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LESSONS FROM SEA LAUNCH

by

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Preface

Over the past 12 years I have been involved in the space business. First as an orbital analyst at Cheyenne Mountain tracking space objects. From there I went to Schriever Air Force Base (AFB) where I was a Defense System Communications Satellite controller. My last space operations job was at Vandenberg AFB where I was a Delta II launch controller and the chief of spacelift evaluations. During these assignments I gained a tremendous appreciation of the intricacies of orbits, satellites and the gargantuan effort to put a satellite in the correct orbit.

I realized that the Air Force has been in the spacelift business now for 50 years and today we're doing spacelift essentially the same way. This would be no problem if the context we're living in were the same, but the 21st century expects more from us than the century gone by. We need to provide routine, reliable and affordable access to space. Our military depends on it and our nation demands it.

This paper was both a challenge and a very worthwhile task. I couldn't have done it without the guidance of Lt Col Midge Ward, my ACSC faculty advisor, and Lt Col Tom Walker from Air War College. Also, a very special thank you goes to my sister, Amy Sufak, for editing this paper. Finally, thank you to my family, James, Katie and Jasmine, who supported me throughout this demanding year at ACSC. We did it as a team.

Abstract

This paper looks at the problems with space launch and what the United States can do to improve it. Specifically, the paper presents the argument that military space launch is not changing with the times and there are innovative ideas in the commercial launch sector, particularly the Sea Launch program, from which the United States can learn. Primarily, the United States needs to make spacelift more affordable, reliable, and responsive because providing robust spacelift, that meets these standards, will support the US national security and economy. The research methodology included analysis of existing literature, congressional records, and interviews.

Chapter 1

Introduction

> *Short of warfare, space launch is the fastest way of destroying a $1 billion –plus investment ever invented, as the USAF managed to demonstrate three times in nine months between August 1998 and April of last year.*
>
> —Jane's International Defense Review March 2000

Statement of the Research Question

As startling as this quote may be, it begs the question, what can the United States do to improve space launch? This paper examines the issues and problems with space launch. The purpose is to determine what the United States can do to make space launch more affordable, reliable, and responsive. Providing robust space launch, that meets these standards, will support the United States' military and economy.

The study accomplishes three tasks. Initially, it describes how United States space launch isn't affordable, reliable, or responsive. Then it delves into the future of space launch, highlighting Sea Launch, an international commercial venture, and discusses what the United States could learn from this consortium. Finally, it provides recommendations aimed at improving the United States' future in space launch.

Background and Significance of the Problem

Past. Since its inception in the 1950s, spacelift has long been considered the Achilles' heel of space operations. Spacelift hasn't been reliable, cost effective, or flexible. The rule of thumb in spacelift was, if it wasn't broken don't change it. After all, each launch was a testament to an amazing engineering feat. However, times did change and spacelift had to enter into the 21st century with new concepts.

Changing Times. Throughout the 1990s commercial satellite launches were on the rise – quickly outpacing the dozens per year of military satellite launches. This in turn begged the question – what does space launch mean to the US as a country? For example, does the US want to be an international industry leader in getting to space? Is the US' international prestige and commerce on the line if the US doesn't have the most robust space launch system in the world? More specifically, is access to space so important to the US that it would be considered a vital national interest? Furthermore, military requirements have changed.

The military changed from using space assets as a "gee whiz" capability to an essential part of planning and employing forces. This in turn meant that space assets were expected to be responsive, reliable, and ready on demand. If the satellites were expected to respond to such tasks, certainly the transportation to get satellites into space – spacelift – must be just as responsive. So what could the US do to improve space launch?

Future. The Sea Launch program, an international civilian consortium, is an innovative example from which the United States can inspect launch problems and bring about creative ideas in solving these problems. Starting in 1995, the Sea Launch program tried to rectify the exorbitant costs of launching, the bottle neck in the launch schedules at Vandenberg AFB and Cape Canaveral AFB, the outdated range equipment, the legacy rockets' limited capacity, and lastly the dilapidated launch infrastructure. All of these areas need monetary investment and new ideas to improve the prospect of the Sea Launch consortium to make money on their venture. Similarly, the US can learn from this consortium, as these were the problems they were trying to solve. This study addresses some of Sea Launch's novel approaches.

Limitations of the Study

This study doesn't cover the full range of influences on the United States space launch program. Other papers and studies have previously done this. This paper is limited to a cursory glance of cost, reliability, and responsiveness of military space launch. In addition, it does not provide a comprehensive list of recommendations for launch improvements. Rather this paper uses one commercial example, Sea Launch, and hones in on three broad reaching lessons learned – limiting costs, improving reliability, and reducing response time.

Preview of the Argument

The United States civilian and military sectors have long understood space launch as a challenging task. Space launch was a task in which cost and responsiveness were not the primary focus. Furthermore, in the United States space launch was reliable until the past 3 years. Times changed. Assuming the United States wants to stay competitive in commercial and military space ventures, the United States must quickly work to improve space transportation.

Chapter 2

What the US Needs

Space affects a globally interdependent United States economy, protecting vital national security interests, promoting political international relationships, and protecting and advancing the quality of life for mankind.

—Edward C. Aldridge, Jr, Congressional Testimony, September 28, 2000

National Priority

Space is recognized as a national priority for its commercial and military value. President Clinton's National Space Policy stated that "access to and use of space is central for preserving peace and protecting U.S. national security as well as civil and commercial interests."[1] More specifically, The 1998 Commercial Space Launch Act, addresses the means to get to space. It says, "Space transportation is an important element of the transportation system of the United States, in connection with commerce of the United States there is a need to develop a strong space transportation infrastructure."[2] The importance of space, in particular space transportation, continues to be at the forefront of United States legislation and national policy because it is a vital national interest.[3] Since space transportation is critical to the United States, the question then becomes – what is the status of the United States' space transportation?

The following sections will address space launch's most pressing issues – the high cost, and the lack of reliability and responsiveness. In particular, each section provides information on why it's important to the United States and updates the reader on the current status of costs, reliability, and responsiveness. The first section starts with the largest hurdle facing the United States launch program, the expense.

Cost

It's necessary to consider space launch expenditures due to their inherent astronomical costs. Furthermore, limited budgets curb future development. To adequately address this issue, one needs to study how the high costs came about. In particular a discussion of the military legacy programs (Delta, Atlas, and Titan) helps frame the topic. Finally, the last part of this section will look at cost-cutting future concepts.

The largest single obstacle to the progress of space exploration and using space for human benefit, is the cost of space transportation.[4] "The cost of access to space has remained so high that only two customers can afford it: the federal government, and the geosynchronous telecommunications satellite industry."[5] As a result the space launch industry has stagnated with proven but costly old systems and procedures.

One of the reasons the fleet of expendable boosters was so expensive was that the Delta, Atlas, and Titan evolved from 1950s/1960s intercontinental missiles. These legacy boosters focused on military, not commercial attributes. To perform their military mission of long-range nuclear delivery, the boosters were built to maximize performance. They were ready at a moment's notice, required minimum weight to accommodate their deployment schemes, and provided one-way trips with no reusable parts. When these boosters were pressed into space launch service, they provided maximum performance and minimum weight, but they were not optimized for cost.[6] Similarly the manned space flight program's top priority was not cost savings.

The manned space flight program from its infancy was focused on achieving certain operational goals vice minimizing costs. Recall President Kennedy's 1961 agenda to place a US astronaut on the Moon by the end of that decade. Like the legacy systems of the past, Mercury, Gemini, and Apollo, the Shuttle is focused on factors other than cost. The Shuttle is focused on achieving reliability maximization, human space flight capability, and an airplane-like recovery mode.[7] Although manned space flight and the Shuttle aircraft-like design have considerable benefits, these designs are not cheap.

It costs millions of dollars to fly aboard any of these systems. Whether one considers the total cost of the mission or the cost per pound it's very expensive. Looking at the legacy systems, in 1993 dollars, the cost to launch the Delta II was $45-50 million, the Atlas IIA $80-90 million, the Titan IV $170-$230 million, and $350-547 million for the Space Shuttle.[8] A more accurate method to compare costs is to break down the cost into price per pound. By this method the costs would be (in 1993 dollars), Delta II $4,275, Atlas IIA $5,414, Titan IV $5,128, and the Space Shuttle $8,352 per pound of payload.[9] This translates into a very expensive trip to space. As a result, a flourishing commercial space sector of the United States economy, eagerly anticipated since the early 1980s, never materialized."[10] This great expense has kept most commercial companies out of the space business, but not to be deterred, there are some companies trying to enter the launch business.

Many private companies are devising creative launch concepts in order to make space launch more affordable. In the reusable launch vehicle market there are at least 10 companies (Kistler, Rotary, Kelly, Pioneer, Space Access, Rutan, Advent, Vela Technology, Lone Star Space Access, and Lockheed Martin) with concept of operations and plans for a test flight in the coming year.[11] To illustrate the savings these companies propose, the cheapest concept of the ten is the Kistler K-1 vehicle. The K-1 booster will have a 2-stage vertical takeoff and it will return with a parachute. The firm estimates the cost will be $17 million per launch or approximately $1,530 per pound of payload.[12] Another way to cut costs is with expendable launch vehicles.

In 1997 the Pentagon decided the Air Force should buy launch services from both Lockheed Martin and Boeing Evolved Expendable Launch Vehicle (EELV) programs. EELV is a family of launch vehicles for small to large military payloads based on brand new Delta IV and Atlas V launch vehicles. It plans to be 25-50 percent cheaper than current launch costs and ready for launch in 2002.[13] Given that any launch failure would be devastatingly expensive, it's pertinent to study the United States' space launch reliability.

Reliability

Space launch reliability is important to the United States because it's directly related to launch costs and it has a national security and economic impact. This section will discuss the reliable history of space launch, the costly failures in the past 3 years, and the monetary impacts of losing launch vehicles and payloads. Furthermore, it will address the issue of international prestige in space for both the military and the economy. Finally, the last part will look at what the United States is doing to improve space launch reliability.

The United States has had a reliable history of space launch. Since 1958 the United States has successfully launched 777 Delta, Atlas, and Titan missions.[14] These missions deployed DoD satellite constellations, space probes, and carried the Mercury and Gemini astronauts to orbit. They were also the foundation for the United States commercial launch industry. Their reliability averaged between 94-95 percent. [15] However, in the past 3 years things changed considerably.

Between August 1998 and April 1999 there were three Titan IV-related failures and two Delta III commercial failures. The Air Force Accident Investigation and Safety boards discovered one of the Titan IV missions failed because of an electrical short in the core vehicle and the other two failed due to problems (one was a human error – loading the wrong code) with the upper stage. The Titan IV launch failures were carrying very expensive payloads. The three payloads impacted were a reconnaissance satellite valued at $1.4 billion, a Defense Support Program Satellite valued at $600 million, and a MILSTAR satellite valued at $1.1 billion.

The Delta III failures were blamed on design and engineering flaws.[16] The Delta III vehicles were also carrying expensive payloads – Galaxy and Orion communications satellites. Together the Titan and Delta problems brought the failure rate well above the historical rate – 5 of the last 25 flights failed. Between 1985-1997 the launch success rate was 95 percent for 280 launches. Between 1998-1999 the launch success rate dropped to an all time low of 87 percent for 64 launches. Although the launch frequency isn't constant, it identifies a growing reliability problem with the launch programs. The Air Force's three Titan IV launch failures between August 1998 and May 1999 cost the government $3 billion.[17] There are other factors besides costs that degrade as our reliability plummets.

The United States' international prestige both in the military and economic sectors may be affected if the United States can't reliably access space. *The Executive Summary of DoD Assessment of Space Launch Failures* highlighted these problems when it stated:

> The failure of the three government missions combined with the failure of two commercial missions within the same time frame, sparked widespread concern in our ability to assure access to space. Because assured access to space is critical to the overall strength and stability of our national security, commercial, and civil sectors, both the Executive and Legislative branches asked the Department of Defense, in coordination with the director of Central Intelligence and the Administrator of the National Aeronautics and Space Administration, to examine the failures and provide a

report on the causes and corrective actions being taken to prevent their reoccurrence and to ensure future access to space.[18]

The military needs a reliable access to space to be a viable threat to our enemy. The vision for the Air Force is to have space superiority – assuring US forces freedom *from* attack and freedom *to* attack.[19] In the medium of space it will be difficult to have superiority if the United States doesn't have reliable access. In addition to the military necessity, the United States economy is dependent on reliable space access.

The space launch business is a growing international marketplace. Since the United States wants to be part of the $6.5-7 billion a year global launch market,[20] the United States needs to improve its launch reliability. Increased commercialization of the launch industry threatens to put unreliable boosters out of business. Today the United States space industry is finding competition from launch providers in Europe, Russia, Ukraine, China, Japan, India, Israel, and Brazil.[21] Many of these countries are new to the launch business and haven't seen success, however in the case of the Russians, their launch reliability is on par, and in some cases better, than the United States' launch reliability.[22] The United States currently holds one-third of the world's launch market and is making strides to improve their market share by improving reliability.[23]

The United States is looking at two areas to improve space launch reliability. The first is to fix the current problems with the launch vehicles, specifically the Titan IV and the Delta III. Then, they will take those lessons learned and integrate them into the EELV, comprised of the Delta IV and the Atlas V launch vehicles.[24]

The Space Launch Broad Area Review, a group chartered by the Air Force to conduct an examination of the launch failures and to make recommendations, determined the problems with the Titan IV and Delta III launches were design, engineering, quality, process, staffing, and skill retention. The report suggests the underlying problem was the contractors who were "focused heavily" on closing out the old systems to acquire and organize for the new EELV.[25] The DoD has implemented corrective actions and is taking aggressive action to improve launch practices and procedures for future missions.[26] The "aggressive action" appears to have worked because there have been four successful Titan IV launches and one successful Delta III launch since the August 1998 failure.[27] [28] These lessons have been turned over to the EELV program.

In addition to lowering the cost for launching and improving reliability, a top priority for the military is assured access to space. This entails getting a payload up in space quickly in response to a perceived threat to US interests.

Responsiveness

Launch responsiveness is key to the United States primarily for its national security applications. First, this section addresses the doctrinal reasons the military needs responsive, or on-demand, access to space. Then, it will discuss the long road ahead to responsive space launch.

According to Air Force Doctrine Document 1-1, space superiority is one of the Air Forces' core competencies. An essential element of space superiority is getting into space. This means the need for rapid, responsive space lift. So how responsive is military space lift? When the United States goes to war, does it meet the Combatant Commander's needs?

It takes from 25-180 days to put a satellite into space using the Delta, Atlas, or Titan launch systems. This is not "launch on demand." For example, during the build-up to DESERT STORM, "US Central Command requested Air Force Space Command launch more communication satellites. Air Force Space Command could not comply with the request. In fact Air Force Space Command had to wait for the rocket's upper stage to be completed. Of the six military satellites that did join the existing network during DESERT SHIELD and DESERT STORM all of the launches were previously scheduled. US Space Command continued to reflect a policy of launching on schedule, not on demand. It simply could not respond to short-notice requests."[29] Around the same time frame, the Commander in Chief United States Space Command (USSPACECOM) identified what was wrong with space launch.

In July 1990, General John Piotrowski, Commander in Chief USSPACECOM, described the US military launch infrastructure as lacking characteristics key to other military forces: combat readiness, sustainability, and force structure. To meet the military launch needs a new generation of launch vehicle was to come on line, the National Launch System. It was aimed at achieving, 98 percent reliability, a 95 percent launch on schedule probability, a vehicle availability of 90 percent or better, a 30-day or less launch response time, and a surge capability that would accommodate seven payloads within a 5 day period.[30] However, due to the high cost this program was ultimately cancelled and eventually replaced with the EELV.

The current state of affairs with the EELV doesn't propose any solutions to the responsiveness issue. According to the requirement documents for EELV, the goal is to meet a 25-50 percent reduction in costs from the legacy vehicles of the Delta, Atlas, and Titan. The EELV requirement document doesn't address the need for rapid and responsive space lift.[31] This concept won't meet USSPACECOM's future needs for responsiveness outlined in joint and Air Force doctrine.

According to the Long Range Plan, "On-demand satellite deployment capability will be necessary starting in 2008, so we can augment and replenish constellations to support crises and combat operations. With the high dependence on space-based systems, launches must be on-demand." Furthermore, USSPACECOM's goal for 2020 is to compress the time it takes for an "on-demand" satellite launch from the present years/months to days.[32]

It should be clear at this point that it's important to the United States to decrease costs, improve reliability, and compress response times for space launch. It should also be evident that both the military and civil sectors are making strides in each of these areas, but that progress is slow. The next chapter delves into an innovative approach taken by an international consortium, Sea Launch. In 1995 Boeing, Ukraine, Norway, and Russia were successful getting private funding, and to this date have had five launches. What lessons in cost, reliability, and responsiveness can the United States learn from them?

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Chapter 3

What Sea Launch Has Done

Sea Launch was formed in response to increased market demand for a more affordable and reliable commercial satellite launch service.

— Sea Launch Home Page, February 2001

Why is a company launching from the sea? The Sea Launch consortium is launching from open ocean locations to get flexibility in launch azimuth and independence from government owned launch facilities. In addition, the international privately funded consortium, which includes Boeing (40%) and companies from Ukraine (15%), Norway (20%), and Russia (25%), predicts to capitalize on a growing commercial launch market.[1] Furthermore, to keep launch costs down and reliability at an optimum they built an entire launch infrastructure and working launch system using reliable components in combination with a new automated launch processing system.[2]

The following sections will address Sea Launch costs, reliability, and responsiveness. Specifically, focusing on what the Sea Launch concept is and following it up with the status in those areas. This will provide a baseline for comparing and contrasting Sea Launch with current United States military launch operations.

Cost

Sea Launch advertises that it is cost beneficial because their marine operations reduce launch infrastructure, the equatorial site allows for heavier payloads, and their location and independent range scheduling help avoid expensive launch delays.[3]

The company advocates, by reducing launch infrastructure it can save on operational costs while still providing the customer with a variety of options. The Sea Launch system is made up of the assembly and command ship, *Sea Launch Commander*, and the self-propelled, semi-submersible launch platform.[4] These ships have the basics of what every launch customer would need - a mobile, self-contained spacecraft assembly, test, and launching complex.[5] Wary of seeming not to have enough, the company's marketing goes on to say that it has "the facilities and amenities of a US site." Additionally, they have ample satellite processing facilities near their home port in Long Beach, California.[6] Overall, Sea Launch has minimized the amount of launch infrastructure that is out to sea during the launch. This keeps costs down while still providing customers with land-based options. In addition to saving money by reducing launch infrastructure, Sea Launch can extend the spacecraft life (with more satellite fuel aboard) by launching from the Equator.

Optimizing the launch site at the Equator can prolong the satellite life, thereby saving the launch customer money. The launch site is approximately 3,000 miles from the port at Long Beach California. It's cost beneficial to travel 11 days out to the Equator because the Earth spins faster at the Equator and slowly decreases its spin rate up to the poles. This gives the launch an extra boost – similar to a slingshot. This extra boost means that a launch vehicle launched from the Equator can lift a payload 10-15 percent larger than the same booster launched from Cape Canaveral AFS (located at 28.5 degrees latitude).[7] This in turn means that the satellite aboard the launch vehicle can carry more fuel, extending the life of the satellite. Launching out on the open seas not only provides an optimized Equatorial launch site, but it also provides freedom from a continental launch site.

Launching on the sea has two major pluses that prevent expensive launch delays for the satellite customer - range scheduling is independent of the government and the weather on the open seas is typically better than the weather on the continental coasts. First, the satellite customer doesn't have to compete with higher priority government launches that could bump the launch position of the commercial user. Also, due to its location, Sea Launch doesn't need to get on the busy schedule at the continental ranges at Vandenberg AFB, California and Cape Canaveral AFS, Florida. The second focus is the weather. The weather on the coasts is often foggy and inclement (too hot or too cold) causing costly launch delays. As of the first six launch attempts, the weather hasn't prevented a single launch at the equatorial Sea Launch site.[8] These are Sea Launch's concepts for cost cutting. Has Sea Launch delivered a cost-beneficial product?

Sea Launch status remains true to their word on the cost benefits. They have reduced launch infrastructure while still providing a myriad of customer options. Also, the equatorial site has launched the heaviest commercial payload in history.[9] Finally, to date there have been no range scheduling delays due to range conflicts or poor environmental conditions. All of these areas will benefit Sea Launch and in turn provide their customers with a cost-effective method of launching their satellites into space. Another aspect that closely correlates to the cost of launching a satellite is the reliability of the space transportation.

Reliability

There are two areas Sea Launch touts as key to their reliability – proven high performance components and efficient operations. Using proven, reliable components from the world's premier companies is the hallmark of Sea Launch. The Sea Launch vehicle's first and second stage are the robust heavy-lift (11,000 lbs to high orbit)[10] Russian built Zenit 3-SL boosters, along with the Russian Energia third stage, and Boeing built enclosures and interfaces.[11] In addition to combining proven reliable technology into one booster, Sea Launch modernized launch operations.

Sea Launch's concept is streamlined integration and automated launch operations.[12] On their home page it says, "From analytical integration to spacecraft encapsulation to vehicle integration to automated launch processing, The Sea Launch partnership provides a complete launch service package backed by half a century of experience and best practices."[13] It's evident that Sea Launch is combining the reliable technology with the updated computer systems to optimize launch reliability. How have they fared?

Sea Launch's high performance and efficient operations have had successes and failures. The first two launches – a demonstration payload and the DirecTV satellite were resounding successes for the new program. However, the third launch the ICO F-1 communications satellite, landed in the ocean. Eight minutes after liftoff, the launch vehicle's second stage software program inadvertently left a valve open, causing the second stage pneumatic system to loose pressure. Since the second stage pneumatic system also controls the steering, the loss of pressure most likely triggered the automatic flight termination system.[14] On the fourth launch, Sea Launch successfully launched the PanAM broadcast communications satellite. Then on October 20, 2000 Sea Launch sent the heaviest commercial payload in history into the correct orbit.[15] Finally, on January 8, 2001, to be the sixth launch, the launch was halted only 11 seconds before launching due to "worries" about a satellite reading.[16]

As it tuned out, there was nothing wrong with the XM-1/Roll satellite but proceeding so far down in the countdown would cause long delays for the Zenit rocket. Since the Zenit engine had already initiated its pre-start sequence, Sea Launch decided they needed to refurbish the Zenit engine before they make another launch attempt. Sea Launch has shaved off launch costs and learned lessons on reliability, but where do they stand on responsiveness?

Responsiveness

Note once again Sea Launch's marketing concept –"*Sea Launch was formed in response to increased market demand for a more affordable and reliable commercial satellite launch service.*"[17] It addresses cost and reliability, but not responsiveness. As a savvy business however, it is inherent that Sea Launch is responsive to their customer needs. They have been flexible when satellites were late, moving the launch dates to a future date on the schedule. They have also had their share of delays caused by their own systems. For example, after the unsuccessful January launch attempt of the XM-1/Roll satellite and the subsequent decision to have the Zenit engine refurbished, the ship left the Equator for the 2-week trip back to its home port of Long Beach. There, Sea Launch will have the Zenit engine refurbished. To speed up the launch turnaround time, Sea Launch decided to use a Zenit first stage they had in storage instead of waiting for the original engine to be refurbished. The launch is now scheduled for mid March 2001.[18]

Sea Launch cut launch costs by minimizing launch infrastructure, optimizing the launch location, and preventing launch delays caused by busy range schedules and inclement weather. Sea Launch has also capitalized on the high performance and proven reliability of international launch components as well as automated launch systems. However the biggest obstacles for this relatively new venture is to continue to meet launch reliability and responsiveness. This synopsis provided a baseline to learn from Sea Launch's concepts and lessons. The final section identifies findings and provides recommendations for the United States military launch programs.

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[10] Don Walsh, U.S. Naval Institute Proceedings: "Update: Sea Launch Gets First Bird in Space," February 2000, 105.
[11] http://www.sea-launch.com/special/sea-launch/why_sea_launch.htm
[12] http://www.sea-launch.com/special/sea-launch/why_sea_launch.htm
[13] http://www.sea-launch.com/special/sea-launch/why_sea_launch.htm
[14] http://www.canoe.ca/CNEWSSpace0003/30_sealaunch.html
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[16] http://www.spaceflightnow.com/sealaunch/xm1/status.html
[17] http://www.sea-launch.com/special/sea-launch/why_sea_launch.htm
[18] http://www.spaceflightnow.com/sealaunch/xm1/status.html

Chapter 4

Conclusions

There will not exist an effective or capable military, intelligence, civil or commercial space program in the Untied States without reliable, predictable, and cost-effective access to space.

—Edward C. Aldridge, Congressional Testimony, September 28, 2000

Cost

The expensive launch vehicles of the past did not have cost savings as their number one priority. The expendable systems were based on the highest performance and minimum weight to accomplish a military mission. The manned systems were based on operational goals and reliability. The future expendable and reusable launch systems do have costs savings as their number one priority, but they are concepts and haven't been tested. Although the United States has goals to cut launch costs the goals are based on concept vehicles. Sea Launch has had five launches. What has Sea Launch done to successfully cut costs?

Sea Launch has succeeded in cost-savings by reducing launch infrastructure at sea, launching at an equatorial site which allows bigger payloads, freedom from the busy United States ranges, and good weather to avoid launch delays. The United States can capitalize on Sea Launch's concepts.

To cut long-term costs for United States space launch, the United States needs to invest in the future – the future launch vehicles and update launch ranges. Commercial concepts are a start when it comes to increasing competition but the concepts need to be proven. That is going to cost money and a change in attitude. The United States should continue to encourage cheaper pursuits to space with additional funding and easy access to the launch ranges. In addition, a launching company must not be afraid to take a calculated risk. Very few of Van Braun's rockets worked on the first attempt. In addition, there are many problems with our current space launch ranges.

The United States space launch ranges need updated equipment and policies. "Obsolescent equipment and instrumentation and obsolescent Federal law covering burgeoning commercial launches at the range have left both the Air Force and the commercial operators unhappy."[1] The ranges should be equipped with GPS navigation, Autonomous Flight Termination system, Satellite Telemetry Relay, and improved weather forecasting systems. Also, the future vision of space launch ranges needs to include both the government and commercial users. The users both government and commercial, should be involved in updating and standardizing range operations. The key is to make the ranges more efficient while still protecting the surrounding population.

Reliability

The United States is dependent on reliable space launch for national security and economic reasons. Until the past 3 years, the United States was a nation to emulate in the space launch arena. The problems with the Titan IV and Delta III failures appear to be fixed and lessons learned integrated into the fleet of EELVs. If the United States wants to remain a viable power in space and a player in the global space economy, the United States must continue to demonstrate reliability. Similarly Sea Launch has dealt with reliability problems.

Sea Launch's use of high performance parts and efficient/automated operations is still in the infancy stage. From the two launch anomalies, Sea Launch has learned important lessons. The catalyst of one anomaly was poor satellite operator training so far down in the launch count that the Zenit's engine pre started. Sea Launch ultimately decided the engine needed refurbishment before attempting another launch. Proper training and contingency procedures could have averted this problem. The other anomaly was programming the second stage software. This problem could be averted if a quality check was done on the programming or a more comprehensive test was accomplished. As the Sea Launch program illustrates not all anomalies will be averted by using the highest performance parts or the most automated systems.

To continue a history of reliable space launch for both national security and the economy, the United States can't get lax on procedures and proven methods. Furthermore, the United States must realize that with every new space launch vehicle comes inherent risk. They must be willing to accept calculated risk, learn from the lessons, and continue to evolve. Areas the United States should invest in are preparing contingency operations and better modeling and simulation for space hardware.

Responsiveness

At this point in time, the military sector of space launch is primarily concerned with launch responsiveness. The military is focused on a future of space power and space superiority. To realize this, the military must have assured access to space, which means on-demand launch capability. On demand currently is not available since the processing time for a launch is measured in months. However, USSPACECOM projects to compress the processing timeline to days by the year 2020. However, there is a gap between new systems coming on line (EELV) and what our doctrine's vision is for the future of space launch. Although the definition for responsiveness in the military is different than responding to customers of a business, there are some similar concepts.

Sea Launch has come up with creative ideas to respond to their customer needs but there is still room for improvement. For their launch customer they were very flexible on slipping the launch date if the satellite wasn't ready in the expected time. Furthermore, if the satellite was ready as planned, they launched according to their proposed schedule. On the contrary, during the last launch attempt, Sea Launch had to travel 2-weeks back to home port simply to refurbish the main engine. Adding another 2-weeks on for a return trip to the Equator meant a 1-month turnaround time simply for the transportation. This was not very responsive. Another factor to consider is that Sea Launch has a minimal launch schedule – only planning 6 launches per year of which they have only attempted 3 launches per year.[2]

The United States needs to make launch scheduling more flexible and reactive. To do this, the US needs to limit the time the booster is on the launch pad. For example, horizontal processing then erect the booster on the pad – similar to the Russian Proton or vertical processing in a vehicle assembly building and move it out to the pad just about ready to go – similar to the Shuttle and Titan IV and the proposed Delta IV. The US also has to construct more launch pads. Building more launch pads will allow a margin to handle launch "surges," accommodate launch slips, support anomaly resolution, and accept pad downtime for modernization.

Implications of the Study

The implications of space launch for the United States are far reaching. The United States depends on space launch for national security and the economy. The primary factors are cost, reliability, and responsiveness. There is an inherent risk involved when trying to reduce costs and increase reliability at the same time. In addition, the more responsive you expect a system to be, the more requirements you will incur. This will also bring up the price tag. This shouldn't deter the United States from progressing. The United States must continue to invest in launch vehicles and launch ranges because the United States' future security and economy depend on it.

Notes

[1] Bill Gregory, Armed Forces Journal International: "Reshuffling the Deck: US Space Launch Operations Get a Whole New Look," August 2000, 43.

[2] http://www.sea-launch.com/special/sea-launch/history.htm

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