United Launch Alliance Rideshare Capabilities To Support Low-Cost Planetary Missions

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Abstract. The United Launch Alliance (ULA) family of launch vehicles - the Atlas V, the Delta II, and the Delta IV - all have rideshare capabilities that could be used by the science community for launching small, inexpensive payloads to planetary locations. These capabilities support a wide range of spacecraft sizes, from the smallest CubeSats, to the largest dual-manifest payloads. This paper will provide a technical overview of each of the rideshare capabilities that are either available today or are currently in development. Details on each capability will be provided, including mass and volume; interface hardware; development statuses; and launch availability. The capabilities that will be discussed include P-POD dispensers, the C-Adapter Platform (CAP), the Atlas V Aft Bulkhead Carrier (ABC), the EELV Secondary Payload Adapter (ESPA), the Integrated Payload Carrier (IPC), the eXternal Payload Carrier (XPC), and the Dual Spacecraft Systems (DSS-4 and DSS-5).

Keywords: United Launch Alliance, ULA, Atlas, Delta, rideshare, secondary payload

1. Introduction

United Launch Alliance (ULA) expendable launch vehicles have a long history of providing high-value payload accommodations for a variety of customer spacecraft and missions, including planetary missions to Mercury, Mars, Pluto, comets, and the Asteroid Belt (Figure 1). These missions have allowed scientists to collect a wealth of information, and they have given us a better understanding of our solar system. These missions have usually been launched as primary payloads and have used the full capability of the launch vehicle, yet there are lower-cost alternatives for achieving similar science objectives.

2001	Mars Odyssey
2002	CONTOUR
2003	Mars Rover A (Spirit)
2003	Mars Rover B (Opportunity)
2004	MESSENGER
2005	Deep Impact
2005	Mars Reconnaissance Orbiter
2006	New Horizons
2006	STEREO
2007	Phoenix
2007	Dawn
2009	Lunar Reconnaissance Orbiter

Figure 1. ULA Interplanetary Missions, 2001-Present.

1.1 Rideshare For Low-Cost Planetary Missions

Rideshare - the approach of sharing with a secondary spacecraft the available performance & volume margin that would otherwise go unused by the primary payload - provides principal investigators the opportunity to get their spacecraft to orbit and beyond in an inexpensive and reliable manner. The advantages of rideshare to the planetary science community are numerous. First and foremost are the cost-savings that are realized by sharing a ride with a primary payload. The secondary payload customer receives the benefits of a full-up launch service at a reduced price, allowing more funding to be applied to the science mission. Another advantage is the launching to orbit on a highly reliable launch vehicle, increasing the possibility of mission success.

Such an approach was successfully demonstrated in 2009, when the Lunar Crater Observation and Sensing Satellite (LCROSS) was flown as a secondary payload on a ULA Atlas V launching the Lunar Reconnaissance Orbiter (LRO) mission to the moon. This launch proved that alternative ways to exploring the solar system in a cost-effective manner can be successfully achieved, and these types of missions will become more commonplace as new ULA rideshare capabilities become available.

2. ULA Rideshare Capabilities

To date, ULA has completed development or is continuing to develop a large number of rideshare capabilities and hardware, each with its own set of mass, volume, and interface parameters that can support a multitude of payload shapes and sizes. Each of the capabilities is at difference stages of development, but all are expected to be available to support launch opportunities by the middle of this decade. An overview of the technical specifications and development status of each individual capability is shown in Figure 2.

While each rideshare capability may not be large enough to support all planetary mission opportunities, a technical overview of each one is still provided below. This survey of all ULA rideshare capabilities is provided to support future mission planning for the entire science community.

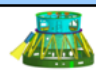
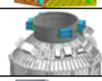
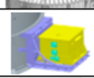
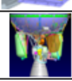
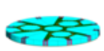
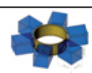
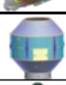
CAPABILITY		MAXIMUM MASS PER PAYLOAD	VOLUME	INTERFACE	MAXIMUM # / LAUNCH	COMPATIBILITY			STATUS
						DII	DIV	AV	
Delta II **Second-Stage Mini-Skirt**		1.0 kg (2.2 lb)	10 cm^3 (4 in^3)	P-POD	6 Cubesats	X			ILC 2011
Delta IV **Equipment Shelf**		1.0 kg (2.2 lb)	10 cm^3 (4 in^3)	P-POD (NPSCuL)	24 Cubesats		x		Concept Development
ULA EELV P-POD		1.0 kg (2.2 lb)	10 cm^3 (4 in^3)	P-POD	24 Cubesats		x	x	Concept Development
CAP **(C-Adapter Platform)**		45 kg (100 lb)	23 cm x 31 cm x 33 cm (9 in x 12 in x 13 in)	15" clampband	4		x	x	ILC 2012
ABC **(Aft Bulkhead Carrier)**		77 kg (170 lb)	51 cm x 51 x 76 cm (20 in x 20 in x 30 in)	15" clampband or P-POD	1			x	ILC 2012
A-DECK **(Auxiliary Payload Deck)** ***(Adaptive Launch Solutions)***		905 kg (2,000 lb)	152-cm dia. (60-in dia.)	15", 23", 37" clampband	1		x	x	ILC 2012
ESPA (EELV Secondary Payload Adapter) ***(Moog CSA Engineering)***		180 kg (400 lb)	61 cm x 71 cm x 96 cm (24 in x 28 in x 38 in)	15" bolted	6		x	x	Operational
IPC **(Integrated Payload Carrier)**		910 kg (2,000 lb)	137-cm dia. (54-in dia.)	8", 15", 37" clampband	1		x	x	Operational
XPC **(External Payload Carrier)** ***(Special Aerospace Services)***		1,590 kg (3,500 lb)	20.1 m^3 (710 ft^3)	60" diameter	1			x	PDR 12/2010
DSS-4M **(Dual Spacecraft System - 4M)**		2,270 kg (5,000 lb)	254-cm dia. x 127 cm (100-in dia. x 50 in)	37" clampband	1		x	x	ILC 2012
DSS-5M **(Dual Spacecraft System - 5M)**		5,000 kg (11,000 lb)	4-m dia. x 6.1 m (13.1-ft dia. x 20 ft)	62" bolted	1		x	x	Concept Development

Figure 2. ULA Rideshare Capabilities Overview

2.1 CubeSats/Poly Picosatellite Orbital Deployer (P-POD)

CubeSats are small spacecraft that are a 10-cm cube and weigh 1 kg each. While a single CubeSat, also referred to as a 1U, may be too small to support major planetary science missions, larger payloads can be built, such as a 2U or 3U Cubesat.

The common carrier for this class of spacecraft is the Poly Picosatellite Orbital Deployer (PPOD) developed by California Polytechnic University, San Luis Obispo. An individual P-POD is a relatively simple dispenser, and can accommodate up to 3 CubeSats, or a single 3U Cubesat. ULA has pursued a number of P-POD interface solutions for the Atlas and Delta vehicles. The first launch of P-PODs on a ULA vehicle will occur on a Delta II in the 3rd quarter of 2011 (Figure 3).

Another system is the Naval Post Graduate School (NPS) CubeSat Launcher (NPSCuL), shown in Figure 4 on the Delta IV second-stage equipment shelf. The NPSCuL hosts eight P-PODs for a total of 24 CubeSat slots. This device is currently being integrated onto the Atlas V Aft Bulkhead Carrier, and it could also be fitted onto an EELV Secondary Payload Adapter (ESPA).

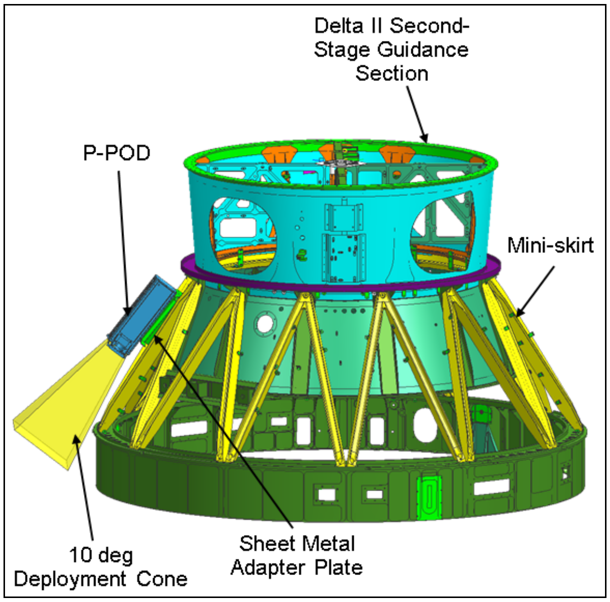


Figure 3. Delta II P-POD Interface.

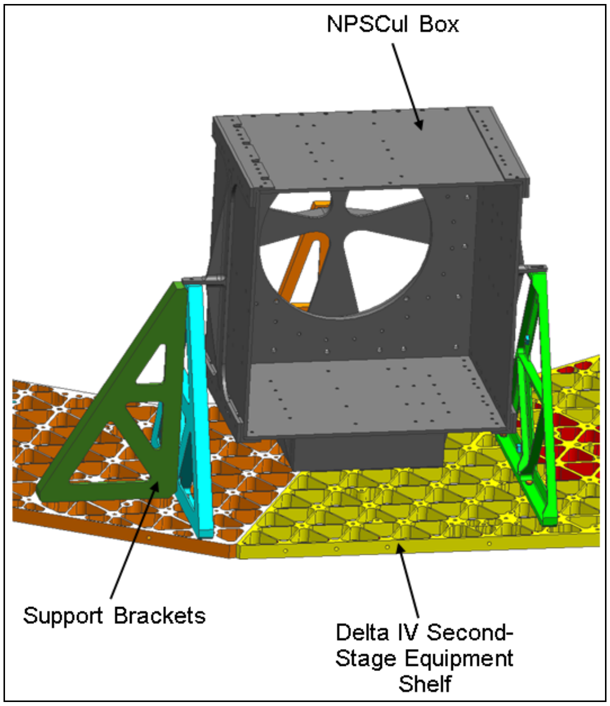


Figure 4. Delta IV/NPSCuL P-POD Interface.

2.2 C-Adapter Platform (CAP)

The C-Adapter Platform (CAP) is a cantilevered platform that is located within the payload fairing and is attached to the side of a C-adapter. It can carry an auxiliary payload with a mass up to 45 kg (100 lb). With additional qualification, it may be possible to increase this mass limit. Figure 5 shows its location on the side of a typical C-Adapter. The number of CAPs and the positioning of the CAPs around the circumference of the C-adapter are subject to available mission margins and mission requirements, but up to four CAPs could be accommodated on a single flight. The CAP can accommodate various deployment options, and it is large enough to accommodate an 8-inch Motorized Lightband, which can be mounted on either the base of the CAP or on the back wall. The CAP is compatible with both the Atlas V and the Delta IV.

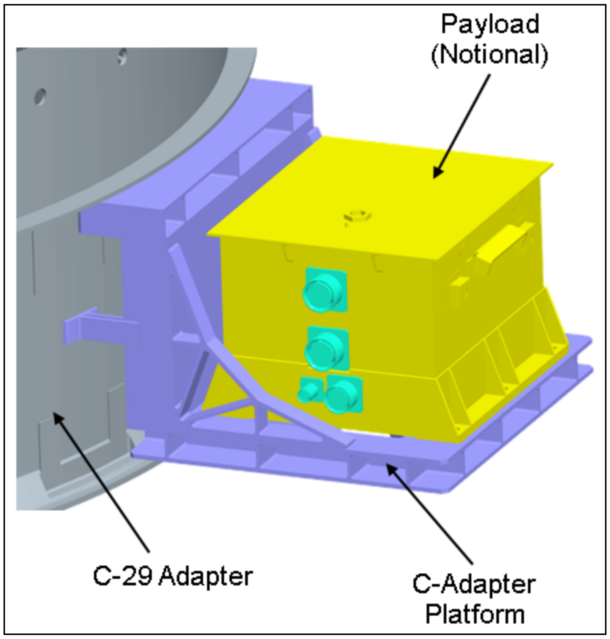


Figure 5. C-Adapter Platform (CAP).

2.3 Aft Bulkhead Carrier (ABC)

The Aft Bulkhead Carrier (ABC) utilizes volume on the Atlas V Centaur aft bulkhead previously occupied by a helium bottle that is no longer required. The ABC can carry an auxiliary payload with a mass of up to 77 kg (170 lb). Located on the aft-end of the Centaur second-stage near the RL10 engine area, and using mounting attachment points that use the existing tank doublers, the ABC provides a usable volume as shown in Figure 6. The ABC can accommodate both separating and non-separating payloads, with a volume that is slightly larger for non-separating payloads. The ABC is large enough to accommodate a 15-inch Motorized Lightband separation system.

Since the ABC is on the aft-end of the Centaur, it has the advantage of not interfering with the primary payload environment. It also has the ability to be deployed into low-Earth orbit during the Centaur first-coast portion of the mission. 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.

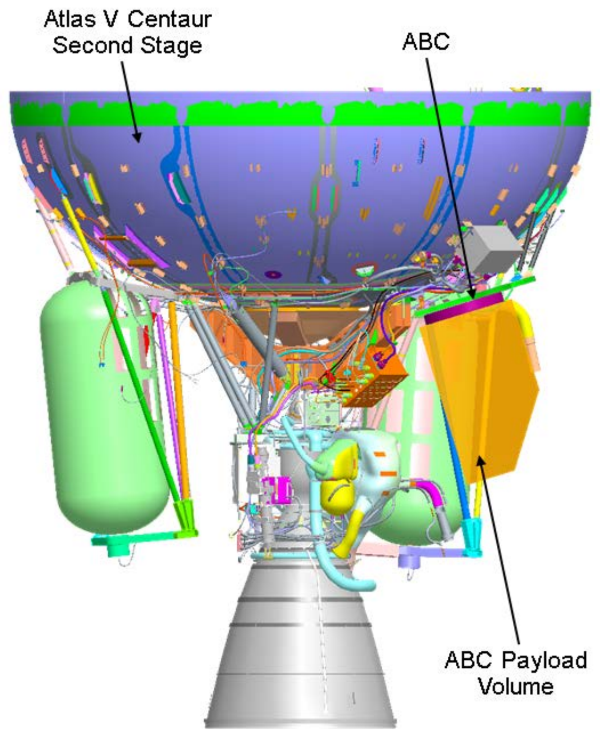


Figure 6. Aft Bulkhead Carrier (ABC).

2.4 EELV Secondary Payload Adapter (ESPA)

For missions with an excess amount of volume within the fairing, larger auxiliary payloads can be launched using the EELV Secondary Payload Adapter (ESPA), a 1.5-m-dia (62-in diameter), 61-cm-tall (24-in-tall) ring structure that can support up to six auxiliary payloads around its circumference. Developed by Moog CSA Engineering, the ESPA is mounted between the top of an Atlas V or Delta IV second-stage and the bottom of the primary payload's spacecraft adapter, duplicating the EELV standard interface plane (SIP), and passing the electrical interfaces through to the primary payload (Figure 7).

The auxiliary payload may be attached to the ESPA with a ULA-supplied separation system or directly through a customer-provided adapter. The ESPA ring contains six 381-mm-dia (15-in diameter) bolt circle interfaces, with each being able to accommodate a single auxiliary payload of up to 180 kg (400 lb) in mass, and a volume of 61.0 cm x 71.1 cm x 96.5 cm (24 in. x 28 in. x 38 in.). This total volume includes a 5.33 cm (2.1 inch) separation system operational envelope. Only the separation system, its mounting hardware and its harness are permitted inside the separation system operational envelope.

The first launch of an ESPA occurred on the Department of Defense Space Test Program launch STP-1 in March 2006.

Detailed information on the ESPA and its mission integration requirements are documented in the ESPA Rideshare User's Guide, available from the US Air Force or United Launch Alliance.

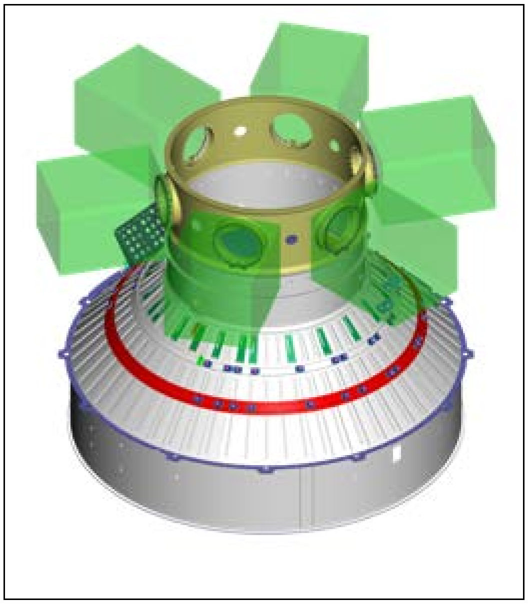


Figure 7. EELV Secondary Payload Adapter (ESPA).

2.5 Integrated Payload Carrier (IPC)

The Integrated Payload Carrier (IPC) is a flexible stack of ring segments that can provide an interior volume (Figure 8) that can accommodate various auxiliary payload types by providing a variety of configurations depending on the particular needs of the mission. It consists primarily of a mix of C-adapters of various heights (13, 15, 22, 25, or 29 inches). Additionally, a D-1666 separation system can be added in order to separate the upper portion of the IPC from the lower portion. Also, an ESPA ring can be added in place of a C-adapter in support of multi-manifest missions. Several examples of possible configurations are shown in Figure 9.

Using either an isogrid flat-deck (Such as the A-Deck being developed by Adaptive Launch Solutions) or a conic section inside the IPC as the spacecraft interface, ULA EELVs can deploy one or multiple auxiliary payloads from within the internal volume. The internal diameter of a C-Adapter segment is 60 inches, and can accommodate auxiliary payloads diameters of up to approximately 50 inches. The height available to the auxiliary payload can vary by the types and number of adapters used.

A combined IPC/ESPA stack was successfully flown on the LRO/LCROSS mission to the Moon in 2009.

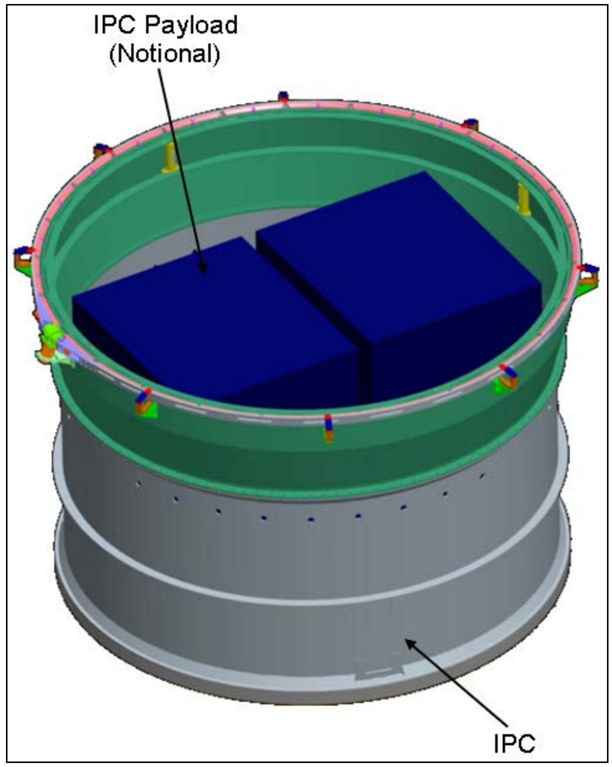


Figure 8. Integrated Payload Carrier (IPC).

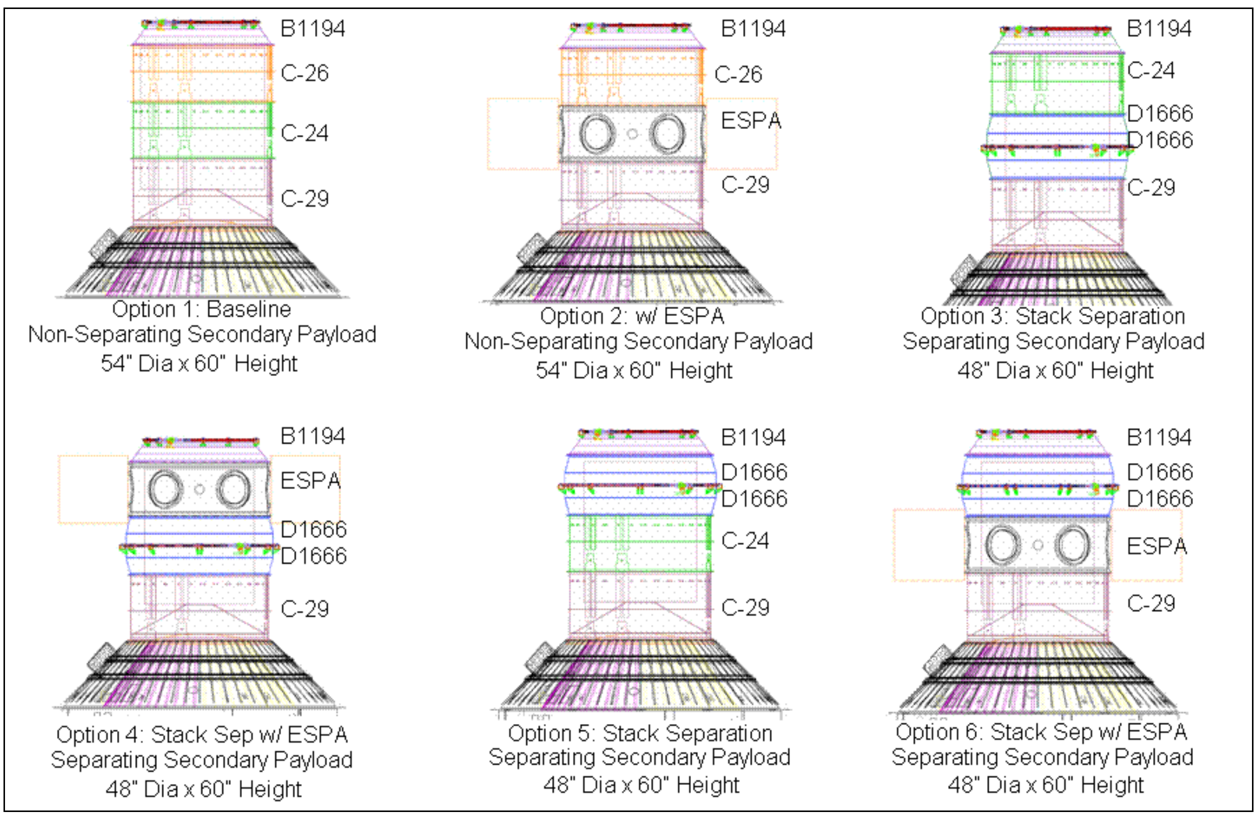


Figure 9. Integrated Payload Carrier (IPC) stack options.

2.6 Dual Spacecraft System, 4-m (DSS-4)

The Dual Spacecraft System, 4-m (DSS-4) enables the launch of two independent, small-to-medium class spacecraft on a single Atlas V 4-m or Delta IV launch vehicle, as shown in Figure 10. The DSS-4 makes extensive use of existing components with well-understood capabilities. The launching of two similarly-sized dual spacecraft has already been demonstrated four times over the past decade on the Delta II Dual Payload Attach Fitting (DPAF). The launch processing and on-orbit concept of operations for the DSS-4 is very similar to the DPAF.

Figure 10. Dual Spacecraft System, 4-m Fairing (DSS-4).

The DSS-4 structure consists of two back-to-back Centaur Forward Adapters (CFAs) with an optional addition of one, two, three, or four DSS plug sections to provide flexibility in the heights of the forward and aft spacecraft volumes. The CFA is an assembly of one cylindrical stub adapter and a conical adapter attached by a common ring. In the DSS-4 application, the cylindrical parts of a lower, inverted CFA and an upper, non-inverted CFA mate together. This creates a canister which contains the lower spacecraft. The Atlas V or Delta IV 4-m-diameter payload fairing completely encloses the upper spacecraft and the DSS, while the DSS itself encloses the lower spacecraft. The DSS supports the upper spacecraft and therefore all the loads from the upper spacecraft are carried by the DSS during vehicle flight.

The forward interface of the DSS is the 62-inch Standard Interface Specification (SIS) payload interface, permitting use of existing payload adapters. The aft interface attaches to the Atlas launch vehicle using a standard C13 cylindrical payload adapter. The DSS can be flown within any Atlas V or Delta IV payload fairing as needed, based on the lengths of the two spacecraft and the DSS.

2.7 Dual Spacecraft System, 5-m (DSS-5)

Similar to the DSS-4, the DSS-5 is designed to dual-launch two medium-to-intermediate class payloads within an Atlas V or Delta IV 5-m payload fairing. The DSS-5 consists of a newly designed composite cylindrical canister and upper cone structure that encloses the lower payload and provides structural support for the upper payload. There is no change to the structural support of the lower payload.

A mission-unique adapter is used to attach the launch vehicle to the interface of the lower payload. The DSS-5 provides support for the ULA-provided electrical harnessing to the upper payload, instrumentation, and upper payload separation system.

The lower DSS-5 spacecraft volume is approximately 4-m dia. x 6.1 m (13.1-ft dia. x 20 ft), while the upper spacecraft volume is slightly larger. The DSS-5 is designed to fly on both the Atlas V and the Delta IV. A notional DSS-5 payload stack is shown in Figure 11.

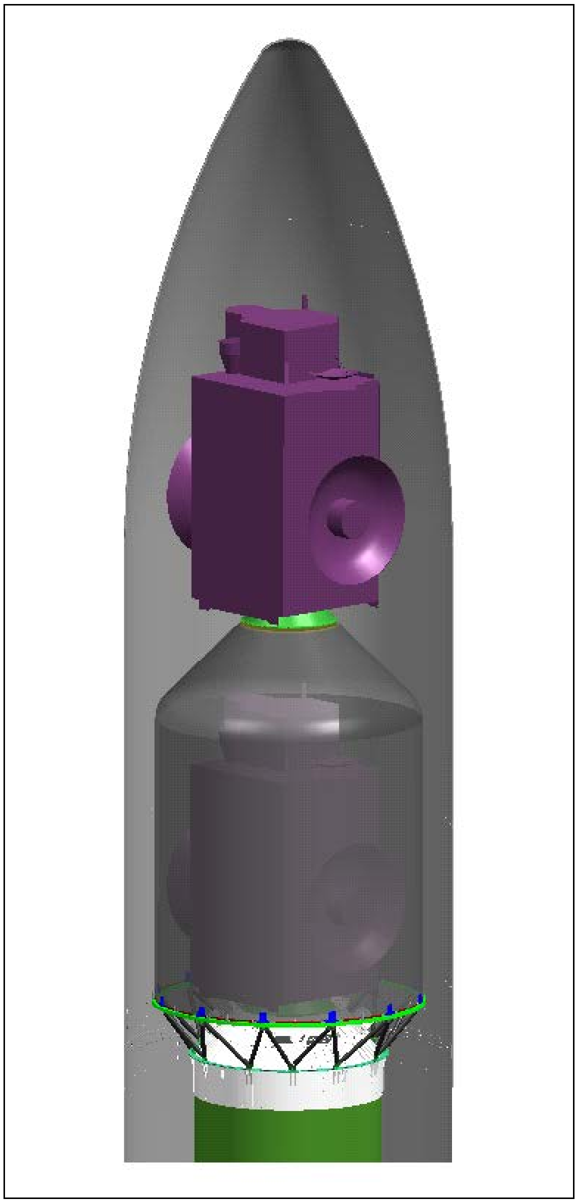


Figure 11. Dual Spacecraft System, 5-m Fairing (DSS-5).

2.8 eXternal Payload Carrier (XPC)

An atypical approach to rideshare, the eXternal Payload Carrier (XPC) is a payload carrier external to the Atlas V first-stage. Looking like an existing solid rocket motor, the XPC will ride with the booster up through booster separation. At this point in the ascent, the XPC would be flying at a velocity of Mach 14 at an altitude of 700,000 ft. The XPC cover will jettison, allowing the internal payload to be released into a hypersonic suborbital trajectory.

The XPC will provide a 5 ft diameter and 750 cubic feet of volume. Technology development programs that would find the XPC beneficial may include Mars re-entry, Scramjet technology, or micro-gravity fluid dynamics and aerosols.

Currently the XPC is under development by an industry team led by Special Aerospace Services (SAS).

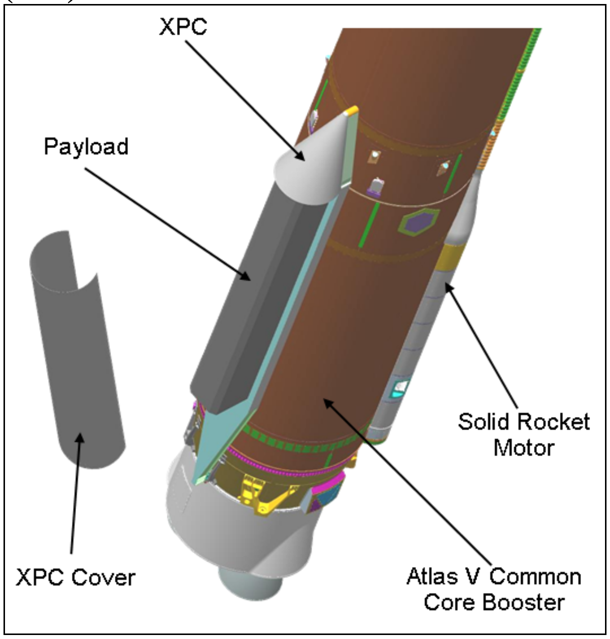


Figure 12. eXternal Payload Carrier (XPC).

3. Mission Opportunities

With a manifest full of missions on its family of launch vehicles, ULA can offer a number of rideshare opportunities to support low-cost planetary missions. Figure 13 lists these potential opportunities. Each mission combination would need to be assessed and coordinated with the primary payload customer. Contact ULA for more information.

MISSION	TIMEFRAME	ORBIT
AEHF	2011-2020	GTO
DMSP	2012-2015	LEO
GPS IIF	2011-2015	MEO
GPS III	2014-2020	MEO
SBIRS	2011-2020	GTO
LDCM	2012	LEO
MMS	2014	GTO
RBSP	2012	GTO
TDRS	2012-2017	GTO
CLS 1	2013	LEO
CLS-2	2014	LEO

Figure 13. Potential ULA Rideshare Launch Opportunities.

4. Conclusion

With a wide variety of available rideshare capabilities that have been newly developed by United Launch Alliance, the international science community is in a position to harness these capabilities in support of their future planetary missions. The use of rideshare for such endeavors is a flight-proven solution that can dramatically increase our knowledge of the Solar System and beyond.

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About The Author

Keith Karuntzos serves as manager, Business Development, for United Launch Alliance (ULA). In this position, he is responsible for supporting Department of Defense, National Reconnaissance Office, and other U.S. government national security customer launch needs, which includes understanding and assisting with mission requirements that will match closely with Atlas and Delta launch vehicles. Keith received a Bachelor of Science degree in aerospace engineering from the University of Southern California. He began his career in 1992 as an officer in the U.S. Air Force where he held leadership and management responsibilities as an acquisition program manager. He was first assigned to the Training Systems Program Office as a system safety manager, working on Air Force flight simulator programs and the T-3A Enhanced Flight Screener aircraft. He then transferred to the Delta II Program Office where he was the mission integration manager for the GPS IIA-27 and P91-1/ARGOS launches. In 2000, Keith joined Boeing Launch Services as a customer engineer, developing technical solutions to U.S. government and industry customers on new launch opportunities. He also served as the point of contact for all secondary payload business activities.

Acronyms

ABC - Aft Bulkhead Carrier
DPAF - Dual Payload Attach Fitting
DSS - Dual Satellite System
ESPA - EELV Secondary Payload Adapter
EELV - Evolved Expendable Launch Vehicle
GTO- Geosynchronous Transfer Orbit
IPC - Integrated Payload Carrier
LEO - Low-Earth Orbit
LRO - Lunar Reconnaissance Orbiter
MEO - Medium-Earth Orbit
XPC - External Payload Carrier
P-POD - Poly Picosat Deployer
SAS - Special Aerospace Services
ULA - United Launch Alliance