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Low-Cost, Reliable Spacelift for Small Satellites Using a Peacekeeper ICBM Derived Space Launch Vehicle and Multi Payload Adapters

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Abstract

The Air Force Rocket Systems Launch Program (RSLP) is charged with the storage and reutilization of surplus Intercontinental Ballistic Missiles (ICBMs). This responsibility places RSLP in a unique position to support small Research and Development satellites by providing low-cost, reliable access to Low Earth Orbit (LEO). The greatest challenge for small R&D satellites is to obtain a ride to orbit and stay within budget. It is common for the cost of a ride to orbit to be twice the cost of the satellite itself. Many groups are trying to reduce the large cost of a ride to orbit. Early commercial Small Launch Vehicles (SLVs) were relatively inexpensive but the cost of a launch service quickly grew by a factor of 2-3. NASA and the Air Force have been supporting initiatives to develop a true low-cost SLV for over ten years. While some of these initiatives show great promise, none have succeeded in producing a true low-cost launch vehicle (around 500 lbm to orbit for under $5 million). RSLP's access to surplus boosters allows it to produce lower cost SLVs. These boosters represent the highest cost component for the launch vehicle hardware. Typically, boosters represent 90% of the cost of launch vehicle hardware. Surplus ICBM boosters, integrated into launch vehicles using modern avionics, offer a way to shave 30%-50% off the cost of comparable launch vehicles composed of new commercial boosters. While these cost savings do not result in a true low-cost SLV, they do represent a significant cost savings and serve as an excellent interim capability until a truly low-cost SLV is developed. RSLP has used surplus Minuteman I and Minuteman II boosters to support target and sub-orbital launch missions for over 30 years. RSLP has been using surplus boosters, coupled with new commercial boosters to support the launch of U.S. Government R&D satellites since 1998. In 1998, RSLP supported its first orbital mission by launching an R&D satellite using a Peacekeeper ICBM Stage 1 to replace the Castor 120 booster on a Taurus SLV. This strategy saved the satellite customer about $6M. RSLP developed the Minotaur SLV under the Orbital Suborbital Program (OSP). The Minotaur SLV is composed of the first two stages of a Minuteman II ICBM, a modified Pegasus Stage 2, Stage 3, avionics section, and fairing. Despite the fact that two of the four rocket motors on the Minotaur stack are commercial motors, the use of Minuteman II motors resulted in a SLV with a 50% increase in payload capacity for a launch cost that is about 60% that of a comparable SLV.

The inaugural flight of Minotaur in January 2000 lofted five small satellites, including four student projects, into LEO. This mission not only demonstrated that the Minotaur design was viable, it also served as an example of how to achieve true low-cost rides to orbit (around $4M per satellite) by leveraging relatively low-cost launch vehicles assembled from surplus motors with Multi-Payload Adapters (MPAs) that allow several payloads to share the launch vehicle cost. Since that mission, RSLP in cooperation with the Air Force Research Laboratory Space Vehicles Directorate (AFRL/VS), located at Kirtland AFB, New Mexico, have developed several payload adapters for use on Minotaur and the new Peacekeeper SLV (PKSLV). This paper will focus on a scheme to use the large capacity and low cost of the PKSLV coupled with two new payload adapters to provide reliable, low-cost spacelift for the R&D satellite community. PKSLV provides about three times the lift capacity of Minotaur for about the same mission cost. This cost saving results from the fact that PKSLV uses only one, relatively inexpensive, commercial motor along with the first three Peacekeeper ICBM motors, a new manufacture interstage, proven Minotaur avionics, and the proven Taurus 92" fairing. This launch vehicle can lift over 2200 lbm to a 400 nm Sun synchronous orbit. It has a generous payload volume with a dynamic envelope of over 80" in diameter and over 120" long. This launch vehicle configuration could lift eight 300 lbm satellites into a two-year polar orbit for around $20M. This equates to a spacelift cost of about $2.5M per satellite. A more typical mission would be to carry a primary satellite payload massing around 1000 lbm along with three 300 lbm secondary satellites carried to a similar orbit. The primary satellite's share of the launch costs would be around $10M with each payload contributing about $3.3 M each. This scenario results in a ride to orbit for the primary satellite that is about one-half the cost of a solo lift on a comparable SLV. The lift costs for the secondary payloads result in a savings of over $15M each payload over the cost of a solo ride to orbit. The keys to achieving these low lift costs are a relatively large SLV with lower launch costs coupled with a payload adapter that can fly several payloads using the available spacelift to maximum efficiency. Innovative multi-payload management schemes coupled with low-cost satellite manufacturing methods complete the equation for cheap, reliable spacelift to orbit.

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Introduction

The Rocket System Launch Program (RSLP) is charted with storage and reutilization of deactivated ICBM systems. RSLP used this charter to develop several SLVs in support of DoD small satellite missions. The first SLV derived from surplus ICBM components was the Minotaur SLV first launched in January 2000. Minotaur was developed under the Orbital Suborbital Program (OSP). This vehicle flew twice in 2000 and currently has three other missions on contract for launch in 2004 and 2005. In 2002, RSLP conducted a source selection for the next round of ICBM derived SLVs. The Orbital Suborbital Program 2 (OSP-2) re-competed the Minuteman derived systems and added a Peacekeeper derived system. This paper will discuss the capabilities of the OSP-2 SLVs and suggest a strategy for supporting multiple small satellite launches using these launch vehicles and payload adapters being jointly developed by RSLP and the Air Force Research Laboratory Space Vehicles Directorate.

The Orbital Suborbital Program 2 (OSP-2)

In 2002 RSLP ran a competition to select a contractor to develop space launch vehicles using surplus ICBM components. This program added a Peacekeeper ICBM derived SLV to the existing Minuteman II capability. The Minuteman derived SLV capability was well understood based on RSLP's experience with the Minotaur SLV. RSLP wanted a larger vehicle to complement the Minuteman SLV. The decision to draw-down the Peacekeeper ICBMs offered a unique opportunity to develop the larger vehicle and still obtain substantial cost savings by using the excess rocket motors. Orbital Sciences Corp was selected as the winner for both the Minuteman II and Peacekeeper derived vehicles. The proven Minotaur SLV was selected as the Minuteman derived system and a new development Peacekeeper SLV was selected as well.

Figure 1. Minotaur SLV

The Minotaur is composed of two excess Minuteman II motors and two commercial motors. These are an M55A1 first stage, an SR19 second stage, an Orion 50XL third stage, and Orion 38 fourth stage and are topped by a Pegasus derived avionics section and fairing. There is also a larger fairing that was jointly developed by AFRL/VS and RSLP. The Minotaur SLV is capable of carrying multiple payloads using two Multi Payload Adapters (MPAs) developed for this vehicle.

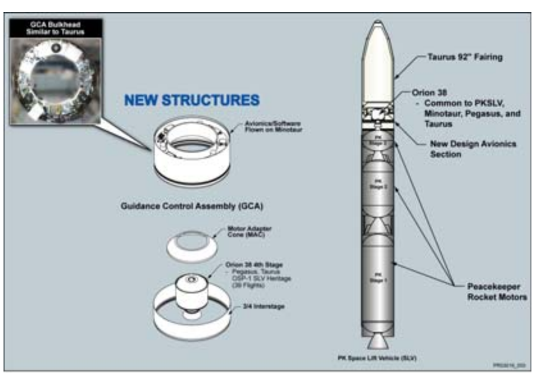

Figure 2. Peacekeeper SLV

The Peacekeeper SLV required a simple development/integration effort to become operational. The Peacekeeper SLV is composed of a Peacekeeper ICBM fist, second, and third stage, a new development fourth stage powered by an Orion 38, a new Minotaur-derived avionics suite, and the proven Taurus 92-inch payload fairing. A larger payload fairing is also being considered to supplement the standard configuration. The Peacekeeper SLV offers outstanding value to the small satellite community. Recurring costs for a Peacekeeper SLV launch are about the same as for a Minotaur launch with about three times the lift capacity. MPAs are also in development for the Peacekeeper SLV.

Minotaur Space Launch Vehicle

The Minotaur SLV first flew on 26 January 2000. It lofted a multiple payload suite composed of five minisatellites and six picosatellites. This mission serves as the template for the kind of mission envisioned in this paper. The original payload for this mission was the Joint Academy Weber State Satellite (JAWSAT). JAWSAT was supposed to be a joint satellite project between Weber State University and the Air Force Academy. The Academy dropped out of the program and developed a new satellite of their own called FalconSat. In 1997, the Air Force decided that the inaugural flight of Minotaur would loft two payloads. JAWSAT would serve as a structural payload and carry three Space Test Program (STP) payloads as well as FalconSat on top of JAWSAT. This plan stayed in place until about mid-procurement of the first Minotaur launch service when STP decided to drop out of the JAWSAT mission. The Air Force elected to use this event as an opportunity to demonstrate a multi-payload capability on Minotaur. The Air Force manifested Arizona State University Satellite 1 (ASUSAT-1), Orbital Picosat Autonomous Launcher (OPAL) built by Stanford University, AFRL Optical Calibration Sphere (OCS), FalconSat 1, and JAWSAT. JAWSAT served as a structural payload and MPA carrying all of the other payloads. This mission was highly successful as a launch vehicle and multi payload demonstration. The JAWSAT mission was followed by the MightlySat II.1 mission, which launched a single AFRL/VS satellite into orbit in July 2000. Both missions were highly successful with nearly identical performance well below the three-sigma maximum parameters. The Minotaur payload volumes and lift capacity are shown in Figures 3 and 4 respectively.

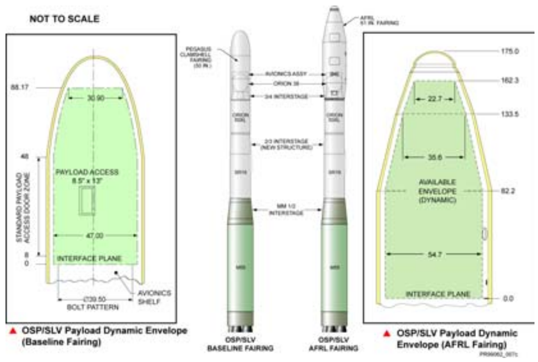

Figure 3. Minotaur Payload Volume

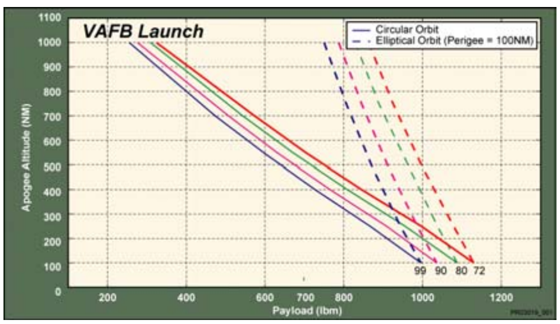

Figure 4. Minotaur Lift Capacity

Peacekeeper Space Launch Vehicle

The Peacekeeper SLV represents a positive step in the agenda to use surplus ICBM motors to provide relatively cheap and reliable spacelift for the US Government community. The vehicle is simpler than theMinotaur with only one commercial motor. This was possible due to the larger size of the Peacekeeper ICBM over the Minuteman II ICBM. This means that the Peacekeeper SLV can avoid the procurement of a larger commercial motor and still have acceptable lift capacities. The use of Minotaur derived avionics and Taurus structural concepts results in a new SLV that has a relatively simple development/integration. This lowers risk for the first mission. The first mission for the Peacekeeper SLV will be procured using a Cost Plus Incentive Fee (CPIF) strategy to limit risk to Orbital Sciences Corporation of unforeseen technical problems. The first mission is also planned to have a 24-month period-of-performance. Cost estimates for the first mission indicate that it will cost about $26M - $29M in recurring and non-recurring costs. Subsequent Peacekeeper SLV missions will have a Fixed Price Incentive Firm (FPIF) strategy with an 18-month period-of-performance. Subsequent missions are estimated to cost about $20M for a simple mission. The Peacekeeper payload volume and lift capacity are shown in Figures 5 and 6 respectively.

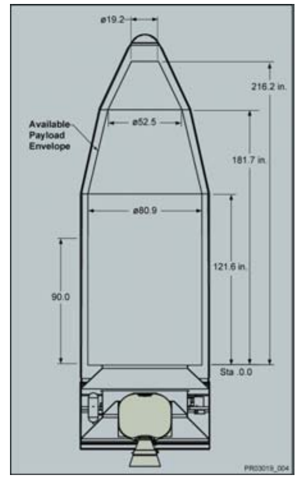

Figure 5. Peacekeeper SLV Payload Volume

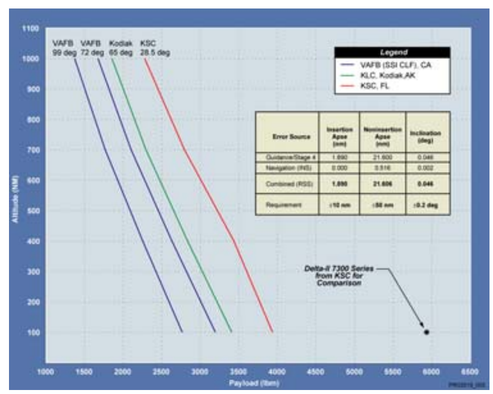

Figure 6. Peacekeeper SLV Lift Capacity

Minotaur Multi Payload Adapter

RSLP and the AFRL/VS have jointly developed a MPA specifically to support Minotaur missions using a Small Business Innovative Research (SBIR) program architecture. This MPA is of metal composite construction and is composed of several flat plates. These flat plates can be configured in a variety of architectures to meet Minotaur multi payload missions. This system has been structurally qualification tested and is ready to support Minotaur missions. The adapter requires a 6-month delivery schedule. Figure 7 shows the

Minotaur MPA in one of its many configurations.

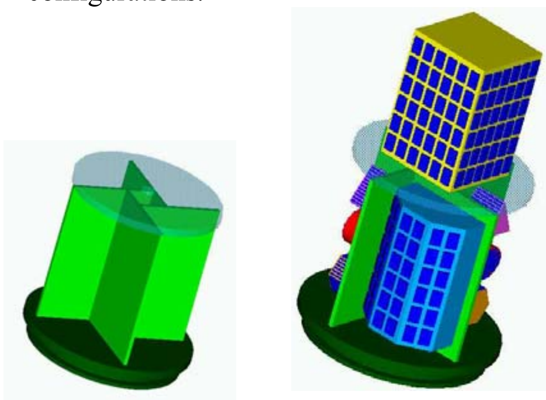

Figure 7. Minotaur MPA

PKSLV Multi Payload Adapter

The AFRL/VS and RSLP are developing a Peacekeeper SLV MPA using a SBIR as well. This adapter is composed of a flat plate with multiple bolt circles to support various payloads. RSLP has standardized Peacekeeper interfaces to the 62.01 inch EELV adapter at the Peacekeeper SLV payload interface, a 38.8 inch Pegasus/Minotaur interface for medium sized payloads and a 15-inch EELV Secondary Payload Adapter (ESPA) for smaller satellites. This adapter can use a flat-plate architecture due to the larger diameter of the Peacekeeper SLV over the Minotaur vehicle. The Peacekeeper SLV MPA has integral payload isolation built into the adapter structure. Figure 8 shows the Peacekeeper SLV MPA in its one large and four small satellites configuration.

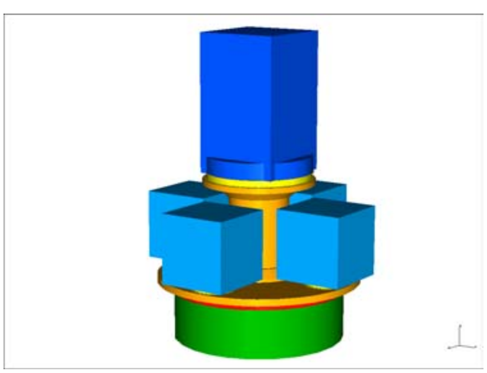

Figure 8. Peacekeeper SLV MPA

PKSLV Dual Payload Adapter

The second adapter for the Peacekeeper SLV is a Dual Payload Adapter (DPA) also using a SBIR project as a contract vehicle. This adapter is composed of a flat plate interface for the lower payload or payloads, a structural can that carries rocket loads around the lower payload volume, a removable cover on the structural can, and a payload interface for the upper payload. The Peacekeeper SLV DPA also has integral payload isolation built into the adapter structure. Figure 9 shows the Peacekeeper SLV DPA in its one large and four small satellites configuration.

Figure 8. Peacekeeper SLV DPA

The Opportunity

Development of a relatively low-cost SLV with much larger payload volume and capacity coupled with development of MPAs and DPAs makes Peacekeeper SLV the ideal SLV to support the small R&D satellite community. The large lift capacity of Peacekeeper SLV allows it to carry one large satellite ganged with several small satellites on a single mission. A scenario that uses the larger payload (1000-1500 lbm) to cover most of the cost of the launch service, ganged with several smaller satellites "hitching a ride" to space by using the excess Peacekeeper SLV launch capacity, represents an economical use of Peacekeeper motors. The large payload gets a mission that is at least half the cost of other small launch vehicles, while the small payloads get a lower cost each to pay for integration. The MPA/DPA and Peacekeeper assets are fully used to provide lower-cost, reliable spacelift to the U.S. Government science community. It is not unreasonable, given the Peacekeeper SLV and its MPAs to envision a "pipeline to space" mission architecture involving a series of planned Peacekeeper SLV launches every few years. This mission architecture would involve a manifesting segment about 1.5 years long that would select the payload manifest and plan for the manufacture of the appropriate MPA or DPA. Once the mission payload suite was manifested, the Peacekeeper SLV 18-month period-of-performance period would kick in to allow normal space mission operations. This cycle could be staggered to allow Peacekeeper SLV missions every calendar year. This mission architecture would remove the uncertainty of the access to space problem that most small satellites face and allow for routine mission planning and execution.

Conclusion

The OSP-2 contract with its Minotaur and Peacekeeper SLV capabilities coupled with new DPAs and MPAs under development offers a unique opportunity for the small satellite community to solve one of its most difficult problems…low-cost, reliable access to space. These tools enable a mission architecture composed of a series of periodic Minotaur and Peacekeeper SLV missions flying multiple payloads on each flight that could maximize the opportunity for small satellites to get to Low Earth Orbit and ensure that each use of a surplus ICBM to lift satellites provides as much value to the government as possible.