

Evolved Expendable Launch Vehicle Secondary Payload Adapter - A New Delivery System for Small Satellites -

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Abstract. Small satellites are used throughout the United States to satisfy many experimental and, ever increasingly, operational mission requirements. Unfortunately, the costs of expendable launch vehicles, coupled with insufficient secondary launch opportunities, reduce the cost-effectiveness of delivering small satellites to space. Further, all US government payloads must be launched using US launch vehicles, which limits the affordable launch opportunities available for Department of Defense (DoD), NASA, and other government agency use. However, the DoD Space Test Program (STP) and the Air Force Research Laboratory Space Vehicles Directorate (AFRL/VS) have joined forces and developed a low-cost

method of providing small satellites a new secondary payload capability. Intended for use on both the Boeing and Lockheed-Martin Evolved Expendable Launch Vehicle-Medium (EELV-M) boosters, the EELV Secondary Payload Adapter (ESPA) will provide increased access to cost-effective launch opportunities for 180-kg (or smaller) class satellites. Over the last year, the ESPA design has matured from a composite ring into a stiffness-driven aluminum ring, capable of carrying six secondary payloads along with a 15,000-lb primary payload into space. ESPA has also been manifested on its very first mission, as it will fly on STP's EELV-M mission (the MLV-05 mission) scheduled to launch in the first quarter of FY05.

Introduction

The Department of Defense (DoD) Space Test Program (STP) has joined together with the Air Force Research Laboratory Space Vehicles Directorate (AFRL/VS) to provide a low-cost option for small satellite access to space. Designed for the Medium version of the Evolved Expendable Launch Vehicle (EELV-M), the EELV Secondary Payload Adapter (ESPA) will carry up to seven payloads (one primary payload and up to six secondary payloads) to orbit. The first demonstration of this capability will occur in the 2005/2006 timeframe as ESPA has been manifested on its first mission. It will fly as the centerpiece to STP's EELV mission – the MLV-05 mission (known also to the community as TSX, but further referred to as MLV-05).

This paper presents the status of the ESPA design, followed by an overview of ESPA's future. The paper wraps up with a brief discussion on integration with potential small satellites.

Design Characteristics

In addition to the desire to always keep costs low, a major goal of the ESPA program is to minimize the impact to the primary payloads that may fly on it in the future. Keeping these in mind, the ESPA design has undergone numerous mechanical and electrical design changes over the last year. However, the general design/integration philosophy remains the same - ESPA and its secondary payloads will only get what is left over on the launch vehicle once the primary payload's requirements are satisfied.

Recent Design Changes

ESPA is still designed to carry up to a 15,000 pound primary payload (PPL) with six 400

pound secondary payloads (SPLs), but now its material has been set (7050-T7451), complete with an established manufacturing process. The payload shelf on the inside of the ring has



Figure 1 The ESPA Ring

been removed from prior designs due to its inherent complexity. The final significant mechanical design change has been the addition of three 4" access holes, positioned 120° apart along the sidewall, allowing access inside the ring while all of the payloads are integrated.

The electrical requirements for ESPA remain the same, but there are now more solid methods of satisfying those requirements. For

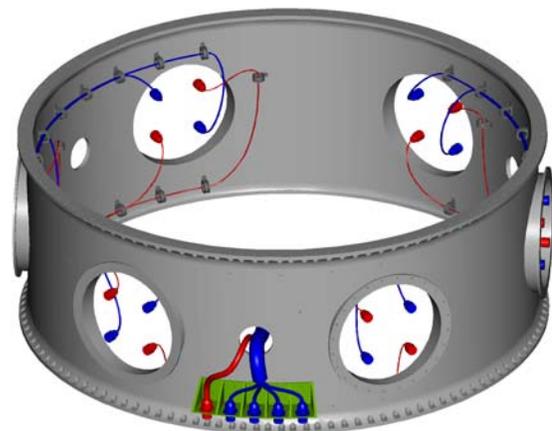


Figure 2 Example Electrical Harness Layout

example, in order to maintain the ability to assemble, integrate, and test secondary

payloads with ESPA separately from the EELV and the PPL, a standard electrical interfaces (connecting ESPA and the EELV) has been designed into the ring. Further, new electrical tie-down points along the upper and lower halves of the sidewall have also been added, allowing cable routing on the inside or outside of the ring. Coupling these two changes together, ground support equipment (GSE) can now be connected to one point on ESPA, and depending on mission specific requirements, all of the secondary payloads can be electrically charged and/or tested separately from the EELV and the PPL.

Primary Payload Interface

Keeping with the primary goal of minimizing impacts, and therefore risk, to the primary payload, ESPA's PPL interface remains in exact agreement with the EELV Standard Interface Specification (SIS).

The electrical interface also remains the same, with the exception of the added cable length required to pass through ESPA. There may be some modifications necessary to connect the launch vehicle with the SPLs, but these will not affect the connection or the availability of signals to the PPL.

Secondary Payload Interface

In order to maximize the type of separation systems available to secondary payload customers, the secondary payload interface, or secondary standard interface plane (SSIP), on ESPA is a flange cantilevered on the outside of the ESPA sidewall (note – STP does not provide separation systems). A 15" bolt circle of 24 holes, using #10 bolts, is drilled into each flange with a drill template that will be provided to SPL customers.

The electrical interface to SPLs will not be finalized until a mission is manifested and

interface issues are hammered out. Imposing a set connector on SPLs would hinder the ESPA team's desire to keep payload integration flexible.

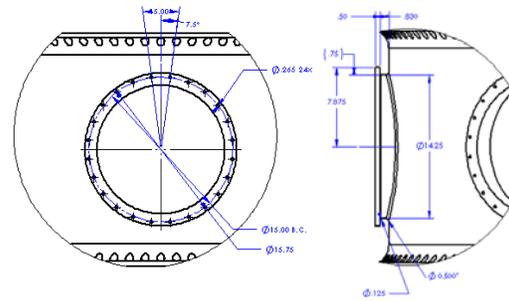


Figure 3 ESPA Secondary Payload Interface

Significant Secondary Payload Design Constraints

One electrical and two mechanical/physical constraints are imposed on SPL customers, with the intent to minimize integration risk and complexity. One constraint relates to volume, the other to mass. In the future, as ESPA becomes a proven technology and PPL customers become more comfortable with the design, these constraints may be relaxed.

Secondary payloads should require as few electrical connections to the launch vehicle as possible. This constraint exists because of the nature of secondary payload integration – secondary payloads always get what is left over once the primary's requirements are satisfied. However, at the very least, SPL customers can be assured to get one non-redundant separation signal. As a particular mission's development progresses and payloads begin to work with the launch vehicle, additional signals may become available.

Total volume is an important mechanical/physical constraint for SPL customers to adhere to. Each SPL is allocated a standard volume envelope: 24" x 24" x 38" ($Y_{SPL} \times Z_{SPL} \times X_{SPL}$). Everything must fit

inside this envelope, including separation systems, SPL-to-ESPA adapters, appendages, etc (violations will be handled on a case by case basis by STP). By designing inside this envelope, SPLs can be assured that they will not affect, or be affected by, PPL appendages or adjacent SPLs.

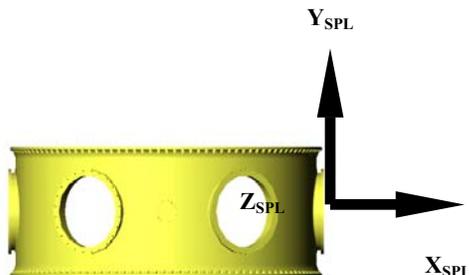


Figure 4 ESPA SPL Coordinate System

Mass is the other important mechanical/physical constraint that must be considered when pursuing a ride on ESPA. With margin, ESPA is designed to carry 400 pound satellites with a 20" center of gravity at each SPL location. The 20 inches start at the ESPA flange, which means that the separation system and any necessary payload adapters will need to be included in the mass/CG budget.

By following these constraints (along with the physical interface described above), SPL customers are guaranteed compatibility with ESPA capabilities (note – being manifested on a mission cannot be guaranteed, but SPL chances may be increased).

Future Plans

The ESPA team is currently in the process of studying integration possibilities with major DoD primary payloads. Part of this study includes the current design of ESPA, and how it will affect PPL integration and mission

execution. Although the ESPA Critical Design Review has been successfully accomplished, until this study is complete (to a rational extent), the ESPA design may continue to change.

However, STP has a need to fly ESPA in 2005 with MLV-05, eliminating the option of waiting for PPL feedback. Therefore, the team has decided to pursue the development of the ring as currently designed, especially since the expected feedback will have very little affect on the MLV-05 mission. This decision splits the ESPA road ahead into two paths – one for the MLV-05 ring, and one for the “standard” ring.

The “Standard” ESPA

Once STP has received sufficient feedback from potential primary payloads, and all design and integration issues are resolved, AFRL will build the first “standard” ESPA. This model will be used as a qualification unit, and will be used to verify (or demonstrate) the maximum strength of ESPA. There are no plans to use the qualification unit as a flight model, or as flight spare for that matter; however, further rings will be built on a mission-needed basis.

The qualification unit will be subjected to 125% of its max expected static launch loads. Then, once sufficient margin has been demonstrated, AFRL will attempt to test the unit to failure. However, ESPA has been so overdesigned (to minimize risk, again) that the team is still not sure that it *can* be broken (at least not with currently available tools, anyway).

AFRL does not know the meaning of the word “*can't*”, though. Therefore, in the spirit of perfection, they have designed and are currently building what the team affectionately calls, “The Crusher” to take on the arduous task of testing and breaking ESPA. By

connecting to all secondary and primary payload flanges at the same time (along with a payload attach fitting that mounts to the bottom flange), the Crusher will be capable of testing the ring to much worse than “worst-case” loads. The Crusher is expected to be ready in the June/July 2001 timeframe.

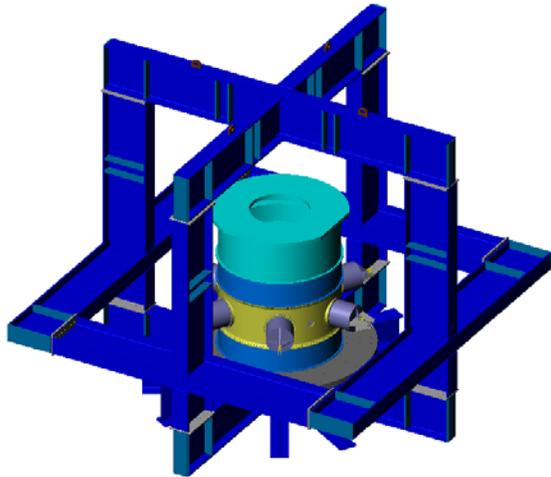


Figure 5 “The Crusher” – ESPA Qualification Structure

Now, because ESPA is so robust, and all analyses show incredible margin, there are no plans to include random vibration testing in the qualification of ESPA. However, during the integration and test phase of each and every mission, a random vibrate test using the payloads or their mass models should be included to verify the stack will not only survive the predicted loads, but meet coupled loads requirements.

MLV-05 Engineering Design Unit

The first stepping stone of the MLV-05 ring is an engineering design unit (EDU). The EDU will be used to satisfy all qualification test requirements; however, it will not be tested to the extent that it will be unusable as a flight spare, should the need arise.

Big plans exist for the EDU this year. Once it is fabricated and delivered to AFRL, currently expected in the mid-August time frame, the team will put it through human factors and integration testing. For about a month, rough mass and/or volume simulators will be used to determine the best method of integrating the secondary payload stack. These tests will indicate how much clearance there will be between payloads, and whether or not the available “elbow-room” will be enough to integrate the payloads with currently available tools. If there is not enough room, STP will have the foresight to levy additional requirements on the SPLs, simplifying integration of the real payloads in 2005.

The human factors and integration testing will also provide insight into thermal blanket placement options. Although a specific thermal analysis has not been done on the mission yet, it will be good to know how much room is available when the time comes.

One last objective of the human factors and integration testing is a rough electrical harnessing analysis. Based on the locations of the SPLs and their launch vehicle connections, the team can get a first hand look at how much wiring will be required, as well as where it should be located (the inside vs. the outside of the ring). Although a further, more detailed analysis will be done as the mission timeline progresses, this will be a good first cut.

Once the human factors and integration testing is completed, the EDU will be subjected to static loads testing. Typically, an EDU would see 125% of the max expected loads of a particular mission. However, to get an idea of how much margin is available, the MLV-05 program office has agreed to allow the ESPA team to test to worst case loads (expected to be much greater than 125% of the MLV-05 loads). This is expected to happen in the October/November time frame.

ESPA’s worst-case loads include a 15,000 pound primary payload and six 400 pound secondaries. The qualification test will be run three times, using different load cases for the primary payload each time. The PPL flange will see 6.5 g’s maximum, while each secondary payload flange will see 10.0 g’s in both the X_{SPL} and Z_{SPL} directions (for a combined load of greater than 14 g’s), all simultaneously. For each load case, the SPL flange will see the 10.0 g’s.

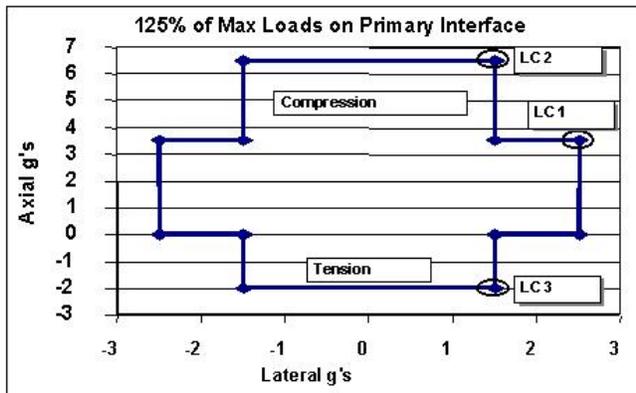


Figure 6 Primary Payload Load Case Illustration

As in the case for the “standard” ESPA, current plans to vibrate the EDU do not exist at this point in time. However, once reliable mass models of the payloads (perhaps not for another year or more), the EDU will be subjected to this testing.

Payload Integration

Payload requirements will change with each mission, which means that integration with ESPA will never be standard. There are some general rules and guidelines, however, that SPL customers can follow to make their lives just a little easier. For example, all SPLs must be at CDR level at Launch-24 months in order to enter the contractual 24 month EELV integration schedule (right at the beginning of the schedule is a Final Design Loads Cycle

(FDLC), which means that a finite element model will be necessary at this time). For this reason, the ESPA team recommends scheduling at least 36 months prior to launch to begin mission development. Backing this up even further to allow for contract negotiation and award, L-48 months would not be too early to start planning for a mission.

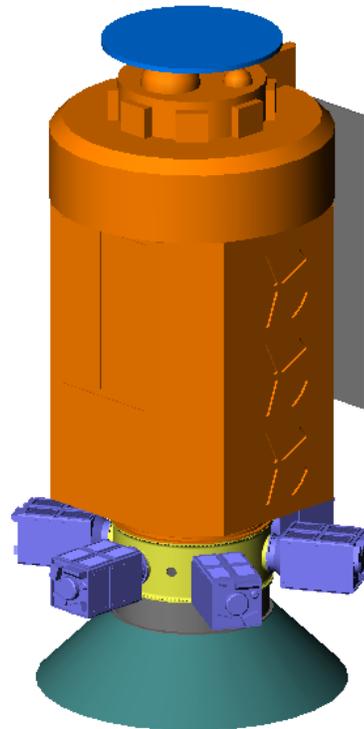


Figure 7 Fully Integrated ESPA Mission

Another general integration issue is the requirement to keep ESPA balanced. Adding up to 2,600 additional unbalanced pounds to the EELV second stage may or may not introduce control issues, but nobody will be willing to chance it. Therefore, SPLs may be required to add ballast to their location, thereby reducing the allowable payload height. Thus, as SPL development begins, it would be wise to hold margin to the payload envelope (this information should be known prior to CDR).

Conclusion

ESPA has always had the potential to bring a new method of providing access to space for small satellites for the United States. Now, with the help of MLV-05 and other primary payloads, it's becoming a reality. With the goal of minimizing additional risk to the primary always in mind, ESPA will take advantage of the incredible performance of the EELV and effectively reduce the cost of spacelift to a regime that is commensurate with the budgets of small satellite programs.