## Multi Payload Ejector (MPE), Bridging the Gap in Recurring Space Access

Jeffrey A. Reddish NASA Goddard Space Flight Center Code 840, Range and Mission Management Wallops Flight Facility, Wallops Island, VA 23337; (757) 824-2100 Jeff.Reddish@nasa.gov

**ABSTRACT:** The continuous increase in the number of small satellites under development today is in direct contrast to the number of launch opportunities available for that payload class. The NASA Goddard Space Flight Center, Wallops Flight Facility (WFF) recognized this problem and in 2004 started an effort to reform the system supporting small satellites. The Multi Payload Ejector (MPE) is a fundamental part of this new pathway.

The MPE is an orbital carrier that uses common interfaces. It is capable of accommodating a flexible set of small, stand-alone spacecraft, ranging from cubesats to ESPA-class satellites with masses ranging from 2 to 400 pounds. The MPE offers the flexibility to trade mass, volume and orbital altitude, along with the quantity of individual spacecraft, through the modular addition or removal of mechanical sections.

Being developed in parallel with the DARPA Falcon Low Cost Launch Vehicle Program, the MPE does meet the vehicle requirements of that program, but it has also been designed to be compatible with more traditional vehicles such as Minotaur I, Minotaur IV, Pegasus, Taurus and Delta, flying as a primary or secondary payload. This mission flexibility allows the MPE to take advantage of a variety of available launch opportunities in the industry. The MPE is an instrumental part of a WFF strategic plan called, "Small Launch Vehicles Research Project" (SLVR). The goal of the SLVR project is to provide end-to-end mission support for the payloads and selected vehicles on a recurring basis, depending upon demand and available launch opportunities.

## SPACE ACCESS GAP

Another year has passed and the landscape in the launch vehicle business has yet to experience the definite breakthrough that would make the smallsat business affordable. Multiple efforts are being pursued in the government and private agencies to develop a new low-cost family of expendable launch vehicles, but as of today, and for the near future, it remains the obstacle that prevents the small satellite developer from finding an affordable ride to space. Because access to space is very expensive, student-built university payloads have neither a commitment nor a reasonable expectation to fly. As a result, university efforts in design and developing satellites miss the final stage of their journey and students graduate before they can validate their work. For the last 20 years, the Space Shuttle provided the primary means of conducting educational payloads and small satellite missions. The Shuttle Small Payloads Project carriers, including Get-Away Special and Hitchhiker, had provided over 200 low cost, reliable missions for student-built satellites such as Starshine 1 and 2, and MightSat 1. But due to changing NASA missions and priorities, following the loss of Columbia during STS-107, the Shuttle Small Payloads Project was terminated.

Without the Space Shuttle, the only other way that educational and private smallsat developers can get their payloads to space is by sharing a ride and sharing the cost. Even with this approach difficulties still remain. The availability of a launch vehicle is minimal,

and if excess space is available, many primary payloaders are not willing to accept the risk to their own payload to fly a secondary payload(s).

A perfect example of this situation can be seen in the cubesat community. Since 2003, 31 cubesats have been launched or are ready to be launched, of which 18 are U.S. made. None of these cubesats were launched or are planned to be launched from the United States by a U.S.-built launch vehicle. This situation becomes even more apparent considering that since 2003, there have been upward of 30 U.S. launches to low Earth orbit (LEO). The first local possibility is now being planned using a Falcon 1 flight on SpaceX in 2007.

The recurring question that is being asked in the small satellite community is, "What can we do as an aerospace industry, in both private sector and government agencies, to reduce the cost of getting to space so private and student-built small satellites can fly and make a difference to the engineers and scientists of today and tomorrow?"

### MPE BRIDGING THE SPACE ACCESS GAP

The two variables that drive the high cost of space access, and the same paradigm that continues to plague the small satellite community, are the high cost of the launch vehicle and the limited availability of small payload space. Fortunately, 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 expendable launch vehicles (ELVs) under the Falcon Program. The DARPA Falcon small launch vehicle program is working to develop a low-cost launch system that is capable of lifting 1,000 pounds to low Earth orbit. But the difficulties with developing a low-cost launch vehicle are still real and significant. The other alternative that will help reduce cost is making launch opportunities more available for the small satellite developer without being dependent upon any specific launch vehicle.

It makes little difference to a student satellite or a private technology development smallsat on whether it flies as a primary or secondary payload. But what becomes important is that a smallsat can be developed around a standardized interface and be mounted to a structure that can fly on board any of the available launch vehicles. The MPE meets these requirements. The MPE is a low-cost, multi payload carrier that can be used for educational, scientific and exploration program technology experiments. The MPE carrier is designed to accommodate multiple primary, secondary and tertiary payload configurations. With this approach, multiple flight opportunities become available every year to the small satellite community, with the flexibility for developers to choose preferred orbits and altitudes.

### MPE SYSTEM DESCRIPTION

The MPE was designed and built by a team of NASA and Swales Aerospace (Wallops Engineering Services Contract) engineers at the Wallops Flight Facility. The MPE is a modular structure that supports small individual payloads ranging from 10 pounds to over 400 pounds (ESPA Class). The MPE is configurable, with as many as three segments, each with two secondary spacecraft, and a primary spacecraft mounted on top. This flexibility allows customization of mass and size envelopes to meet many different requirements. Many of the MPE configurations fit in an envelope and orbital insertion mass that are consistent with the DARPA Falcon demonstration launch objectives of 40-inch diameter and 60-inch height. The launch mass estimate for a one-segment configuration is ~ 770 pounds, the two-segment configuration is ~ 1030 pounds, and the three-segment configuration is ~ 1230 pounds. Figure 1 shows three sample configurations of the MPE.

### **Recurring** Cost

An added feature that makes the MPE economical is the low recurring cost for reproduction. The MPE was designed with a simple package that can be quickly reproduced at a minimal cost. The complete MPE system, fully tested and waiting on payloads, can be reproduce in less than 6 months with a cost of approximately \$1M.



<u>**1 Segment Configuration**</u> Primary Microsat (400 #) 2 Secondary Microsats (100 #)

2 Segment Configuration Primary Microsat (300 #) 4 Secondary Microsats (100 #) Tertiary P-POD Launchers (Cal Poly) <u>3 Segment Configuration</u> Primary Microsat (200 #) 6 Secondary Microsats (100 #) 4 Tertiary P-POD Launchers (Cal Poly)

Figure 1: MPE Sample Configurations With and Without a Nosecone

### **MPE UNIQUE SERVICES**

Services that were once only available to the primary payload are now available to the secondary payloads as standard features on the MPE. These unique features are explained in more detail below.

### Payload Battery Charging

After integration to the MPE, the designated primary and secondary payloads will receive battery charging. This service will be available until the last 8 hours prior to launch or upon request from the (launch vehicle (LV).

Battery charge hardware is designed as a GSE service and is supplied by the MPE, but payloads wishing to take advantage of the battery charge feature of the MPE must provide their charging/trickle-charging algorithms for their particular battery chemistry (for Lithium-Ion the MPE will accommodate a pass-through power source). The charging algorithms are limited in scope to constant-current or constant-voltage, but the MPE is capable of receiving temperature information to optimize the battery charge.

### Separation System

As a standard design, the MPE utilizes the Planetary Systems 15" Motorized Lightband separation system, but can accommodate different separation systems depending upon payload requirements. The MPE separation sequence is initiated by a separation signal sent by the LV after orbital insertion. The MPE will ingest the LV separation signal and generate discrete separation signals to each of the payload separation systems using a pre-programmed timer. Flight analysis will be performed to verify timing and ejection rates to minimize probability of any MPE or payload re-contact.

### Tertiary Accommodations

A total of 4 Cal Poly P-Pods can be mounted on the exterior of the MPE  $2^{nd}$  segment. Each P-Pod can accommodate 3 cubesats for a total of 12 for any MPE manifest. As an alternative and depending on the diameter of the LV, a cluster of 4 P-Pods can be mounted in a secondary slot.

### **Telemetry System**

The entire mission of the MPE is scoped at less than one orbit in duration after reaching the required altitude, which should accommodate safe separation timing of all payloads. The MPE will provide confirmation of separation for the primary and secondary payloads through real-time telemetry provided by the WFF-developed low-cost TDRSS transmitter (LCT2) via breakwire and three-axis rate sensor data. Other data that will be available in the telemetry stream will include bus voltages, currents, and battery and instrumentation temperature.

## **QUALIFICATION TESTS**

The MPE is qualified through multiple steps throughout the development effort. Following design completion the subsystems were built and tested to assure that all aspects of the design are covered and verified.

The next qualification step will occur when the first launch opportunity is identified. The MPE, with payload mockups, will be structurally and functionally tested at project qualification levels.

The last qualifying step is to mate the manifested payloads to the MPE and the entire system will go through a final round of testing. The test requirements will be related to the specific launch vehicle and will be focused on the verification of the MPE-payload mating and ejection systems.

### POTENTIAL MPE MANIFEST OPTIONS

The MPE can accommodate between 3 and 30 small payloads, depending on launch vehicle performance and static envelope. Assuming the performance and volume is typical of a Space-X Falcon 1 commercial launcher or Minotaur I class vehicle, any of the manifest options shown in Table 1 would be possible. Refer to Gary Letchworth's, NASA/WFF Code 802 paper entitled, "Multiple Payload Ejector for Education, Science, and Technology Payloads," paper number SSC05-V-1 from the 19<sup>th</sup> Annual AIAA/USU Conference on Small Satellites, for additional information on DARPA requirements and MPE design requirements.

	Number of Segments						
	1	1	2	2	2	3	3
Fits Minimum DARPA							
Envelope?	Y	Y	Y	Y	N	N	N
Use a secondary slot							
for 12 Cubesats*?	N	Y	Ν	Y	Ν	Ν	Y
Primary	1	1	1	1	1	1	1
Secondary	2	1	4	3	4	6	5
Tertiary (Cubesat*)	0	12	0	12	12	12	24
Total Spacecraft	3	14	5	16	17	19	30

\* 3 Cubesats packaged into one P-Pod

**Table 1: Launch Manifest Options** 

### THE OPPORTUNITIES

The opportunities in the small satellite community become significant if a low-cost launch vehicle is developed and married to the MPE. This low-cost platform would offer great benefits to academia, science, and technology.

From a student's perspective, being able to build a small satellite, integrate, test, launch and do on-orbit operations or post flight analysis within his academic tenure creates a great excitement that keeps the next generation of scientists and engineers abundant. With a recurring flight program, it is not out of the question for students to design and fly more than one satellite in their academic careers. With the benefit of the MPE being able to fly different sizes and complexities of satellites, the student could actually begin at the small cubesat payload to gain experience and by graduation design and fly a larger more complicated secondary or primary satellite. Another great benefit is that WFF would facilitate the development of mentoring relationships and knowledge sharing between the scientists and engineers of today with the scientists and engineers of tomorrow. This mentoring structure is already established in the Sounding Rocket and Balloon programs managed at WFF, which provide multiple launch opportunities for students each year.

The science community, with the miniaturization of science sensors and instruments, would receive great benefits from the MPE. In addition, the newer concepts of formation flying of multiple small payloads as sensor webs and distributed apertures can replace the larger more expensive spacecraft and the development time can be significantly reduced.

The NASA Exploration initiative possesses a great need to test unproven technology in a very short time. The MPE can provide the opportunity to prove designs and reduce risk, both in schedule and cost.

The common theme that runs through all the current stakeholders is the necessity for low-cost, responsive

access to space. The MPE and the SLVR Project can deliver the goods. It can provide the opportunity to be the test bed for design verification and a risk mitigator, thus elevating technology readiness levels (TRL) prior to flying the design on a high price satellite mission. When near term results are necessary, the small satellite projects are the only way to meet those needs.

### Flying as a Secondary Payload

Even if a low-cost vehicle is not developed in the near future, the MPE can still reduce the cost to access space for the small satellite community. The MPE can fly as a primary satellite on traditional vehicles such as the Pegasus or Minotaur vehicles, or it can serve as a secondary payload on the larger ELVs, such as Taurus and Delta II.

The problem with secondary payload is that it creates a large risk to the primary payload because of the integration process, the interface issues, and the cleanliness concerns. For this reason many times the primary payload will buy the extra space to eliminate that risk.

The MPE was developed to be as risk adverse to primary payloads as possible. The MPE can be fully integrated and tested at WFF, separate from the primary payload, within the cleanliness requirements necessary. The electrical interface is minimal. The launch vehicle separation signal is all that is necessary to initiate the separation sequence for the payloads on the MPE.

## WALLOPS FLIGHT FACILITY ROADMAP

To make a launch opportunity as inexpensive as possible, it is essential that one centralized program manage the elements outlined in this paper. One program can develop and use standardized interfaces and processes to streamline schedule and cost. WFF has used this strategy in the Sounding Rocket, Balloon, and Shuttle Small Payloads programs. Using and leveraging the experiences from these programs, WFF

has developed a strategic plan to do the same in the small satellite community, with the MPE being one of the main elements in this plan. That program is called the "Small Launch Vehicle Research Project".

### SMALL LAUNCH VEHICLE RESEARCH PROJECT (SLVR)

SLVR is a systematic approach to providing end to end capabilities, a "one stop shop", as a sustained flight program for small payloads. SLVR is composed of six discrete elements, depicted in Figure 2, that are critical to making missions frequent, affordable, and flexible.

### Experiment Management and Brokering

The first element will provide "Experiment Management" which is intended to solicit and coordinate candidate payloads from multiple agencies and universities, as well as broker upcoming mission opportunities.

### Experiment Carrier

The second element will provide the small satellite carrier system, MPE, so multiple payloads can take advantage of a single launch opportunity. In addition to the MPE, follow on design concepts for experiment carriers and reentry freeflyers are being developed.

### Low-cost Launch Vehicles

The third element is to provide small, low cost launch vehicles by entering into a launch services contract with the vehicle manufacturer.

### Low-cost Launch Range Services

The fourth element is to provide low cost launch range services. That WFF launch range is the only NASAowned launch facility in the world and would provide these services. With over 60 years of launch experience and the ongoing advanced range technology effort to reduce launch costs, WFF is the leader in low-cost, flexible launch capabilities for the small launch vehicle.

### Streamlined Integration and Testing

The fifth element that makes up the SLVR program will provide a streamlined process for the integration and testing of small satellites. As both a launch range and a flight projects organization, WFF offers opportunities to design, build, test, and fly hardware at a single inhouse location, a "one-stop shop" for the small satellite community.

### Standardized, Distributed Payload Operations

Lastly, the sixth element of SLVR is to provide standardized, distributed payload operations. This will include the development of standardized, flexible spacecraft operations software that will limit mission unique engineering. The Control-Center-in-the Classroom initiative, under development by Goddard Space Flight Center, can be leveraged for educational payloads.

### Example Cost of a SLVR Managed Mission

The estimated cost for a SLVR managed mission is less than \$15M. The details can be seen below in Table 1.

### Table 1: Cost Estimate for a SLVR Mission

ELEMENTS	COST
(1) Experiment Management	\$200K
(2) Carrier/MPE	\$1M
(3) Launch Vehicle	\$10M
(4) Range Support	\$1M
(5) I & T	\$300K
(6) On-Orbit Operations	\$1M
<b>Total Cost for a SLVR Mission</b>	\$13.5M

With the successful implementation of the SLVR effort, routine opportunities for small science and exploration technologies and educational satellites can become a reality again.

For more detailed information on the SLVR Program, please refer to the small satellite paper # SSC05-X-1, entitled, "SLVR: A NASA Strategy for Leveraging Emerging Launch Vehicles for Routine, Small Payload Missions" written and presented by Bruce Underwood, NASA Code 802, at last year's 19<sup>th</sup> Annual AIAA/USU Conference on Small Satellites.



Figure 2: Pictorial Overview of SLVR Program

### CURRENT STATUS OF THE MPE

The two segment MPE will be completed and on the shelf by September 2006. The structure will be fully integrated with all the electronic subsystems and thoroughly tested at ambient conditions. At that point, the system will be put into hibernation waiting for a launch opportunity.

### Launch Opportunity

In exchange for NASA's contribution to the DARPA Falcon program, DARPA is allowing NASA to manifest payloads on some of the flight demonstration missions. The AirLaunch vehicle is the leading candidate for providing the MPE with its maiden voyage. The estimated date of this launch is early 2008. But WFF is open to other launch opportunities that could come earlier than the 2008 timeframe.

## **Return from Hibernation**

Once a launch opportunity is identified, the MPE will come out of hibernation. It will take approximately 4 months for the MPE to return out of hibernation and be launch ready. Two months will be required to environmentally test the MPE to launch vehicle specification. Following this testing, an additional 2 months will be necessary to integrate payloads and functionally test the complete system. The integrated structure will be vibrated to launch vehicle specifications and again functionally tested to verify the system is ready for launch.

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## REFERENCE

- Letchworth, G.F., "Multiple Payload Ejector for Education, Science, and Technology Experiments", Paper #SSC05-V-1, Proceedings of the 19<sup>th</sup> Annual AIAA/USU Conference on Small Satellites, Logan, Utah, August 2005.
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