partly because both vehicles use expendable rockets that must be replaced or refitted prior to every launch. Also, due to the suppressed demand for launches at the current price, the economies of scale once anticipated for these space vehicles cannot be achieved.

To develop an economical alternative several countries actively support RLV development projects. For example in the US the National Aeronautical and Space Administration (NASA) participated in endeavors with private companies, military organizations and other countries to develop the numerically identified X-vehicles. The European Space Agency (ESA) began gathering support for its RLV program, Future Launch Technologies Programme (FLTP), during the 1990s, but, unfortunately, key players Britain and Germany declined to

* The US shuttle Columbia first launched on April 12, 1982, and the Russian Soyuz craft was first introduced in 1967.

join.[1] Germany declined to join because it supports a national program, as well as collaborating with NASA and the ESA on the X-38 vehicle that would serve as a crew return vehicle for the International Space Station. All of these programs experience waxing and waning support due bureaucratic and political reasons.

As government efforts to design a RLV flagged during the 1990's, a group of investors in St. Louis, Missouri originated the X-Prize. They modeled the X-Prize after the early aviation monetary awards sponsored by wealthy industrialists and companies to reward innovators who overcame specific problems or built aircraft that accomplished milestone missions.[†] The X-Prize, a monetary reward of $10 million dollars ($US), encourages private aeronautical development teams to design, build and successfully test reusable launch vehicles (RLVs) that can carry a crew into orbit and be reused. Under the conditions of the competition, the winning RLV program must fly two successful test flights, and the second launch of the vehicle must occur within fourteen days of the previous landing. The RLV will carry one person and a specified amount of ballast (demonstrating a capacity for a minimum of three adults) to an orbit of 100km (62 miles) before touching down safely. Additionally no more than 10% of the vehicles non-propellant mass may be replaced between flights. The award seeks to promote the development and flight of spaceships able to provide low-cost commercial transport of humans into space.

Currently, 20 teams have registered to compete for the X-Prize.[2] These teams are from various countries, including the US, Canada and Great Britain. The various X-Prize entrants operate at different stages of the development process. Several of the teams have prototypes for testing various aspects of the vehicle, while other still seek initial funding. The few already working with prototypes are beginning the process of getting appropriate government licenses and permits for test flights of an unproven space vehicle. Because these vehicles rely on unproven combinations of technology and launch methods the governmental agencies must adapt their current launch approval methods to accommodate new situations and concerns. The experiences of the teams in or nearing the test phase reveal interesting insights about the non-engineering issues and challenges that currently affect the development of commercial space flight vehicles.[‡] The issues discussed herein include challenges to securing financing during

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[†] For example Charles Lindbergh won the $25,000 Orteig prize for his trans-Atlantic flight. Part of aviation's advancement and growth during its earliest years can be credited to the independent technological developments pushed by these awards.

[‡] Teams releasing current information about their projects originate in the US, Canada and Britain. While researching this paper attempts were made to contact these teams and several others. Teams from Canada and the US agreed to discuss their experiences; however, several requested that any information shared in the paper be kept anonymous. To respect their request no information is directly attributed to a specific team. Unfortunately, the British and Brazilian teams did not respond to inquiries for interviews nor do the governments make on-going licensing review information public, so the information and experience discussed focus on the experiences of Canadian and US teams. Several teams refuse to disclose any information including whether they are still actively involved in the RLV program. I would like to thank all the RLV development teams member who took time to talk with me and the government officials at Canada's LSO and the US's FAA who proved very helpful.

development, the licensing process and the current insurance situation. Finally, a few drawbacks and benefits of the X-Prize competition itself will be reviewed.

Financing for Development

Financing for infant industries often comes from the government, large financial investors or companies in related fields. The current X-Prize rules state that competitors are precluded from using a launch vehicle substantially developed under a government contract or grant.[3§] Entrants that receive direct funding, subsidies, grants of money, goods, or services from any government (or otherwise tax-supported entity) can be disqualified from the competition. Under this restriction participants in the contest must either make a strong case to the financing market for their vehicle to induce companies and investors to provide research and development financing or provide ample advertising opportunities.

Current Financing Status of Teams

The search for initial funding from private sources still dominates the project for many X-Prize registrants. Some teams seem to undergo funding drives in spurts to support particular portions of the development process, such as obtaining materials and skilled labor to build prototypes.[2] A few teams have begun promoting and even offering rides on their completed vehicle to attract funds.[2] Whether these financing difficulties reflect a dearth of financial sources or low confidence in the proposed plans that fail to secure steady backers remains to be seen. However, several teams have managed to overcome initial funding issues and appear to be able to proceed with development with adequate financial support.[2] Most of their acknowledged sponsorship comes from aerospace companies or other engineering or material suppliers. Undisclosed financing from investors may play a part in the private RLV industry, but until more information becomes publicly available this cannot be confirmed.

The Financial Case for Investing

An examination of the current demand for human space transportation and satellite launches reveals the challenges private RLV programs face in showing a future market for their product when soliciting investors. Historically, RLV developers envisioned enabling human space flight as the primary market for RLVs. However, the measurable market for crew transportation centers on measurements of the past and future needs of government space programs. Even if all government space programs began using a RLV for human space travel, these needs would not prove sufficient to justify private development. In the 1990's promoters of private RLV programs began promoting the use of RLV to launch non-geosynchronous orbit (NGSO) payloads with a specific focus on low-earth orbit (LEO) satellites. The satellite industry in the late 1990's anticipated a significant increase in the LEO launches needed per year. Unfortunately, recent developments in the satellite industry have adversely impacted the anticipated market for RLV services.[**] The limitations of these measurable markets force private RLV programs to rely on the development of a commercial space tourism industry.

Government-procured launches for human crews have high actual and opportunity cost because most government space agencies work within the constraints of a limited budget. Governments initially

§ The current rules are considered tentative and will be confirmed once all funding of the $10 million dollar prize has been secured.

** Specifically the LEO launch market was adversely impacted by the demise and down-sizing of several LEO satellite communications systems.

began developing RLVs anticipating that economies of scale and being able to amortize the cost over numerous yearly flights would reduce the cost of launches to a fraction of their current price making research in space more budgetable. Even though several governments directly finance development of their own RLV, investors and developers of private RLVs believe that governments could be induced to use a private RLV provider or purchase a privately designed RLV to meet crew launch needs if the RLV achieves the cost per flight goals.

In fact, the United States signaled it would be receptive to paying for a private vehicle when NASA terminated its X-33 and X-34 programs in the spring of 2001 due to the private contractors determined that the commercial launch market would not support their continued development investments.[4] At that time NASA announced a new program, the Strategic Launch Initiative (SLI), that shifted its involvement in the development work from active participant and partner in developing a RLV that meets NASA mission needs to sponsor through awarding contracts to private companies.[5] However, NASA envisions a limited role for the RLV. Using the RLV as a supplement to the Shuttle fleet to allow for increased flexibility in mission planning and provide an emergence space access vehicle. Even if other governments prove equally receptive, governmental budgets cannot immediately accommodate new expenses. Unless funds already budgeted for use on RLV development can be shifted to pay for immediate flights using a private RLV, this market will not develop until several years after the vehicle becomes commercially available. For example, Britain's current space objectives drove it to decline participating in the ESA's optional RLV program, so it has not allocated funds for crew launches in the near future. Therefore, unless governments change their current space flight plans to use the RLV as the primary space access vehicle and increase the anticipated number of space flights a year the government market demand for a private RLV service cannot support the cost of development.

While the satellite industry does not require a vehicle with the particular characteristics of a RLV, it would be interested in any proven, low cost access to launch services.[6] Launch companies currently use expendable launch vehicles (ELV) to satisfy the market needs for satellite launches. Developments over the past several decades increased the success rate of ELV launches while lowering the cost. To compete with ELV cost for satellite launches, RLV programs must focus on the niche launch market of NGSO payloads. Because of the high cost of using the powerful rockets often associated with ELVs to deliver light GEO payloads or short distance LEO payloads this market offers the greatest potential for RLVs to achieve an economic advantage.

The current market analysis does not look promising for RLV initiatives that plan to rely on the satellite market to recover development cost. A recent study by the Air Force's Developmental Planning Directorate at the Space and Missile Systems Center concluded that future RLVs would have to launch almost 40 payloads of 30,000 pounds (13,600 kilograms) each and upwards of 160 payloads of 10,000 pounds (4,536 kilograms) each per year to reach their "investment break-even" mark.[7] Clearly, this results in a capacity for which the satellite industry does not have demand. Additionally, the failure of several companies that were expected to increase the demand for LEO flights to launch communications satellites have further eroded this market.[8]

An untapped and unmeasurable market for RLV services exists in the budding tourist industry. Recent flights by private citizens at incredibly high cost rekindled the average armchair astronaut's dream of going into space. Unfortunately, this market cannot currently be quantifiably measured to ensure it will support investment in the design and development of a private RLV. RLV teams seeking to inspire investors draw on examples, such as the computer market. Several decades ago only governments and large corporations could afford computers, but technological innovations and innovative designs made computers available to the average consumer.

Fortunately, several investors appear willing to take a risk that the demand for RLV will develop. Several X-Prize teams obtained financial support from private investors or space industry corporations.[2] The exact amount of support from the various sponsors remains undisclosed, but at least three teams appear to have sufficient funds to allow them to develop prototypes for testing and have begun the preliminary licensing discussions for test launches.

Licensing Unmanned and Manned Test Flights

Teams from five different countries have registered for the X-Prize competition.[2] These X-Prize entrants who have advanced sufficiently to approach government agencies about licensing needs originate in the US, Canada and Britain. To date no one has plans for their vehicle to embark and return to different countries, therefore, each team deals with only one country during this process. Each team faces a slightly different regulatory process each with different advantages and disadvantages.

The licensing and permitting government agencies in each country primarily focus on protecting public safety during a launch. The current international liability regime places the burden for damages related to launch accidents on the launching state.[9] Therefore, government officials review the proposed launch and return flight plan to determine if applicants successfully minimize the probable losses to third parties from a launch accident and carry sufficient third-party liability insurance. Usually the launch vehicle providers and the launching facility sign cross-waivers, so the governments do not need to address the risk faced by the parties involved. RLV launch risks undergo additional scrutiny because the launch involves a landing and, ultimately, a crew.

Identifying Launch Risk

When considering a launch three readily identifiable risk to third parties must be evaluated.[6] First is the potential damage resulting from the vehicle impact during a crash. Depending on altitude achieved and the range of particle debris this could affect a relatively large area. Second, the risk of fire and explosion increases depending on the fuels used. Several proposed RLVs utilize explosive propellants and their payloads often would contain additional sources of explosive materials.[6] The amount of risk from these materials diminishes as the launch progresses and fuels are consumed. Finally, some materials and fuels used by RLVs and in payloads may be carcinogenic or toxic.[6] The resulting debris from a fire or crash would pose contamination risk to the impact area or non-consumed fuels could spread to contaminate areas not affected by the initial impact. Most licensing governments already posses a detailed methodology for evaluating these types of risks from previous experiences in licensing ELV launches.

Government officials anticipate additional concerns will need to be addressed when licensing a RLV launch. The unique considerations for a RLV launch center on the risk associated the landing and the presence of a crew. The risk calculation for a landing may account for the same factors but must be done separately, because velocities and the presence of explosive fuels or payloads would result in different calculated risk levels. The more problematic evaluation revolves around crew safety. Technically the crew does not qualify as a third party, however agency officials expressed that they would expect applicants to include information documenting the safety measures taken to provide for crew survivability if an accident were to occur.

United States: The teams operating in the United States obtain permits according to the rules established by the Federal Aviation Administration's (FAA) Associate Administrator for Commercial Space Transportation (AST).[10] All RLV launches need a mission specific license that evaluates safety risk based upon the design of the specific vehicle for identified launch and re-entry sites (including a possible alternative re-entry site).[††] AST issues a commercial space launch license when it determines that the proposed launch and reentry does not threaten public health and safety, the safety of property, national security or foreign policy interest.[11]

The licensing process involves a pre-application consultation, the formal application review and compliance monitoring. The pre-application review period does not have a time limit but exists to provide the applicant and the FAA a chance to ensure the application provides sufficient information for the FAA to complete its reviews and evaluations. Once the FAA accepts an application for review US statute mandates that the review be completed within 180 days. The complete application evaluation consists of a policy review, a safety review, a payload review, a determination of financial responsibility, and an environmental review.[11] Each stage in the review requires an independent approval before moving on to the next part of the application review. The rules and regulations give very specific instructions about the data needed in the application and the safety thresholds that must be met.[11] Most applicants appreciate the transparency of the review guidelines because it provides structure and allows them to anticipate potential problems in gaining final approval.

In the United States the licensing procedure places the burden on the applicant to demonstrate that the proposed flight missions meets all safety requirements.[11] Because of the judgment calls associated with providing this data for unproven vehicles, this part of the application process could easily be used to hinder a RLV developer's attempts to obtain a launch license for testing purposes. In the past such ventures often faced skepticism inside the government, as well as from private sources approached for funding and support. The natural progression of the private RLV industry was expected to follow that of the development and testing of a vehicle by or under the auspices of a government agency. A government developed vehicle seeking commercial launching authority would be able to demonstrate a proven success record and could provide information on the a variety of risk factors that now must be estimated by the applicant and agency. However, RLV developers dealing with the FAA indicate their expectations for private RLV development appears to be shifting.

In recent agency rule-makings the AST office worked with industry representatives to craft the launch application's requirements and develop

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[††] The FAA does not release filed applications for public review, but does release environmental and final licensing information. To date no information indicates that any X-Prize competitors have filed a launch application. However, Kistler Aerospace Corporation apparently has an application pending to test a two-stage RLV at the Nevada Test Site. A final launch license has not yet been granted.

methods for calculating potential launch risk for RLVs.‡‡ On September 19, 2000 the Federal Register published the final Commercial Space Transportation Reusable Launch Vehicle and Reentry Licensing Regulations.[12] Additionally, a recent Advisory Circular (Circular) provided information that will allow RLV launch applicants to submit an application for test launches that undergo a streamlined review process.[13] In the Circular the AST clarified that an operator does not need to have complete vehicle capabilities to be licensed as long as the vehicle meets the criteria of a RLV and the definition of a launch.§§ The Circular stated that licenses are not given for test flights specifically, but could be obtained for a serious of mission flights where the vehicle operates at lower than maximum performance capabilities or flight for purposes other than design reference missions. The Circular then proceeded to explain a particular methodology for showing the vehicles fitness for flight and its satisfaction of safety requirements that would result in a streamlined application review. Any licenses issued under this review would have tailored and limited authority but would allow testing to proceed.[13] The major condition placed on applicants attempting to meet these streamlined requirements limited the testing range to remote or sparsely populated areas.

<u>Canada:</u> The teams operating in Canada work with the Launch Safety Office(LSO) at Transport Canada.[14] The LSO issues launch authorization when satisfied that adequate measures are in place to ensure the safety of the launch. The Canadian licensing process is not as meticulously outlined in regulations as the US procedures; however, it generally follows a similar pre-application review period before the filing of a final application. During the pre-application review the LSO authorities ensure that the launch proposal has sufficiently considered all risk and implemented adequate safety precautions and procedures. During this period the LSO can provide additional information for the launch applicant to include or consider. The process truly resembles a partnership in creating a mission plan that meets the safety requirements than a judging of the information provided. While US companies openly expressed concerns about the potential arbitrariness of the informal pre-review process, no Canadian counterpart shared this concern. In fact the LSO authorities were commended on their willingness to work with teams and generally positive support for RLV endeavors.

The test licenses currently under discussion require a safety analysis substantially similar to a license for an ELV launch. How the LSO will address the additional safety concerns surrounding a crew in the RLV cannot be determined from this experience. Whether the final licenses needed for RLV test launches will contain restrictions or be granted quickly remains to be seen. However, given the overall positive experience RLV developers have enjoyed working with the LSO any extra scrutiny of safety related to the presence of a crew should not be a major stumbling block.

‡‡ New laws directly addressing the development of a private RLV necessitated the rule-makings. During the rule-making process industry participants expressed concern with the inclusion of 14 CFR 431.11, which allows the FAA to place terms and conditions on a RLV mission license to ensure compliance with the safety rules. Developers objected on the grounds that this provision allowed for harassment and capriciousness in the licensing process.[12] To date this provision has not been a problem.

§§ Generally, to be a RLV a vehicle or concept must have recoverable parts that are reused in later launches and must return to a reentry site on a planned trajectory.

Availability of Insurance

Licensing countries generally require private launch licensees to carry an amount of third-party insurance that will cover most of the estimated potential third party losses in case of an accident. In 2001 the typical amount of third-party liability insurance required fell in the $100 million-$300 million (US$) range.[15] The premium for typical third-party launch liability insurance was estimated to be in the range of $100,000 to $400,000 per launch.[15] Several events have occurred since this survey that dramatically increased the cost of insurance.

Within the past year insurance markets have experienced problems due to increased risk of exposure and economic problems. The aviation insurance market encountered more problems than most due to security issues and several pending large liability claims. However, Insurance policies for space launches represent a small fraction of the aviation insurance market. In fact a FAA study estimates that the amount of third-party liability insurance premiums collected for commercial space launches represent only about 0.1 percent of all aerospace insurance premiums.[15] Brokers for launch insurance generally use several underwriters to provide the overall policy coverage. The underwriters then tend to reinsure to insulate themselves from losses. This process spreads the risk. Prior to September 11, 2001, it was estimated that about $1 to $1.5 billion of capacity per launch is available for third-party liability insurance.[15] The capacity fluctuates with the general health of the aerospace insurance market. Because of the large losses experienced by the aerospace insurance market this capacity decreased to $500 million by February 2002.[15] An increase in premiums accompanied the contraction. By February 2002 premiums increased by 50 to 400 percent depending on the loss record of the insured and the risk aversion of the specific underwriters involved.[15] The launch liability niche may be partly insulated from some of the adverse impacts because exclusions for war risk or terrorism have appeared in the launch liability insurance certificates for years. Fortunately, government officials reported that no companies seeking launch authority have reported being unable to find and afford the required amount of insurance yet.

Benefits of the X-Prize Contest

With the availability of private and government financing for RLV projects the need for the X-Prize may be questioned. While, many people would be thrilled to win a ten million dollar prize, for most commercial space flight projects this award covers only a fraction of their budget to develop and get the RLV to market. So motivates teams to enter the X-Prize competition? The answer to this question is varied. Realistically most teams did not undertake this endeavors to win the monetary award. Most people become involved in these projects because they believe they can make money while developing an industry that excites the mind and spirit by pushing the limits of scientific and engineering accomplishment. Therefore it is fair to say the X-Prize more likely rewards innovation rather than encouraging it.

However, the prize provides benefits to participants despite not being the motivating factor behind the projects. First the X-Prize provides an immediately available source of positive publicity to the public and potential investors. Second, the contest defines a milestone based on the scientific accomplishment rather than financial returns to measure success. Finally, the X-Prize promises an infusion of cash when the development teams must shift focus from design the vehicle to development of a commercially viable company.

The X-Prize organization through its website and media activities provides a centralized source of information for the general public. By providing brief summaries and contact information on most registrants the X-Prize organization supplies the public with an easy way to identify groups developing commercial space flight technology and follow their progress. The contest gives the lengthy process of design and development an interesting hook to keep people's attention. But mostly importantly the publicity provides positive attention to help attract investors. Given the challenges of attracting financial support to develop a commercial vehicle for an unproven space travel market, the existence of the X-Prize enhances the argument that the space tourism industry will develop to support these endeavors. Many teams benefited from the added legitimacy provided by the contest when attracting sponsors. Further the constant publicity provides a channel through which the sponsor can be assured that they will receive a certain amount of advertising in return for sponsorship.

The X-Prize also provides a definition of success. As industries develop goals must constantly be moved to keep driving development. Because the focus remains on the next step, or next advance, people often feel that significant mid-project accomplishments fail to be rewarded. The X-Prize provides a point in the development of the commercial space flight industry when the attention of the public and the industry will be focused on appreciating and rewarding the accomplishments achieved thus far. The X-Prize also helps to counteract the tendency of commercial ventures to focus solely on fiscal accomplishments as the measure of success.

Finally the monetary reward does provide an incentive to meet the flight requirements outlined by the X-Prize rules. The monetary reward provides a guaranteed influx of capital at a pivotal business stage in the development of a commercially viable RLV company. Once the vehicle successfully completes test flights and then the group must begin to focus on making the transition from research project to launch market participant. To begin to market and produce more than just test prototypes, additional capital will needed. How successfully any team accomplishes this transition ultimately depends upon management skills, but the prize provides a stepping stone at a crucial time in the development of a viable company.

Drawbacks of the X-Prize Contest

For all the benefits of the X-Prize contest several drawbacks must be acknowledged due to the nature of competition and the structure of the rules. From the outside the most frustrating result of the prize has been the unwillingness of some participants to discuss their RLV projects. For the entrants the most frustrating limitation of the contest may prove to be the restriction against receiving government funds.

Competition can bring out the worst in people. Unfortunately, several of the teams contacted were hesitant to discuss anything related to the project. The competitive nature of the experience caused some teams to absolutely refuse to talk about their experiences, even once it was made clear to them that proprietary information was not sought. There may have been additional explanations for people's hesitancy to discuss their work and experiences, but everyone gave the competition as their reason for remaining silent. The inability to learn more from the experiences restricts the ability of financiers and government agencies to respond to the needs of the infant industry.

The X Prize organization states that the financing restrictions serve to exclude government-sponsored vehicles from the competition. However this blanket restriction may be remarkably short-sighted. The X-Prize organization does not explain how excluding teams that accept government funds promotes the development of a RLV for low-cost transport into space. For instance, some government programs, including the SLI, may allow any company to submit proposals and do not control or actively participate in the design stage. A RLV developed by a private company using these government funds would be available for private ventures. In promoting the development of a commercially available low-cost vehicle there may be no notable differences between government grants and corporate grants. NASA's SLI program began after many of the United States teams had registered for the contest. At least one registered X-Prize participant, Kelly Space & Technology may already be disqualified, as it received a SLI contract. Given the unpredictable future market for a RLV restricting access to funds appears unrealistic. RLV teams need to be able to accept funding from any source willing to support their work.

Many aspects of interpreting this rule could prove to be problematic. The rule claims it intends to exclude projects substantially developed under government sponsorship but fails to address the fact that government sponsorship could be funneled through a private company supporting the team. If the rule means to ban teams that access government technology or assistance then the rule should look at the assistance sponsoring corporations that work on space related projects with government agencies. Some of the participants enjoying the backing of large aerospace companies may have access to technology obtained through government projects that are not available to the general public. The rule also fails to consider that just because a government provides financing does not make the project a government-sponsored vehicle. The lack of control and direct participation in the project could mitigate any advantage from receiving government funds compared to receiving funds from any other source.

Additionally, the rule fails to tie its financial restriction to the ultimate goal of promoting a commercially available vehicle that allows for low cost space access. The large sponsoring companies might agree to support the development stages in return for sole access to any technology developed or place future sale restrictions on the vehicle.[***] A restriction more consistent with the stated goal of the X-Prize might eliminate teams who accept finding from sources that try to control the development process, discriminate on factors other than feasibility of the proposal or place limitations on who may use the final product.

Conclusion

While the X-Prize may not be the driving factor behind the development of a RLV its has galvanized the community by focusing positive public and investor attention on this burgeoning industry. Even with positive community support the greatest challenge facing the participants, aside from any engineering and scientific problems, arises when seeking financial support. Making the case for a future market cannot rely solely on traditional market measures, so investors and sponsors must be induced to make a leap of faith or consider support merely a current advertising expense. Experience shows that while not all teams will successfully gain funding, there are sources of financing available. And once financed the current regulatory environment does not hinder launching an unproven vehicle.

[***] These scenarios are all speculative. Because support agreements are not disclosed this type of information cannot be obtained at this time.

[1] ESA website at http://www.esa.int/export/esaLA/GGGMRJF3KCC_index_0.html and http://www.esa.int/export/esaLA/ESA95SG18ZC_index_0.html.

[2] The X-Prize website provides a list of teams accompanied by short descriptions of their proposals and links to entrants websites at http://www.xprize.com/teams/teams.html. Some of the more informative websites used to gather information on team activities include http://www.bristolspaceplanes.com/, http://www.canadianarrow.com/, http://www.kellyspace.com/, http://www.starchaser.co.uk/, http://www.davinciproject.com.

[3] X-Prize Competition Guidelines at http://www.xprize.com/teams/guidelines.html (last checked September 29, 2002).

[4] NASA News Release 01-31, March 1, 2001.

[5] *The Space Launch Initiative: Technology to pioneer the space frontier,* NASA Fact Sheet, FS-2002-04-87-MSFC, April 2002, http://www1.msfc.nasa.gov/NEWSROOM/background/facts/slifactstext.html last visited September 28, 2002)

[6] FAA and DOT *Liability Risk-Sharing Regime For U.S. Commercial Space Transportation: Study and Analysis*, Section 7.3.2 (April 2002).

[7] *Advanced Space Lift Architecture Study,* Directorate of Developmental Planning, *SMC/XR*, Space and Missile Systems Center, Los Angeles Air Force Base, Los Angeles, CA, April 2001.

[8] *The Space Launch Initiative: Technology to Pioneer the Space Frontie*r, NASA Fact Sheet, FS 2001-02-43-MSFC, January 2002, p. 3.

[9] United States Treaty, 1972, Convention on International Liability for Damage Caused by Space Objects, March 29 (24 U.S.T. 2389, T.I.A.S. 7762).

[10] 49 USC, Subtitle IX, Chapter 701 – Commercial Space Launch activities ; Commercial Space Transportation Competitiveness Act of 2000 (H.R. 2607/P.L. 106-405).

[11] 14 CFR §400-435.

[12] Fed. Reg., Vol. 65, No. 182, p. 56618-56667 (September 19, 2000).

[13] Advisory Circular, Licensing Test Flight Reusable Launch Vehicle Missions, AC 431.35-3, August, 2002.

[14] Transport Canada is responsible for rocket launch activities by virtue of the *Aeronautics Act*, which in Section 4. (1) and 4.9(w) authorizes the creation of the *Canadian Aviation Regulations*. LSO issues permits pursuant to the requirements of CAR 602.44.

[15] FAA and DOT *Liability Risk-Sharing Regime For U.S. Commercial Space Transportation: Study and Analysis*, Appendix D, D-2 (April 2002).