

## Reducing the Cost of Launching Small Satellites: A Perspective From the Field

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### **Abstract**

The Rocket Systems Launch program (RSLP), SMC Det 12/RP, AFSPC, has been working to reduce the cost of launching small R&D satellites since 1995. This effort started when RSLP assumed responsibility for the Pegasus XL Small Launch Vehicle (SLV) program in 1995. The Air Force Small Launch Vehicle (AFSLV) program provided Pegasus XL launch support to the DoD Space Test Program (STP). RSLP launched the Radiation Experiment II (REX II) in 1996 and the Fast On orbit Recording of Transient Events (FORTE) and Space Test Experiments Platform Mission 4 (STEP-M4) satellites in 1997 using Pegasus XLs. RSLP transferred the Standard Small Launch Vehicle (SSLV) program from DARPA in 1997 and used it to launch the Space Test Experiment (STEX) satellite in 1998 and the Multi-spectral Thermal Imager (MTI) satellite in 2000. These launches used Taurus vehicles and represented the first time that RSLP attempted to use surplus ICBM assets to reduce space launch costs. Each of

these missions used an excess Peacekeeper Stage 1 to replace the Castor 120 commercial Taurus Stage 0 resulting in a \$6M (30%) savings per mission. RSLP continued pursuing its goal to provide low-cost, reliable spacelift for the R&D community by reusing surplus Minuteman II boosters to reduce the cost of launching small satellites. In 1997, RSLP awarded a contract to develop and fly the Minotaur SLV. This vehicle used Minuteman and Pegasus boosters to provide lower cost, reliable spacelift. The Minotaur SLV represented a two-fold decrease in the cost-per-mass-to-orbit equation over contemporary commercial SLVs and lifted the Joint Academy Weber State SATellite (JAWSAT) and MightySat II.1 satellites in 2000. RSLP placed the Peacekeeper derived SLV (PKSLV) on contract in 2003. This vehicle can lift three times the mass that the Minotaur can lift for a similar price and represents a six-fold decrease in the cost-per-mass-to-orbit equation over contemporary commercial launch vehicles. This paper provides a historical perspective on the cost of launching small satellites from the RSLP

perspective. It outlines the elements that drive launch costs and illustrates the issues that keep the cost of spacelift relatively high. Finally, it outlines several methods that have worked to successfully drive launch costs down and outlines several proposals to lower spacelift in the future.

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### Introduction

The Rocket System Launch Program (RSLP); located at Kirtland AFB, New Mexico, has been the custodian of rocket motors from deactivated ICBM systems and other deactivated rocket programs for over 30 years. RSLP has conducted over 600 rocket and missile launches using these surplus motors. The use of surplus motor assets has resulted in great cost savings over the alternative of developing new launch systems to meet the various mission requirements. In fact, RSLP has pioneered the use of surplus motor assets to reduce launch costs. Currently, the lowest cost spacelift opportunities for a dedicated ride use surplus ICBM motors. These systems are operated by RSLP (The Minotaur and the Peacekeeper SLV) and the Russians (Rokot).



**Figure 1: RSLP Launch Configurations**



**Figure 2: The Pegasus XL**



**Figure 3: the Taurus SLV**



**Figure 4. The Minotaur SLV**



**Figure 5: The PKSLV**

### **The Rocket Cost Equation**

There are several components that make up the total or “fly-away” cost of a launch service. These costs are composed of:

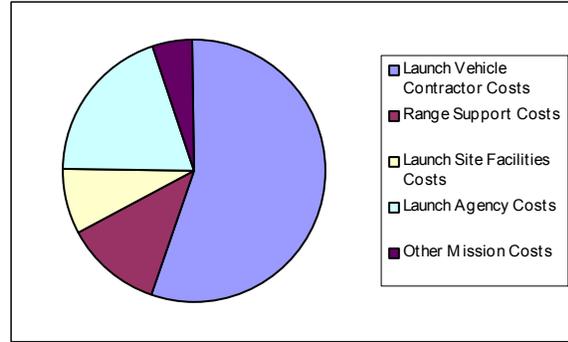
1. Launch vehicle contractor costs
  - a. Basic contract costs
    1. Hardware, analysis, etc.
  - b. Additional services costs
    1. Studies, enhancements, etc.
  - c. Profit and mission success payment costs
2. Range costs
  - a. Mission planning costs
    1. Range safety approval and meeting support.
  - b. Mission execution costs
    - 1) TM, safety, control rooms, etc.
3. Launch site facilities costs
  - a. Payload and launch vehicle processing
  - b. Launch facility costs
    - 1) Commercial spaceport costs
4. Launch agency costs
  - a. Equipment costs
    - 1) ICBM boosters, etc.
  - b. Operating costs
    - 1) Personnel, travel, etc.
  - c. Mission Assurance costs
5. Other costs
  - a. Payload adapters, isolation, studies, etc.

It is important that all the costs of a launch service be identified to ensure that the satellite payload customer understands the total bill that they will be responsible for after the payload is delivered to orbit.

Using the Minotaur and Peacekeeper derived SLV costs as a template; the following tasks comprise the indicated percentages for each component of the fly-away cost:

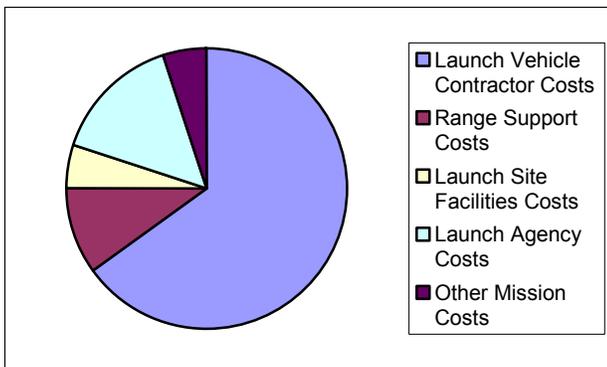
1. Launch vehicle contractor costs: 65%
2. Range costs: 10%
3. Launch site facilities costs: 5%
4. Launch agency costs: 15%
5. Other costs: 5%

In general, the launch vehicle contractor costs account for a little more than half of the fly-away cost of the launch service.



**Figure 7. Launch Cost Allocation (Lower Cost SLV, \$13M Fly-away Cost)**

**Launch Vehicle Contractor Costs**



**Figure 6. Launch Cost Allocation (Minotaur, \$20M Fly-away Cost)**

If a \$7M launch vehicle contractor cost is postulated, then the relative percentages change since most of the other components of the fly-away launch service cost are relatively fixed. The estimated percentages for a mission with a \$7M launch vehicle contractor cost and a \$13M fly-away cost is:

1. Launch vehicle contractor costs: 55%
2. Range costs: 12%
3. Launch site facilities costs: 8%
4. Launch agency costs: 20%
5. Other costs: 5%

Launch vehicle contractor costs represent the largest single element of the rocket cost equation. This is reasonable since the launch vehicle contractor accomplishes the majority of the effort in executing a space launch mission. There are two basic launch vehicle contractor tasks that drive the cost of the launch service. The first scenario occurs as part of the first flight of a new launch vehicle configuration. There are a variety of tasks that must be accomplished in order to prove the launch vehicle design and manage the risk of the first launch. Examples of this effort include wind tunnel testing, structural design and analysis, electrical interface design, etc. The first flight effort may also include an electrical and mechanical "Pathfinder" mission. This task involves proofing the launch vehicle procedures and verifying the interface by assembling an inert launch vehicle on the launch pad that will be used to launch the first mission. The Pathfinder mission can add \$250K-\$500K to the cost of a first mission. If an inert booster is not available, the total cost of a Pathfinder could be on the order of \$1M. RSLP first flight missions typically have launch vehicle contractor costs that are 170% of the launch contractor costs for subsequent flights of a given launch vehicle configuration. While this additional cost of the first flight is

somewhat painful to bear, it is absolutely crucial to follow this architecture to avoid a costly first mission failure. It is universally true that the first mission of any launch vehicle must be successful in order to instill confidence in the payload customer community. RSLP launch contractor costs for subsequent missions are on the order of \$12M. This relatively high cost represents the cost of procuring the launch vehicle boosters and other vehicle components, accomplishing several mission critical analyses such as the Coupled Loads Analysis (CLA), labor costs for management, engineers, and technicians, the cost of the launch campaign (travel, launch site operations, etc.) and allowable charges such as overhead and taxes. This cost level has been relatively stable across several launch vehicle configurations and over a five-year time span. This level of launch vehicle costs is indicative of the level of effort required to launch a small satellite (or several ganged payloads) costing \$10M-\$100M. This level of effort offers the high probability of success required by all but the simplest satellite payloads.

### **Range Costs**

Launch Range costs are composed of several elements. These elements include planning costs, facilities costs, range safety approval costs, and the costs of supporting the actual launch mission. One of the largest components of the range related cost is the cost of the day-of-launch support. This involves providing essential technical services such as telemetry tracking, communications, and range safety. This cost is currently estimated at \$1M-\$1.3M. This large cost is driven by the requirement for the range to recoup the costs of launching the mission as well as the costs associated with maintaining the range as a national resource (yearly operation costs shared by all range

users). Another relatively high range related cost element is the cost of getting the launch vehicle range safety system approved for flight. Some of these costs are part of the planning element of the range costs but most are hidden in the labor costs for the launch vehicle contractor and the program office technical support. The range safety requirements also drive the need to procure and test very expensive range safety equipment required to ensure that a launch vehicle that fails to fly on the approved trajectory can be destroyed. While the labor cost for range personnel engaged in the range safety system approval is a small part of the launch service cost, the total cost of the range approval process (hardware procurement, qualification testing, launch vehicle contractor and program office labor, etc.) can be several million dollars for a first flight and over a million dollars for subsequent flights. The planning costs are relatively small and represent labor and travel costs for range personnel to participate in the launch service planning process. A final relatively large range related cost element is the cost of the launch facility necessary to launch the rocket. RSLP uses commercial spaceports to provide the launch facility. This cost element represents \$1M-\$2M of the total cost of a first mission and about \$1M in the launch service costs for a subsequent mission. Range costs represent about 10-15% of the total cost of a launch service.

### **Mission Assurance Costs**

Mission assurance costs are necessary to provide the insight into the launch vehicle contractor and range approval process required to obtain approval for the launch mission to take place. Typical RSLP satellites cost \$20M-\$100M and are used to accomplish tasks on orbit with critical national security impacts. The mission assurance process includes independent

analysis and verification of critical mission software and hardware. This effort looks at critical elements of the launch vehicle contractor process, independently checks the data, and provides an assessment to the launch approval managers that the launch vehicle is ready to lift. In addition, the mission assurance process also includes program office technical support as well as a Mission Risk Assessment (MRA) provided to the program office and senior Air Force management. The mission assurance process typically costs about 10% of the launch vehicle contractor costs.

### **Other Costs**

There are several other cost elements that are not necessarily part of all RSLP launch service effort. Most of these are due to specific requirements levied on RSLP by the satellite customer. An example of this is a special study conducted to provide risk reduction analysis prior to the customer selecting an RSLP launch vehicle to support their mission. RSLP has also structured their available contract options to include the basic launch vehicle and mission execution (this is the minimum effort that all satellite customers would require) supplemented with a menu of "Enhancements" that the customer can choose from to customize the mission support effort. Typical examples of this are highly clean (Class 10,000 or better) environments, separation systems, increased launch vehicle telemetry, payload isolation systems, etc. These enhancements typically add several million dollars to the mission costs.

### **Opportunities for Improved Costs**

RSLP is committed to reducing the costs of launching small satellites to the lowest levels without compromising the mission. RSLP focuses on the basic elements of the launch

service as required by all customers. They want their precious satellite payloads delivered to the right orbit, working, on schedule, and on budget. These basic mission requirements cannot be compromised by cost reduction efforts. Looking at the components of the rocket cost equation in order:

Launch Vehicle Contractor costs: This cost is coupled to the number of people working on the effort. A typical launch team may have 40-50 members with the average equivalent of around 10 people working the mission full time. This level of effort appears to be about the same for all small launch vehicle contractors. The more people working on an effort the more that effort will cost. The best way to reduce the labor costs of small launch vehicle operations is to reduce the number of people working on a given launch effort. The trick is to keep the number as low as possible and still have the breadth and knowledge base required to reliably work all of the launch service problems. Smaller companies have reduced labor costs but also lack the in-depth analysis and engineering expertise that is sometimes required. Of course, smaller companies without a complete in-house analysis capability can outsource these tasks to several excellent analysis companies to do this work. The hardware cost of an RSLP rocket is a relatively small part of the total launch vehicle contractor costs. The hardware costs for most RSLP launch vehicles is less than 40% of the total launch vehicle contractor costs. Some of this is due to the fact that the government; from its stocks of surplus ICBM motors, provides most of the boosters. Using existing hardware has produced the lowest launch service costs in the United States and Russia. Another way to reduce the hardware costs of a space launch is through economies of scale. A launch vehicle costing \$20M might cost \$5M-\$7M less if sortie rates of 10-20 per

year could be flown. This would allow substantial reductions in the cost of various components such as avionics, would allow efficient "production line" operations, and would reduce the "standing army" cost share from a few missions per year to 10-20 missions per year. An example of this for a company with operating costs of \$20M per year may be instructive. If the company launches two missions per year then each launch must bear its share at \$10M per mission. If that same company launches 10 missions per year then the per mission cost share is \$2M. A related method that would reduce the costs for a basic launch service is to procure the launch service in lots of multiple missions. Currently each mission is procured individually forcing the launch vehicle contractor to procure the components for that launch in single unit purchases. If the launch vehicle contractor could procure components for 5-10 mission than those components would cost much less. Unfortunately, 10-20 missions per year for each of the six existing and several small launch vehicles in development are unrealistic.

Range/Launch Facility costs: Several things drive this cost element. A streamlined range safety approval process would greatly reduce the cost of first missions and would lower the costs of subsequent missions. The current range safety process was developed over several decades and works exceedingly well. The mission of the range safety officials is to ensure that no rocket launched from their range endangers lives or property. The perceived risk of rockets and the fact that they fly autonomously after lift-off (you can't call them back or redirect one to the correct course), coupled with the relative proximity of large population centers to the major launch ranges, drives extreme conservatism in the range safety process. This conservatism is crucial to maintaining the

enviable safety record of our launch ranges. The trick is to do this critical function at a lower cost with absolutely no compromise in the reliability of the process. The costs associated with day-of-launch support and the use of launch facilities would be greatly reduced if many more launch missions occurred in a given year. The mechanism is the same as for the launch vehicle contractor economies of scale reduction. The chief benefit is that the per mission share for the team/facility operating costs would be greatly reduced.

Launch Agency costs: The launch agency costs are relatively fixed. The booster refurbishment costs are about 10% of the costs of new boosters. This particular RSLP cost is a substantial bargain and does not offer many ways to economize while still preparing the boosters to support the launch. The mission assurance process is also relatively stable with a cost that is roughly 10% of the launch vehicle contractor cost. RSLP typically assigns two government engineers to manage and monitor the process (a mission manager and deputy mission manager). One or two technical support contractors and several part time support people (contracting, fiscal, etc.) support these managers. This lean team is responsible for all actions relating to the successful accomplishment of the launch service.

Other costs: The payload customer drives these costs. The customer can control these costs by eliminating these unnecessary "requirements" and choosing only those enhancements that are absolutely required for the successful execution of the launch service.

### **Summary/Conclusion**

Reducing the relatively high costs of launching small satellites represents a

daunting challenge. The brute force energies required to deliver the payload to Earth orbit require brute force engineering and hardware to reliably accomplish the launch service. These methods will always be costly to execute. There is room to lower the large costs. The most obvious way is to operate more efficiently. This means to hire the best people in only the numbers necessary, to develop hardware that gets the job done reliably without additional costs, to develop systems that have focused and efficient operations, and to guard against wasted effort and materials. Another way that has led to some unrealistic cost estimates for launch services is to greatly increase the launch rate for a given year and generate huge economies of scale cost savings. The most obvious way to reduce the costs of launching individual payloads is to manifest several payloads on one launch vehicle. This method offers the fastest and most viable way to achieve launch costs under \$5M per satellite.

### **References**

1. Schoneman, S., Buckley, S., et. al, "Orbital Suborbital Program (OSP) "Minotaur" Space Launch Vehicle: Low Cost Space Lift For Small Satellites Using Surplus Minuteman Motors", AIAA Paper AIAA-2000-5068, AIAA Space 2000 Conference, September 19-21, 2000, Long Beach, CA.