Commercial Launch Services: an Enabler for Launch Vehicle Evolution and Cost Reduction

Bernard F. Kutter*

Lockheed Martin Space Systems Company

Denver, CO

Expanded space utilization for exploration or exploitation has been stymied partially by the high cost of space access. These high costs are driven primarily by the technical challenge of space flight and the low launch rates. Since the Apollo era, numerous efforts have been under taken to significantly reduce the cost of space access. The assumption has been that development of a low cost launch system will stimulate demand, enabling new uses of space for the betterment of mankind.

The retirement of the space shuttle and the transition to the VSE provides a unique opportunity for America to encourage competitive, commercial launch resulting in a stronger, healthier, more robust launch industry. Such a robust, commercial launch industry reduces launch costs for all. This unique opportunity consists of opening the ISS service requirements and elements of the exploration program to commercial competition. Combined, the ISS servicing and exploration launch requirements offer the opportunity to increase America's competitive launch demand by more than a factor of four. Such a huge increase in launch demand offers the opportunity to provide a solid foundation from which industry can make investment decisions and dramatically lower cost.

This paper proposes that NASA commercially purchase all future launch services, including ISS service and the launch requirements for all phases of lunar exploration and beyond. This commercial purchase of launch services will provide the foundation of a robust commercial launch industry and dramatically lower cost. This paper also shows how NASA's currently planned exploration architecture readily accommodates and even benefits from commercial launch services.

NASA's use of commercial launch services is consistent with President Bush's mandate for the Vision for Space Exploration: "Promote international and commercial participation in exploration to further U.S. scientific, security and economic interests." This is also consistent with Griffin's public remarks: "We believe that when we engage the engine of competition, these services will be provided in a more cost-effective fashion than when the government has to do it."

* Sr. Staff, Manager Atlas Evolution, Lockheed Martin P. O. Box 179 Denver Co 80201 MS T9115, AIAA Senior Member.

Acronyms

AR&D	Autonomous Rendezvous and Docking
CEV	Crew Exploration Vehicle
CLV	Crew Launch Vehicle
CTB	Centaur Test Bed
EDS	Earth Departure Stage
LEO	Low Earth Orbit
LSAM	Lunar Surface Access Module
TEI	Trans Earth Injection

I. Introduction

Expanded space exploration and utilization has been stymied partially by the high cost of space access. These high costs are driven primarily by the technical challenge of space flight and the low launch rates. For over 2 decades America's annual (medium to heavy) launch rate (excluding Shuttle) has consisted of about 15 to 20 launches, comprised of a combination of DoD, Civil and commercial missions, Figure 1.

The demand for access to space has proven to be inelastic. With the longer life of modern satellites and competition from terrestrial communication systems the historic uses for satellites has required a relatively static launch tempo. The emergence of potential growth markets such as broad band communication, manufacturing or space tourism has remained elusive. Even the launch cost reduction of more than a factor of two achieved over the past two decades due to competition, foreign launch entrants and the EELV's has not been sufficient to stimulate new space markets, Figure 2.

The current world wide over-abundance of launch systems, Space Shuttle, Atlas V, Delta IV, Ariane, Proton, Sea Launch, Long March, H2, etc. has fractured the international launch industry such that none of these launch systems has sufficient rate to enable them to be produced at cost effective rates. Even the relatively large American government launch requirements (medium to large payloads), split between four systems: Space Shuttle, Atlas V, Delta II and Delta IV, has guaranteed that each of these systems barely limps along.

Due to national security and economic interests it is critical that the American government help support America's launch base. As such, government has a role to play in supporting development of enhanced space access, especially where government and commercial interests overlap.

II. Historic Efforts to Improve Space Access

Since the Apollo era, numerous efforts have been under taken to significantly reduce the cost of space access. The assumption has been that development of a low cost launch system will stimulate demand, enabling new uses of space (NASA, DoD and commercial) for the betterment of mankind.

NASA

NASA's promise 30 years ago that the Space Shuttle, Figure 3, would enable routine, in-expensive access to space was stymied by technical complexity and never materialized. NASA's continued efforts to reduce launch

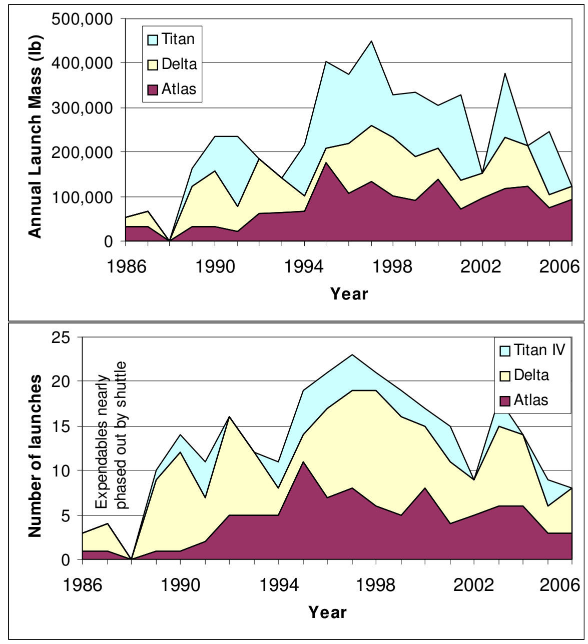

Figure 1. America's historic launch rate and mass of medium to large payloads (excluding shuttle) has been insufficient to support a robust commercial launch industry.

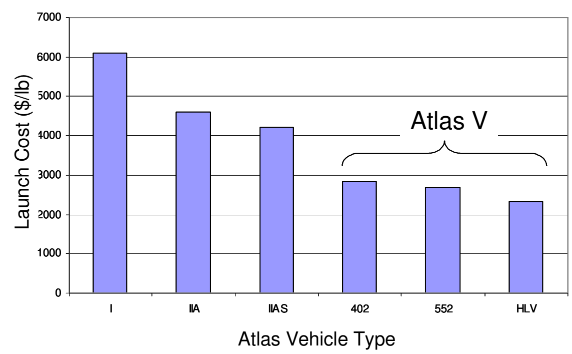

Figure 2. As Atlas has evolved to meet new customer requirements, it has managed to reduce launch costs by more than a factor of two while simultaneously improving reliability.

Figure 3. The Space Shuttle's promise to enable routine, in-expensive access to space was never realized. Credit: NASA

costs over the past two decades, ALS, SLI, NASP, NLS, RLV to name a few, have investigated interesting new technologies and launch concepts, Figure 4. However, none of these novel concepts has managed to survive the technical and political hurdles to make first flight.

DoD

The DoD efforts to stimulate a low cost space launch industry also continue to show more promise than success. The ongoing responsive space Falcon program is an attempt to develop low cost launch for small payloads. However, with a demand for only a few launches per year, this goal has also proven elusive.

More successful has been the EELV program with the fielding of the Atlas V and Delta IV rocket families, Figure 5. EELV has achieved significant cost reduction and operability improvement relative to the legacy systems, Delta II, Atlas II and Titan IV. However, the low launch rate resulting from the collapse of the commercial broad band communication satellite industry and continued DoD satellite schedule slips has eroded some of the cost reduction potential of these vehicles.

Commercial

During the past 20 years the promise of an expanding space launch market, driven by commercial demand, has encourage numerous entrepreneurial entrants into the launch market. Start up companies such as Beal, Kistler, Rotan, etc.; have invested hugely in their new launch vehicles only to find the commercial demand an unfulfilled illusion. This lack of market and the realization that the cost of developing a launch system was much greater than expected has led the majority of these start up companies to exit the business, typically before their first launch. The continued efforts of new entrants, such as Conger, Blue Origin and Space X, have shown that this historic lack of success has not managed to dampen the spirits of space enthusiast and those willing to fund them.

III. Launch Rate

The launch industry is a very capital intensive business. Launching rockets requires significant infrastructure consisting of manufacture sites, integration facilities and launch sites. Similar infrastructure is required independent of launch rate. At low launch rates, the fixed infrastructure costs and the investment recuperation dominate the launch costs. As launch rate increases this fixed cost is spread over more launches and economy of scale can be realized. Figure 6 illustrates the affect of rate on launch costs using representative values assuming a 90% rate cost curve. This figure shows that below ~5 launches per year the fixed costs dominate the launch cost.

Figure 4. NASA, DoD and independent investment have developed novel launch concepts in an effort to reduce launch cost, with only partial success. Credit: NASA

Figure 5. The DoD/Industry partnership resulted in the Atlas V and Delta IV families of rockets replacing earlier Atlas vehicles and the Titan IV.

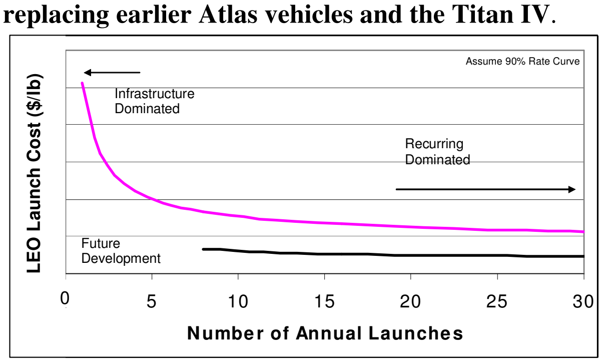

Figure 6. Due to the extremely high fixed infrastructure costs of typical launch systems, rate has a very profound affect on cost of space access.

At rates above ~10 launches per year, vehicle costs and the ability to benefit from bulk buys of hardware tend to dominate the launch cost. Continued development may provide significant future cost reduction, similar to that achieved by the EELV program.

IV. Unique opportunity:

The retirement of the space shuttle and the transition to the VSE provides a unique opportunity for America to encourage competitive, commercial launch resulting in a stronger, healthier, more robust launch industry, with reduced launch costs for all. America's current competitive (medium to large payload) launch market is comprised of the launch of DoD, NASA science and commercial satellites launching approximately 346 klb (157 mT) on 15 launches per year, Figure 7. The DoD launch requirements dominate and control this launch market. Without the strong emergence of commercial tourism or similar new launch markets it is expected that this current competitive launch market will remain relatively static for the foreseeable future.

NASA's future launch requirements consist of ISS servicing and exploration. These requirements offer the opportunity to increase America's launch demand by a factor of four. This increases the annual launch requirements from today's 346 klb (157 mT) to 1,546 klb (700 mT), Figure 8. NASA will control the bulk of this future launch market. As such, NASA has the ability to control America's future launch environment.

NASA has the opportunity to commercially purchase all of its future launch needs. Such a huge increase in the American launch market may well stimulate a new era of competition and advancement resulting in significantly lower launch costs and enhance space access for all; NASA, DoD and commercial users.

Indeed, NASA's aggressive use of competitive launch services is consistent with President Bush's policy for the Vision for Space Exploration. President Bush's policy states: "Promote international and commercial participation in exploration to further U.S. scientific, security and economic interests", Reference 1. The president's commission on the implementation of U.S. space exploration policy, Reference 2, further articulates this mandate: "In NASA decisions, the preferred choice for operational activities must be competitively awarded contracts with private and non-profit organizations". Further: "The Commission recommends NASA recognize and implement a far larger presence of private industry in space operations with the specific goal of allowing private industry to assume the primary role of providing services to NASA, and most immediately in accessing low-Earth orbit."

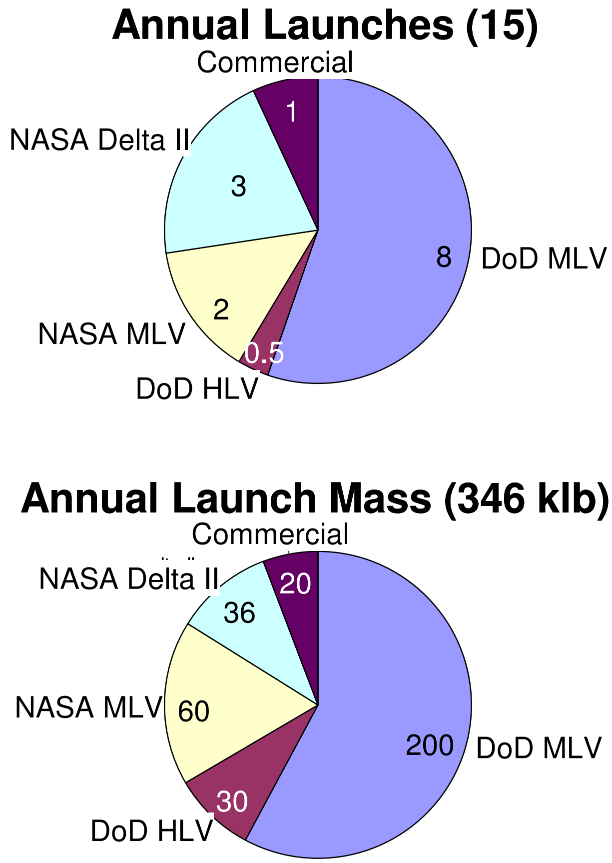

Figure 7. America's expected future competed medium to large launch market consists of satellite and robotic payloads split between the DoD, NASA science and commercial customers.

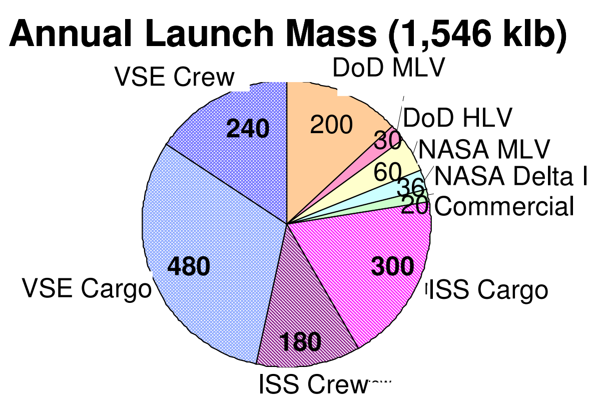

Figure 8. The emergence of ISS servicing and exploration promises to significantly expand and dominate America's launch requirements.

ISS Servicing

NASA’s goal to utilize commercial launch services for ISS cargo and crew launch are key avenues toward encouraging a growth in the commercial launch market. ISS launch requirements may represent as much as 25% of America’s future launch requirements, Figure 8. Between crew and cargo services, the ISS launch requirements may well exceed America’s entire current competitive launch market.

Vision for Space Exploration

Exploration represents NASA’s second and largest opportunity to encourage and enhance the commercial launch market. The planned two annual lunar missions are expected to require on the order of 660 klb (300 mT) worth of hardware and propellant in LEO. This launch mass is primarily composed of propellant, consisting of LO2, LH2, MMH and N2O4 stored in the EDS, LSAM and CEV service module. The launch of this exploration hardware and propellant offers a convenient opportunity for NASA to benefit from commercial launch services while simultaneously enhancing NASA’s exploration mission reliability and capability and significantly reducing NASA’s launch costs. Commercial launch services can support NASA’s current in-space VSE architecture and actually enhance the overall exploration mission. Mike Griffin has even indicated his desire to take advantage of commercial launch services: “We believe that when we engage the engine of competition, these services will be provided in a more cost-effective fashion than when the government has to do it,” reference 3. .

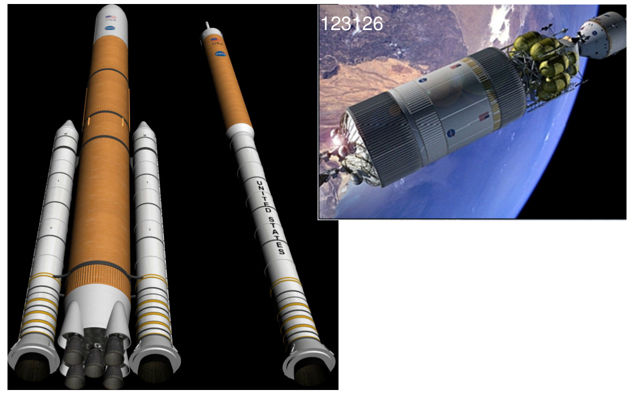

Figure 9. NASA’s current plans for launching the VSE is composed of the Aries I and V launch vehicles. Credit: NASA

V. Potential Exploration Launch Architecture

The currently planned exploration architecture utilizes the Aries V heavy lift launch vehicle to place the EDS and LSAM, fully fueled, into LEO. Some 30 to 95 days later, the Aries 1 lofts the crew, CEV and service module into LEO for rendezvous with the EDS, Figure 9.

Numerous alternative exploration launch architectures are possible that take advantage of commercial launch services and enhance America’s global competitiveness. One option consists of launching the EDS and empty LSAM, followed by numerous launch providers delivering fuel on orbit and concluding with the launch of the CEV, Figure 10. In this architecture during the first launch the upper stage would perform its burn to deliver itself and the empty LSAM to LEO. The upper stage of this first launch once refueled can support the EDS roll. Potential mission peculiar kit enhancements required to enable this upper stage to perform double duty and support the long duration of the EDS are discussed in Reference 6. Subsequent commercial launches would fill the EDS and LSAM with the appropriate propellants. Once the EDS and LSAM are fully fueled and checked out the CEV and crew would be launched. The use of on-orbit refueling is consistent with Griffin’s “Gas Station in the Sky” comments, reference 4

Unlike suggested in the ESAS report the multiple launches required in this architecture actually improve mission reliability. Use of launch vehicles that support frequent commercial missions allows these vehicles to be continuously improved based on actual flight lessons learned. The use of multiple launch providers for propellant delivery ensures reliable, timely delivery, even with delays or mishaps at one of the propellant providers. NASA would only pay for successful delivery. Most importantly, the proposed architecture is quite insensitive to launch delays or higher than expected boil-off rates. Any lost propellant would be made up through additional commercially delivered propellant. The CEV is only launched once the EDS and LSAM are fueled and ready to go.

This in-space propellant could be delivered by any and all American launch entrants. Indeed, this architecture offers a convenient opportunity for international participation, potentially allowing for more frequent exploration missions. The propellant could be delivered in any convenient individual quantity; a ton at a time, launched frequently on small low cost launchers, or 55 klb (25 mT’s) at a time on larger launch vehicles. Ultimately the realities of the

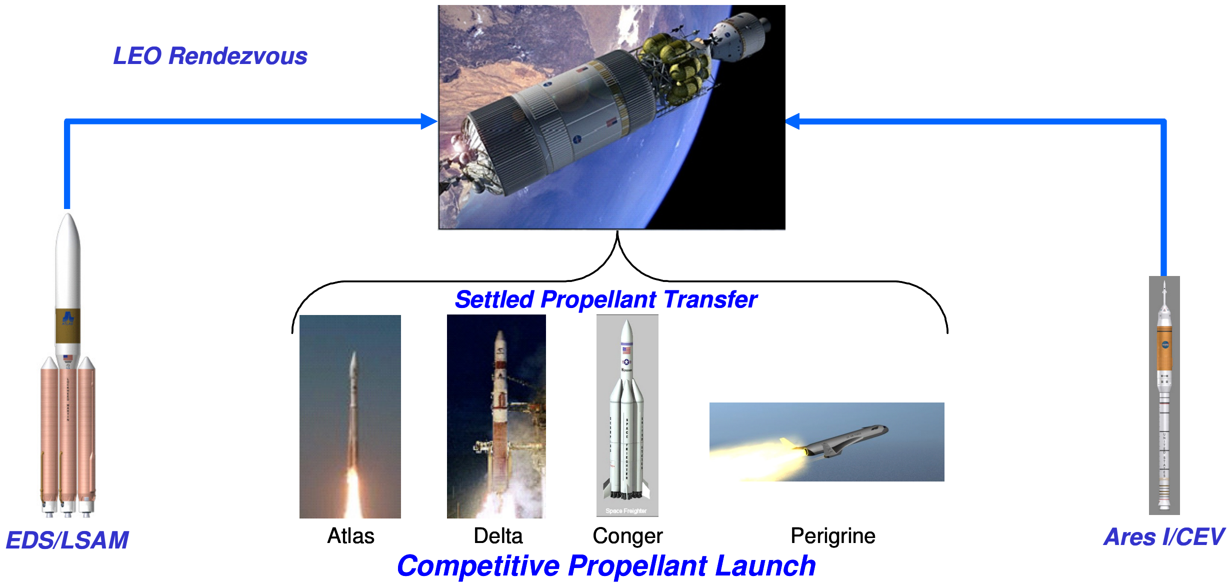

Figure 10. NASA can stimulate America's commercial launch market through the use of commercial launch services resulting in lower costs for exploration as well as all other uses of space, potentially enabling new markets such as commercial space tourism and manufacturing. Credit: NASA, Boeing Photo – Carleton Bailie, Conger, Andrews Space

launch business will define the cheapest, most reliable operational concepts, overcoming the current paper analysis debate regarding the best launch vehicle that has plagued the industry for decades.

A significant benefit associated with NASA's use of commercial launch services is NASA's potential to significantly reduce the cost of exploration. This savings in turn would allow NASA to start the lunar exploration well before the current baseline of 2018. This savings would also allow NASA to fund other high priority elements, such as science and technology development. An added benefit of commercial launch services is that NASA would not be locked into a single launch solution as its needs and priorities change. For exploration a major benefit of relying on orbital fuel transfer is the flexibility to support evolving mission needs such as weight growth or Mars exploration without wholesale revamping of the Earth to orbit launch system.

VI. Enabling Technologies

The technologies enabling commercial launch services for NASA missions, specifically AR&D and propellant transfer are critical to supporting all future robust space programs including exploration and space utilization. NASA's support in developing and enhancing these capabilities can help enable such endeavors as satellite servicing, commercial space tourism, and space manufacturing.

AR&D

Russia has been performing AR&D for years in support of their various space stations, including ISS. Most recently, with the 2.5 year shuttle hiatus, the ISS relied on the Russian progress and it's AR&D for all supplies. Although development of AR&D has languished in America, several on-going efforts are designed to overcome this short fall. Dart, XSS-11 and Orbital Express are all designed to further America's AR&D capability. Dart was an attempt to demonstrate autonomous rendezvous technologies. Sadly errors in the GPS supported guidance algorithms led to excessive propellant consumption and an unplanned "bumping" of the target spacecraft. Incidents such as this provide important lessons and lead to improved capabilities. XSS-11, launched in early 2005, has fully demonstrated effective autonomous rendezvous and proximity operations over numerous rendezvous operations during the past year. XSS-11 continues to provide excellent data supporting future, more advanced AR&D needs. Orbital Express, set to launch in November of 2006, is designed to demonstrate AR&D as well as orbital servicing, including the transfer of N2H4 and He, Reference 7. The CEV and COTS 2 are also planning to use AR&D for ISS cargo delivery.

In-Space Propellant Transfer

Orbital Express will provide valuable experience with the autonomous transfer of storable propellants. Future missions, such as the proposed Centaur Test Bed (CTB), figure 11, offer the opportunity to gain similar experience with cryogenic propellants, Reference 8. The use of very low settling can enable cryogenic propellant transfer using primarily existing technology and flight experience, significantly reducing the development risk, Reference 9.

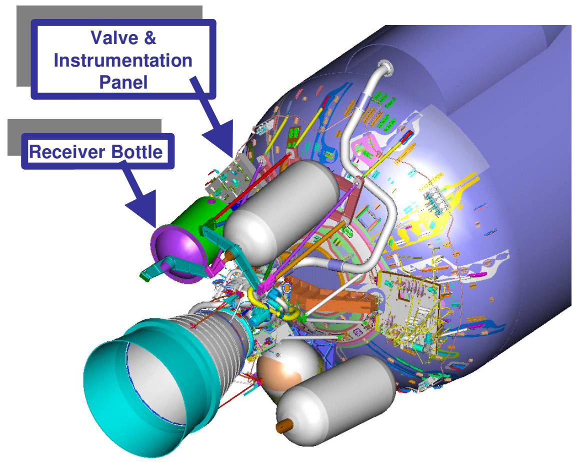

Figure 11. The Centaur Test Bed (CTB) offers a near term, low cost method to demonstrate in-space cryogenic fluid management and transfer.

Future missions can build on these demonstrations to develop the robust AR&D, propellant transfer and in-space servicing that is required to enable any future, sustainable robust space economy. Flight demonstrations are critical to truly understanding system operation in space. Through the creative use of ride share and other options such flight demonstrations need not be horrendously expensive. Ideas such as the CTB take advantage of existing mission hardware, residuals and performance excess to provide the engineering foundation enabling the low risk development of the future in-space capabilities. Development of these capabilities and frequent use of them will provide the flight experience to demonstrate and enhance their reliability. These capabilities are absolutely vital to expanded use of space and the eventual human exploration of Mars.

VII. Conclusion

Expanded space exploration and utilization has been stymied partially by the high cost of space access. Since the Apollo era, numerous efforts have been under taken to significantly reduce the cost of space access in the hope that development of a low cost launch system will stimulate demand, enabling new uses of space for the betterment of mankind. These efforts at reducing the cost of space access through launch vehicle development have had mixed results.

Although the EELV DoD-industry partnership made significant improvement in America's space access, continued enhancement is ham strung by the very low launch requirement of the existing space market. For decades the promise of commercial space business has promised to hugely increase this demand, resulting in continued, significant space transportation cost reduction. Continuously this commercial promise has proven to be a mirage.

NASA's ISS and VSE mission requirements offer a unique opportunity to increase the launch demand by a factor of four. If NASA takes advantage of this opportunity through the use of competitive commercial launch services, NASA has the opportunity of providing the catalyst and guide the launch market to a new era of cost cutting, innovation and competition. This reinvigorated launch market can benefit America's national security and economic prosperity while enabling a sustainable, robust space exploration program. The key is for NASA to competitively bid ISS servicing and VSE launch services.

This paper has offered one of many potential opportunities for NASA's VSE to benefit from the use of commercial launch services. The use of commercial launch services allows NASA the potential to significantly reduce the cost of exploration. This savings allows NASA to fund other high priorities such as science and technology development and earlier trips to the Moon, Mars and beyond. A major benefit of NASA not owning its own launch vehicles will be improved flexibility to take advantage of improved launch technology or changing NASA priorities. On-orbit refueling offers NASA improved flexibility to accommodate launch delays, weight growth, and future missions to Mars and beyond without the need for wholesale revamping of the Earth to orbit launch system each time the exploration mission requirements change.

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