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The Atlas V Aft Bulkhead Carrier - Requirements for the Small Satellite Designer

George Budris
United Launch Alliance
PO Box 277005, Littleton, CO 80127-7005; 303-977-9040
George.J.Budris@ulalaunch.com

ABSTRACT

United Launch Alliance (ULA) developed the Aft Bulkhead Carrier (ABC) system for mounting small satellites onto the Atlas V launch vehicle. Payloads with a maximum mass of 176 lbs and volume of 20 x 20 x 34 in. are viable candidates to fly. ULA has already built flight hardware and is preparing a User's Guide to document the technical interface information required by spacecraft designers.

When working with the rideshare community, primary payload mission managers expect the small satellite programs to meet high standards for requirements, management, and closeout during integration on their mission. Successful integration of small satellites onto the ABC takes place following a disciplined approach to meeting and verifying mission requirements. It is vital that the community comprehend what these requirements are and follow an established process to meet them. By doing so, access to orbit can be reliably achieved for small satellites via the ABC. Failed integration efforts cost time, money, and customer good will.

This paper summarizes the ABC system and progress of the development to date. Additionally, it provides a summary of the ABC User's Guide, identifying the generic requirements any payload must meet to successfully launch. Additional insight is presented as to the type of verifications needed, their expected quality, and timing during the integration schedule. A case study on the integration of the ADAMSAT payload is reviewed, providing a real-life example of lessons learned from the attempt to integrate this Cubesat Dispensing system to the ABC/ Atlas V.

INTRODUCTION

The Aft Bulkhead Carrier (ABC) is designed to carry a small payload on an Atlas V launch vehicle. The ABC is a plate attached to the aft end of the Centaur upper stage (Figure 1) capable of supporting and deploying small satellites. The system is designed to be compatible with any Atlas V mission, with ABC providing a rideshare opportunity with selected primary missions. The Customer team is looking at near-term primary missions that could be matched with an ABC. ABC is ready to fly non-separating ADAMSAT Cubesat Dispenser type spacecraft and will have the capability to fly and deploy single satellites at the completion of this current design phase in September 2010.

A small satellite's best chance to fly on an Atlas mission is to meet mission requirements and provide quality verifications. The ABC User's Guide provides all requirements for the small satellite to fly on the Atlas V and is planned for release in September 2010. Once a mission is selected, the integration process begins and an Interface Control Drawing is prepared which focuses requirements for that mission. In addition to meeting technical requirements, the small satellite must meet program requirements, such as mission schedule and program reviews. It is critical that the small satellite start the integration process at the beginning of the primary integration cycle, which is typically 2 years before launch.

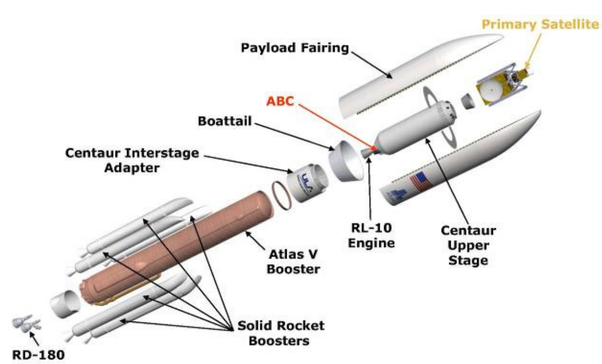

Figure 1: ABC Location (Atlas V 500 Series)

During the ABC/ADAMSAT integration, valuable lessons were learned, in the areas of safety, integration timeline and program visibility, which can help future efforts be more successful.

AFT BULKHEAD CARRIER OVERVIEW

ABC is a platform with a bolt pattern compatible with the EELV Secondary Payload Adapter (ESPA) to support small satellites. It is located on the back end of the Atlas V Centaur Upper Stage, as shown in Figure 2. The ABC system utilizes a volume on the Centaur aft bulkhead previously occupied by a helium bottle which is no longer required. ABC can carry a small satellite with a mass of up to 80 kg (176 lb). The ABC attaches to existing structure on the aft tank of the Centaur upper stage.

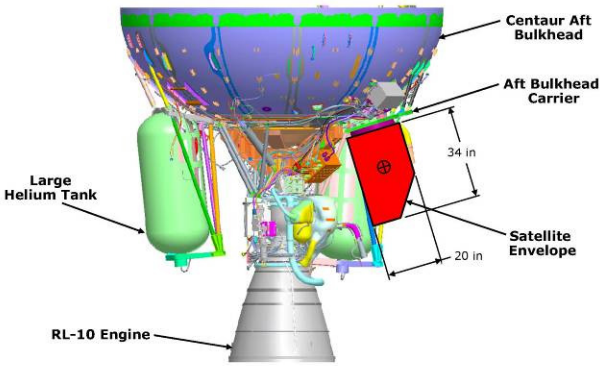

Figure 2: ABC Flight Configuration

Satellites compatible with ABC include both non-separating (bolted to the plate) like that of the ADAMSAT; and those which separate using the ABC-provided 15-inch Motorized Lightband. The maximum volume available to a satellite is 20” x 20” x 34” with a chamfer (Figure 3). This information may be found in the Atlas V Launch Services User’s Guide as well as the ABC Auxiliary Payload User’s Guide. Since the ABC is on the aft-end of the Centaur, it has the advantage of not significantly interfering with the primary payload environment. The separation plane of the ABC is tilted 17 degrees relative to the longitudinal axis of the Centaur, providing clearance and no re-contact with the Centaur. To avoid contamination or plume impingement, the Centaur inhibits the normal settling thrusters during the period of deployment.

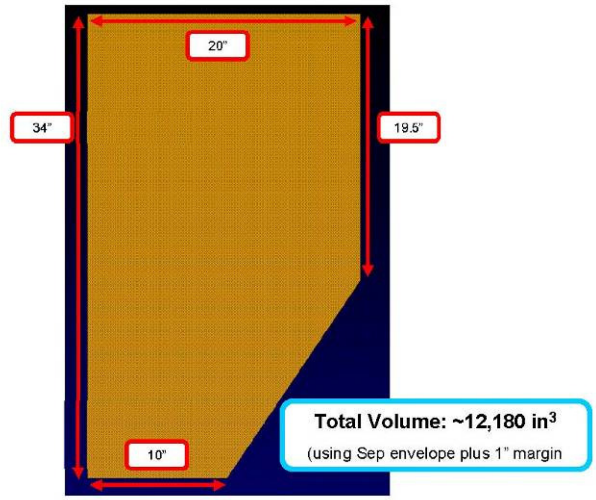

Figure 3: ABC Usable Volume (Separating Payload)

The ABC program summary appears in Figure 4. To date, ABC development has completed three phases and is currently active in the final development (Phase 4). Phases 1, 2, and 3 are complete, taking ABC through generic requirements and concept development and ADAMSAT integration. Phase 3 built flight and ground support hardware and started the ADAMSAT integration. ABC is now integration-ready for an ADAMSAT-like Cubesat dispenser. Phase 4 will complete the generic ABC capability (Started in Phase 1) to include a separation system for a single satellite. No future development is planned after Phase 4; however, a new integration opportunity will likely become available.

Figure 5 shows the ADAMSAT spacecraft. It is designed to dispense up to 24 1U Cubesats using 8 P-PODs. There are three components to the ADAMSAT: the NPSCul-lite structure, designed by the Naval Post Graduate School; the Poly Picosatellite Orbital Deployer (PPOD), provided by California Polytechnic State University, San Luis Obispo; and an

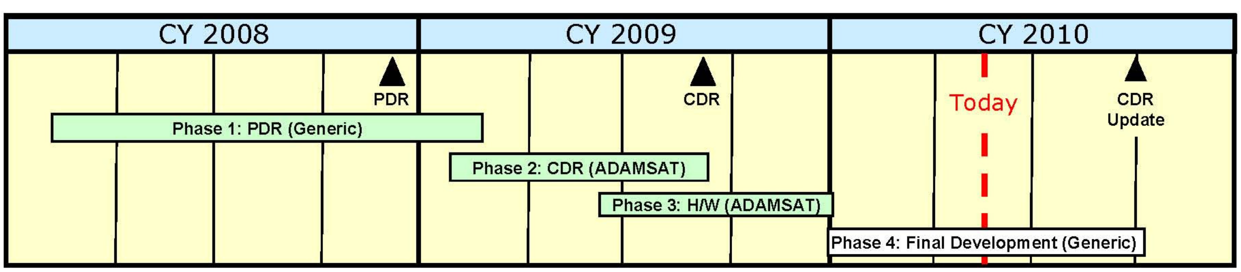

Figure 4: ABC Program Plan

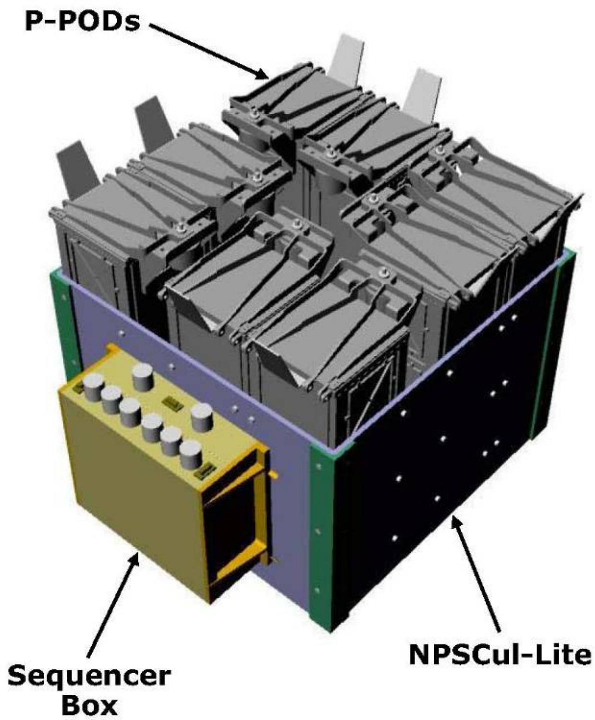

Figure 5: ADAMSAT Auxiliary Payload

electronic sequencing box developed by Ecliptic Enterprises, designed to provide door opening signals in sequence to the P-PODs.

The organization chart for the ABC/ADAMSAT integration effort (Figure 6) shows the coordination challenge that the ABC team faced. At the beginning of the integration, ULA had to coordinate mission requirements across all the suppliers and customers. Later in the program, The Customer provided an integration contractor to simplify the small satellite-to-launch vehicle coordination.

To find a mission for ABC, an Atlas V compatibility chart was developed to track all missions for all customer types, including Government, civil, and commercial opportunities. Key parameters tracked are performance margin, orbit type (LEO, MEO, GTO), launch date, and vehicle type (4-meter or 5-meter payload fairing). A similar process led to mission managers matching ABC with ADAMSAT on an Atlas V mission.

Mission, interface, and environments requirements for the secondary payload appear in the ABC Auxiliary Payload User's Guide. The User's Guide provides worst-case small satellite requirements for the applicable Atlas V missions. Small satellites designed to the requirements in the User's Guide will be able to fly on the applicable Atlas V missions. By incorporating Atlas V requirements into the design from the very beginning, the small satellite will be in the strongest position to meet and verify the requirements.

The mission requirements section contains requirements relative to the primary mission orbit. The secondary payload has no influence on the mission orbit, but residual capabilities of the centaur upper stage

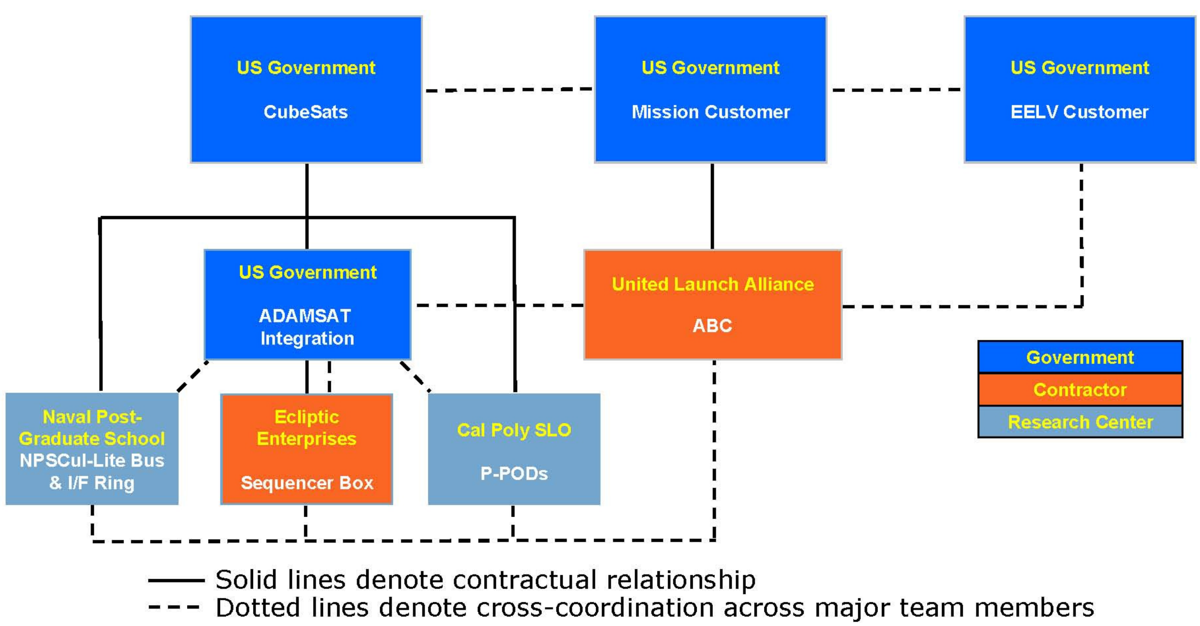

Figure 6: ABC/ADAMSAT Responsible Organizations

(after the primary has separated) can be used to support small satellite needs. Certain considerations may be made to support a desired small satellite deployment attitude. This section identifies the small satellite allowable mass properties as well.

Small satellite volume, attachment bolt pattern, and required stiffness are key examples of mechanical requirements in the interface section. The primary mission will require a backout plan should the small satellite not meet its delivery date. To this end, a section has been added with the requirements for a small satellite provided mass simulator. The mass simulator would simulate mass and center of gravity of the small satellite deploying from the ABC, and must be made available to the mission if required. Avionics interfaces include launch vehicle-provided ground services, including T-0 battery charging and separation sequence initiation.

The interface section also covers Range and System Safety interfaces. ABC secondary payloads will demonstrate compliance to the applicable Range requirements by the generation and submittal to both Range Safety and ULA of an acceptable Missile System Prelaunch Safety Package (MSPSP). An adequate MSPSP identifies hazards inherent in the hardware and operations, identifies design features that preclude or mitigate the hazards, and summarizes how the effectiveness of the hazard controls will be verified. Hazardous commodities and propellants are not baselined for ABC payloads.

Relative to facilities and processing, the secondary payload is responsible for its own processing and processing facility. The secondary payload is delivered to the ASOC/Building 7525 in a mate-ready configuration to support Centaur processing. Nominally, this is expected by L-90 days. The time mated to the Centaur can be long depending on the primary mission processing schedule. Small satellites must be able to withstand these timelines.

Likely stressing to the secondary payload, the thermal prelaunch environment (due to hot purge conditions immediately before launch), must be addressed. Electromagnetic compatibility, contamination, loads, acoustics, vibration, and thermal environments are other notable flight environments and are defined in the users guide.

Initial release of the ABC/Secondary Payload User's Guide is scheduled for September 2010. Subsequent to its release, the User's Guide will be prepared for public release as an unrestricted launch vehicle planning document.

Once a mission is identified, an Interface Control Document (ICD) will be prepared, including mechanical and electrical interface drawings as appendices. Reduced requirements may be possible for particular vehicle integrations.

Table 1: Auxiliary Inputs into the Integration Process

AP Standard Data Input	Approximate Need Date
Program Kickoff (KO) Meeting	L-23 months
Initial Small Sat Weight, Orbit, Separation Attitude	L-23 months (at Program Kickoff Meeting)
Interface Requirements Document	L-23 months (at Program Kickoff Meeting)
Preliminary Small Satellite MSPSP	L-23 months (at Program Kickoff Meeting)
Intact Impact Breakup Data	L-23 months (at Program Kickoff Meeting)
Inflight Breakup Data	L-23 months (at Program Kickoff Meeting)
Preliminary Coupled Loads Model	L-23 months (at Program Kickoff Meeting)
Preliminary CAD Model	L-22 months (Program KO Meeting +1 month)
Range Safety Mision Orientation Briefing Input	L-19 months (Program KO Meeting +4 month)
Final CAD Model	L-17 months (Program KO Meeting +6 month)
Final Coupled Loads Model	L-16 months (Program KO Meeting +7 month)
Procedures Used at the Processing Facility	AP Arrival - 2 months
Thermal Models	L-12 Months
Final MSPSP	L-8 Months
AP EMI/EMC Analysis	L-7 Months
AP EED Analysis	L-7 Months
AP Environment Qualification Test Reports	L-5 months
Procedures Used on Launch Site	L-4 months
Final AP Weight, Orbit, Separation Attitude	L-90 days

Each requirement in the ICD will require verification, either by the launch vehicle program or small satellite customer. This is a formal process with evidence of verification provided on launch vehicle-provided forms. Evidence must meet the standard required by the mission team to adequately verify that the requirements have been met.

A typical launch integration timeline is 2 years. Table 1 summarizes the necessary inputs for the Atlas V team during integration. As shown in the table, many secondary payload deliverables are required at the beginning of the integration window. Regular program meetings occur during the 2-year timeline, where the secondary payload customer will be expected to provide status of their readiness for launch.

OBSERVATIONS FROM INTEGRATING THE ADAMSAT PAYLOAD

The Customer team selected a mission for ABC/ADAMSAT to manifest with. However, the primary spacecraft mission team had already started its integration process. Adding ABC/ADAMSAT to the mission required revisions to a number of in-work analyses, most notably coupled loads and mission design. Even though ABC/ADAMSAT was added mid way through the primary mission integration, mission managers were willing to go forward with the integration pending a successful result from a separate rework of the coupled loads analysis.

Integration Successes

The ABC mission team was able to take an existing Computer Aided Design model of the ADAMSAT from NPS and show the necessary clearances with the RL-10 engine and other nearby Centaur components. Additionally, positive clearances were calculated for the separating Cubesats deployed by the PPODs.

To support the handling and installation of the ABC/ADAMSAT to the Centaur upperstage, the team had to design and build complex ground support equipment. Platforms, ladders, mate stand and lifting fixture were designed, built, tested and delivered on a very tight schedule. Additionally, the ABC flight hardware was delivered on-time to the factory to meet a very tight window for Centaur upper stage processing and checkout.

ADAMSAT Integration Challenges

The ULA Loads Team was able to rework the previous primary mission loads analysis through the addition of the ABC/ADAMSAT. This analysis would determine the extent of loads changes to the primary mission caused by adding ABC and ADAMSAT and if there were any loads exceedences in critical areas. Ultimately, the results showed no load increases in any critical areas and ABC/ADAMSAT was approved to start integration. A number of meetings were held during the loads analysis process including an out brief of the results to keep the primary mission team informed of the progress.

Orbit modifications (after the primary separation) were required to support the function of ADAMSAT. The ULA flight design team was able to change a fairly mature mission design to meet both primary and ADAMSAT needs. Again, there was much discussion with the primary mission team before the modified flight design was accepted.

The ADAMSAT type satellite gave quite an integration challenge to the ABC team. When integration with ADAMSAT was first started, the ABC team had to interface individually with the suppliers of the three major components (NPS structure for loads analysis, Cal Poly for separation clearance analysis and the Ecliptic for compatibility between sequencer and the Atlas V avionics). ULA certainly has the capability and expertise to be the integrator, but was not in a contractual or financial position to do so. ULA continued interfacing with each of the ADAMSAT suppliers until an integration manager for the ADAMSAT was assigned.

The Final Outcome

Key Cubesat satellites declared they could not meet the integration schedule and financial obligations, so ADAMSAT was withdrawn from the mission. Even though ABC flight hardware were already installed to the rocket, mission managers determined that sufficient time existed in the integration schedule to return the mission to a pre-ADAMSAT state. No mass simulator was needed and ABC flight hardware was removed from the vehicle.

CONCLUSIONS

Safety Lessons Learned

An MSPSP, compliant with AFSPCMAN_91-710, Volume 3, Attachment 1 requirements, is the primary price of admission onto the launch vehicle and launch range. Small satellite organizations must acknowledge Attachment 1 and describe the features and capabilities inherent in the design that adequately preclude, prevent, mitigate or ameliorate hazards. A top-level description of the program objective, and/or the underlying physics is appropriate, but detailed performance parameters or capabilities that do not impact safety should be excluded. For example, if the mission is earth observation, hazardous materials in the "camera" could present a potential safety concern and thus warrant discussion; resolution capability, operating wavelength/spectral range, "targets," or similar performance parameters that do not affect safety probably do not, especially if proprietary or classified.

Small satellite organizations need to demonstrate a thorough understanding not only of how their hardware functions, but also of how it might malfunction, and what conditions or circumstances could induce a malfunction. For example, controlling the hazards associated with battery leakage or rupture typically warrants significant attention. Battery hazards may derive from inherent flaws in the materials of construction or in the manufacturing process. Alternatively, hazardous battery malfunctions may be induced by faults/failures in the charge/discharge control circuitry. Electrolytes and their decomposition products may be toxic, corrosive, or flammable. The MSPSP needs to address all of these issues.

Early range coordination is a must. Any ride-sharing small satellite program organization should consult and coordinate with Range Safety to establish ground rules, appropriate requirements, roles and responsibilities, and (at least) top-level documentation delivery schedules. ULA should be present at these discussions, but establishment of the applicable requirements is the responsibility of the Range. Similarly, it is the responsibility of the small satellite program organization to perform the necessary hazard analyses and assessments and to document the results per Air Force Space Command Manual 91-710 (AFSPCMAN_91-710) requirements.

Small satellites do not necessarily present small hazards. Hazard causes, usually component faults/failures or operator errors, should be examined for the potential to propagate into critical or catastrophic conditions that could further lead to a mishap. Appropriate levels of fault tolerance (FT) and/or design-to-minimum-risk (DFMR) features must be incorporated into the design.

Schedule Lessons Learned

Small satellite customers must prepare a schedule with milestones that support the launch vehicle and primary payload integration and be prepared to status their development and production activities at the program meetings held regularly during the integration process. There are numerous analyses that must be performed to meet launch vehicle and primary mission requirements. These analyses depend upon the upperstage parameters where the small satellite has a direct contribution. Small satellite developers need to understand launch vehicle timelines and understand that there is the potential for significant cost and program impacts if they do not provide timely inputs or change mass properties, orbit parameters, etc.

A small example of the fallout that can occur when program timelines are exceeded happened to the ULA mechanical ground support equipment team during the integration of the ADAMSAT satellite. The ADAMSAT design team developed an electrical harness that interfered with lifting operations. The launch vehicle development team went over what could and could not be done, yet several months later the ADAMSAT team fielded a harness that still interfered with the lifting hardware. The outcome of this routing caused redesign of a certain piece of launch vehicle ground support equipment and rework of hardware in work at the supplier. Fortunately, the redesign was straight forward and the rework was able to use much of the equipment already made.

Program Lessons Learned

The launch vehicle team prefers working with a single point of contact from the beginning of the integration. A strong integration contractor was particularly helpful for the ADAMSAT integration. Once on board, the integration contractor was the single point of contact to ULA. The integration contractor’s position was to ensure the launch vehicle requirements were met and verifications prepared for the NPS, PPOD, Sequencer, and Cubesats. The contractor had a thorough understanding of the technical and programmatic requirements and an understanding of the verification process. Before the integration contractor was put in place, however, ULA provided this role and worked closely with each supplier to help them through the requirements/ verification process.

Integrating a secondary payload to a primary mission affects numerous drawings, analyses and hardware. Programmatic support and funding commitment from the secondary payload program office will give the primary mission team the assurance that there is adequate funding and resources to complete the integration process. In addition to the program support, a small satellite program plan must be developed. The mission team expects to see the secondary payload program plan and its compliance with the mission schedule.

One cannot over emphasize to the small satellite team the phrase, “Do no harm to the primary payload.” Small satellite customers need to understand the extent to which the must prove to the primary mission and the Range that they have the proper inhibits, design margins, etc., built into the payload. In the launch business, mission success is paramount.

VIEW OF THE FUTURE

ABC is a new capability designed to be compatible with separating and non-separating small spacecraft. ABC can be launched on any Atlas V launch vehicle, from either coast, for almost any orbit. ULA is providing support for the selection of another Atlas mission for ABC and is in the process of developing a recurring cost structure for integrating small satellites using ABC. The ABC User's Guide will be released for use by the small satellite community by the end of 2010

References

1. Aft Bulkhead Carrier Secondary Payload Users Guide (draft), ULA-ATLAS-UG-08-001
2. Atlas V Launch Services User's Guide, Revision 11, March 2010