Small Satellite Access to ESPA Standard Service

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ABSTRACT

The DoD Space Test Program (STP), the Air Force Launch and Range Systems Wing (LRSW), and United Launch Alliance (ULA) are teaming up to provide a rideshare service to small satellites (<400lb) using an Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter (ESPA). This rideshare service is an opportunity on EELV missions with margin to carry auxiliary payloads (APLs). This paper will define the ESPA, the standard rideshare service provided to APLs, and how APLs can access this service. We will discuss the roles and responsibilities the different government organizations, ULA, and the small satellite provider have in accessing and implementing ESPA Standard Service. In brief, ULA builds the EELV and performs the launch service, LRSW is responsible for developing and acquiring EELVs from ULA, and STP is responsible for identifying and manifesting APLs that meet ESPA Standard Service requirements. We will further define the processes and procedures required to implement ESPA Standard Service to include: how a particular EELV mission is selected to host ESPA Standard Service, the selection process for auxiliary satellites to utilize the capability, the requirements and timelines small satellites must meet to qualify, and the scope of services provided by ULA as part of Standard Service.

ESPA Standard Service

On 13 Feb 2008, the Secretary of the Air Force (SECAF) issued a policy to leverage excess capacity on Evolved Expendable Launch Vehicle (EELV) missions. "We should leverage this excess capacity by maximizing use of the EELV Secondary Payload Adaptor (ESPA)." This was in response to the successful DoD Space Test Program (STP) launch of STP-1, which successfully demonstrated ESPA capability in Mar 2007. The SECAF's guidance was "to make ESPA-hosted satellite launches a routine operation starting NLT FY12." In addition the guidance stated, "provide routine and affordable access to space for scientific, research, development, and Operationally Responsive Space (ORS) missions." The Air Force (AF) implemented Program Directive Memorandum III (PDM III) which established the

Figure 1: STP-1 ESPA and Payloads

funding to implement ESPA Standard Service (Std Svc) with a first launch tentatively in FY12. To implement the AF guidance the following organizations are teaming up to provide a rideshare service to auxiliary payload (APL) small satellites (<400lb) using an ESPA: the Launch and Range Systems Wing (LRSW), the DoD STP, and United Launch Alliance (ULA).

This paper will define the ESPA, the standard rideshare service provided to small satellites or auxiliary payloads; and how auxiliary payloads can access this service. ESPA Standard Service is an integrated process that requires participation from STP, LRSW, ULA and the APL community. We will discuss the roles and responsibilities the different government organizations, ULA, and the small satellite provider have in accessing and implementing ESPA Standard Service. LRSW is the program office responsible for acquiring and executing EELV launches and ensuring overall mission assurance for successful launches. LRSW provides a key role in identifying EELV launch missions with excess weight margin. AF Space Command's (AFSPC) Auxiliary Payload Approval Policy states, "the DoD STP is the front door for all auxiliary payload launch service requests on COCOM missions." In addition, the Space and Missile Systems Center's (SMC) ESPA Implementation Plan (I-Plan) states, "STP will serve as the filter and unbiased broker for determining which program may take advantage of EELV APL launch opportunities." ULA builds EELV launch vehicles and provides launch services for payloads on their vehicles; ULA will also provide APL launch services as part of ESPA Std Svc. Currently the small satellite provider is any government-sponsored organization seeking space flight as an APL.

STP developed the ESPA as Small Business Innovative Research (SBIR) project to develop a capability to fly APLs while minimizing the impact to the primary payload. The AF Research Laboratory (AFRL) Space Vehicles directorate managed the development effort, with CSA Engineering, who ultimately produced the ESPA ring. ESPA is a structural ring that fits the 62" payload interface, can support a 15,000 lb primary payload, and can hold up to six 400 lb APLs. STP recognized the requirement to demonstrate the ESPA capability so the team developed the STP-1 mission. Normally the primary payload sits on top of the stack; however, on STP-1 the primary payload, STPSat-1, was one of the small satellites attached to an ESPA port. The STP-1 mission launched in March 2007, successfully demonstrating ESPA as a viable means to use excess capacity on EELV missions for APLs.

ESPA Mission Selection

As stated earlier, PDM III provided the ESPA funding to LRSW to complete the non-reoccurring engineering (NRE) and establish ESPA Std Svc launches. ESPA Standard Service is an integrated process that requires participation from STP, LRSW, ULA and the APL community. LRSW is responsible for many of the processes; LRSW developed and maintains a database of available capability on all planned launches. This database includes key factors such as; the primary payload weight, probable launch vehicle configuration, and access performance margin. Those missions with the most excess performance margin become the primary targets for ESPA Std Svc. The Launch and Range Systems Wing Commander (LRSW/CC) in conjunction with the STP Director approve the target missions for ESPA Std Svc.

Upon mission selection for ESPA Std Svc implementation, LRSW will notify the primary payload program office. At this point, only a dire circumstance, which requires a request from primary payload program office's commander, can prevent ESPA integration onto the mission. The LRSW/CC can still disapprove the request to "not include" ESPA on the mission. The LRSW/CC has the authority to authorize or disapprove ESPA on a mission. It is important to remember the government/ULA team holds the APL community to the highest of standards so that they will not impact the primary payload. This is the "tough love" approach agreed to upon by LRSW, STP, and ULA and drives the processes and procedures APL providers must follow.

What is ESPA Std Svc?

We will define at the top level what ESPA Std Svc provides and what the APL provider must do to meet the "tough love" requirements. There are two major rules that all APLs must follow to use ESPA Std Svc; 1) do no harm to the primary payload or the launch

vehicle (LV) and 2) APLs cannot affect the launch schedule. ESPA Std Svc can use all Atlas and Delta LVs with excess margin as long as they have a 62" payload interface and can launch from both east and west coast.

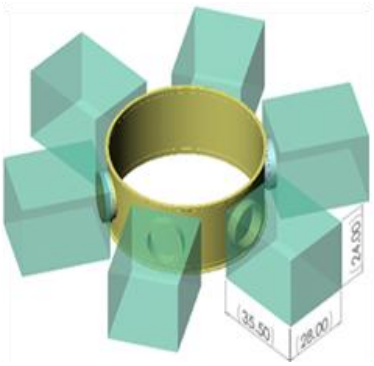

Figure 2: ESPA and Generic APLs

The mission scenarios include: low earth orbit (LEO), medium earth orbit (MEO), geo-transfer orbit (GTO), and geosynchronous earth orbit (GEO). Under ESPA Std Svc rules at this time, the primary space vehicle (SV) separates first and then the APLs separate in the same or different orbit depending on residual LV capability. When the primary payload and APLs separate in the same orbit, the LV will perform a collision and contamination avoidance maneuver between each separation to avoid re-contact. All APLs must comply with the EELV Rideshare Users Guide (RUG), which is an update of the original STP ESPA Users Guide. Key RUG requirements are: the APL must launch inert and turn on 30 plus seconds after separation, the APL meets ESPA SC volume (24" wide x 28" deep x 35.9" length), the APL weight cannot exceed 400 lbs with the separation system, and the APL center of gravity (CG) must be within 20" in the length, and 0.5" in the other axes, and the APL cannot have active propulsion. ESPA Std Svc only provides APL charging and battery monitoring via drag-on umbilical while in the launch stack prior to payload fairing closeout. Currently, the team considers any deviations from the RUG as mission unique (MU) requirements and subject to additional cost. The APL provider is responsible for paying any MU costs attributed to their SC. Regardless, the APL provider must work with STP to request a flight on an ESPA Std Svc mission.

APL Access/Selection Process for ESPA

Both the AFSPC APL Approval Policy and SMC ESPA I-Plan establish ground rules on how STP identifies APLs for launch. Further, the AF is formalizing these policies in AF Instruction 1202-2 Space Test Program Management to ensure APL access to space in the future. STP implements both the APL approval policy and ESPA I-Plan by working with small satellite providers and by recommending APLs for launch on DoD EELV missions. In this capacity, STP will help foster relationships between appropriate primary SVs and APLs. STP will guide APLs through the APL manifest process to obtain a flight opportunity. APL providers can access STP support in two ways. First APL providers can obtain DoD sponsorship and present their experiment to the Space Experiment Review Board (SERB). The SERB approval enables STP to provide access to space for research and development (R&D) experiments that cannot afford space launch within their own budget. The second means of access is to come as a government sponsored reimbursable customer to STP and the AF. The APL manifest process and associated documents are for the most part the same except a reimbursable customer does not have to fill out specific STP SERB documents.

In order to get on the DoD SERB list, the respective APL organization will need to find a DoD organization to sponsor their experiment or payload compliment. The experiment has to show how it is military relevant as military relevance represents 60 percent of the score at both the DoD and the service levels. The DoD organization can be from one of the three primary services Army, Navy, or Air Force or another DoD agency such as the Missile Defense Agency (MDA) or the DoD Advanced Research Program Agency (DARPA). The APL must complete DoD Form 1721 which captures all relevant data on objectives and requirements for spaceflight and DoD Form 1721-1, an executive summary. In addition, the APL must provide a 15-minute presentation about the experiment. The briefing is broken into two parts; 12 minutes for presentation and three minutes of question and answer time. The presentation has six mandatory charts as follows: 1) title chart, 2) experiment concept, 3) technology and development, 4) military relevance, 5) flight requirements or requested STP

services, and 6) technology transition or data applications. Upon approval at the service or agency level, the APL will provide the signed DoD Forms and presentation to the DoD SERB. The DoD SERB will either reject the experiment or accept it and rank based on military relevance, service ranking, and experiment quality. The Under Secretary of the AF for Space Acquisition (SAF/USA) approves the SERB list and provides it to STP to fly the maximum number of experiments based on ranking, readiness, and available budget. STP will try to use ESPA Std Svc missions to fly SERB approved payloads if the APL/experiment requirements line up with a proposed mission.

For APLs that do not have military relevance or do not want to go through the SERB process, they can find a government organization to sponsor them as a reimbursable mission to STP for flight. They can go to any government organization such at the National Science Foundation (NSF), the Department of Transportation (DoT), or the National Astronautics Space Administration (NASA); spaceflight does not require DoD sponsorship. However, since the AF is funding ESPA Std Svc, DoD sponsorship will allow STP more flexibility when choosing APLs for a particular flight. Military relevance in this situation is not as strict as when obtaining SERB approval. Once the APL has a government sponsor, they can request spaceflight from STP and move to the manifest process.

APL Manifest Process

The manifest process starts when an APL identifies basic SC information such as volume, weight, APL flight readiness and specific orbital requirements to STP. APLs must also provide a certification statement that shows funding is available through the first year of operations and APL security requirements. STP will perform an initial bundling assessment to gather APLs that have similar orbital requirements such as altitude and inclination to develop a mission set. As part of the process, APLs also provide an experiment requirements document (ERD) which captures all APL integration, launch, and range requirements. STP consolidates all potential APL ERDs for a specific mission into a single Payload Requirements Document (PLRD). ESPA Standard Service contractually begins with an early integration study (EIS).

To support the EIS, the APL must submit the following: APL drawings, APL electrical schematics, APL mass properties, APL finite element model (FEM) in a Craig–Bampton format, and an APL parts and materials list. STP in conjunction with LRSW provides this documentation to ULA so they can perform an LV early integration study. Typically, the EIS starts between launch minus (L–) 36 and 30 months, with initial results due by L–28 months to determine if the mission is feasible. The EIS will assess the APL LV requirements, coupled loads model, an environmental assessment, and contamination control. The primary SV team reviews the results of the EIS to determine if the ESPA and APLs are compatible. The team uses the EIS results to support the initial APL Baseline Compatibility Review at L-28 months.

The ESPA feasibility study is an important first step in the ESPA process because it determines if the APL coupled with the primary payload mission does not cause unacceptable adverse impact to the primary mission. ULA will present feasibility study results to the LRSW, STP, APL, the primary payload contractor, and System Program Director (SPD). Following this presentation, the primary payload contractor will validate the feasibility of the inclusion of ESPA Std Svc; the SPD will provide concurrence to proceed with the mission. The results of the two studies help to identify the technical risks, capabilities, limitations, and other implications associated with the proposed mission. The EIS will help define the flight profile and refine the concept of operations of the APL as it relates to the LVC and the primary payload. Furthermore, the study will identify mission unique hardware and service requirements that are beyond both the EELV and ESPA standard launch services.

Based upon favorable results from both the early integration and compatibility studies, STP will start the manifest documentation with all the APLs that are part of the mission set. These documents include the following: 1) a Preliminary Mission Risk White Paper, which documents the total risk at the start of the mission, 2) APL Operations Concept paper, which identifies where and how each APL will perform on-orbit operations, and finally 3) STP will write a Memorandum of Agreement (MOA) for all parties to sign. The MOA will document the following: basic

mission parameters, organizational roles and responsibilities, key APL documents and when they are due, meetings the APL provider must attend, APL MU funding requirements, launch delay provisions, and public affairs requirements. Upon completion of these documents, STP will develop a Space Flight Plan (SFP), which documents all key mission parameters and shows funding is in place to complete the mission. The STP Director will approve the SFP, however depending on the MU or other special funding requirements approval may have to go to SAF/USA. STP then forwards the approved SFP and other documents as part of APL approval package to the SMC Commander for approval and then to AFSPC Operations Directorate (AFSPC/A3) for concurrence. When STP receives the approval and concurrence, they will notify the respective APLs they are officially part of the EELV launch mission.

When the APL representatives sign the MOA, they agree to the provisions in the MOA, to abide by the EELV RUG, and the LV/APL interface control document (ICD). STP includes many of the requirements or provisions in the MOA to ensure the APLs do not cause any type of impact to the primary payload, LV, or mission schedule. Some of the MOA provisions include the requirement for APL compliance reviews. ULA leads the APL compliance reviews to ensure the APLs are meeting data delivery requirements or the APLs are on schedule to meet SC delivery date at the integration facility at the launch site. All APLs must meet the ESPA Standard and Addendum ICD requirements. The ESPA Standard ICD documents the interface requirements between the APLs and LV that are common to all APLs. Each APL will have an Addendum ICD, which documents any LV/APL interface requirements specific to the individual APL. ULA and the APL develop the addendum ICD during standard integration; and complete and sign off the Addendum ICD no later than L – 12 months. STP will assist APLs to ensure compliance with the ULA ESPA Rideshare Users Guide, the APL Interface Control Document (ICD), and document an APL addendum ICD (if required). The APLs must satisfy specific Compliance Review success criteria in order to remain manifested on the EELV mission. Besides the individual pre-ship/ readiness reviews, APLs will be subject to four reviews; baseline at L – 24 months mission kick-off, and three compliance reviews at L – 18, L – 12, and L – 6 months respectfully. The reviews will focus on APL readiness and the quality and timeliness of APL mission documentation, e.g. safety input for the Missile System Prelaunch Safety Package, test reports, etc. If an APL is unable to meet the requirements for launch at the compliance review, it may be de-manifested. If the team must de-manifest an APL due to issues at L – 12 months or earlier, the AF may substitute another APL with similar weight and CG offset. At this time, the team intends APLs to provide a flight qualified mass simulator. In the event that a manifested APL fails to meet the required mission criteria, the team will direct the substitution of the mass simulator unless there is a suitable alternate APL.

Table-1 APL Deliverables

APL Launch Vehicle Submittals	**Preliminary**	**Update**	**Final**
Final APL LV Requirements	L – 36 Months EIS	As required by STP / ULA	L – 24 Months
Coupled Loads Model	L – -36 Months EIS	As required by STP / ULA	L – 18 Months
CAD Model	L – 22 Months	As required by STP / ULA	L – 18 Months
APL PL Drawings	L – 36 Months EIS	As required by STP / ULA	L – 12 Months
APL Electrical Schematics	L – 36 Months EIS	As required by STP / ULA	L – 12 Months
APL Mass Properties	L – 36 Months EIS	As required by STP / ULA	L – 12 Months
APL Finite Element Model (FEM)	L – 36 Months EIS	As required by STP / ULA	L – 12 Months
APL Parts List & Materials List	L – 36 Months EIS	As required by STP / ULA	L – 12 Months

Mission Constraints	Mission Kick off	L – 19 & 13 Months	L – 6 Months
APL Schedule Baseline and changes to Milestones	Mission Kick off	Monthly	L – 4 Months
APL Mission Level Risks	Mission Kick off	Monthly	L – 4 Months
APL Ground Operations Plan Inputs	L – 18 Months	L – 13 Months	L – 12 Months
Thermal Model	N/A	N/A	L – 12 Months
APL EED Analysis	N/A	N/A	L – 9 Months
APL EMI/EMC Analysis	N/A	N/A	L – 9 Months
APL Venting Model	N/A	N/A	L – 9 Months
Missile System Pre-launch Safety Package (MSPSP)	L – 24 Months	L – 13 Months	L – 5 Months
APL to LV ICD Inputs	L – 24 Months	L – 13 Months	NA
APL Pre-Ship Review Charts / Documentation	14 Days Prior to Review	NA	At Review
APL System Environmental Test Plans	30 Days Prior to Test	5 Days Prior to Test	At Test
APL System Environmental Test Reports	7 Days Post Test	N/A	30 Days Post Test
Facility Requirements Inputs	L – 24 Months	NA	L – 13 Months
Launch Site PRD/OR Inputs	L – 24 Months	NA	L – 13 Months
Separation System EDUs for bench testing	L – 14 Months	NA	L – 8 Months
Electrical Trailblazer LV harness testing	L – 13 Months	NA	L – 7 Months
Intact Impact Breakup Data	N/A	N/A	L – 5 Months
In-Flight Breakup Data	N/A	N/A	L – 5 months
Field Operations Procedures	L – 13 Months	L – 7 Months	L – 5 Months
HAZ-OPS Procedures	L – 13 Months	L – 7 Months	L – 5 Months
APL ICD Verification Artifacts	L – 13 Months	L – 7 Months	L – 3 Months
System Safety Spaceflight Worthiness Criteria Inputs	L – 13 Months	L – 7 Months	L – 3 Months

You Are On the Mission

ULA uses the deliverables to model the integrated LV, Primary SC, and APL system and to ensure the safety of the mission. In order for ULA integrated analysis to take place, all elements of the system must be accurately modeled or accounted. It is therefore of upmost importance that APL deliverables are accurate and provided on time. If any APL deliverable does not meet the required due date, the entire mission schedule is at risk. ULA and the government will work with the APL providers during the standard integration phase to ensure the team fully understands each deliverable prior to delivery.

The government and ULA will assess APL readiness for launch based on; the APLs ability to meet the required deliverable dates listed in Table 1 and the quality of the deliverables. If progress is satisfactory, the APL will continue with the mission; if progress is unsatisfactory, the APL may be removed from the mission at the L – 12 month compatibility review or required to submit a mass model at the L – 6 month review in order to ensure overall mission success. The government and ULA will assess all APLs progress against ICD compliance.

In addition to the compliance reviews, the APL providers or representatives will also be engaged in several rideshare integration meetings and reviews. ULA ESPA standard service begins with a Mission Kickoff meeting at L – 24 months. Following this will be an ICD Review at approximately L – 18 months where interface requirements and verification plans will be coordinated. ULA will conduct one Ground Operations Working Group (GOWG) at a minimum, to familiarize the APLC with the launch site and ground interfaces to be used for the rideshare service. Immediately prior to APL arrival at the payload processing facility (PPF), ULA will host a Ground Operations Readiness Review (GORR) to review ground operations plans and schedules.

ULA will conduct one Mission Peculiar Design Review (MPDR) in order to ensure that APL customer requirements are correct, complete and that integration analyses and designs meet requirements. ULA prepares and presents the review with participation

from the APL contractor or APL representative. At ULA's discretion, they will hold Technical Interchange Meetings (TIM) or working group meetings during the ESPA to APL integration effort to define technical interfaces and resolve technical issues. The RUG provides a complete list of meetings and the role the APL provider will play in each.

Launch Operations

ULA provides a PPF at the launch site for APL processing and checkout prior to APL mate with the ESPA ring. ULA will integrate the APLs to the ESPA ring using a Planetary Systems Corporation (PSC) Mark II Motorized Lightband (MLB) separation system. ULA personnel perform the mating operation and any APL lifts required during this operation will use the PPF crane and a lift sling supplied by the APL provider. Nominally, the APL should arrive at the PPF at L – 90 days to begin a 30-day processing period (if needed). The APL should be ready for APL to ESPA mate by L – 60 days. Upon completion of APLs integration with the ESPA ring, ULA transports the loaded ESPA ring to the primary SV's payload processing facility for integration. After integration with the Primary SC, ULA encapsulates the entire stack in the LV payload fairing. Then ULA transports the encapsulated stack to the launch complex for integration with the LV. After encapsulation within the LV payload fairing, APLs are no longer physically accessible.

Once integrated with the LV, ULA will supply the APL provider time and space in the Vertical Integration Facility (VIF) or Mobile Service Tower (MST) for APL battery charging and monitoring through a ground servicing umbilical. This "drag-on" umbilical provides ten shielded, twisted-pairs APL providers can use for battery charging and monitoring of voltage, temperature, and pressure. The ten twisted pairs reach the APL through two 15-pin in-flight disconnect (IFD) separation connectors mounted on the MLB. ULA will provide the APL halves of these connectors to APL providers during the standard integration phase for incorporation during their manufacturing. The MLB also has two separation switches for use by the APL to indicate separation during the launch sequence.

ULA will NOT provide physical access to the APLs at this time; APLs must conduct all charging and monitoring through the umbilical lines. At approximately three days prior to launch ULA closes the payload fairing and removes the APL ground servicing umbilicals. After umbilical removal, the APLs will not have a battery charging opportunity until they are on orbit charging via their on-board systems. The time span between umbilical removal and being on orbit could be a long as six days if there are delays in the launch.

On day of launch, the APL providers will not be on a launch console or make go/no-go decisions. Only the Primary SC and the LV teams provide input to the launch decision. The Mission Director has final go/no-go authority.

Key requirements the APLs must meet for a successful launch campaign under standard service are the following:

- APLs must complete checkouts in the PPF with close coordination with ULA
    - ULA will coordinate schedules with other APLs to de-conflict requirements
    - Coordinate with ULA to ensure any power-on in the PPF does not cause electromagnetic interference with other APLs
- APLs will be compatible with the LV, SV and launch site thermal, electromagnetic, dynamic, and contamination requirements as specified in the Standard and Addendum ICDs.
- APLs will comply with all ULA Safety and Range Safety requirements. APLs must comply with the applicable programmatic, design and operating/operational requirements of Air Force Space Command Manual (AFSPCMAN) 91-710, Volumes 1, 3, and 6, as a minimum.
- APLs must be capable of going six days between their last opportunity to charge batteries on the ground and being on-orbit.
- After reaching orbit, APLs must reach a specific separation distance from the LV and

other APLs before powering on to avoid interference. ULA will analyze each mission and provide a sufficient time to delay turn-on after separation.

Conclusion

Working together in response to Air Force objectives, the LRSW, the DoD STP, and ULA are bringing ESPA Std Svc to the small satellite community. This service represents an exceptional opportunity for experimental payloads to reach a variety of orbits on DoD missions with excess margin. The team carefully planned ESPA Std Svc to give APLs standard interfaces and provide straightforward integration with the ESPA ring and the launch vehicle. Compliance on the part of the APL providers with ESPA Std Svc as outlined in the RUG will ensure compatibility and an efficient integration. The number one priority for ESPA is mission success as with any EELV mission. This requires close coordination between the launch team and APL provider, APL compliance, and careful attention to detail on the part of all organizations involved to ensure the successful performance of all vehicles. The Air Force and ULA will hold APLs to the same high standards that the launch vehicle and primary payload meet to ensure mission success.

Acknowledgments

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