United Launch Alliance

Mars CubeSat/NanoSat Workshop
JPL-Cal Tech, CA

ULA Approaches to Interplanetary Rideshare for CubeSats

Jake Szatkowski, phd.
gerard.p.szatkowski@ULAlaunch.com
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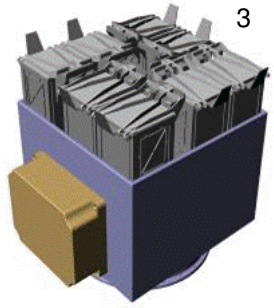
United Launch Alliance

Rideshare Spectrum of Capabilities

A range of capabilities address differing size, mass, and other Requirements, while providing individual operational advantages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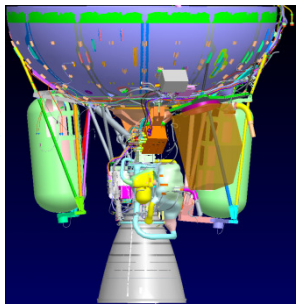

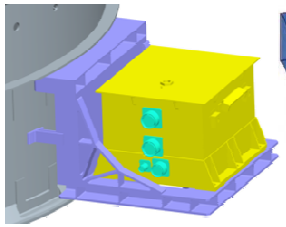

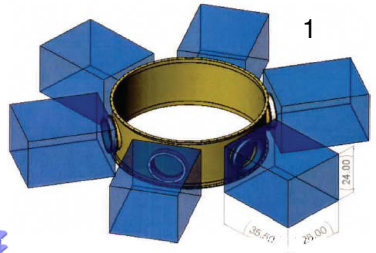
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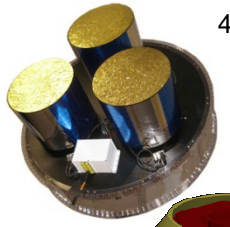
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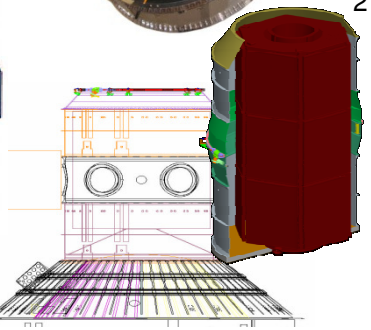
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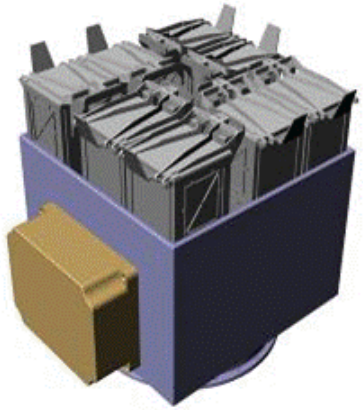
P-Pod°	ABC	CAP	ESPA*	IPC / A-Deck	DSS
Poly PicoSat Orbital Deployer	Aft Bulkhead Carrier	C-Adapter Platform	EELV Secondary P/L Adapter	Integrated Payload Carrier	Dual Satellite System
10 kg	**80 kg**	**100 kg**	**200 kg/ea.**	**500+kg**	**5000 kg**
R&D Development	Releasable in LEO	2-4 Slots per Launch	ESPA Way Fwd Progress	Mix and Match H/W Internal and External P/L	All Flight Proven H/W
Dynamically Insignificant	Isolated from Primary S/C	Less obtrusive than ESPA	STP-1 Flew 2007	SP to 60 in. diameter	Sp to 100 in diam.
First flight ILC 2011	First flight ILC 2010	First flight Fist Flight 2010	SERB List from the DoD Space Test Program	Last Flight LRO/LCROSS	CDR 4Q 2009 ILC 2011

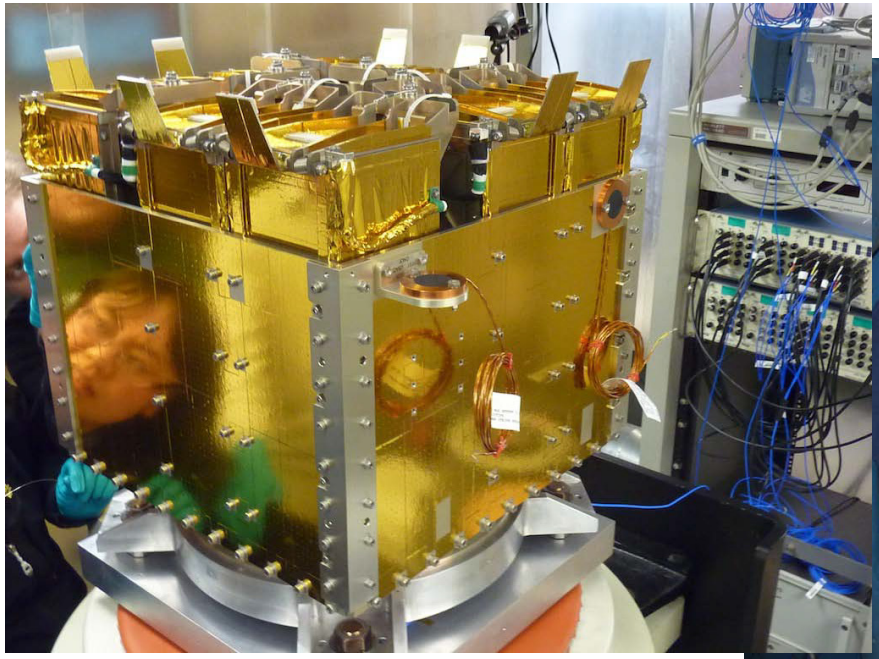
Delivering a Wide Range of Small Spacecraft with the Appropriate Conops and Technical Accommodations

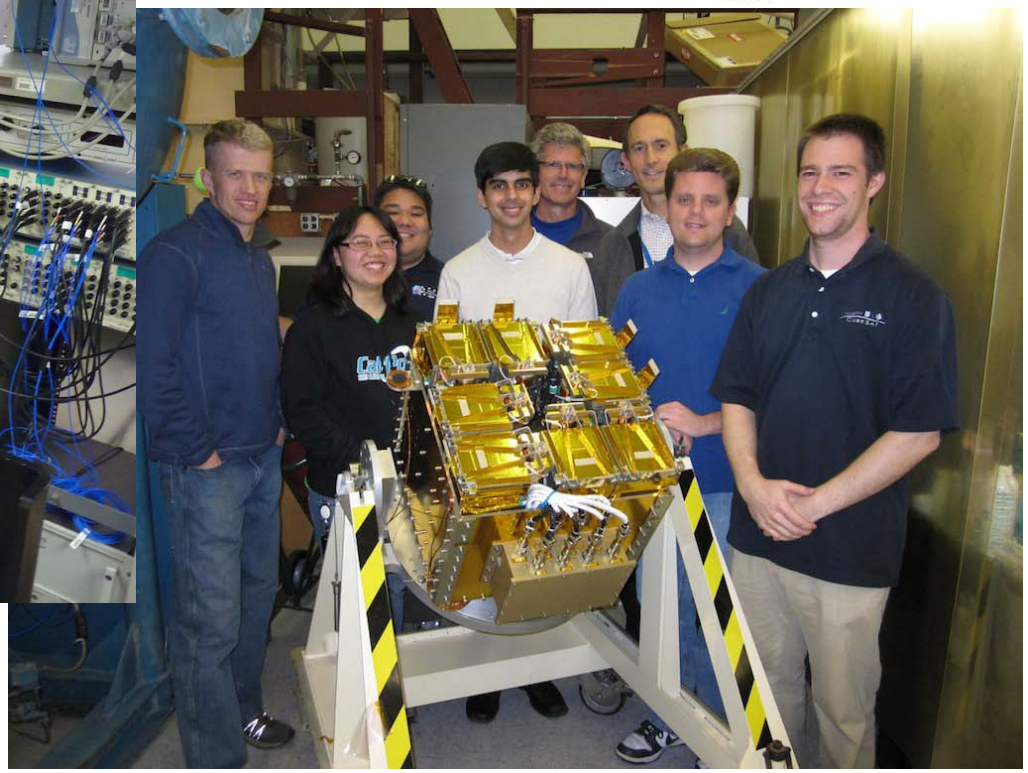
1 ESPA Graphic courtesy of CSA Engineering, Inc
2 COTSAT courtesy of NASA/AMES
3 NPSCuL courtesy of NPS
4 A-Deck courtesy of Adaptive Launch Solutions

NPSCuL Missions

- L-36/OUTSat Launched SEP 2012 (first-flight)
- L-39/GEMSat Launched DEC 2013
- Next: L-55/GRACE, AFSPC-5/ULTRASat in CY15





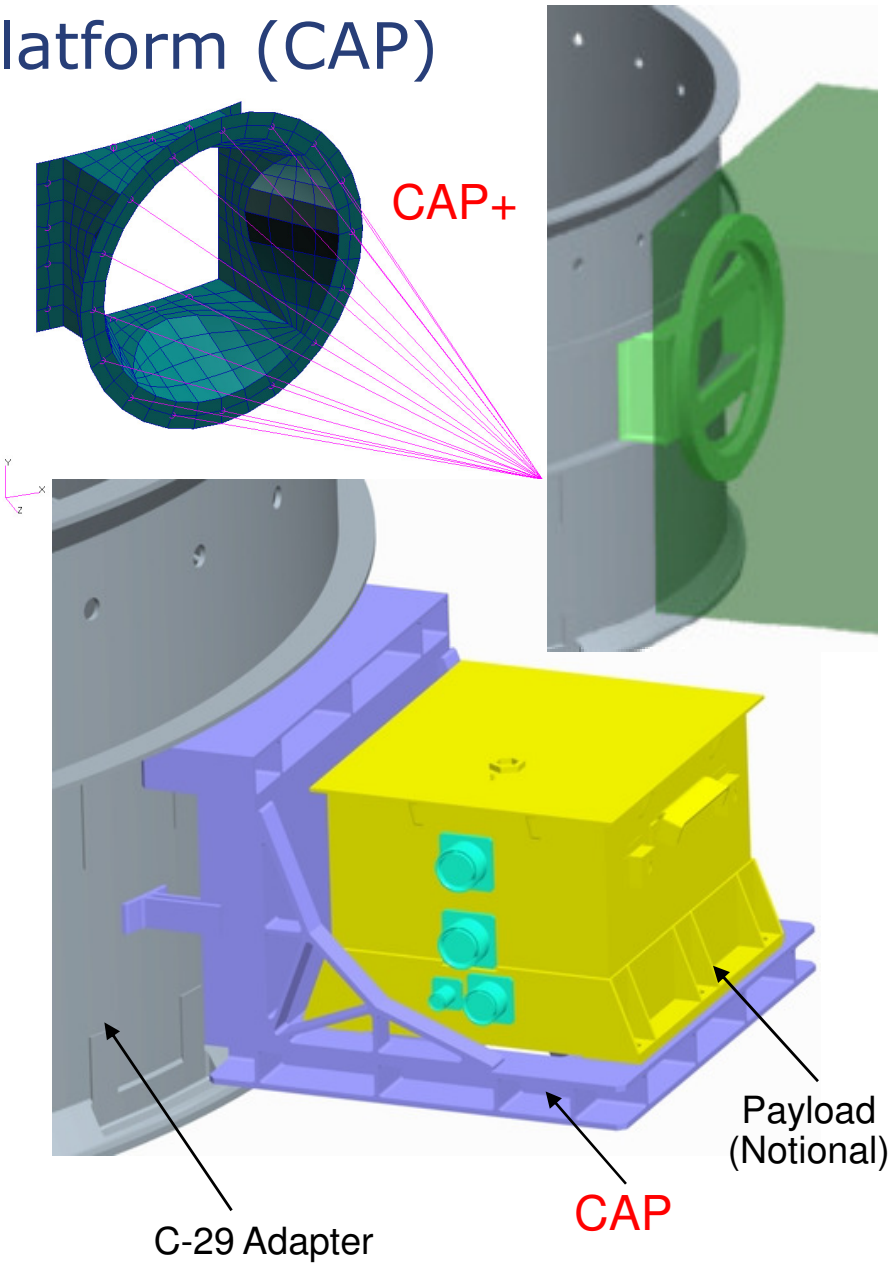


Photos courtesy Maj. Wilcox NRO/OSL

C-Adapter Platform (CAP)

C-Adapter Platform (CAP)	
Description	A cantilevered platform attached to the side of a C-adapter to accommodate secondary payloads
Vehicle	Atlas V, Delta IV
Capacity	4 CAPs per C-adapter
Interface	8-in Clampband
Mass	**90 kg (200 lb)**
Volume	23 cm x 31 cm x 33 cm (9 in x 12 in x 13 in)
Status	First launch TBD

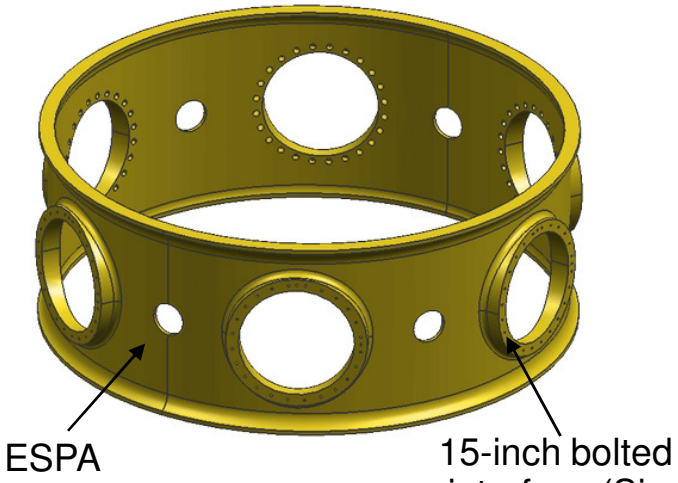
The CAP was originally designed to accommodate batteries that are part of the Atlas V extended-mission kit hardware

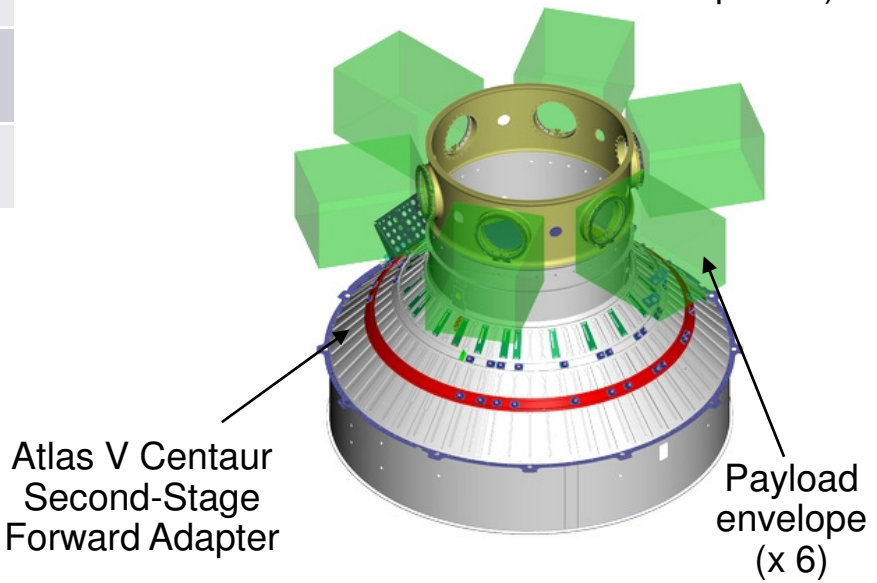


ESPA Ring

EELV Secondary Payload Adapter (ESPA)	
Description	An adapter located between the second-stage and the primary payload, which can accommodate up to six secondary payloads
Vehicle	Atlas V, Delta IV
Capacity	6 payloads per ESPA
Interface	15-in Bolted Interface
Mass	**181 kg (400 lb)**
Volume	61 cm x 71 cm x 96 cm (24 in x 28 in x 38 in)
Status	Operational; first launch 03-2007 on STP-1
Developer	Moog CSA Engineering *(Joe Maly, jmaly@csaengineering.com)*

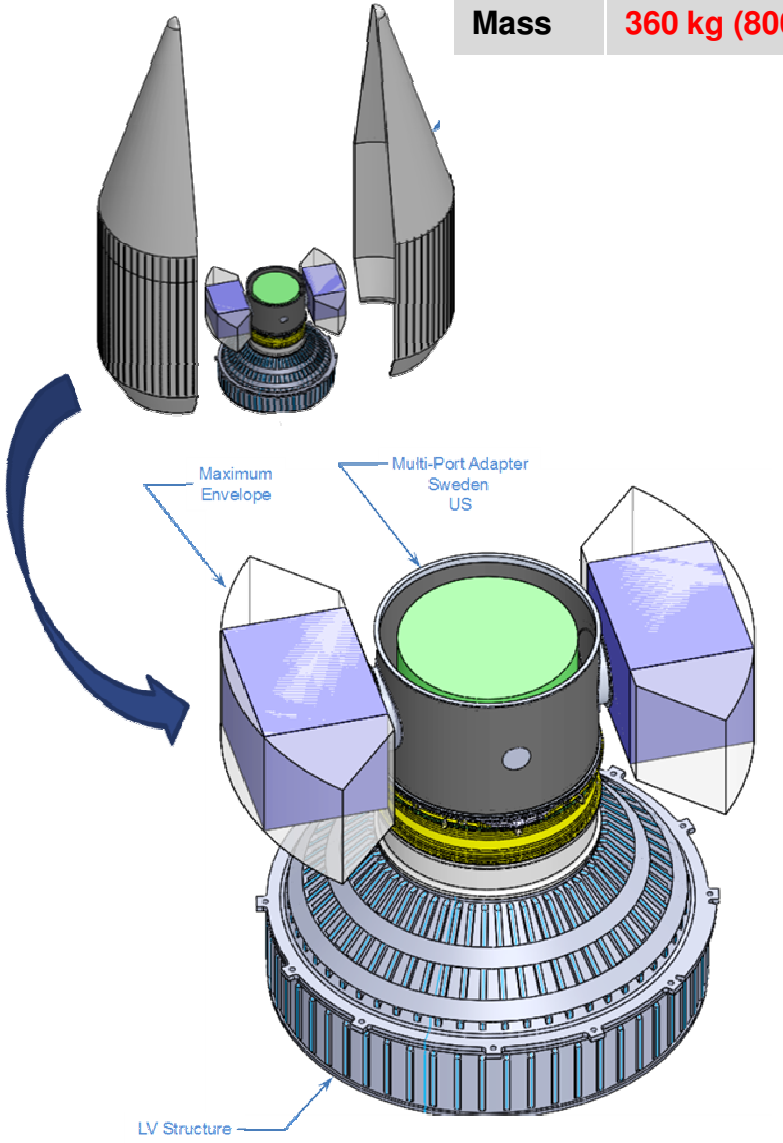
ESPA hardware will be used to launch a rideshare mission in 2014, and additional missions are being evaluated

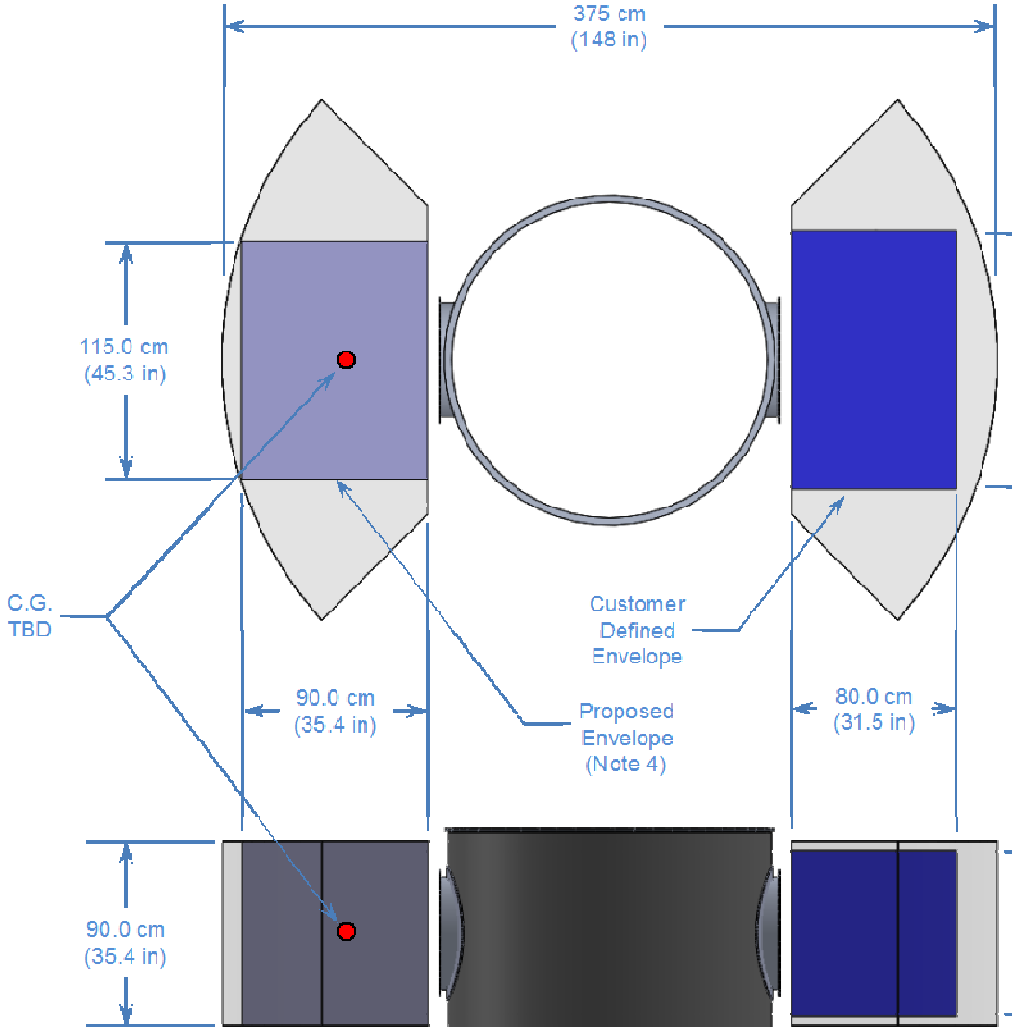




ESPA Grande Class

Mass	360 kg (800 lb)



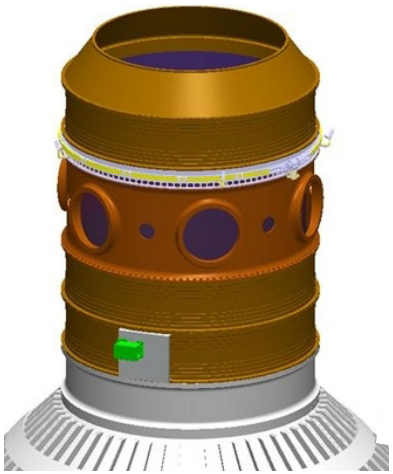


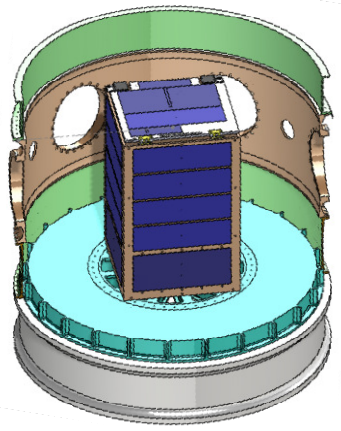
AQUILA

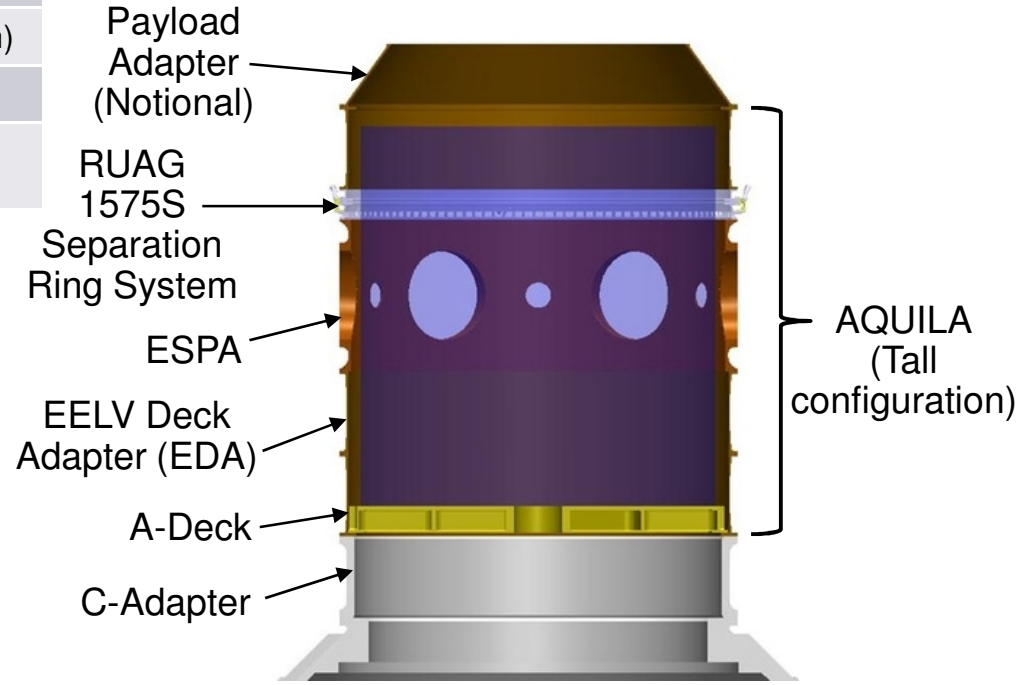
AQUILA	
Description	A flat deck and cylindrical spacers, located between the forward-end of the second stage and the primary payload
Vehicle	Atlas V, Delta IV
Capacity	Multiple payloads per AQUILA
Interface	Variable
Mass	**1,000 kg (2,200 lb)**
Volume	142-cm dia. (56-in dia.) x 152 cm (60 in)
Status	In development; CDR 04-2012
Developer	Adaptive Launch Solutions (ALS) *(Jack Rubidoux, jrubidoux@adaptivelaunch.com)*

Graphics courtesy of ALS

AQUILA modular adapters are rated to support a primary payload mass up to 6,350 kg (14,000 lb)



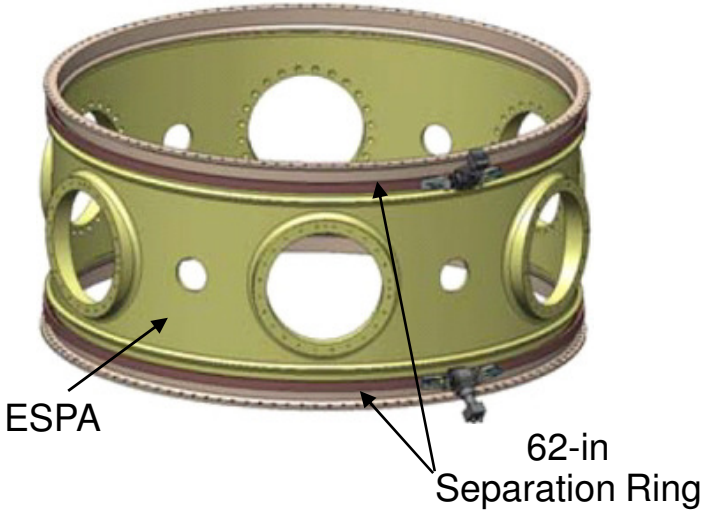


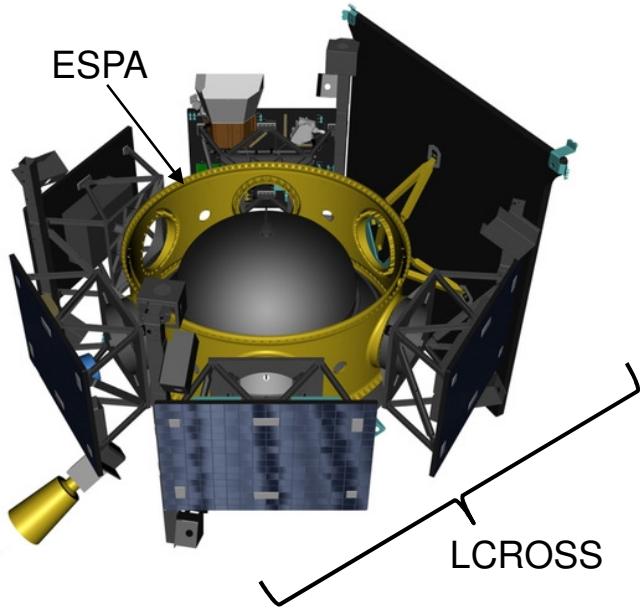


Separating ESPA

Separating ESPA	
Description	A separating rideshare payload that uses the ESPA ring as the structural bus of the satellite
Vehicle	Atlas V, Delta IV
Capacity	Variable
Interface	62-in Bolted Interface
Mass	**1,360 kg (3,000 lb)**
Volume	350-cm dia. x 61 cm (138-in dia. x 24 in)
Status	Operational; first launch 06-2009 on LRO/LCROSS
Developer	Moog CSA Engineering *(Joe Maly, jmaly@csaengineering.com)*

A separating ESPA can use various separation ring hardware solutions from a number of vendors to separate from the ULA launch vehicle



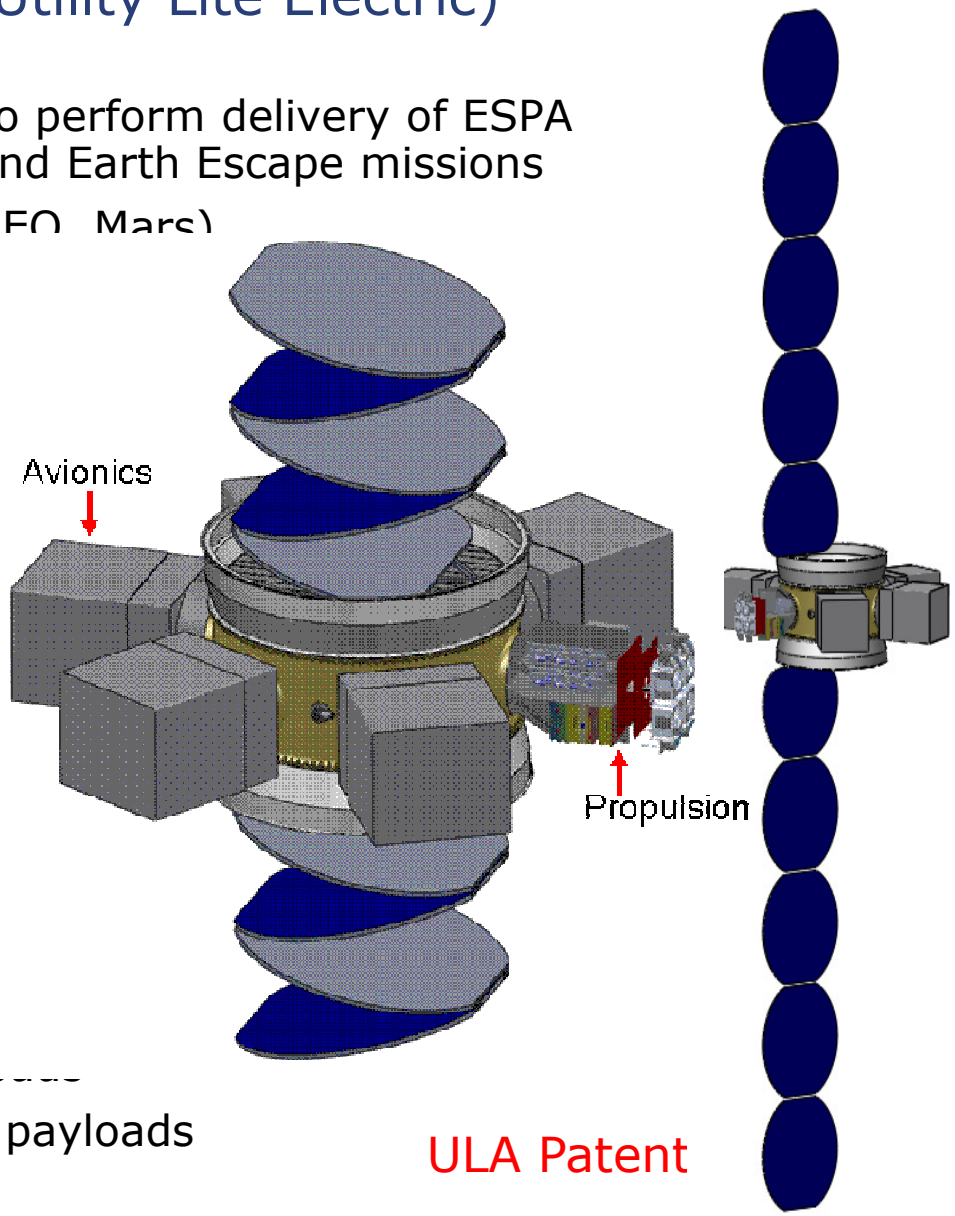


MULE Third Stage
(Multi-payload Utility Lite Electric)

- **MULE stage** provides high deltaV to perform delivery of ESPA class payloads to a variety of orbits and Earth Escape missions
  - Delivery to Earth Escape (Lunar, NEO, Mars)
  - Delivery of a constellation (3 ESPA
  - Solar Electric propulsion
  - 10 m/s delta-V
  - Laser comm or high-gain antenna
  - On-orbit operations multi-yr
  - Potential to add another ESPA

- Co-sponsors:
  - Busek Space Propulsion (Hall Thruste
  - Adaptive Launch Solutions (S/C Inte
  - Oakman Aerospace (Avionics)

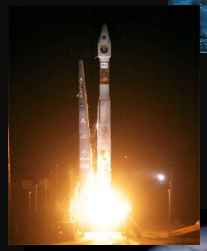
- Specs: 1400 kg wet mass w/o payl
  2400 kg wet w/ (4) 180 kg payloads



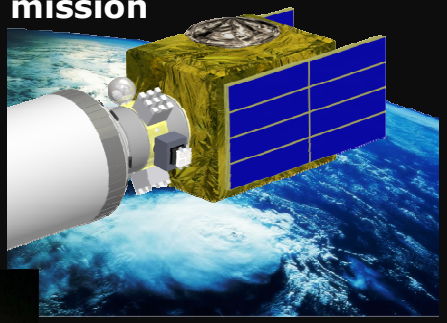
ULA Patent

Mission Concept

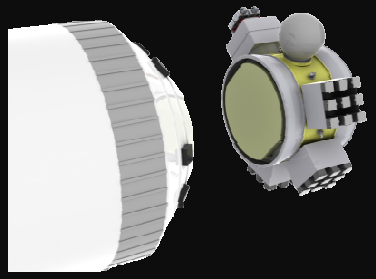
Launch



Rideshare payload w/ Polar or GTO mission

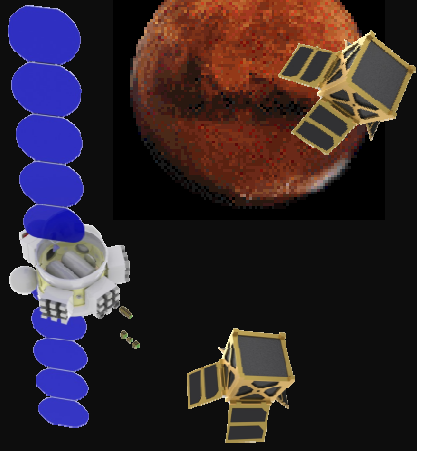


After primary sep Rideshare carrier sep from second stage



Solar panels deployed carrier begins the journey to Mars

CubeSats are deployed after entering Mars orbit



The CubeSat carrier (MULE) using lite-electric propulsion can deliver 27 – 3U CubeSats to Mars.

Future Interplanetary Missions

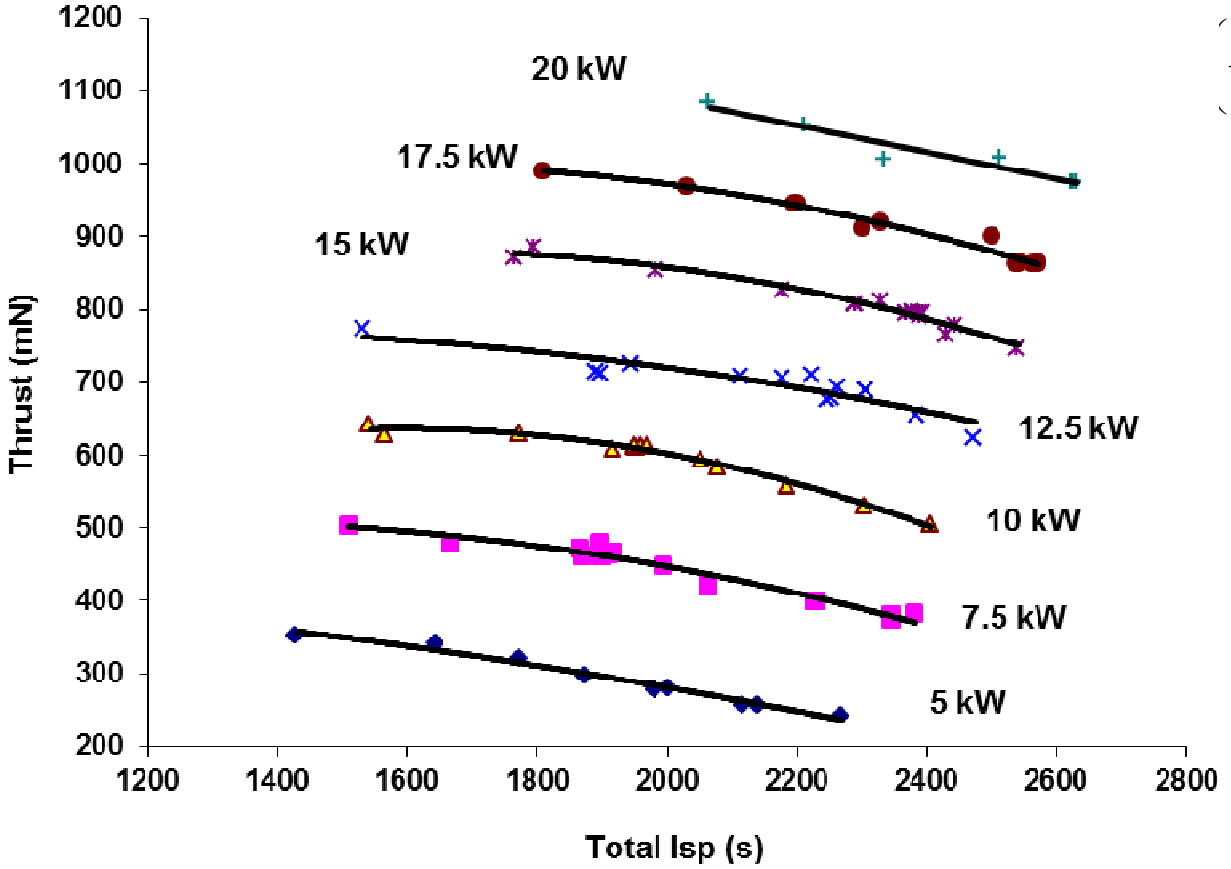
- Example mission: DMSP-19 (flew APR 2014)
  - S/C wt 2559 lbs
  - Atlas 401 (4m fairing, no solids)
  - Single injection burn 460 NM circular polar
  - Disposal burn to Earth Escape
  - Un-used performance to a C3 of 0 > ~3000 lb (1360 kg)
  - Addition of 1 solid (+1900 kg performance)
  - Would have enable Mars MULE mission w/ 3 ESPA payloads

- Potential missions for Rideshare? (protected dates)

WR	WV	(CY16)
	DMSP	(ILC CY17-18)
	LDCM	(CY19)
	Weather FO	(CY21)
ER	GPS IIF	(CY16)
	GEO	(CY17)
	TDRS	(CY18)
	GEO	(CY20)

Thrust vs. Isp (BHT-20K, Xe)

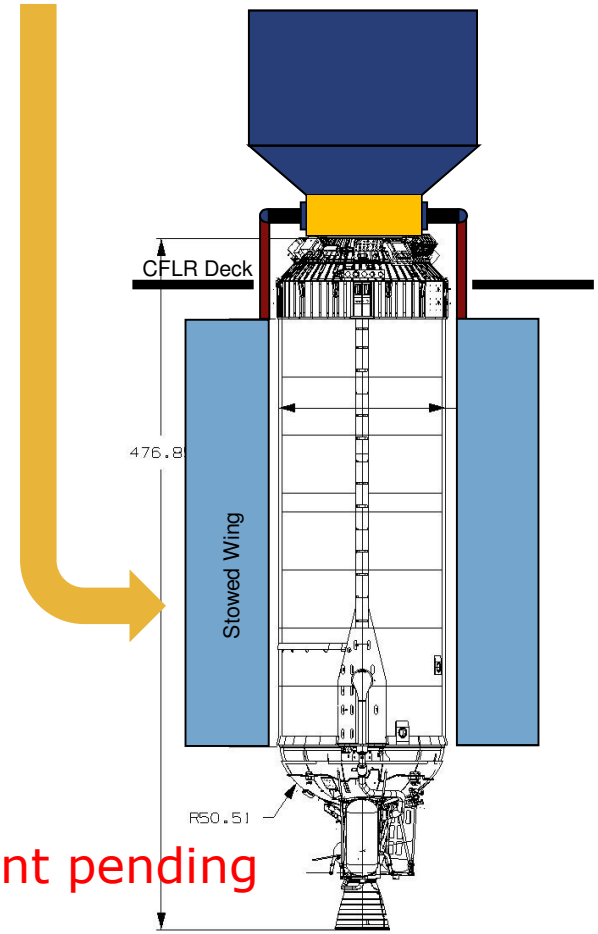
- T>1 N measured at 20-kW.
- Peak T/P~ 70 mN/kW at 200 V and 5 kW.
- Isp from 1430 s (200 V, 5-kW) to 2630 s (500 V, 20-kW).



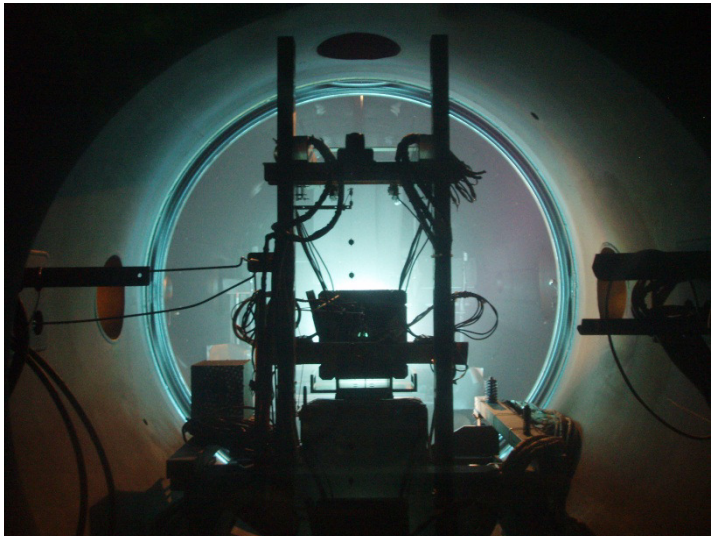
$$\left(\frac{\sigma_{I_{sp}}}{I_{sp}}\right)^2 = \left(\frac{\sigma_T}{T}\right)^2 + \left(\frac{\sigma_{\dot{m}}}{\dot{m}}\right)^2$$

100 KW High Power System

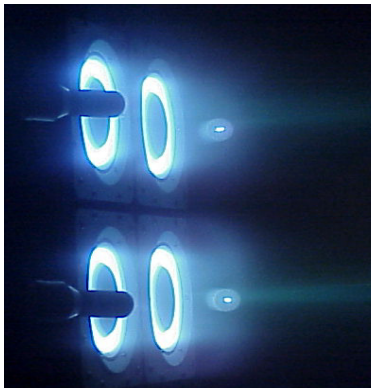
- ULA 100 KW array stowed config.



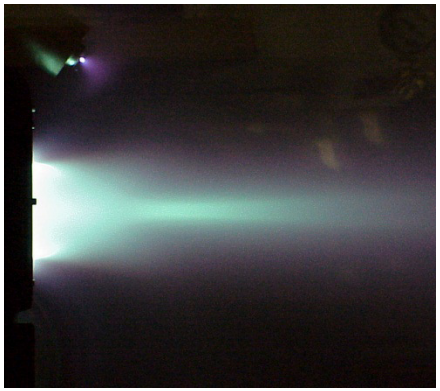
Patent pending



Busek 20-kW Thruster at GRC VF5



Cluster of Busek Xe HETs



1-kW Iodine Plume

What does it mean for Interplanetary Missions?

- Some of our missions (particularly polar ones) do Earth-escape disposal of the upper stage
- Some of the missions have fairly large margins
- It is possible to add up to 5 solids boosters (1000 lbs margin ea)
- It is possible to raise the apogee to beyond L1 for a separation
- The primary will dictate the time of launch and the moon can be anywhere in its orbit.
- However, if a Lunar exploration s/c could loiter long enough it could sync with and be captured by Lunar gravity

- ULA can work to help broker rideshares with primary customers
- ULA can assist for specific mission applications
- ULA can assist in schedule/milestone planning
- New R&D developments are in-work
  - New disposal techniques that add margin coming on-line
  - New heavy solar array system
  - New extended mission systems

Adding Performance via SRM's

- ULA's Atlas V and Delta IV launch vehicles have multiple configurations based on the number of solid rocket motors (SRMs) flown
- For both current missions, or when designing a new rideshare mission, the addition of an SRM can provide an appreciable amount of mass capability to orbit, as shown below

		All values are in kg					
ORBIT	**VEHICLE**	**0 SRMs**	**1 SRM**	**2 SRMs**	**3 SRMs**	**4 SRMs**	**5 SRMs**
GTO (35,786 X 185 km @ 27.0 deg)	**Atlas V 4-m**	- 4,750	*+ 1,200* 5,950	*+ 940* 6,890	*+ 810* 7,700		
	Atlas V 5-m	- 3,780	*+ 1,470* 5,250	*+ 1,230* 6,480	*+ 970* 7,450	*+ 840* 8,290	*+ 610* 8,900
	Delta IV 4-m	- 4,210		6,160 *+ 1,950*			
	Delta IV 5-m			- 5,080		*+ 1,810* 6,890	
LEO Polar (200 km circular @ 90 deg)	**Atlas V 4-m**	- 8,080	*+ 1,900* 9,980	*+ 1,160* 11,140	*+ 990* 12,130		
	Atlas V 5-m	- 6,770	*+ 2,200* 9,060	*+ 2,100* 11,160	*+ 1,720* 12,880	*+ 1,600* 14,480	*+ 1,280* 15,760
	Delta IV 4-m	- 7,690		*+ 2,840* 10,530			
	Delta IV 5-m			- 9,610		*+ 1,990* 11,600	

Reinventing the Wheel for Rideshare Interplanetary Missions