

**SLVR: A NASA Strategy for Leveraging Emerging Launch  
Vehicles for Routine, Small Payload Missions**

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**ABSTRACT:** Orbital flight opportunities for small payloads have always been few and far between, but on February 1, 2002, the situation got worse. In the wake of the loss of the Columbia during STS-107, changing NASA missions and priorities led to the discontinuation of Get-Away Special and Hitchhiker, leaving expendable launch vehicles (ELVs) as the only option for small payload access-to-space. Attempts to establish routine opportunities aboard ELVs, however, have been unsuccessful, due to a suite of technical and management issues.

The prospects for breaking out of this paradigm appear promising as a result of NASA's partnership with DARPA and the USAF in pursuit of low-cost, responsive small ELVs under the Falcon Program. Through this partnership, several new small ELVs are planned that can be used as the basis for a sustained small payload program. Wallops Flight Facility is taking the steps, on behalf of NASA, to leverage these capabilities and develop the remaining building blocks of a systemic solution, including payload carriers, low-cost launch operations, and mission operations, through the Small Launch Vehicles Research Project (SLVR). With the success of these efforts, routine opportunities for small science, technology, and educational satellites, may finally be on the horizon.

## BACKGROUND

Since the 1980's, the primary means for conducting small payload missions has been via the Space Shuttle. The Shuttle Small Payloads Project carriers, including Get-Away Special and Hitchhiker, have provided low-cost (albeit subsidized) reliable service, but changing NASA missions and priorities, following the loss of Columbia during STS-107, have led to the discontinuation of the Shuttle Small Payloads Projects. In spite of the limited opportunities, long queue, and restrictions associated with flying experiments on a human-rated transportation system, the carriers provided sustained, high quality experiment services for education, science, and technology payloads.

The alternative to the Space Shuttle for small payload access-to-space has been and remains expendable launch vehicles (ELVs). The two ELV options are for small payloads to fly as secondary payloads on medium-to-large ELVs or to multi-manifest a suite of small payloads on a small ELV. Finding a compatible primary spacecraft with excess capacity, going to an acceptable orbit, and scheduled to fly in the needed timeframe is rare. Add to this the general lack of interest from most primary spacecraft and

launch service providers in adding to their missions the complexity and technical risk associated with flying secondary spacecraft, for a comparatively low financial offering. The impediment to a small ELV solution for small payloads has always been cost. The cost of small ELVs translates to a significantly higher cost for a given payload than larger ELVs. In fact, the small ELV option is generally considered prohibitively expensive when considering the overall programmatic value of most small payload objectives, which are normally modest, such as for education, technology risk reduction, or low priority science measurements.

## A DEFINED NEED

This access-to-space impediment continues to stunt the small satellite community. There is a backlog of previously planned Shuttle-based small payloads. There are many small orbital payloads being developed at U.S. universities as student projects that have neither a commitment nor a reasonable expectation of flight. Beyond these existing spacecraft, there is an unmeasured, but perceived large market of research and student payloads that would emerge were a transportation solution

available at a significantly lower cost-per-payload pound.

At NASA and other agencies, there is a genuine need and strong advocacy for orbital student flight missions. Currently, the only NASA student flight opportunities are through the use of suborbital sounding rockets, balloons, and aircraft. NASA/Goddard Space Flight Center's Wallops Flight Facility currently provides such opportunities for K-12 and university students. These carriers offer low-cost and valuable hands-on flight experiences for students and have proven highly effective in exciting the next-generation of U.S. scientists and engineers. There are, however, certain research measurements and educational aspects that can only be experienced through orbital spaceflight.

Within NASA, there are two other categories of missions that hunger for an affordable small spacecraft capability. The first is science. As science sensors are miniaturized, and as small multiple spacecraft are designed to be flown in formation as sensor webs and distributed apertures, many historically large spacecraft missions can be replaced by smaller, short development time satellites. Additionally, the experimental nature of many instruments used for large world-class Earth and space science missions exposes a high financial investment to a significant level of risk. The availability of a responsive, low-cost, small payload capability would offer the opportunity to flight-demonstrate prototypes, thereby retiring significant risk and elevating technology readiness levels (TRL).

NASA's Vision for Space Exploration also possesses a strong need. There are a substantial number of unproven technologies to be demonstrated along the path of returning to the Moon and then moving on to Mars. Once again, the need for prototype demonstrations to elevate TRL and retire risk is acute. At least as important as low-cost to Exploration, is the need for responsiveness. Large flight project demonstrations take years to execute. The aggressive schedule that Exploration must meet cannot tolerate extended demonstration missions for technologies on the overall program's critical path. Only small satellite projects can offer the near-term results needed.

NASA's education, science, and Exploration needs cumulatively establish a strong basis for investment in a small satellite capability, presuming the access-to-space cost issues can be adequately addressed. Beyond NASA there are additional needs throughout the federal government, including the U.S. Air Force,

DARPA, Missile Defense Agency, and National Reconnaissance Office who would also benefit from access to a low-cost, responsive small payload capability.

## **HOPE FOR A BREAKTHROUGH**

The cost of the access-to-space component has precluded NASA from sustaining a small orbital payload program. Recently, however, there has emerged a glimmer of hope for breaking through the cost barrier that has stymied small satellite efforts. This glimmer is the DARPA Falcon small launch vehicle program. DARPA, in partnership with the USAF, initiated a program to establish one or more small ELVs capable of lifting 1000 lbs. of spacecraft to low-earth orbit (LEO) or to provide a long-range suborbital flight capability for \$5M per mission (based on 20 missions per year). In July 2004, DARPA selected four contractors to carry their concepts to the Preliminary Design Review stage.

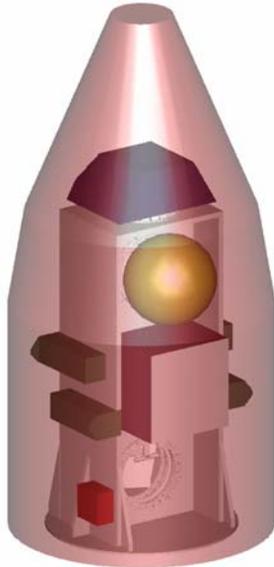
Falcon is the latest in a series of programs initiated by the federal government with the goal of a new low-cost small ELV. Previous attempts did not reach fruition, but contractors under Falcon are seemingly making technical progress and espouse the ability to produce their designs for costs approaching the DARPA cost target. Because of NASA's interest in the emergence of new low-cost small ELVs, a Memorandum of Agreement (MOA) was signed in November 2004 in which NASA agreed to contribute both funding and in-kind services to aid DARPA in the success of Falcon.

Wallops' participation with DARPA as a potential Falcon launch site, its ongoing development of advanced range technologies, along with the new NASA resource commitment, has created a confluence of circumstances that offers the opportunity to establish a sustainable, effective small orbital payload program.

## **SMALL LAUNCH VEHICLE RESEARCH PROJECT (SLVR)**

In exchange for NASA's contribution to the Falcon program, DARPA is providing NASA with the opportunity to manifest payloads on some of the flight demonstration missions. Wallops, already immersed in the launch operations aspect of Falcon and with a strong history of implementing small suborbital and orbital flight projects, has been afforded the opportunity to develop a carrier spacecraft for the multiple small payloads that NASA would fly on a Falcon demonstration flight. This

carrier is known as the Multi-Payload Ejector (MPE).<sup>1</sup>



**Figure 1. Multi-Payload Ejector (MPE)**

Rather than treat the Falcon MPE flight as a discrete, one-time opportunity, Wallops' strategy is to instead use it as a pilot demonstration with an eye toward the establishment of a continuing small payload program in support of NASA, and potentially non-NASA sponsored interests. The larger, long-term vision has been coined the Small Launch Vehicle Research Project (SLVR). SLVR is a systematic approach to providing end-to-end capabilities as a sustained flight program for small payloads. SLVR is composed of a number of discrete elements, each critical to making missions frequent, affordable, and flexible.

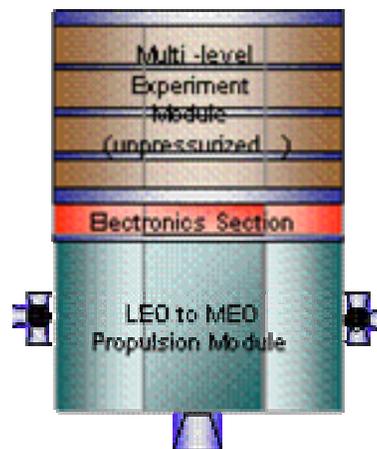
**Element 1: Experiment Management**

SLVR's first element is a management system to solicit and coordinate candidate payloads on a continuing basis. This experiment brokering function is required to maintain the status of candidate payloads for a potential mission, to assess priorities and technical compatibility, and to support a selection process for a given mission. It is anticipated that each mission will involve payloads from multiple sponsoring organizations that will require management coordination. This management responsibility will also serve to coordinate and facilitate integration and testing processes for the various payloads, either at Wallops or at the experimenter's home institution.

**Element 2: Experiment Carrier Suite**

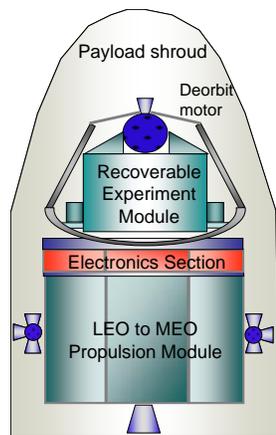
The second key element of SLVR is the establishment of a suite of flight carriers that will possess standard interfaces to the program launch vehicle(s), and accommodate a flexible set of small payload requirements for a diverse customer base. Wallops has taken the first step on this element with the aforementioned MPE. This carrier can provide the accommodations for stand-alone spacecraft ranging from CubeSats to ESPA-class satellites with masses ranging from two to 400 pounds. The MPE offers the flexibility to trade mass, volume, and quantity of individual spacecraft, along with orbital altitude through the modular addition or removal of MPE sections. It also requires individual satellites to design to common interfaces.

Concepts are currently under development for a second type of carrier that provides services to experiments rather than to stand-alone spacecraft. This carrier, the Multi-Payload Experiment Carrier (MPEC), would offer a means to flight demonstrate components, boards, materials, and software systems in a space environment without the burden of developing a host spacecraft. The MPEC would provide standard electrical, data, and mechanical interfaces and provide fixed experiment mass, volume, power, data, and thermal envelopes. Like the MPE, it would be modular offering multiple, stackable experiment sections. The MPEC could fly as a standalone spacecraft, or potentially as a primary spacecraft atop a co-manifested MPE. As it is anticipated that frequent customers of the MPEC may include researchers interested in higher radiation environments than provided in low Earth orbit (LEO), a propulsion module may be included that will move the MPEC from LEO to higher orbits.



**Figure 2. Multi-Payload Experiment Carrier Concept (MPEC)**

A third carrier under consideration is one offering flight opportunities for experiments needing recovery from orbit. These experiments may include biological, microgravity, or space-exposure experiments. This concept emulates the functionality of the Multiple Experiments Transporter to Earth Orbit and Return (METEOR) mission design, sponsored by NASA in the early 1990's. The Freelyflyer carrier, like the MPE and MPEC, would use standard electrical, mechanical, and data interfaces, and require experiments to conform to fixed mass, volume and thermal budgets. It is unclear whether there is a compelling case for orbits beyond LEO, or whether this capability can reasonably be implemented within available mass, volume and cost constraints. This will be assessed during the requirements definition phase. After an established period on orbit, the de-orbit motor would fire, allowing the carrier to reenter back to Earth for experiment recovery and analysis.



**Figure 3. Reentry Freelyflyer Concept**

The MPE, MPEC, and Freelyflyer jointly will serve as a suite of carriers, offering a broad set of accommodations for different applications. They will also share the common traits that their supported payloads conform to standard carrier interfaces, rigorously adhere to defined technical envelopes, and meet mission schedules.

#### ***Element 3: Small, Low-Cost Launch Vehicles***

The third key element of SLVR, as previously discussed, is low-cost space-access. Should the Falcon program produce one or more small, low-cost ELVs, NASA would then be able to enter into launch service contracts supporting regular small payload missions. SLVR presumes a schedule of one or more missions annually.

#### ***Element 4: Low-Cost Launch Range Services***

The fourth SLVR element is low-cost, flexible, and responsive launch range services. As the cost of launch vehicles is reduced, the range costs associated with vehicle-requested services and safety become a more significant component of the overall transportation cost. Steps must be taken to minimize these costs, through limiting the resources and time applied to pre-mission preparations and launch-day operations. This is best achieved through well-designed vehicles and spacecraft that attempt to optimize processing, limit unnecessary services requested of the range, and limit hazardous operations. It is also achieved through recurring operations with minimal mission-unique aspects. The Wallops Research Range and the Falcon contractors are partnering to carry out these strategies. These approaches are complemented by on-going Wallops advanced range technology efforts. These efforts seek to implement changes to historical mission approaches through new technologies that increase automation, reduce ground instrumentation and personnel, and infuse new, lower cost flight hardware. Two notable efforts nearing flight demonstration are the Low-Cost TDRSS Transceiver (LCT2), and the Autonomous Flight Safety System (AFSS). The use of TDRSS as a space-based data relay system can eliminate the need for expensive downrange telemetry instrumentation, but existing transceivers are prohibitively expensive for low-cost flight programs. LCT2 promises to replace existing TDRSS transceivers costing \$300-400K with units costing approximately \$50K. AFSS offers the opportunity for onboard hardware and algorithms to automatically assess a launch vehicle's performance against programmed flight safety constraints and terminate flight if rules are violated. Once again, the AFSS offers the opportunity to eliminate costly down range instrumentation. Jointly, these efforts offer the opportunity to save hundreds of thousands of dollars per mission.

**Element 5: Streamlined Integration and Test**

SLVR’s fifth element is streamlined integration and test operations. As both a launch range and a flight project organization, Wallops offers the opportunity to design, build, test, and fly flight hardware with in-house facilities. SLVR looks to leverage the spectrum of in-house capabilities to reduce the time and cost associated with preparing multiple experiments, integrating them into the host spacecraft carrier, and integrating the carrier with the launch vehicle. The baseline approach would be for experiments to be developed at researcher and student home facilities in parallel with a carrier being developed and tested at Wallops. Experiments would be shipped to Wallops for integration and test with the host carrier, while the launch vehicle is prepared in a neighboring facility. Upon completion the integrated carrier and experiments are integrated with the launch vehicle and moved to the launch site. Accomplishing all of these activities at a common site reduces the time and risk involved with multiple packaging and shipment exercises. It also brings the key individuals involved with the experiments, carrier, launch vehicle, and launch range to interact more frequently and earlier in the preparation process.

**Element 6: Standardized, Distributed Payload Operations**

The final element of SLVR is standardized and distributed payload operations. It is traditional for individual spacecraft to develop quasi-unique solutions for on-orbit payload operations. Development of new payload operations control centers (POCCs) and mission-unique software and communication protocols can be as expensive and time consuming as the spacecraft itself. A key to minimizing payload operations is the development of standardized tools and designs that are usable for a wide array of missions, and that be used with a limited amount of investment by the end user at their home institution. SLVR envisions the wide use of Internet protocol on its MPEC and Freeflyer carriers, as well as by individual payloads on the MPE. Standardized, flexible spacecraft operations software will limit the mission-unique engineering. The Control Center-in-the-Classroom initiative, under development by GSFC, can also be leveraged, for educational payloads.

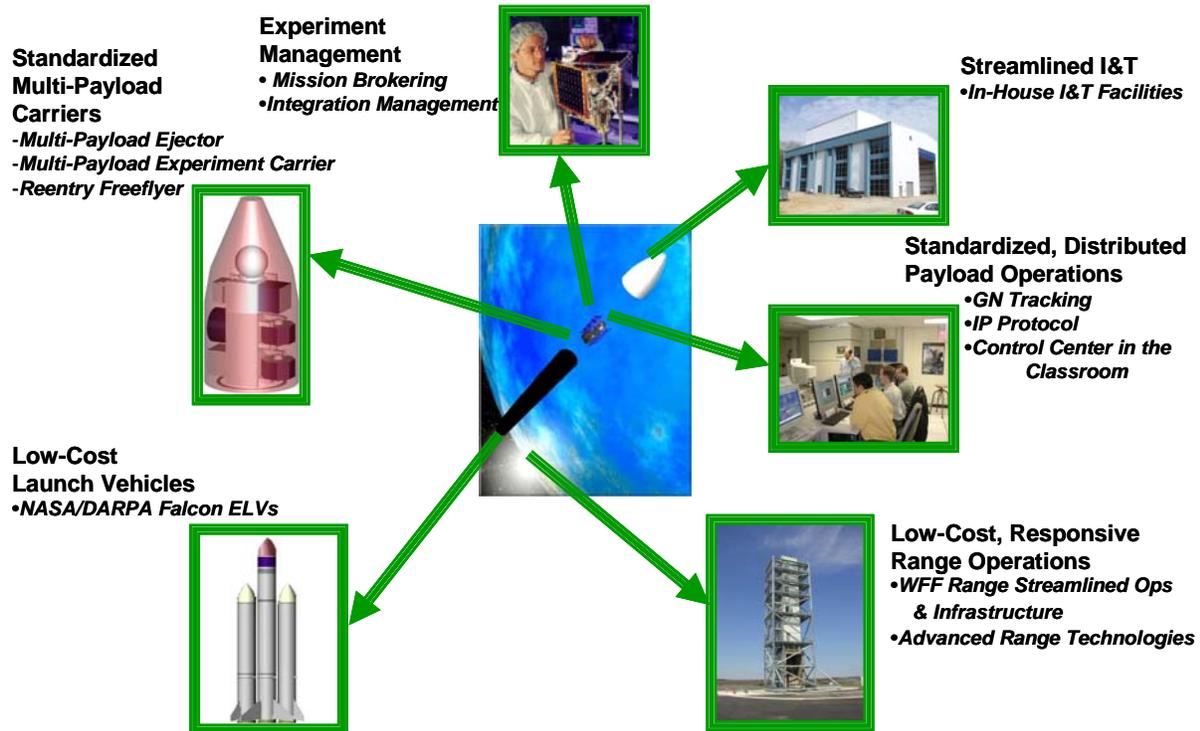


Figure 4. SLVR Element Overview

## KEY SUCCESS CONCEPTS

In order for the SLVR concept to be successful, there are a number of key considerations. One key concept is that SLVR needs to be treated as a sustained program and managed in a systems approach, rather than as discrete missions. Missions need to be implemented on a regular basis and issues involving individual experiments cannot jeopardize the rest of the mission. Also, standardized experiment interfaces to the carriers, and between the carriers and supporting launch vehicles are essential to limit mission-unique tasks. Streamlined and centralized implementation of the various elements is important for continuity and to minimize processes. Implementing a mission risk strategy that is commensurate with the level of investment is also critical. Finally, short schedules in which hardware is built, tested and integrated in months rather than years are key to keeping program costs affordable for this class of mission. These strategies have been keys to the success of the Sounding Rocket, Balloon, and Shuttle Small Payload Projects. Leveraging the experiences of these programs will offer great benefit to the success of SLVR.

## COST OF A SLVR MISSION

Table 1 is a notional assessment of recurring costs associated with conducting a SLVR mission.

**Table 1. SLVR Order-of-Magnitude Mission Element Costs**

ELEMENT	COST
Launch Vehicle	\$6-8M
Range Support	\$0.75M
MPE Carrier	\$1M
MPEC Carrier	\$5-8M
Freeflyer Carrier	\$5-8M
Payload Management & Integration	\$0.5M
On-Orbit Operations	\$1M

While only notional and requiring some additional nonrecurring investments, the intent of this chart is to convey that missions involving from one to thirty discrete payloads could routinely be implemented for investments of \$10-15M per mission (depending on carrier), plus any investment in the experiments. These costs are modest when compared to existing options.

## SLVR STATUS

The MPE development is funded, well underway and is scheduled for completion in mid-2006, to be followed by integration with the manifested experiments for first flight. It is scheduled to fly on one of the aforementioned DARPA Falcon flight demonstrations, currently expected in late 2007. The MPEC and Freeflyer carriers are not yet funded efforts. Concept definition of these carriers continues with a goal of developing advocacy within programmatic funding sources and other potential partners. Range support for the demonstration mission and advanced technology efforts supporting low-cost range operations are underway and marching toward readiness consistent with the Falcon schedule. Integration and on-orbit operations planning have begun and will be complete prior to the initial Falcon demonstration flight. With a successful demonstration in late 2007, a case can then be made to establish a sustained program to support the interests of education, science, and Exploration technology. Let the tidal wave of small satellites begin.

## REFERENCE

1. Letchworth, G. F., "Multiple Payload Ejector for Education, Science, and Technology Experiments", Proceedings of the 19<sup>th</sup> Annual AIAA/USU Conference on Small Satellites, Logan, Utah, August 2005.