Driving Innovation in the ATS Market

(2018 Small Payload Rideshare Symposium)

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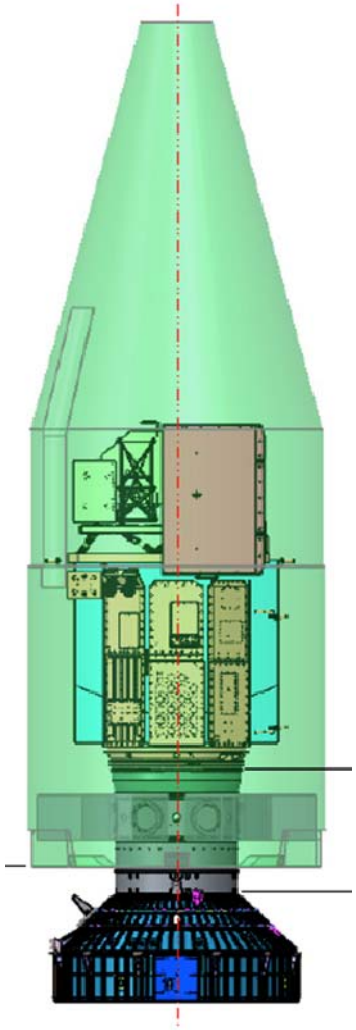
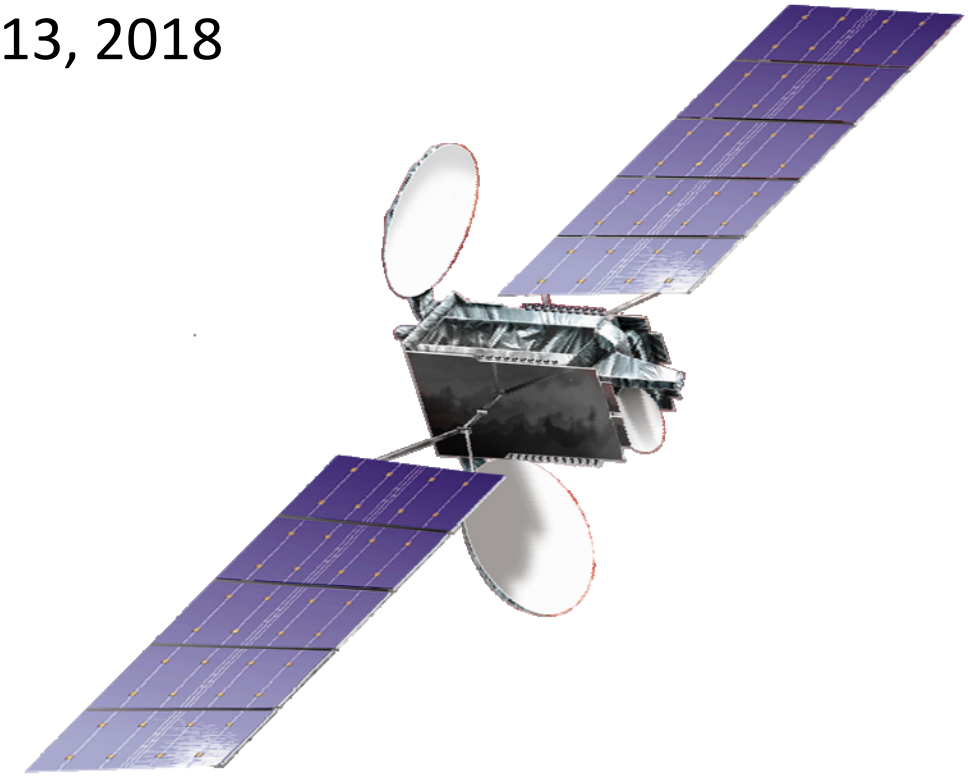
June, 13, 2018

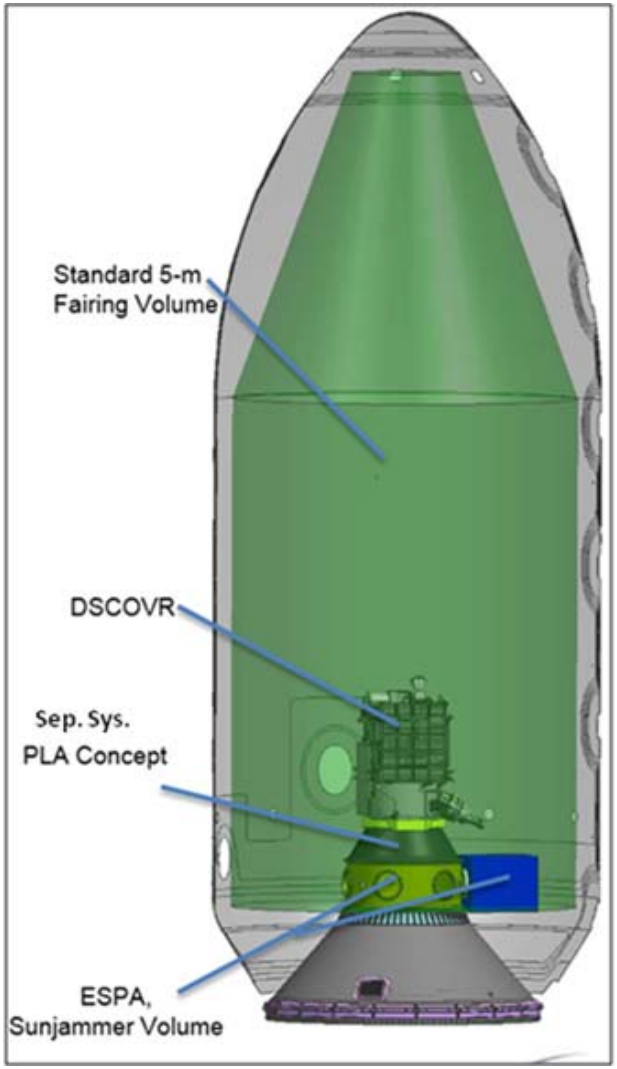


Landsat 9 with an ESPA Ring



Commercial HP (SES/GOLD)

Rideshare Poster-child: DSCOVR & TESS



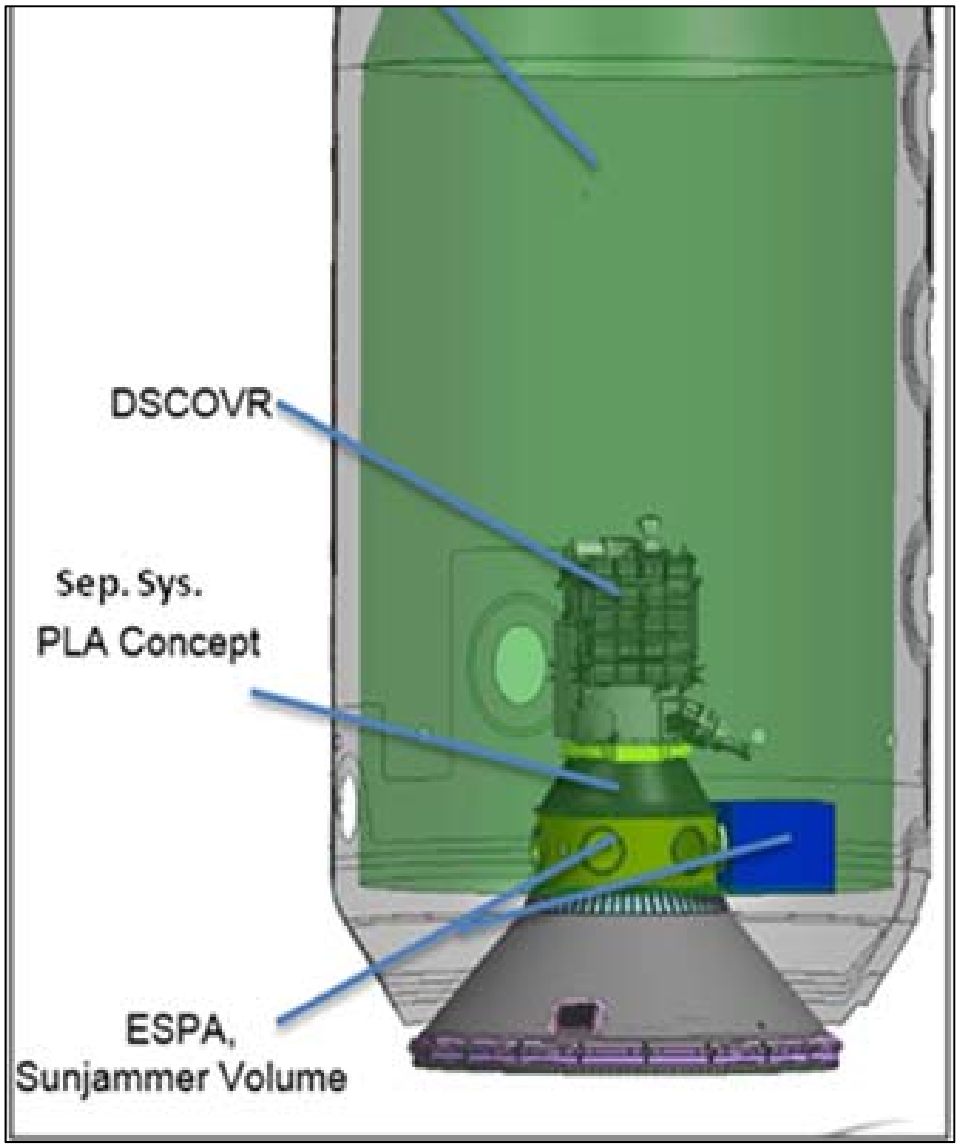
DSCOVR: Feb 2015

2500 kg of unused mass went to L-1

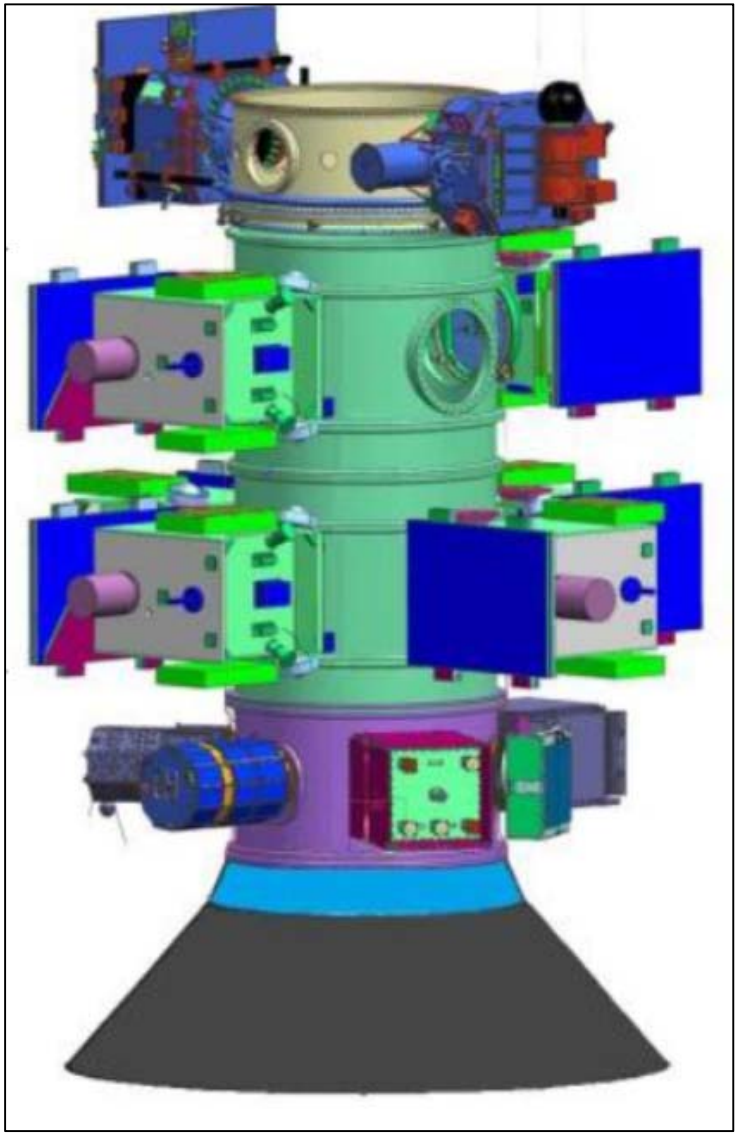
TESS: April 2018

~3000 kg excess on a TLI orbit

Government Rideshare: Past, Present & Future



Past Missions (DSCOVR)



Future Multi-missions (STP-2)

NASA Mission Opportunities:

(http://soma.larc.nasa.gov/standardao/pdf_files/SMDSolicitationPlanningList.pdf)

NASA Science Opportunity	Planned AO Release Date	AO Required Launch Window
Heliophysics STP-5 AO & MOO	NET Q3 FY 2017	AO + ~6.5 years
Heliophysics MIDEX AO/MOO	NET Q1 FY 2018	AO + ~6.5 years
EVI-5 AO (every 18 months)	NET Q2 FY 2018	AO + ~6.5 years
LWS (GDC) AO & MOO	Q4 FY 2018	AO + ~6.5 years
Astrophysics Explorers MOO	NET Q4 FY 2018	AO + ~6.5 years
Astrophysics SMEX	NET Q2 FY 2019	AO + ~6.5 years
EVM-3 AO	TBD	AO + ~6.5 years

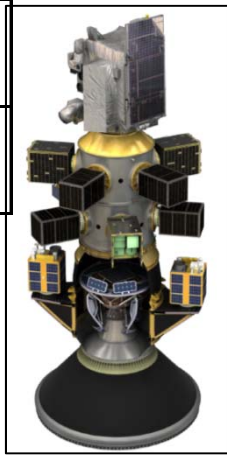
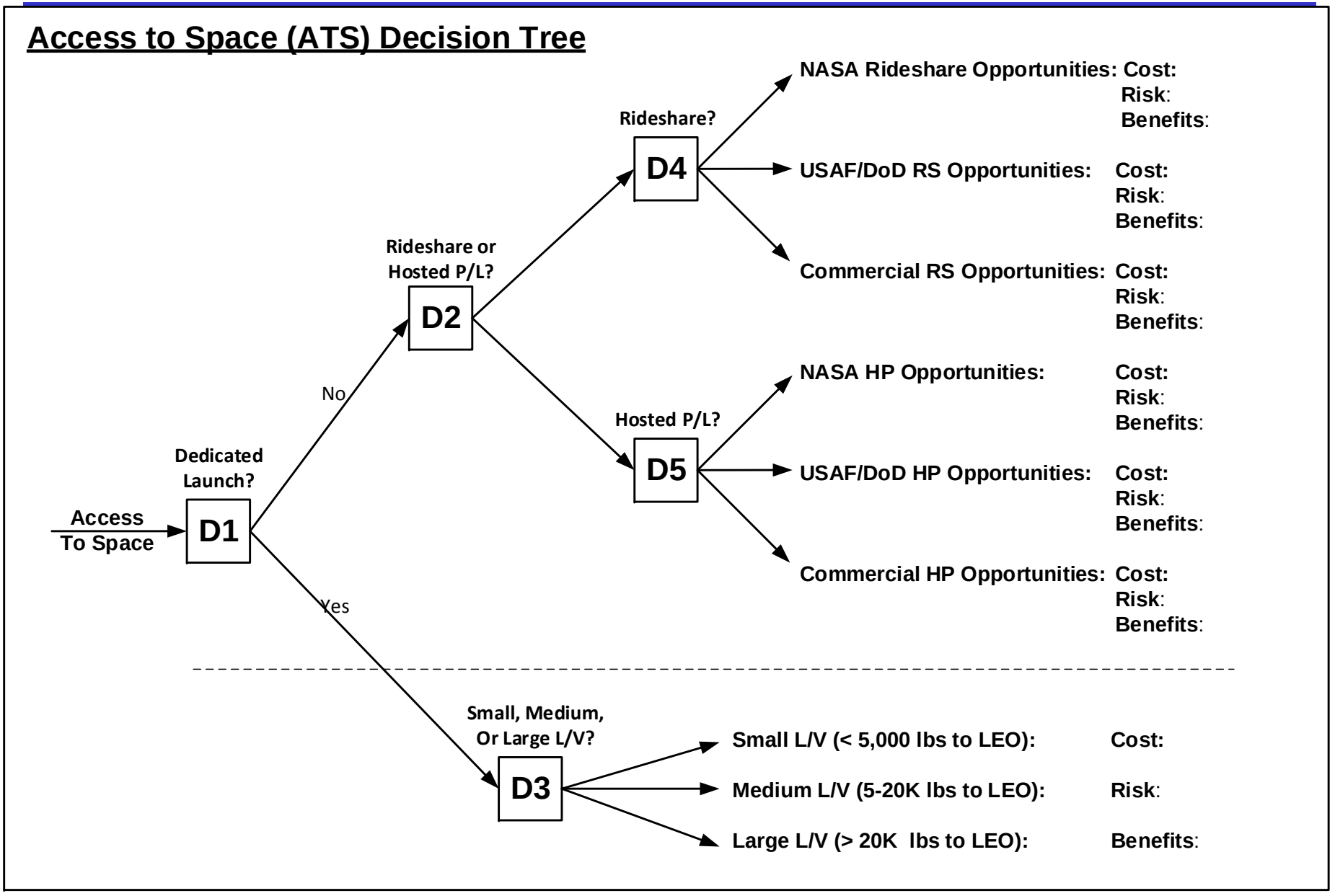


photo credit ORBCOMM, SpaceX, SNC

Access to Space (ATS) Options



Increasing Innovation by Reducing Transaction Costs

- Transaction costs theory:
  - Is defined as the cost of providing for some good or service through the market rather than developing it within a organization
  - There are three elements to transaction costs:
    1) the ***search and information costs***;
    2) the ***bargaining and decision costs***; and
    3) the ***policing and enforcement costs***

- The rideshare process reduces transaction costs to both payload providers and spacecraft providers:
  1) The SPRSA and NASA websites (S3VI, SOMA, etc) will ***reduce the search and information costs*** by collecting data on a) potential rideshare opportunities, b) rideshare spacecraft options, and c) rideshare components and systems
  2) The rideshare market ***reduces bargaining costs*** by following the USAF Rideshare Users Guide (RUG) standard and by using more GSA schedules and FFP contracts
  3) The government Do No Harm (DNH) process will ***reduce the policing and enforcement costs*** by establishing a standard rideshare SMA and DNH process.

- Reducing transaction costs & increasing innovation examples:
  - CubeSats, e-commerce, IBM PC, etc.

S³VI Strategy & Website

https://www.nasa.gov/smallsat-institute

Reducing transaction costs & increasing innovation by reducing search and information costs

SPRSA Access to Space Technical Committee

Reducing transaction costs & increasing innovation by reducing search and information costs

- The committee will provide focus on the access to space issues. The committee will present a summary of our activities at the annual symposium. The presentations, along with key points of contact, will be posted on the Association website for the benefit of the community.
- Rideshare Subcommittee:
  - Will discuss rideshare status, opportunities (AO, RFPs, RFIs, etc.), and issues.
  - The subcommittee will track a list of NASA, Air Force, and commercial rideshare opportunities.
- Spacecraft Subcommittee:
  - Will discuss spacecraft status, opportunities (AO, RFPs, RFIs, etc.), and issues.
  - The subcommittee will track a list of rideshare spacecraft, along with bus capabilities.
- Hosted Payload Subcommittee:
  - Will discuss hosted payload status, opportunities (AO, RFPs, RFIs, etc.), and issues.
  - The subcommittee will track a list of NASA, Air Force, and commercial hosted payload opportunities.

NASA & Air Force Rideshare Opportunities

(Air Force Missions (bold) & NASA (non-bold))

Year	LEO (mid inc)	LEO (hi inc)	MEO	GEO/GTO	Other / TLI
2020		Landsat-9 Sentinel-6 (JPL)	**GPS III-4**	GOES-T	
2021		**STP-S28** SWOT (JPL) JPSS-2	**GPS III-5**	**SBIRS (GTO)**	LUCY
2022		PACE			PSYCHE
2023	**STP-S29**	**USAF**	**USAF**	**USAF (3+)**	EM-2
2024			**USAF**	**USAF (2+)** GOES-U	IMAP New Front-4 EM-3
2025		JPSS-3 **USAF**	**USAF**	**USAF (3 ea)**	GDC EM-4
2026		Sentinel-6b Landsat-10	**USAF**	**USAF (3+)**	Discovery 15 EM-5

Commercial Rideshare Opportunities

Year	LEO (Low Inc.)	Polar (Hi Inc.)	MEO (1100x185)	GEO (35786x35786)	Other
2017	ET, NR, OA, TV	SF, TV		NR	TV (GTO)
2018	ET, NR, OA, TS, TV	SF, TS, TV	TS	SF, NR, TV, AL	TV (GTO)
2019	TV, NR, OA	SF, TS, TV		SF, NR, TV	TV (GTO), TV (EE)
2020	TV, NR, OA	SF, TV		SF, TV	TV (GTO)
2021	TV, NR, OA	SF, TV		SF, TV	TV (GTO)
2022	TV, NR, OA	SF, TV		TV	TV (GTO)

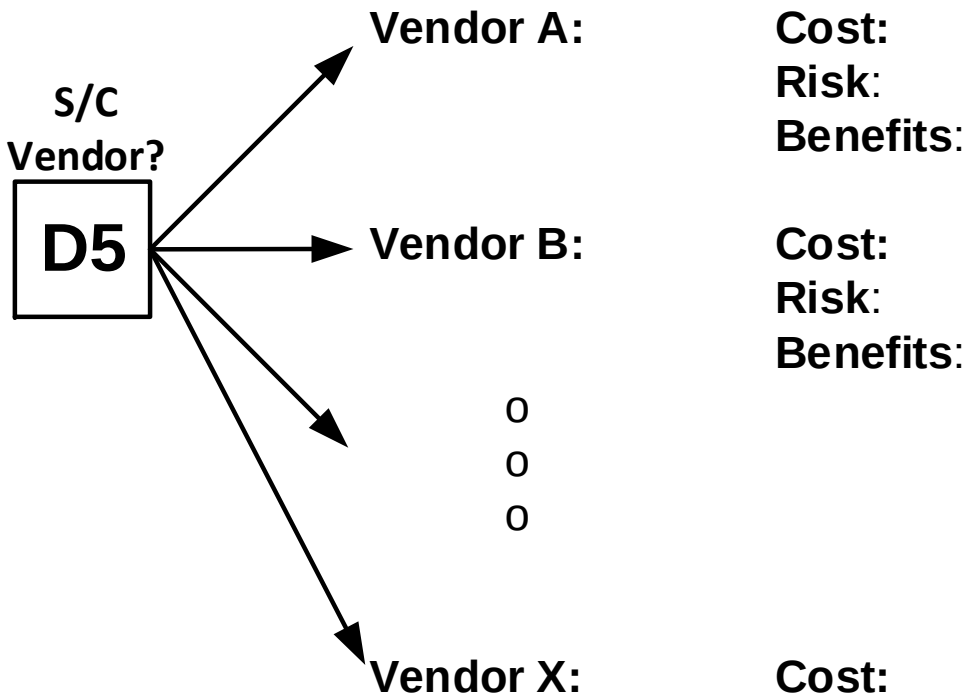
AL - Adaptive Launch Sol. ET - Electron NR - NanoRacks OA - OrbitalATK
SF - SpaceFlight TS - TriSept TV - Tyvcak

NASA Missions That Could Support Rideshare

Candidate Primary Mission	Launch Date	Orbit	Rideshare Adapter	# Ridesshare Spacecraft	Ridesshare Mass (kg)
Sentinel-6 (JPL)	11/2020	Polar, Cir.	ESPA Ring	6	2,057
Restore-L	11/2020	Polar	ESPA Ring	6	2,057
Landsat-9	12/2020	Polar, Cir.	ESPA Ring	6	2,057
SWOT (JPL)	4/2021	Polar, Cir.	ESPA Ring	6	2,057
LUCY (GSFC)	2021	Earth Esc.	ESPA Ring *	6	2,057
JPSS-2	7/2021	Polar, Cir.	ESPA Ring	6	2,057
PSYCHE	2022	Earth Esc.	ESPA Ring *	6	2,057
PACE	2022/23	Polar, SSO	ESPA Ring + ESPA Grande	10	4,068
IMAP	12/2024	L-1	ESPA Grande	5	2,461
New Front-4	2024	TBD	ESPA Ring *	6	2,057
GDC	2025	TBD	ESPA Ring *	6	
EVM-3	2026	Polar, Cir?	ESPA Ring *	6	2,057
JPSS-3	2026	Polar, Cir.	ESPA Ring *	6	2,057
Landsat-9	2026	Polar, Cir.	ESPA Ring *	6	2,057
Sentinel-6b	2026	Polar, Cir.	ESPA Ring *	6	2,057
Discover-15	2026	TBD	ESPA Ring *	6	2,057
Total:				81	33,270

Rideshare Spacecraft Options

Rideshare Spacecraft (RSC) Decision Tree



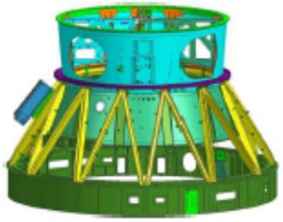
Cost:
Risk:
Benefits:

Cost:
Risk:
Benefits:

Cost:
Risk:
Benefits:

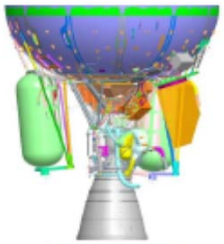
Capturing the cost, risk, and benefits of the rideshare spacecraft options

Rideshare Adaptor Options:



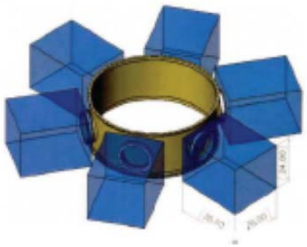
P-POD

10 kg



ABC

80 kg



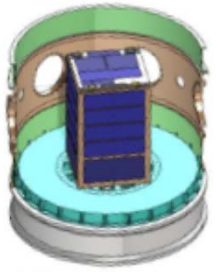
ESPA

200 kg

Rideshare Carrier	Mass Available	Volume Available	S/C Interface
CubeSats	5-10kg	3U-6U	Standard
ABC	80kg	34x20x20	8/15" cir.
ESPA (1 of 6)	~320kg	24x28x38	8/15" cir. & 15" squ.
ESPA Grande (1 of 4)	~450kg	42x46x56 42x46x38	15/24" cir. & 24" squ.
Aquila (A-Deck)	~1,000kg	56-diax60h	24/38" cir.
Propulsive ESPA S/C	~1,500kg	4m-diax24h	PAF
Propulsive ESPA Grande	~2,500kg	5m-diax42h	PAF

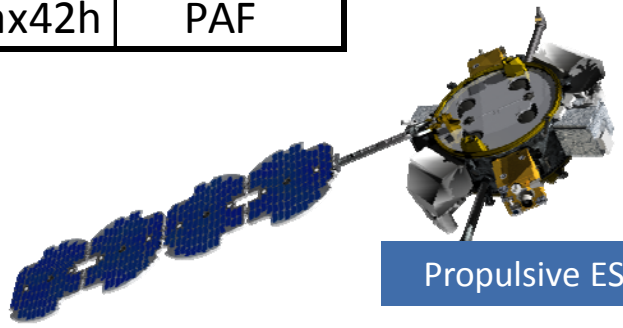
ESPA Grande

~350 kg



A-Deck / Aquila

~1,000 kg

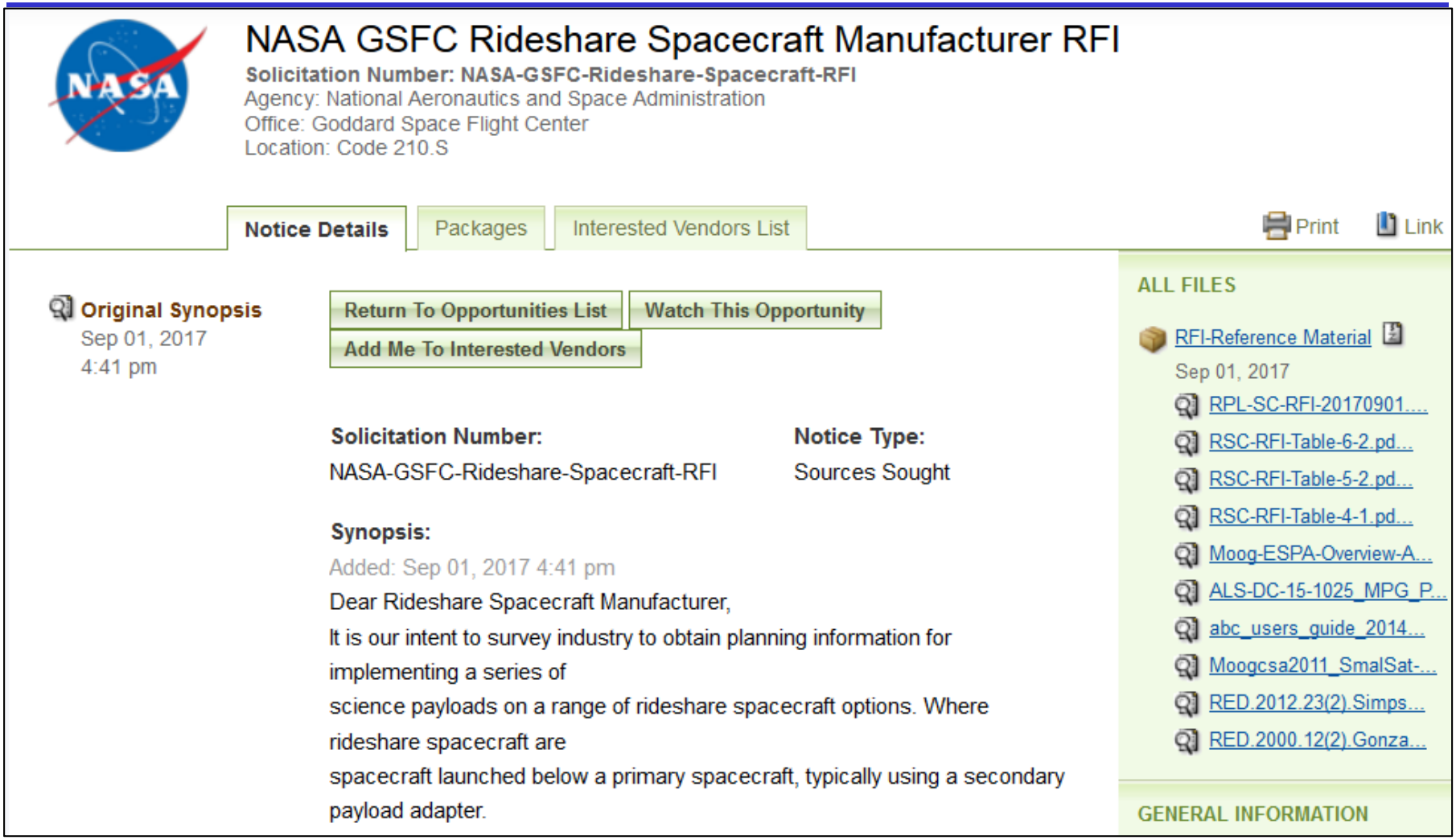


Propulsive ESPA

~1,500 kg

Rideshare Spacecraft RFI

(to support future MDL studies and science proposals)



NASA GSFC Rideshare Spacecraft Manufacturer RFI

Solicitation Number: NASA-GSFC-Rideshare-Spacecraft-RFI
Agency: National Aeronautics and Space Administration
Office: Goddard Space Flight Center
Location: Code 210.S

Notice Details | Packages | Interested Vendors List — Print — Link

Original Synopsis
Sep 01, 2017
4:41 pm

Return To Opportunities List | Watch This Opportunity | Add Me To Interested Vendors

Solicitation Number:
NASA-GSFC-Rideshare-Spacecraft-RFI

Notice Type:
Sources Sought

Synopsis:
Added: Sep 01, 2017 4:41 pm
Dear Rideshare Spacecraft Manufacturer,
It is our intent to survey industry to obtain planning information for implementing a series of
science payloads on a range of rideshare spacecraft options. Where rideshare spacecraft are
spacecraft launched below a primary spacecraft, typically using a secondary payload adapter.

ALL FILES

RFI-Reference Material
Sep 01, 2017
RPL-SC-RFI-20170901....
RSC-RFI-Table-6-2.pd...
RSC-RFI-Table-5-2.pd...
RSC-RFI-Table-4-1.pd...
Moog-ESPA-Overview-A...
ALS-DC-15-1025_MPG_P...
abc_users_guide_2014...
Moogcsa2011_SmalSat-...
RED.2012.23(2).Simps...
RED.2000.12(2).Gonza...

GENERAL INFORMATION

Reducing transaction costs & increasing innovation by reducing search and information costs

Rideshare Spacecraft RFI Overview

1. Rideshare Spacecraft RFI Stakeholders:
   a) Mission Design Lab (MDL) – using the results in design studies
   b) Next Gen Earth Relay – using the results in concept studies
   c) Project #1-3 – Internal Project's in the concept development phase
   d) Rapid S/C Development Office (RSDO) – to use the results in future catalogs

2. Rideshare Spacecraft RFI Responders:
   – Ball, Boeing, Millennium Space, Moog, Orbital-ATK, Surrey (now GA)

3. Elements of the Rideshare S/C RFI:
   a) Rideshare Document Review
   b) Survey Industry's Rideshare Spacecraft Capabilities
   c) Survey Industry's Science Instrument Accommodation Capabilities
   d) Survey Industry's Communication P/L Accommodation Capabilities

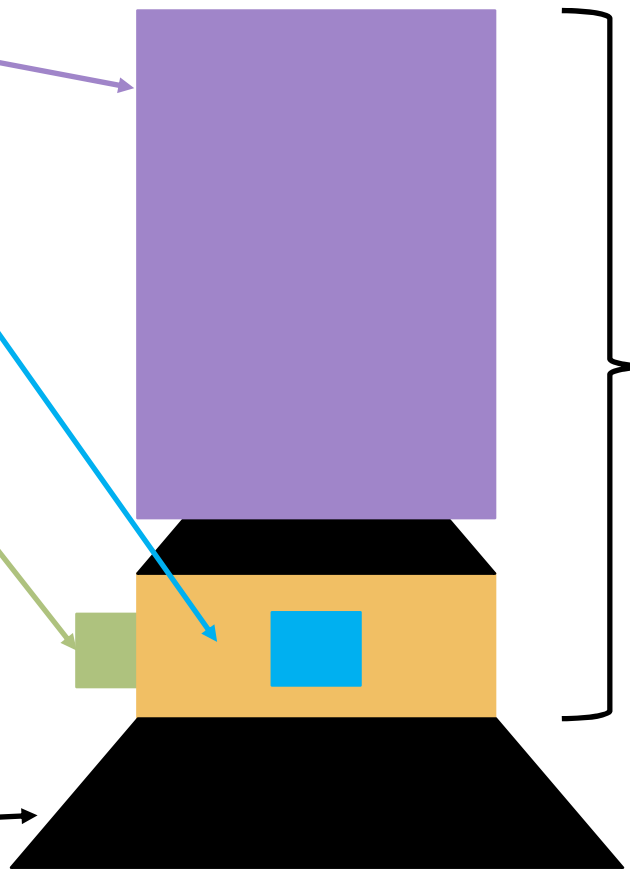
Rideshare Mission Assurance/Do-No-Harm

Primary P/L (PPL) provided by NASA
S/C, Policy Compliance, & DNH Certification: PPL
DNH Risk Assessment: NASA/GSFC

ESPA Flight System (ESPA Ring)
S/C, Policy Compliance, and DNH Certification:
NASA
–**DNH Risk Assessment:** USAF and GSFC

Gov't Multi-mission P/L provided by USAF/DoD
SV, Policy Compliance, and DNH Certification:
USAF/DoD, NASA, or NOAA Sponsoring Agency
–**DNH Risk Assessment:** USAF and GSFC

Launch Vehicle
LV Certification: NASA/LSP
Full Mission Assurance



Launch Authorization Authority: LSP

NASA Primary Mission's Launch Vehicle

ESPA Rideshare Mission:
Do-No-Harm (DNH) Compliance Checklist

P/L	Kick-off/Concept Review IMMC DNH Checklist	Check List Status				Notes, Comments & Reference Documents
SV #1	DNH Summary:	0	0	72	0	
SV #2	DNH Summary:	0	0	72	0	
SV #3	DNH Summary:	0	0	72	0	
SV #4	DNH Summary:	0	0	72	0	
SV #5	DNH Summary:	0	0	72	0	
SV #6	DNH Summary:	0	0	72	0	
IMMC	DNH Summary:	0	0	72	0	
	Mechanical: (23)			23		
	Electrical: (8)			8		
	Thermal: (2)			2		
	Safety & Mission Assurance: (11)			11		
	Separation System: (9)			9		
	Who (prov, app, per, inform): (6)			6		
	Processing: (12)			12		
	Risk Assessment: (1)			1		

Key: Green = Verified, Blue = On track, Red = Not addressed

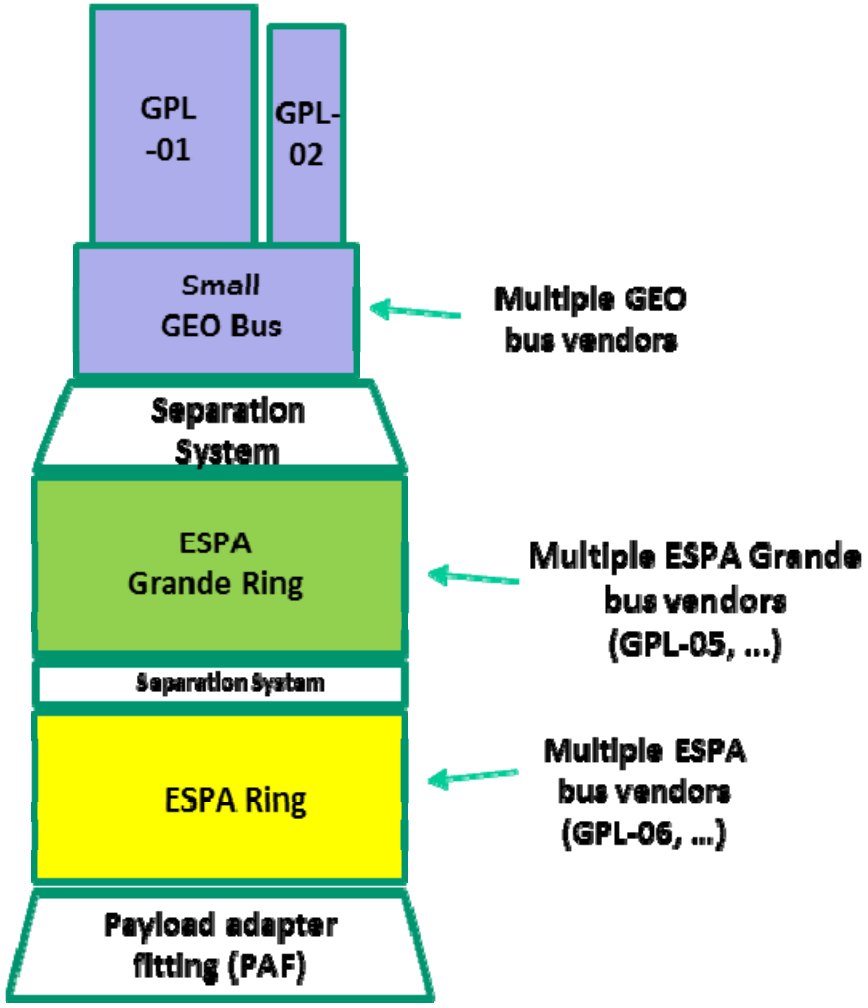
Reducing transaction costs & increasing innovation by reducing policing and enforcement costs

Rideshare Spacecraft RFI Summary

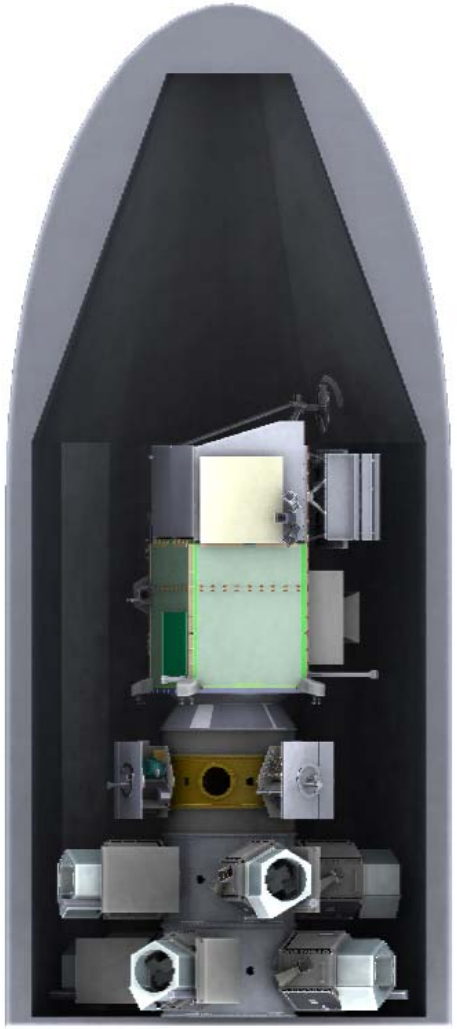
No.	Rideshare Adaptor/Carrier	Ball	Boeing	Millennium	Moog	Orbital-ATK	Surrey
1.0	ABC Class S/C (~80k)						
2.0	ESPA Class S/C (~320kg)						
3.0	ESPA Grande Class S/C (~450kg)						
4.0	A-Deck Class S/C (~1,000kg)						
5.0	Propulsive ESPA S/C (~1,500kg)						
6.0	Propulsive ESPA Grande (~2,500kg)						

Continuing to work with vendors to address open questions & normalize the results

Spacecraft RFI's Results used in Goddard's Rideshare Mission Concept Studies

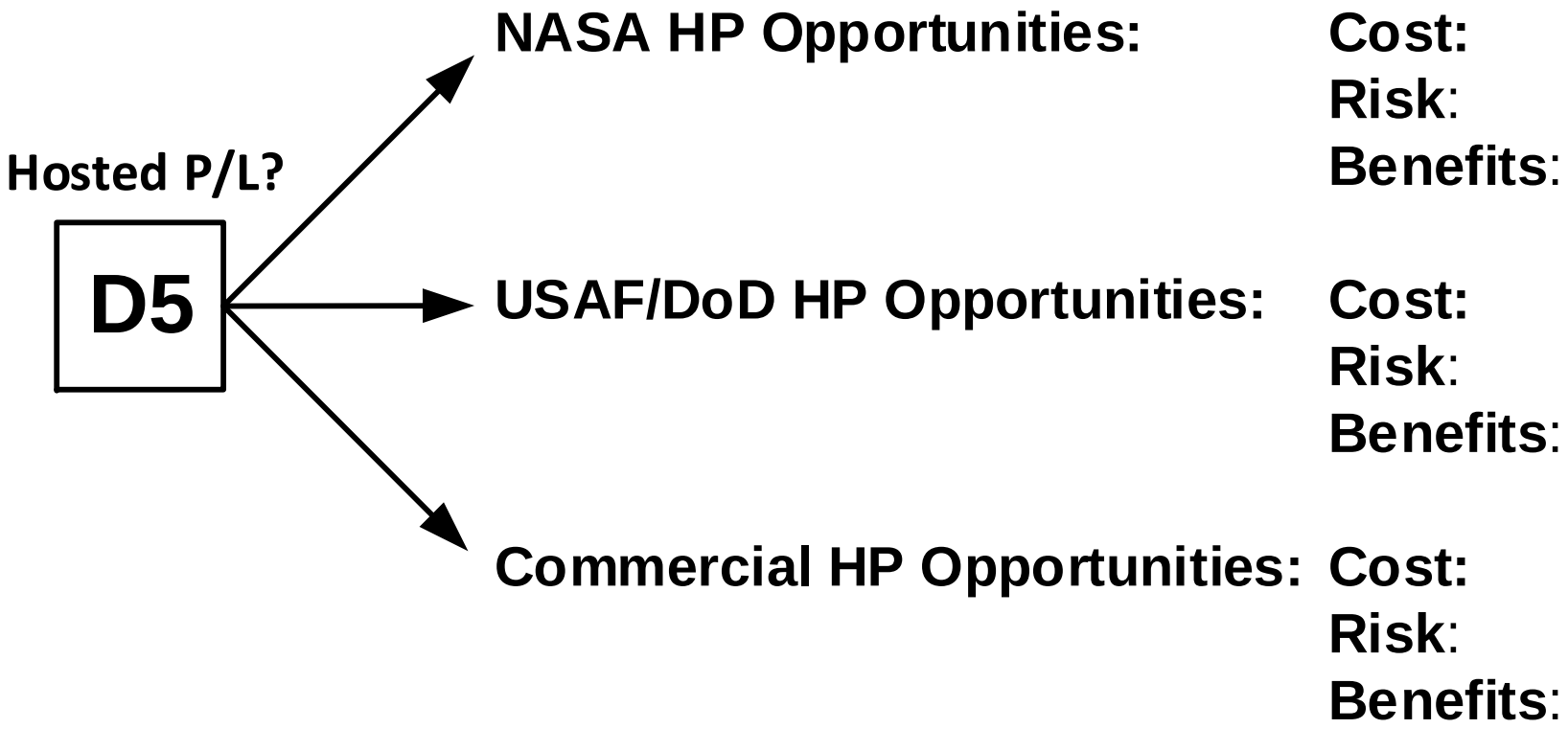


MDL Rideshare Example



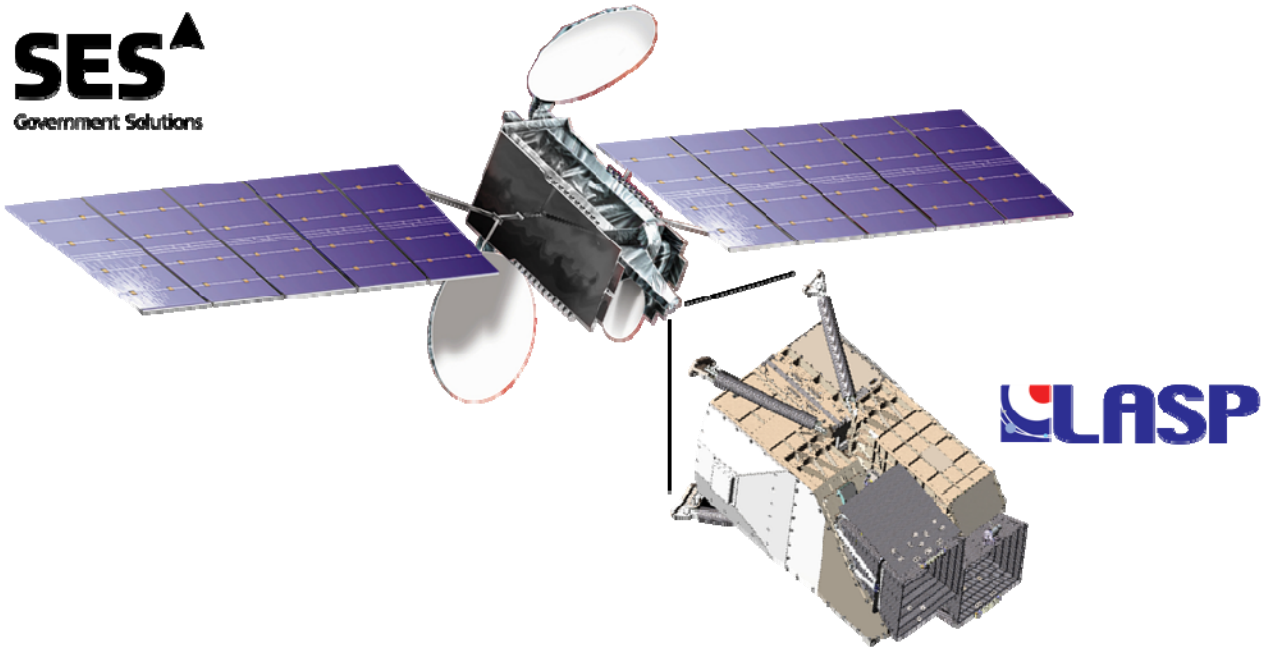
PACE Rideshare Example

Hosted Payload ATS Options

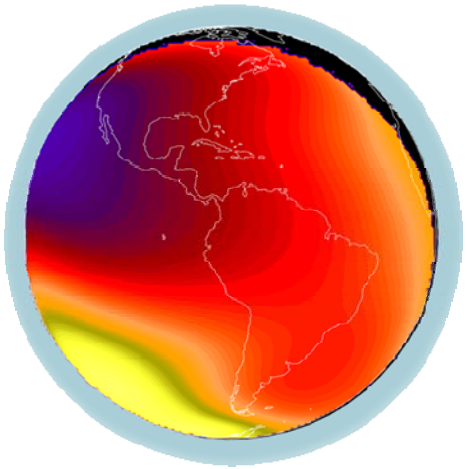


Capturing the cost, risk, and benefits of hosted payload implementation options

GOLD: NASA HP on a Commercial Bus (SMEX)



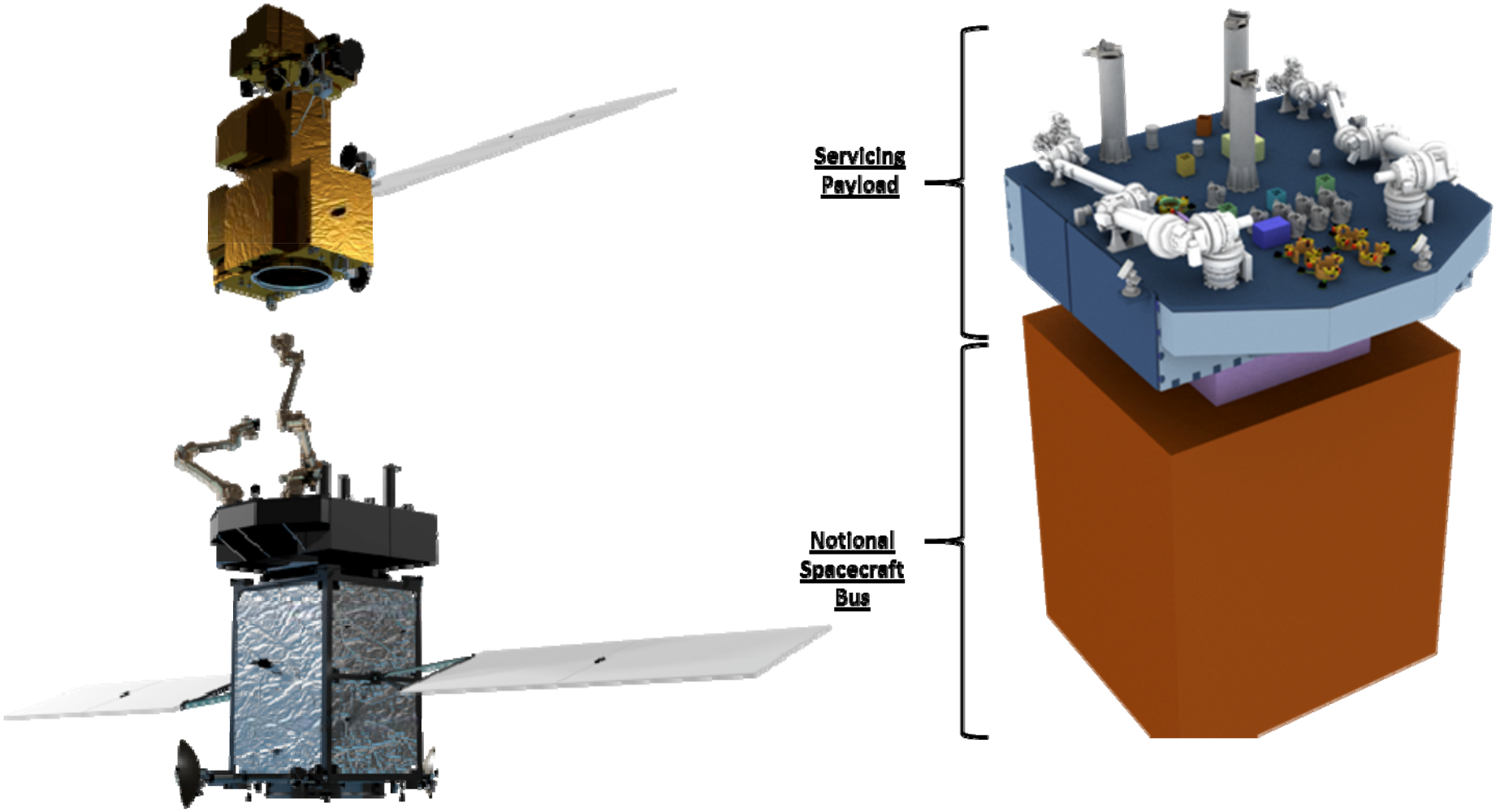
The GOLD spectrograph is mounted as a hosted payload on an Airbus commercial communications satellite in geostationary orbit



Laser Communications Relay Demo (LCRD)
NASA HP on an Air Force Spacecraft

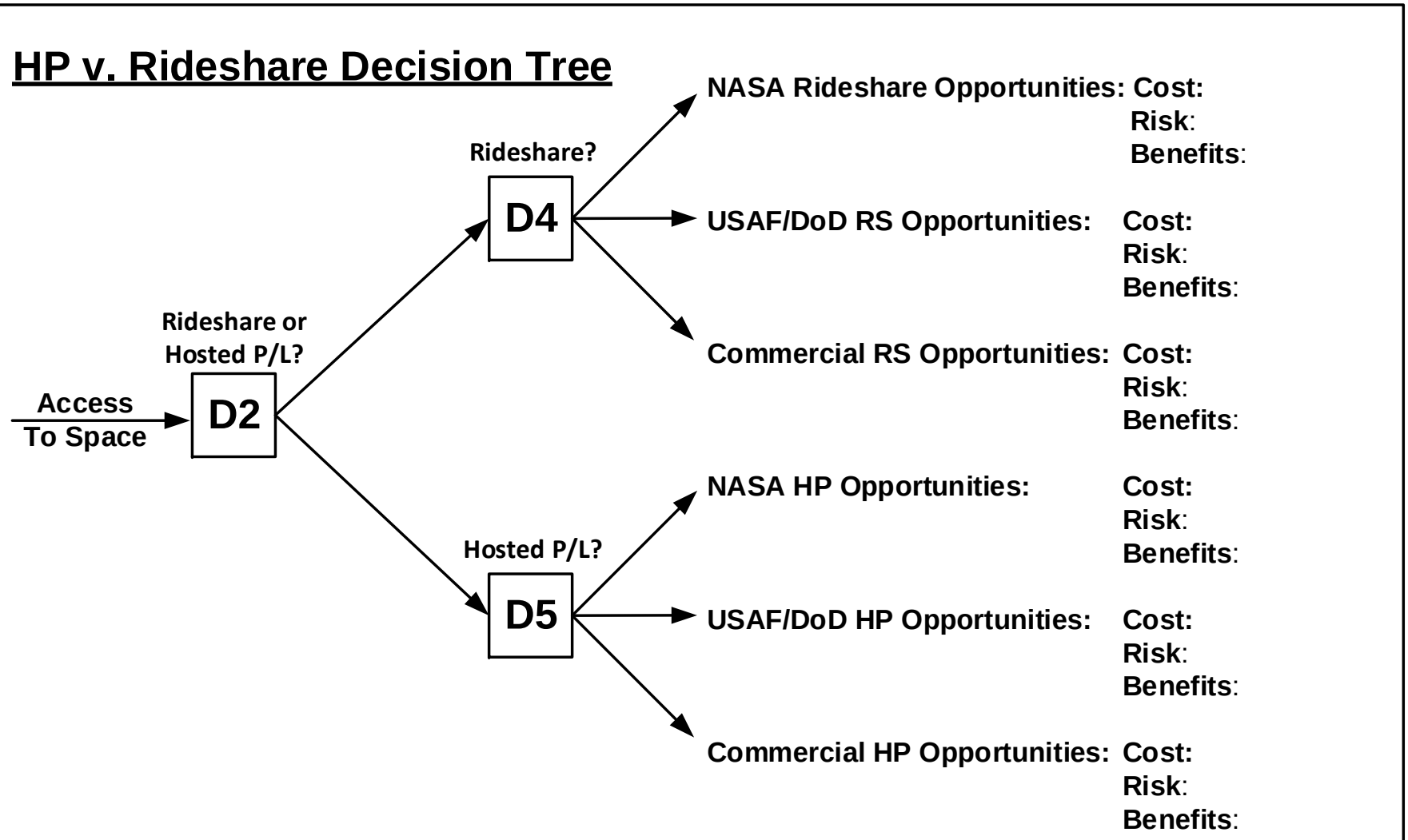
A good use of excess capacity on a USAF bus to fly NASA technology

Potential USAF/STP Hosted Payloads (SERB) on NASA's Restore-L Spacecraft



Restore-L (LRD 2022) has mass, power, space, and ops time available for hosted payloads

Rideshare & Hosted Payload Options



Capturing the cost, risk, and benefits of the rideshare & hosted payload implementation options

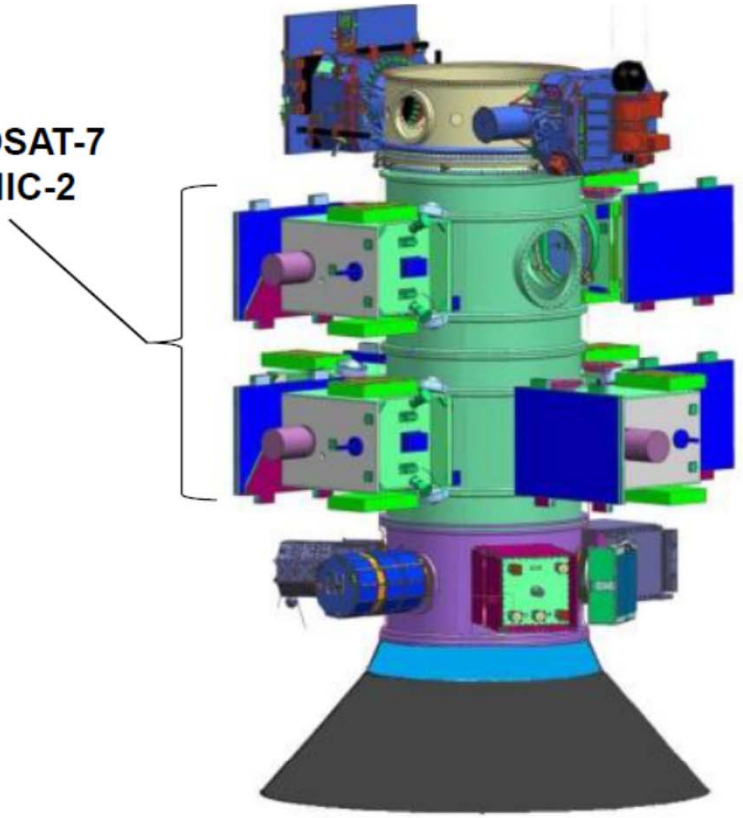
Backup charts …

Government HP & Rideshare on STP-2: OTB-1 & C2A

(A five burn mission delivering multiple payloads into several different orbits)

- Integrated Payload Stack (IPS)
  - Six COSMIC-2 Spacecraft
  - Demonstration and Science Experiment (DSX)
  - Six Auxiliary Payloads (APLs)
  - Dispensers plus ballast
  - Eight PPODs with Twelve Cubesats for LEO
- Falcon Heavy demonstration **February 2018**
- COSMIC-2 launch planned for **June 2018**

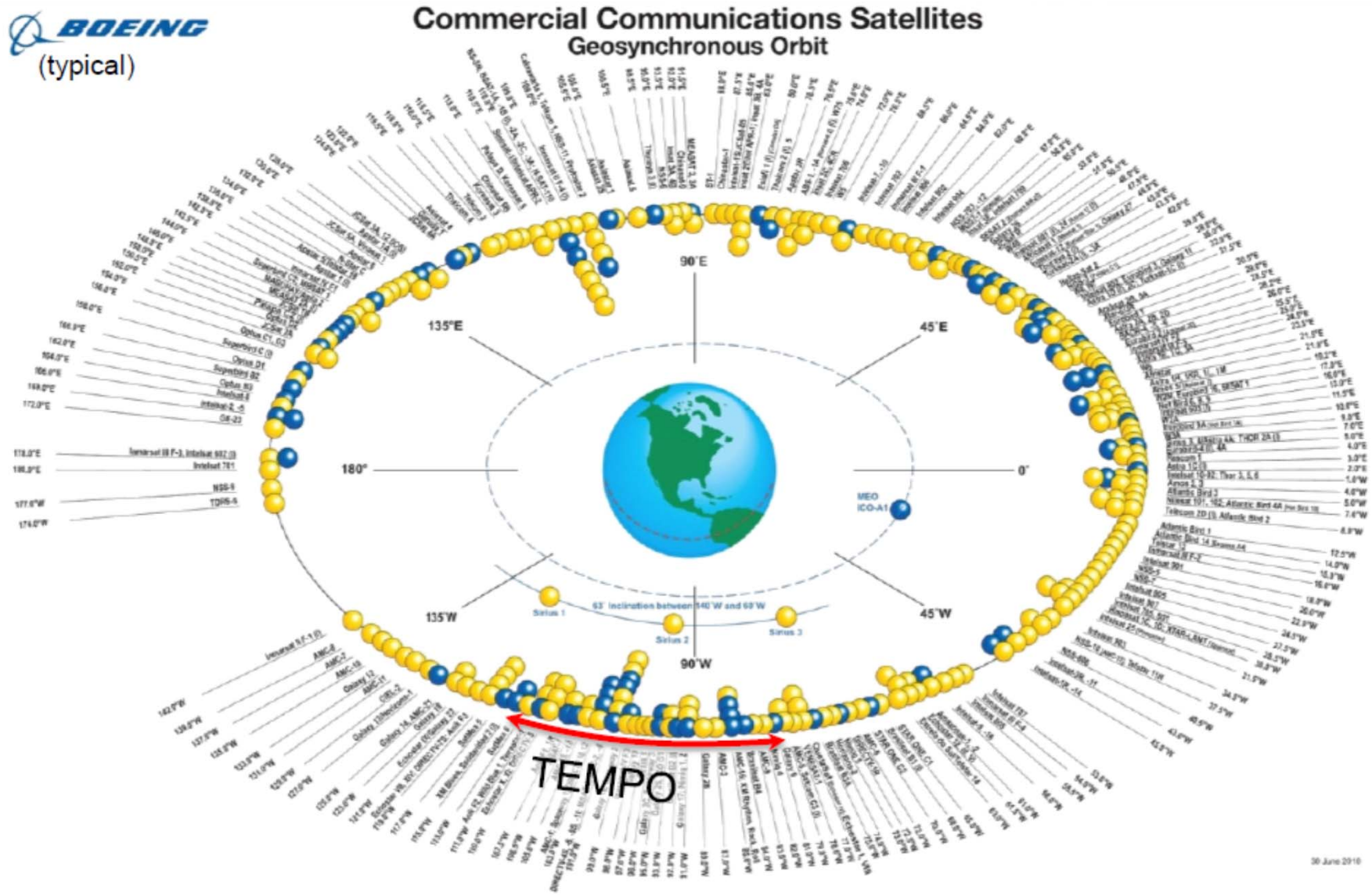
Concept of Falcon Heavy from Launch Comlex-39A CCAFS



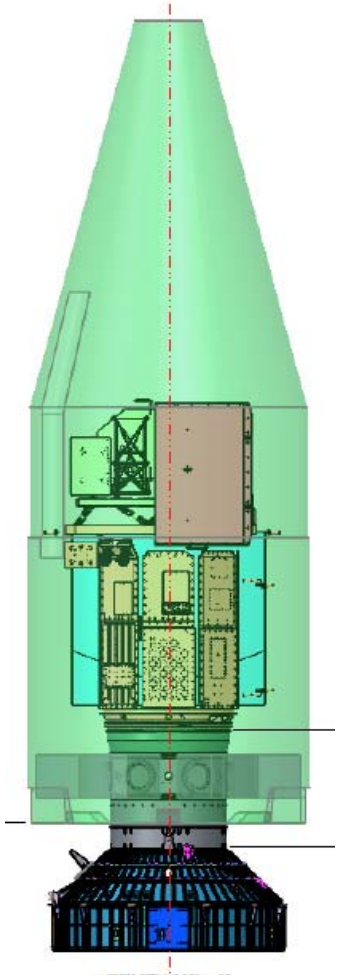
STP-2: multiple payloads, multiple orbits

- Orbit 1: 300 x 720 km at 28.4 deg inc., 1+8 deployed
- Orbit 2: 720 x 720 km at 24 deg inc., 11 deployed
- Orbit 3: 6000 x 12000 km at 45 deg, 1 deployed

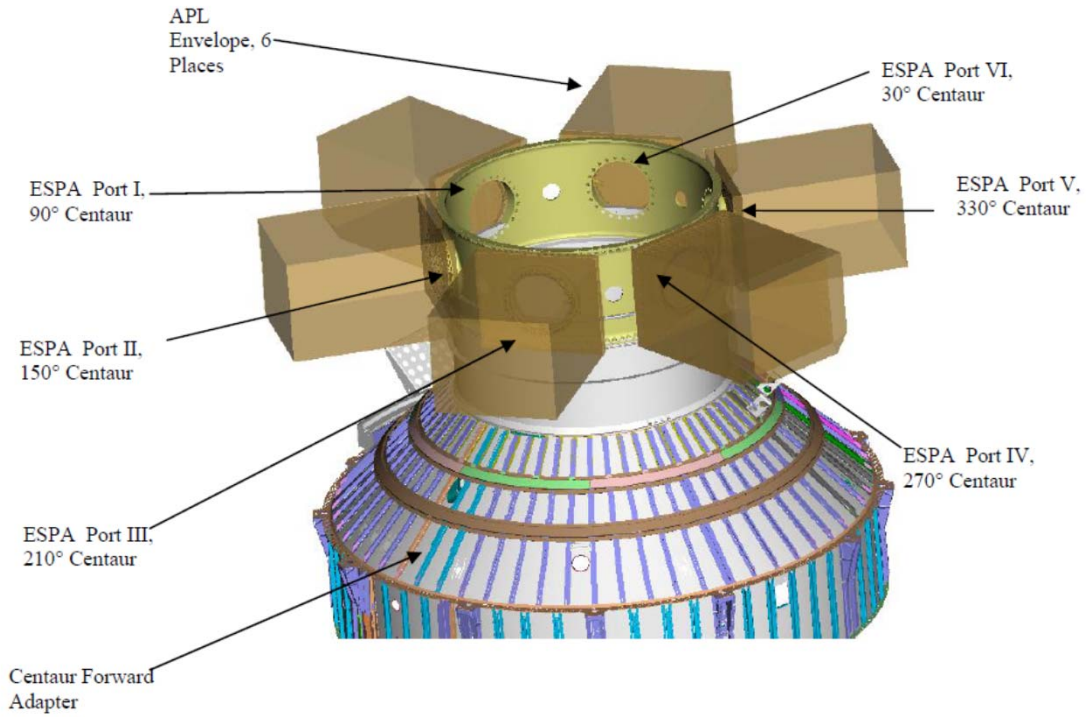
Geostationary Orbit Opportunities



Government Rideshare on Landsat-9

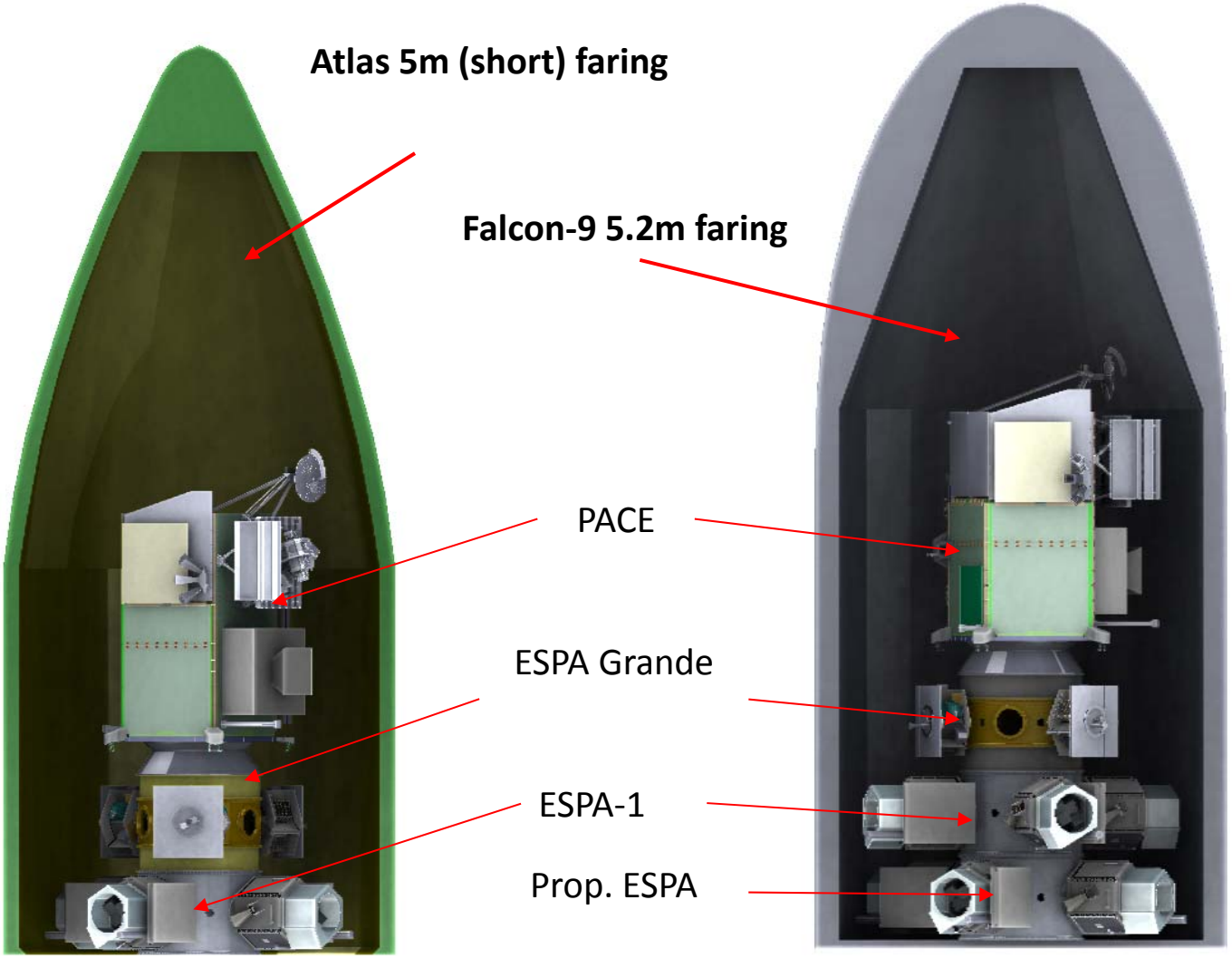


Landsat 9 with an ESPA Ring



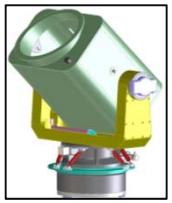
USAF and NASA Payloads on the Landsat-9 Mission (Atlas-V)

A Notional Government Rideshare

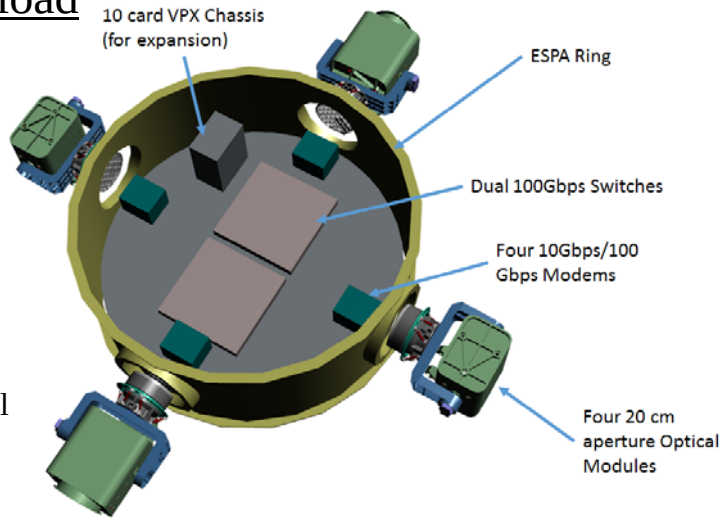


Next Generation Earth Relay Concept

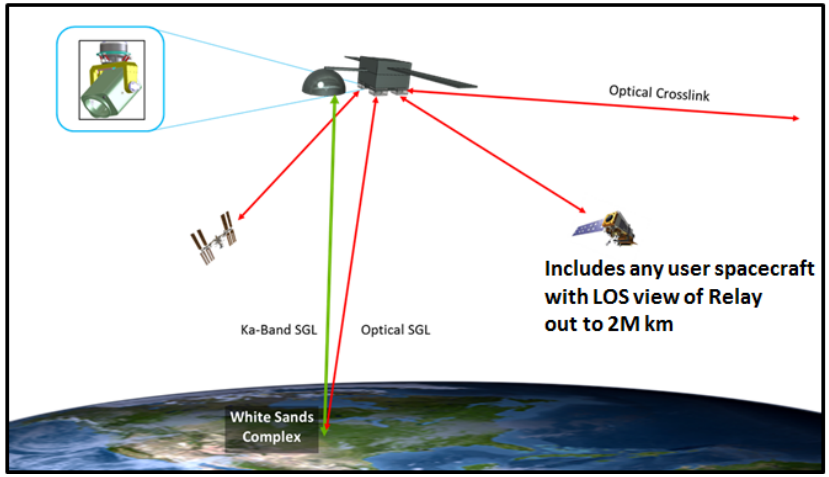
Basic Payload



20 cm Optical Module



Notional view of Relay Node operations



Payload Characteristics

	Mass/ Unit, kg	Number Units	Total Mass, kg	Power, W	Total Power, W	Dimensions per Unit, cm
Space Switching Unit (SSU)	9	2	18	342*	342	4.3 X 44.0 X 44.47
Optical Module (OM)	41.3	4	165			71.2 X 55.9 X 33.1
Modem & Controller	9	4	36	157	628	17.8 X 12.7 X 15***
Harness plus miscellaneous hardware (estimate)	24	1	24			
VPX equipment chassis	15	1	15	100	100	23.3 x 16 x 30.48
Thermal Blankets	1	1	1			
Total Payload			259		1070	
*One switch at a time						

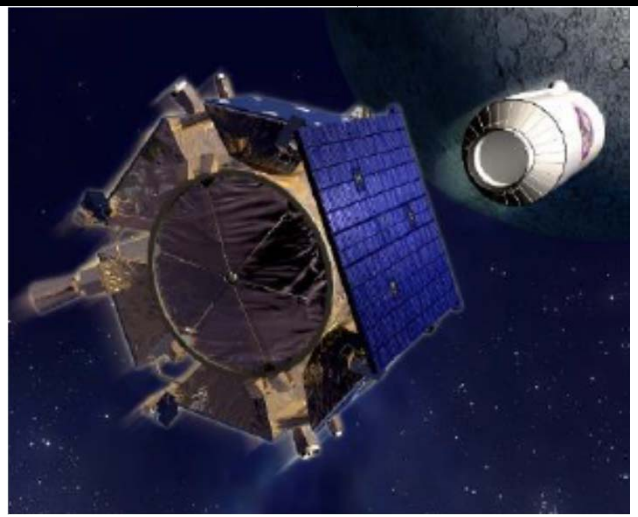
Mission Facts

1. Dedicated optical relay GEO satellite
2. Four optical relay terminals
3. Up to three simultaneous optical relay services (10 Gbps LEO-GEO)
   a) 100 Gbps Optical Space-Ground Link (GEO-GEO and GEO-to-Earth)
   b) One optical terminal can provide 100 Gbps Optical Crosslink instead of user service or SGL
4. Ka-Band Space-Ground Link to be provided by Spacecraft bus provider (1.2 Gbps minimum, uncoded)
5. Compatible with LCRD users and ground stations and CCSDS Optical Communications Standards
6. Desirement for eight year operational service
7. Earliest mission for the first relay node is 2024
8. Long term expectation is a buy for 3 to 6 buses
9. Primary mission is to support LEO, GEO and MEO users, but Lunar, L1/L2, and other missions will be supported

Rideshare / ESPA Heritage: Capacity v. Flown … the lost opportunity of empty slots

Mission	L/V	Carrier	Launch Date	S/C Capacity	S/C Flown	Empty Slots
STP-1	Atlas 5	ESPA	March 2007	6	4	2
LCROSS	Atlas 5	Propulsive ESPA	June 2009	1	1	0
OG2- 1	Falcon 9	ESPA Grande (2ea)	July 2014	8	6	2
AFSPC-4	Delta IV	ESPA/ANGELS	July 2014	6	1	5
OG2-2	Falcon 9	ESPA Grande (3ea)	December 2015	12	11	1
AFSPC-6	Delta IV	ESPA	July 2016	6	0	6
			Total:	39	23	16

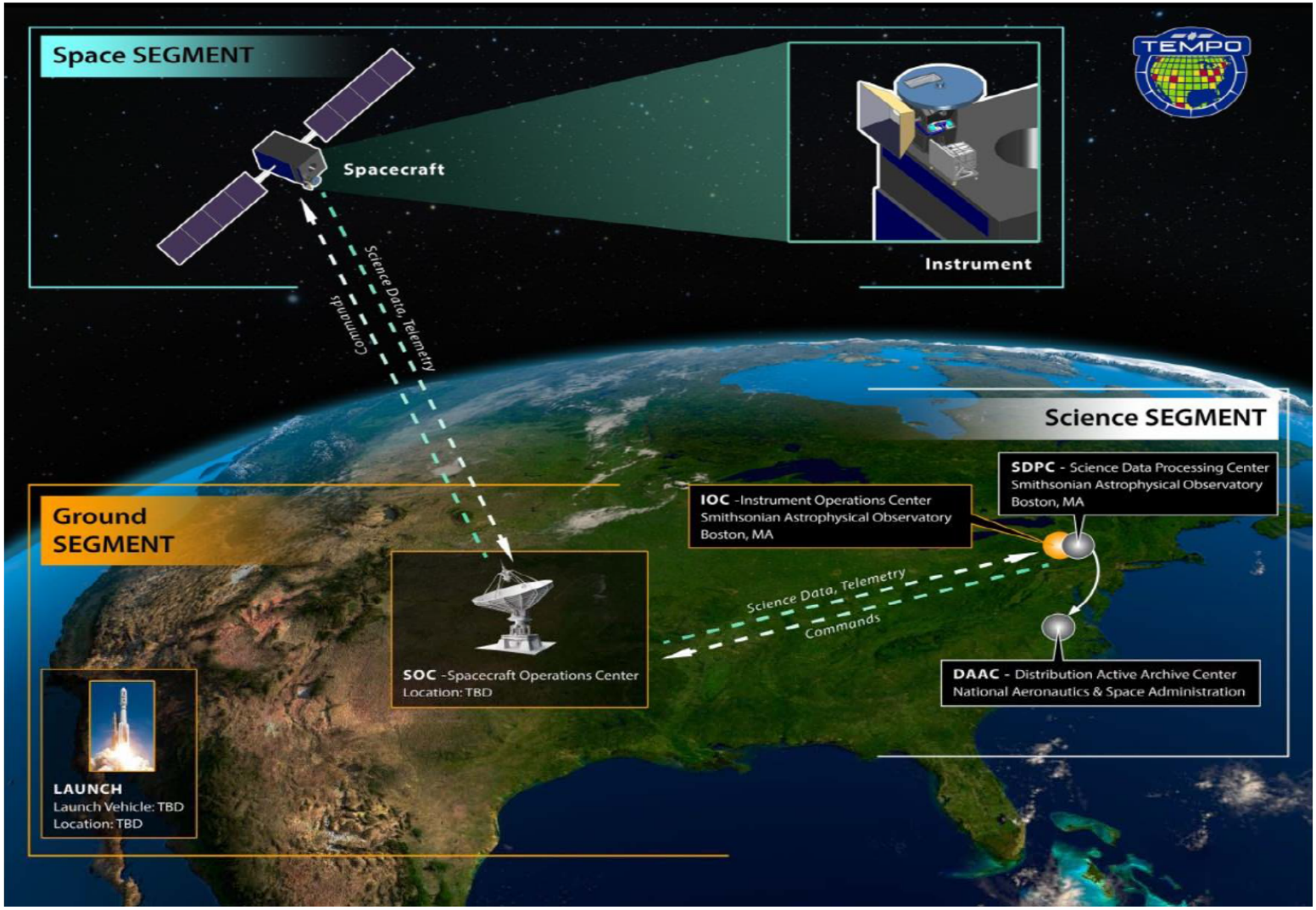
STP-1



LCROSS

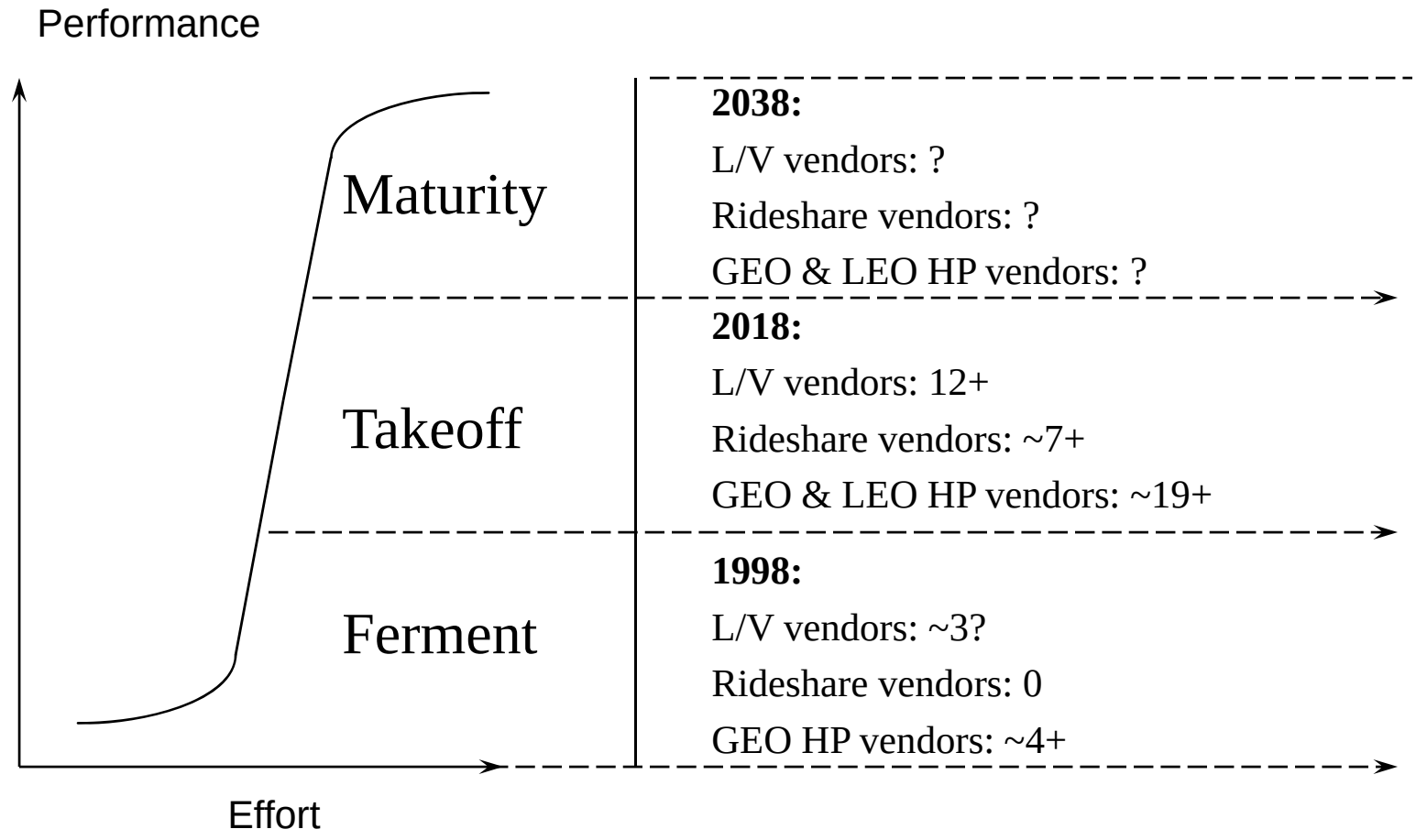
OG2-2

TEMPO: NASA HP on a Commercial Bus (HoPS)



TEMPO: A teaming relationship between NASA, Air Force, and Industry

Access to Space and the S-curve

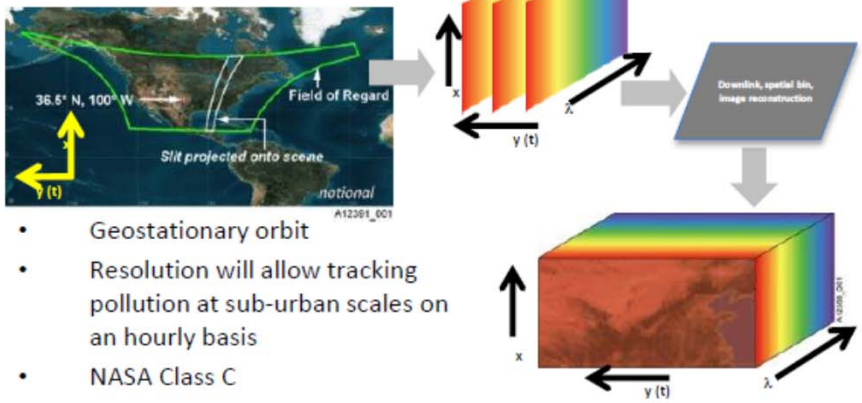


Notes on the S-Curve

- S-Curves and Business
  - Businesses, or the products of businesses, that follow an S curve are characterized by a shallow start, where only early adopters and niche markets buy the product or invest in the company. Then they experience a rapid growth, and the product or business has a dominant position in the market. After the rapid growth, these businesses maintain a high performance level but with little growth, which often signals a mature but saturated market
- Technology
  - Technology businesses, such as computer, software and electronic manufacturers often display an S curve life cycle. One explanation for this, is that initial progress is slow because the principles of the technology are poorly understood. Once researchers get a better understanding of the technology, progress accelerates rapidly. However, as time goes by, the effort required to improve on the technology reaches such a level that increase slows down and the growth curve flattens out. Businesses and technologies with a well documented S curve growth cycle include automobiles, semiconductors, steam engines and disk drives.

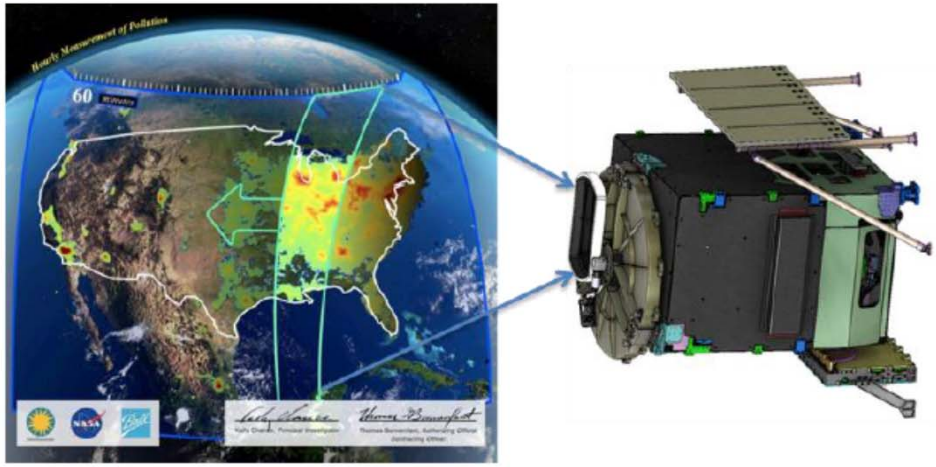
TEMPO: NASA HP on a Commercial Bus

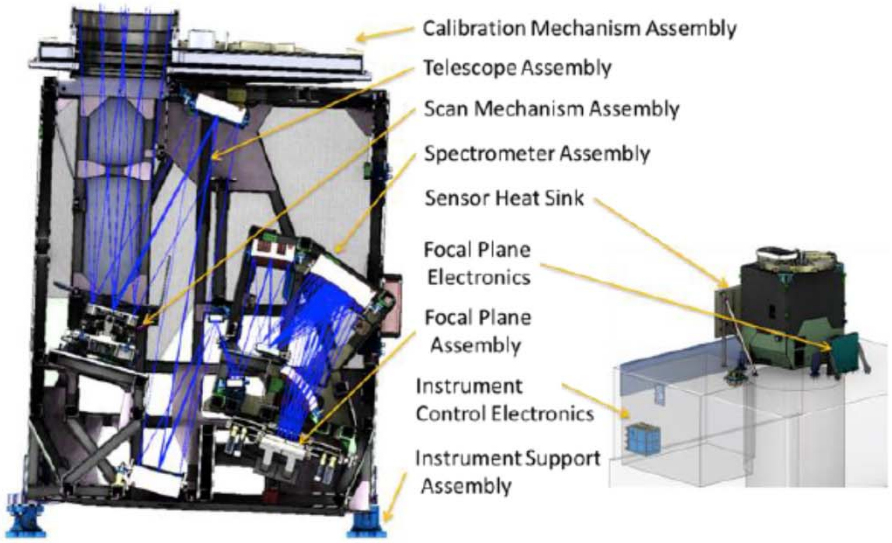
TEMPO: Is a scanning ultraviolet/visible spectrometer to measure chemical species critical to air quality and climate over Greater North America and surrounding areas



- Geostationary orbit
- Resolution will allow tracking pollution at sub-urban scales on an hourly basis
- NASA Class C

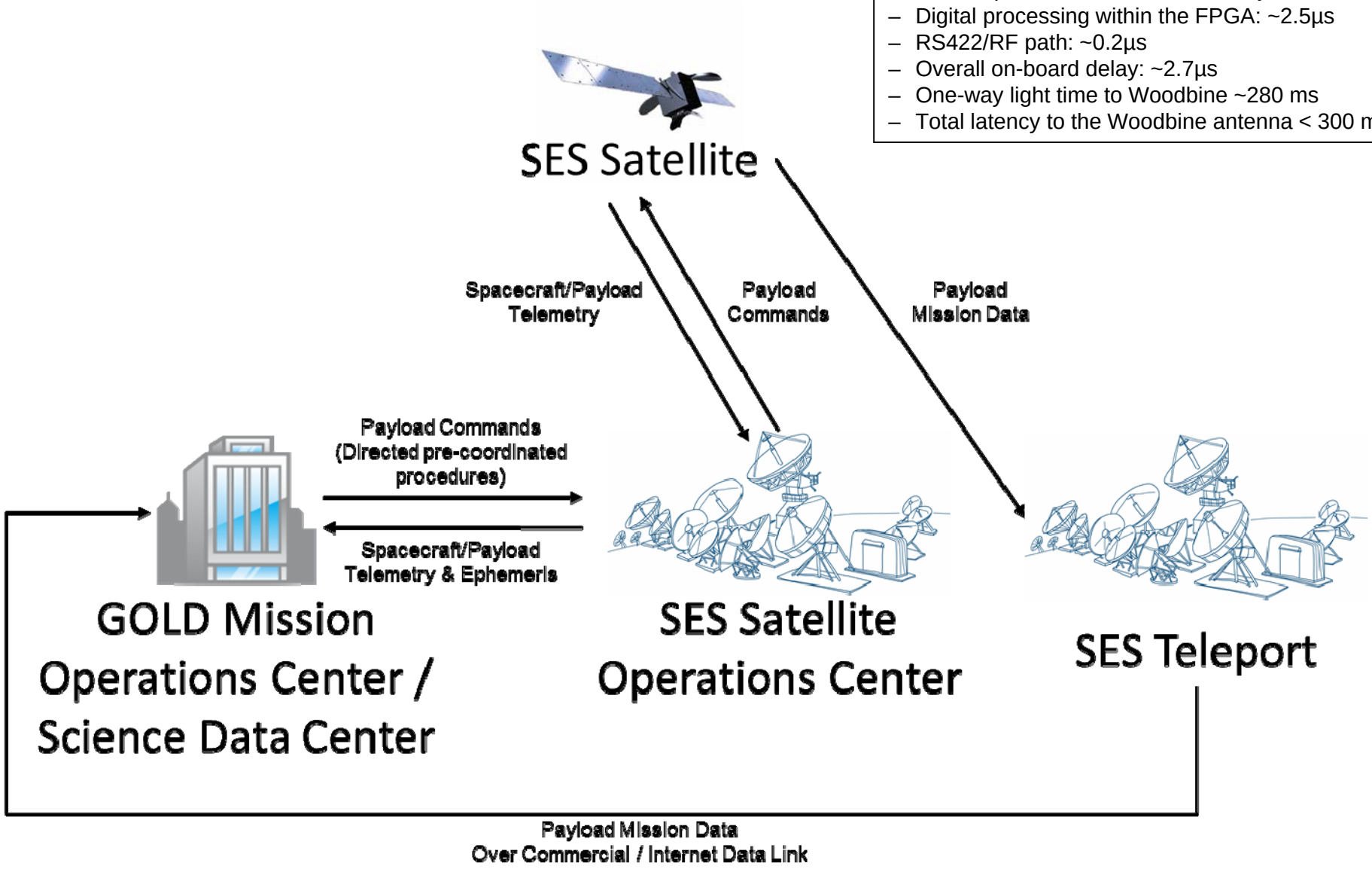
- Wavelength range = 290 – 490 nm and 540 – 740 nm
- Two 2048 (spatial) x 1024 (spectral) pixel CCD detectors
- Step/stare 2-axis scan mechanism
- 60 minute E→W scans performed approximately 2 hours on either side of full sunlight
- Composite M55J truss structure
- Calibration wheel with transmissive diffusers for daily solar calibration
- Sensor and focal plane radiators
- Instrument Control Electronics (ICE) mounted below spacecraft deck
- Images co-added on board before data downlink





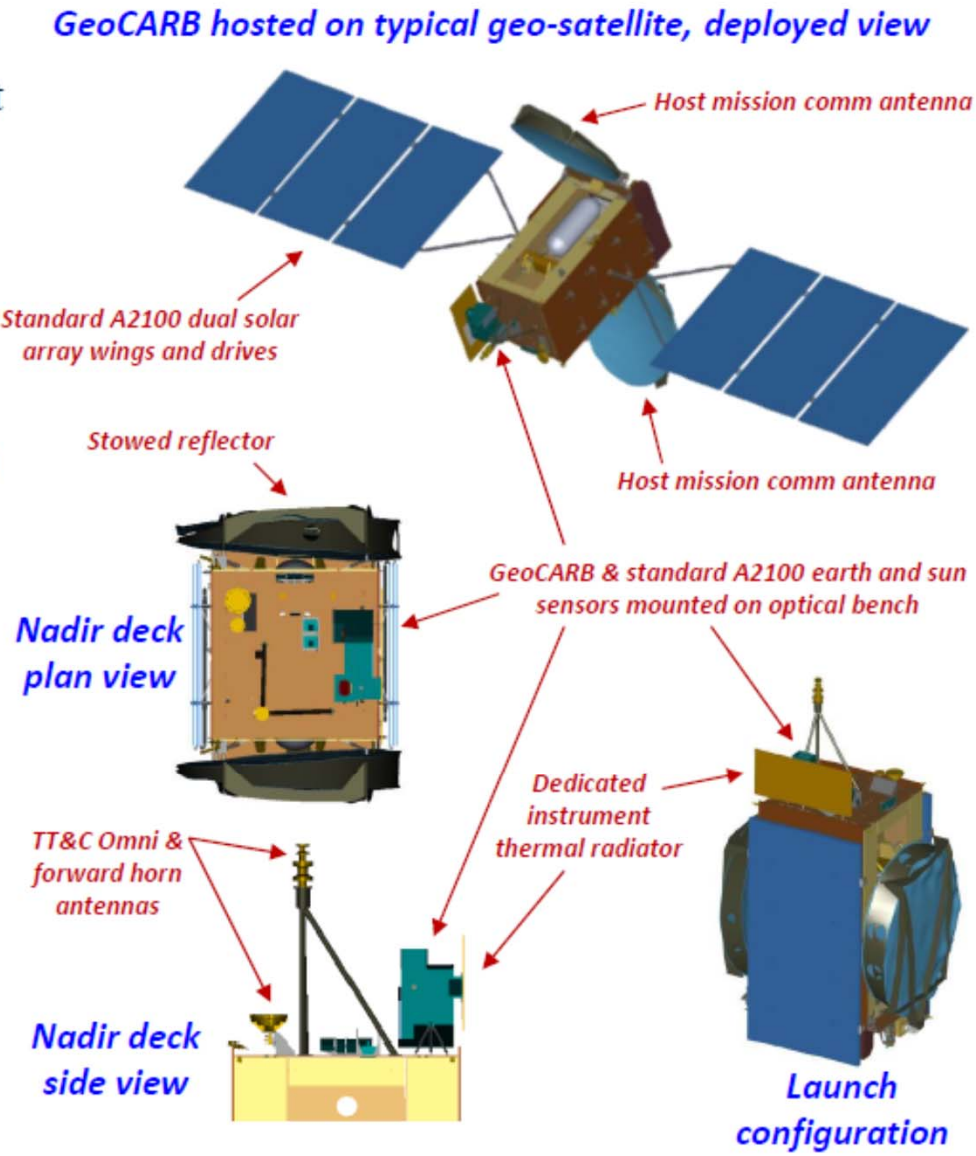
Command, Telemetry, & Data Handling

Airbus DS provided the on-board delays:
- Digital processing within the FPGA: ~2.5µs
- RS422/RF path: ~0.2µs
- Overall on-board delay: ~2.7µs
- One-way light time to Woodbine ~280 ms
- Total latency to the Woodbine antenna < 300 ms



GeoCARB: NASA HP on a Commercial Bus

- Hosted on a typical Geo-Communication spacecraft with added interface items to support instrument
  - Mounted directly to nadir deck
  - Data downlink via host channel
  - Standard attitude & orbit control
- Consumes relatively small amount of mass and power (S/C impacts chart)
- Physical accommodation
  - Requires large part of nadir deck
  - No impact on S/C equipment panels
  - Dedicated thermal radiator
- Electrical accommodation
  - Energy via standard 70 V DC power bus
  - On/off, basic health & safety command /telemetry via standard interfaces



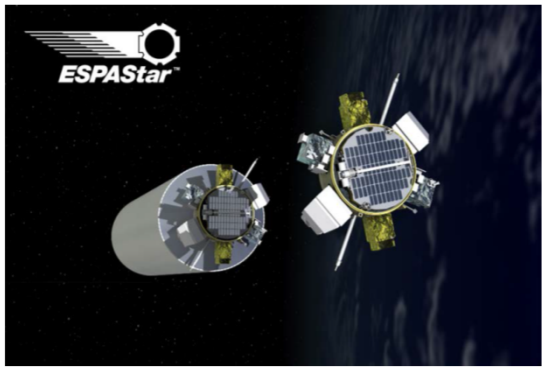
NASA Missions w/Rideshare

Candidate Primary Mission	Launch Date	Orbit	Apogee (km)	Perigee (km)	Inclination (deg)	Rideshare Adapter
Sentinel-6 (JPL)	11/2020	Polar, Cir.	1336km	1336km	66 deg	ESPA Option
Restore-L	11/2020	Polar	670km	670km	98.2°	ESPA Option
Landsat-9	12/2020	Polar	700km	700km	98.2°	ESPA Option
SWOT (JPL)	4/2021	Polar, Cir.	857km	857km	77.6 deg	ESPA Grande
JPSS-2	7/2021	Polar, Cir.	810km	810km	98.5 deg	ESPA Ring
PACE	2022/23	Polar, SSO	675km	675km	98 deg	TBD
IMAP	12/2024	TBD	TBD	TBD	TBD	ESPA Ring
JPSS-3	1/2026	Polar, Cir.	810km	810km	98.5 deg	ESPA Ring

L/V Upper-stage Restart may be an Option for Rideshare Missions

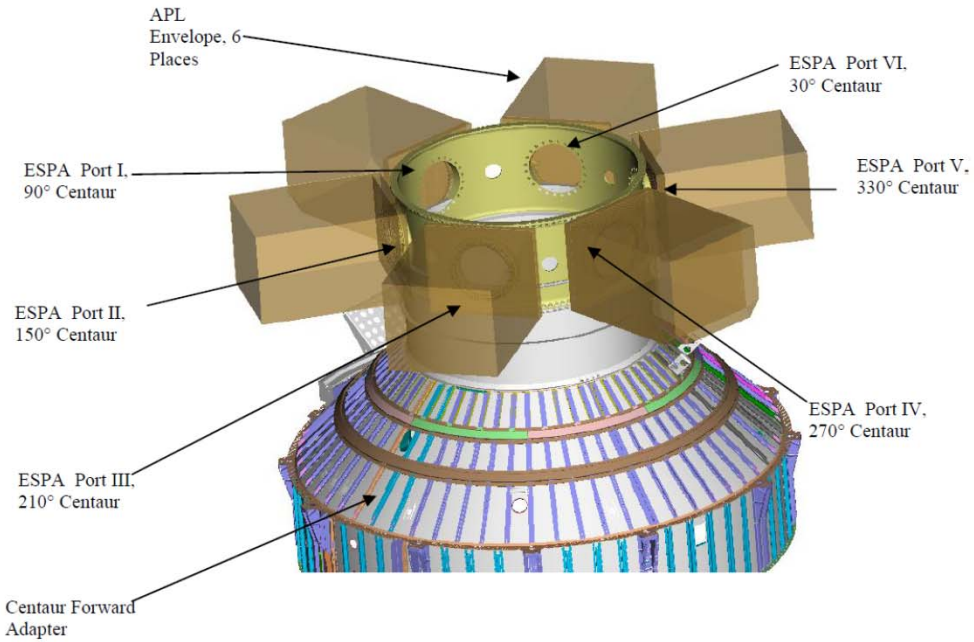
- Lower or raise altitude (Earth escape an option: L1, L2, planetary, etc.)
- Change inclination by ~15 degrees

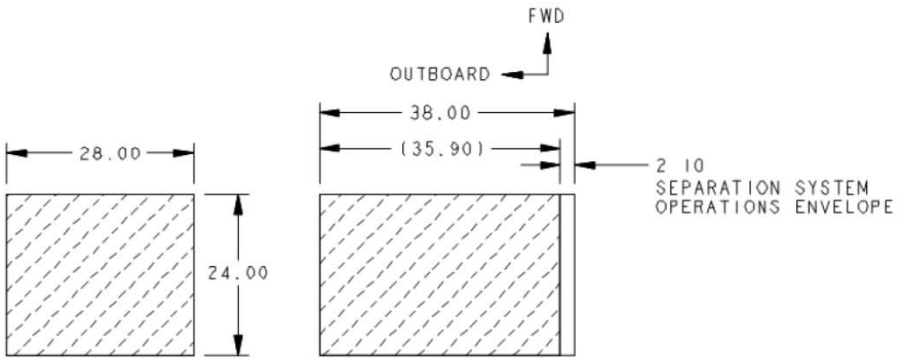
The ESPAStar Propulsive ESPA: A GEO HP Platform

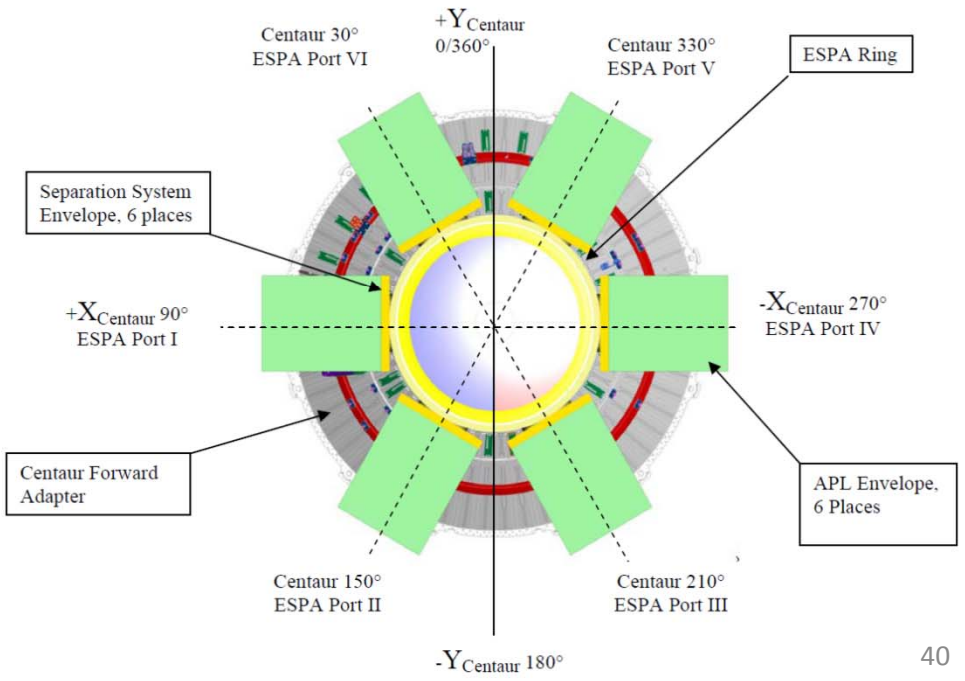


Attribute	ESPAStar
Payload Capacity	6 fixed or up to 12 separable
Payload Mass	1086 kg (181 kg per port)
Mission Duration	5 Years
Downlink	1.6 Mbps, AFSCN-compatible, Type 1 encryption
Attitude Knowledge	< 10 µrad, 1 Sigma
Positional Knowledge	<10 m w/GPS
Jitter	<10 µrad, 1 Sigma, <0.1Hz
Delta V	400 – 800 m/sec (1086-175 kg P/L mass)
Electrical Interfaces	Power, Data, Discrete IO
Power Available to Payloads	950 W
Flight Regimes	LEO, GTO, GEO

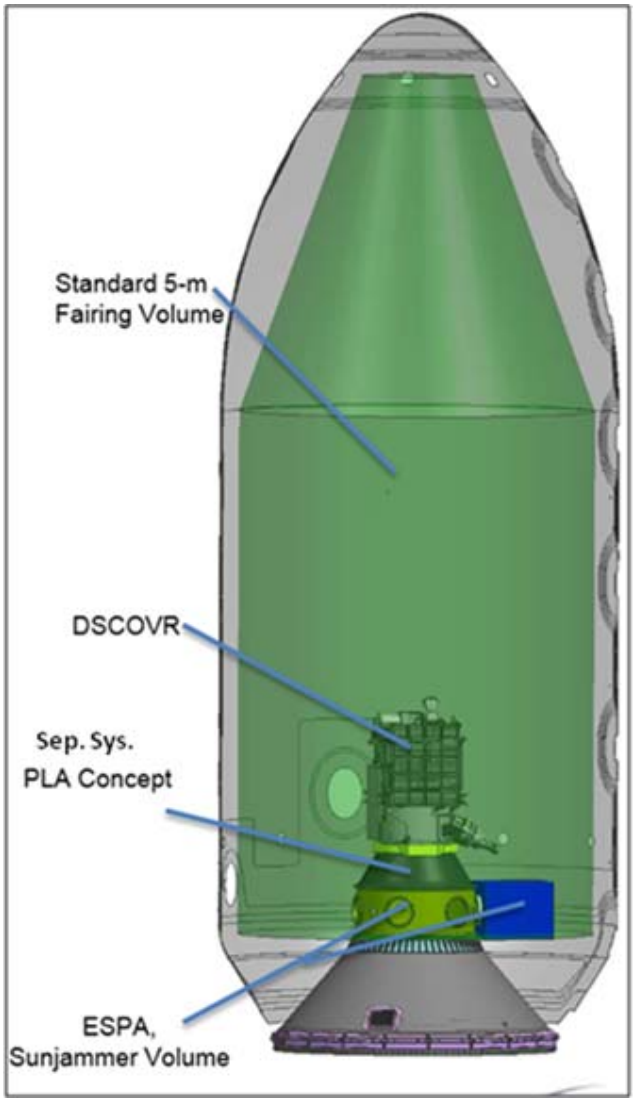
Air Force RUG: ESPA Mechanical Data







Rideshare Poster-child: DSCOVR & TESS

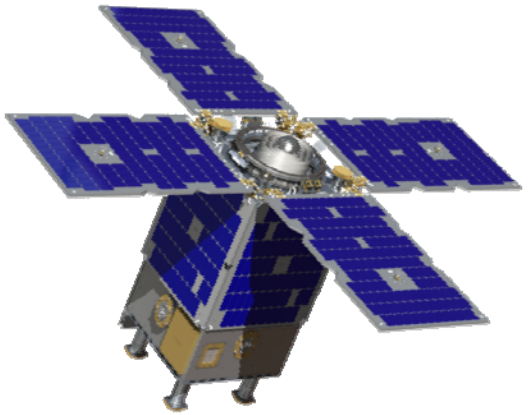


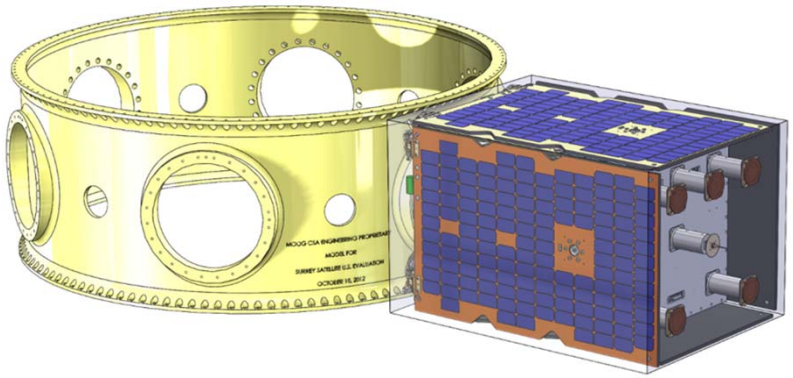
DSCOVR: Feb 2015
2500 kg of unused mass went to L-1

TESS: April 2018
~3000 kg excess on a TLI orbit

Rideshare HP Example: OTB-1 on STP-2

- An orbital test bed for experimentation and demonstration of payloads, subsystems, and equipment
  - OTB hosted payloads
    - NASA JPL Deep Space Atomic Clock
    - USAFA iMESA-R: sampling of electrostatic field, electron density, plasma irregularities
    - AFRL/Vanguard MSA: modular solar panels
    - TUI terminator tape deorbit device: validation of augmented cubesat tether





- OTB payload suite: evaluation, demonstration, heritage
  - FlexRX: programmable receiver
  - RadMon: radiation effects monitor
  - CUSP: University of Colorado collaboration, off-the-shelf components
  - High-efficiency solar cell experiment: performance characterization
  - Electronic Test Bed: new electronic components, processors, and memory devices

Rideshare Example: SpaceFlight SSO-A

(575km SSO, 10:30 and 575km x 40,000lm; 3 burns; LRD: 2018)

Launch Vehicle

SpaceX Falcon9

Vandenberg AFB, CA

Integrated Payload Stack

- Large rideshare microsatellite at top position
- Two SHERPA rings
- One Multipayload Adapter System (MAS), SpaceIL inside

CONOPS

At initial orbit, top position payload separates, SHERPA rings separate, SHERPA payloads then independently deploy via SHERPA sequencer

Falcon 9 relights, goes to a 575 x 40,000km orbit

SpaceIL propels itself to make a lunar intercept

Moog & ESPA Heritage

Mission	L/V	Carrier	Launch Date	No. of S/C
STP-1	Atlas V	ESPA	March 2007	6
LCROSS	Atlas V	Propulsive ESPA	June 2009	N/A*
OG2 Mission 1	Falcon 9	ESPA Grande (2)	July 2014	6
AFSPC-4	Delta IV	ESPA	July 2014	1
OG2 Mission 2	Falcon 9	ESPA Grande (3)	December 2015	11
AFSPC-6	Delta IV	ESPA	August 2016	0**
SHERPA - Spaceflight	Falcon 9	ESPA Grande	Planned for 2017 but canceled	> 80
SSO-A - Spaceflight	Falcon 9	ESPA	2018	6 ports
STP-2 (DSX Mission) - AFRL	Falcon Heavy	ESPA	2018	N/A*
EAGLE – AFRL	Atlas V	Propulsive ESPA	NET 2017	2 S/C + 4 Payloads
LDPE (STP-3) - SMC/AD	Atlas V	Propulsive ESPA	2019	TBD
Developed Mission Concepts (Publically Available Information)				
OMS/Millennium Space	--	Propulsive ESPA	Developed Concept Has not flown yet	Up to 4
MULE/Busek	--	Propulsive ESPA – Electric Propulsion	Developed Concept Has not flown yet	Up to 6
OMEGA / Moog-Surrey	--	Propulsive ESPA Grande	JPL TeamX in 2012	6
ELLIE/Moog (OMV to L1)	--	Propulsive ESPA Grande	Proposal Submitted	4 ports
Moog COMET	--	Propulsive ESPA Grande	CDR Level	Up to 6 ports

*LCROSS and DSX used the ESPA as the spacecraft bus structure and did not deploy payloads
**Did not carry any payloads

Additional Information: Commercial Options

- **Rideshare third-party brokers/integrators**
  - **Adaptive Launch Solutions (ALS)**
  - **NanoRacks LLC**
  - **Spaceflight Industries**
  - **TriSept Corporation**
  - **Tyvak Nanosatellite Systems Inc.**
  - **Moog Inc.**
  - **Surrey Satellite Technology**
  - **bSpace Corp.**
- **Large US L/V w/secondary capabilities**
  - **Antares (including Cygnus) [Orbital]**
  - **Atlas V [United Launch Alliance (ULA)/Lockheed Martin Com. Launch Ser]**
  - **Delta IV [ULA/Boeing Launch Services]**
  - Falcon 9 (including Dragon) [SpaceX]
  - Falcon Heavy [SpaceX]
  - Space Launch System [NASA]
- **US small launchers**
  - ~~ALASA [DARPA/Boeing]~~
  - ~~Alpha [Firefly]~~
  - Athena II [Lockheed Martin]
  - **Electron [RocketLab]**
  - Nano-sat/Micro-sat Launch Vehicle (Vector-1) [*Vector Space Systems*]
  - GO Launcher 1, 2 [Generation Orbit]
  - **LauncherOne [Virgin Galactic]**
  - Minotaur I, IV, V, VI, C [Orbital ATK]
  - Neptune [Interorbital]
  - **Pegasus [Orbital ATK]**
  - Stratolaunch [Vulcan Aerospace]
  - ~~SuperStrypi [Sandia National Labs]~~
  - Terrestrial Return Vehicle (retrieval from ISS only) [Intuitive Machines]
  - Ventions Nanolauncher [Ventions]

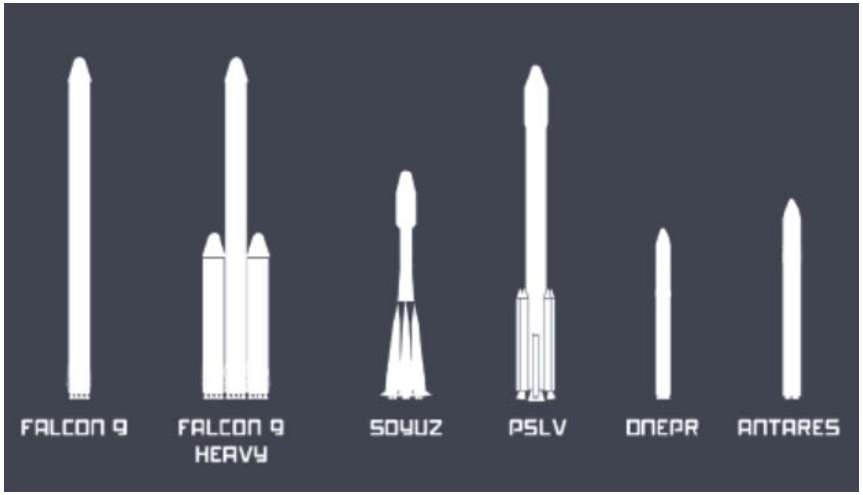
SPACEFLIGHT INDUSTRIES

RIDESHARE PRICE & SCHEDULE TRANSPARENCY

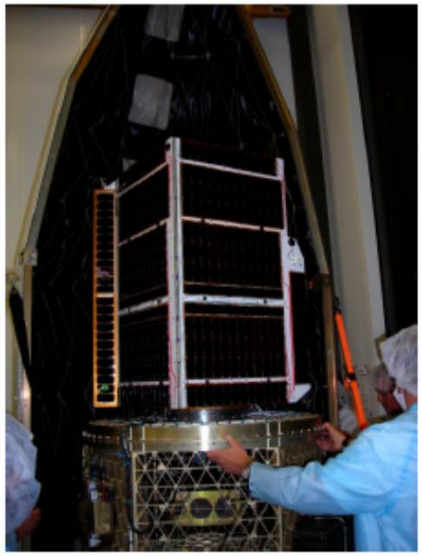
	Containerized			Satellite Class							
Payload Type	3U -5kg	6U-10kg	12U-20kg	50 kg	100 kg	150 kg	200 kg	300 kg	450 kg*	750 kg*	1000 kg*
Length (cm)	34.05	34.05	34.05	80	100	100	100	125	200	300	350
Height/Dia (cm)	10.00	10.00	22.63	40	50	60	80	100	150	200	200
Width (cm)	10.00	22.63	22.63	40	50	60	80	100			
Price – LEO	$295	$545	$995	$1,750	$3,950	$4,950	$5,950	$7,950	$17,500	$22,000	$28,000
Price – GTO	$915	$1,400	$2,750	$4,600	$8,400	$9,800	$11,200	$14,000	CALL	CALL	CALL

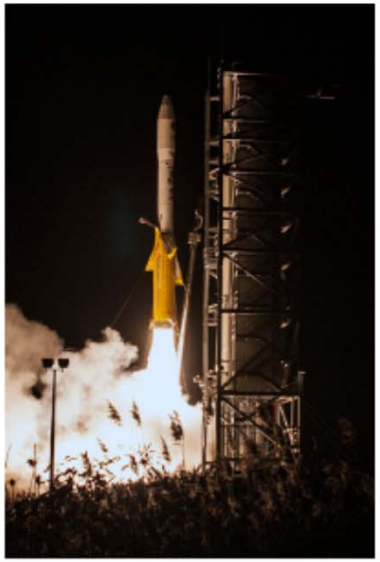
–* Priced in Thousands

- Spaceflight publishes pricing online, as well as a list of rideshare launch opportunities on multiple LV's
- Government Contracts:
  - *KSC Cubesat Launch Basic & Options*
  - *GSA Schedule for launch service*
  - *Subcontractor on NASA Ames Task Ordering launch service contract*
- *Launch Vehicle Agnostic – working with all LVP's to include new entrants*



TriSept Corporation





- *Certified Small Business (Founded 1994)*
- *Average Employee Experience: 31+ Year*
- *100+ spacecraft launched on 20 different LV's from 10 different ranges/sites*
- *Small Satellite Integration Pioneers*
- *Launch / Rideshare brokering*
- *Leading multi-payload mission integrators*

Jason R. Armstrong
Director Small Satellite Solutions
15036 Conference Center Dr., Suite 550
Chantilly, VA 20151
703-297-4622 www.trisept.com
GSA schedule (GS-10F-0118V)
NAICS Codes: 541330, 54130, 541511, 541690, 541712, 541519, 336419

- *Rideshare opportunities for spacecraft from 1U to 1,000's of Kg's*
- *Dedicated small launch mission's*
- *Dedicated Rideshare mission's*
- *Commercial and Government launch services*
- *Integration support for existing mission's*

TriSept : Rideshare Opportunities

TriSept Small Satellite Solutions

Mission	Targeted Launch	Orbit	Status/Comments
TriSept Dedicated Rideshare	1st Qtr 2018	450 km circular, 30° Inclination	Up to 100kgs
Rideshare opportunity	Mid 2018	500 km circular, SSO, LTAN 10:30 or 1:30	Multiple options up to 200kgs and many CubeSat slots (12U, 6U and 3U)
Rideshare opportunity	Late 2018	MEO	Multiple options for SmallSats
TriSept Dedicated Rideshare	1st Qtr 2019	500km, SSO	Up to 1000kgs
Rideshare opportunity	Mid 2019	TBD	Many options still available

Tyvak Nano-Satellite Systems Inc.

3U P-POD

3U NLV Rail-POD

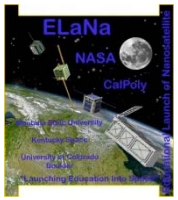
6U NLAS

12U NLAS

ULA ABC ~100kg

ESPA Class

Supporting USG SmallSat Enablers

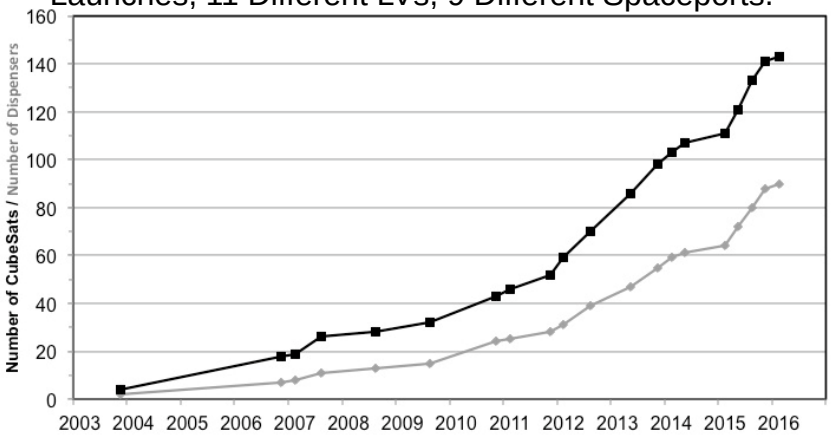


NASA ELaNa and CSLI

DoD, USAF, NRO

Flight Heritage with Cal Poly:

- Completed To Date: 143 SmallSats launched, 21 Launches, 11 Different LVs, 9 Different Spaceports.



Company Information:

- ***VP, Launch Services***
  Roland Coelho
  roland@tyvak.com
  805-704-9756

  Mission Manager
  Justin Carnahan
  justin.carnahan@tyvak.com
  805-405-8890
- 15265 Alton Parkway Suite 200, Irvine CA, 92618
- Tyvak provides turnkey nanosatellite and microsatellite vehicles, launch services and solutions to government and commercial customers at a fraction of the cost of traditional spacecraft service providers .
- Formed in 2011, 50+ engineers, offices in US and Italy
- NASA, DoD, Commercial, International contracts completed and in process. Personnel completed 21 launch campaigns to date and 10+ launch campaigns on contract in 2016-18.

Tyvak SmallSat Launch Process:

Tyvak Responsible For

- Requirements and Interface Definition
- Separation System & SmallSat Mission Support
- Hardware Certification
- SmallSat Integration
- Acceptance Test / CoFR
- Delivery to LV
- Assistance with LV Integration

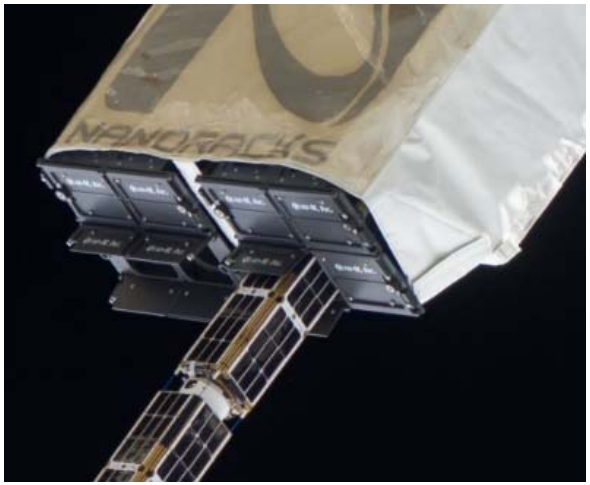
Launch Vehicle Focuses On

- Launch
- Payloads to Orbit

Tyvak Rideshare Opportunities

Year	LEO (~500x~500)	Polar (Apo x Per)	MEO (1100x185)	GEO (35786x35786)	Other
2017	4Q_500km_50deg	1Q_600km_SSO 2Q_500km_SSO 3Q_600km_SSO 4Q_500km_SSO			4Q_GTO
2018	3Q_500km_~40 deg	2Q_500km_SSO 4Q_500km_SSO		2Q_SuperSynch	1Q_GTO 3Q_GTO
2019	Continued Availability to LEO	Continued Availability to SSO		Continued Availability to Sub/Super_Synch	1Q_GTO 3Q_GTO 3Q_Escape
2020	Continued Availability to LEO	Continued Availability to SSO		Continued Availability to Sub/Super_Synch	Continued Availability to GTO
2021	Continued Availability to LEO	Continued Availability to SSO		Continued Availability to Sub/Super_Synch	Continued Availability to GTO
2022	Continued Availability to LEO	Continued Availability to SSO		Continued Availability to Sub/Super_Synch	Continued Availability to GTO
2023	Continued Availability to LEO	Continued Availability to SSO		Continued Availability to Sub/Super_Synch	Continued Availability to GTO

NanoRacks



Heritage / Schedule Information:

- *Commercial ISS Satellite Deployments*
- *External Cygnus CubeSat Deployments*
- *CubeSat Formats*
- *Small Satellite Formats (~100 kg class)*
- *ISS External Platform Hosting*
- *139 CubeSats Deployed to date*
- *Quarterly flights to ISS*

Company Information:

- *Conor Brown, (703) 973-6821, cbrown@nanoracks.com*
- *www.nanoracks.com*
- *Houston, TX, Washington, D.C., San Francisco, CA*
- *40 employees,*
- *established 2009*
- *NASA Services Contract (No Tax ICT)*
- *In partnership with Quad-M*

Product Information:

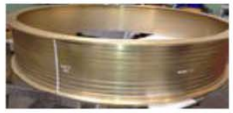
- *NRCSD*
- *Kaber*
- *Cygnus External Deployer*
- *NREP*
- *NR Airlock*
- *Dragon Trunk Deployer*
- *Centaur Aft Bulkhead Deployer*
- *Centaur MegaDeployer*

NanoRacks: Anticipated Launch Opportunities

Year	LEO (~500x~500)	Polar (Apo x Per)	MEO (1100x185)	GEO (35786x35786)	Other
2017	4			1	
2018	4			1	
2019	4			1	
2020	4			1	
2021	4			1	
2022	4			1	
2023	4			1	

Adaptive Launch Solutions

Aquila Multi-Manifest Systems



Deck Adapter

Aluminum Deck

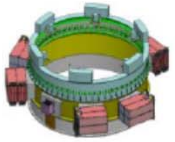
Standard Adapter

Composite Deck

Anisogrid Adapter

Auxiliary Payload Support Unit (APSU)

Integrated Deck & Adapters



Integrated Cubesat Dispensers

Heritage / Schedule Information:

- Aquila meets Atlas V, Delta IV, Antares, Falcon 9 and Minotaur flight and ground environments.

Deck and Adapter Stress Analysis, Dynamic Analysis, Specs & Designs complete. Full Scale Qualification Test (Vibration, Acoustic and Modal Survey) plans, tests and reports complete	 Aquila Full Scale Vibration Test	Reviewed by OSL & ✓
APSU Stress Analysis, Dynamic Analysis, Specs & Designs complete. Qualification Test (Vibration, Shock, Thermal, Thermal Cycle) plans, tests and reports complete. Includes EMI/EMC DET	 APSU Flight Simulation Test	Reviewed by OSL & ✓

Company Information:

- ***Aquila Operations Manager***
  James Parra
  jparra@adaptivelaunch.com
  858-395-2819
- ***Business Development***
  Philip Smith P.E.
  psmith@adaptivelaunch.com
  619-944-2555

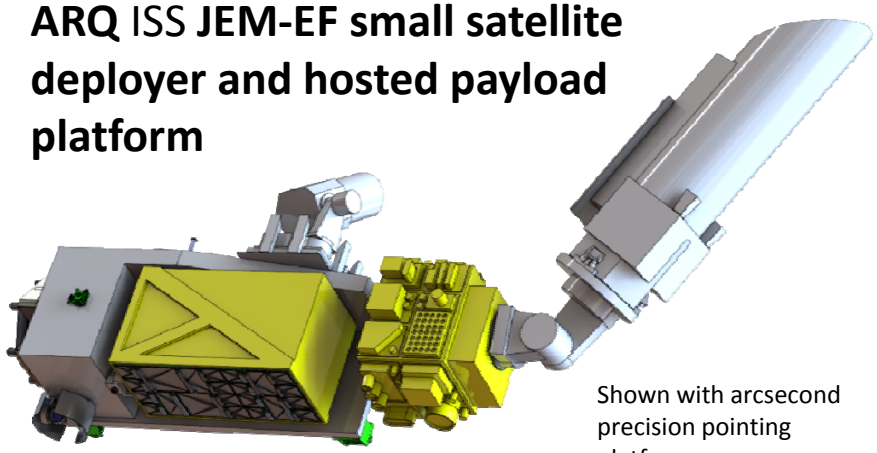
- 10620Treena Street, Suite 230, San Diego, California, 92131
- ALS provides pico, nano, micro, mini and small Auxiliary Payloads rideshare mechanical systems, avionics and integration services on Evolved Expendable Launch Vehicle, Medium Launch Vehicles and Small Launch Vehicles.
- SAM reg, DUNS 962127804, CAGE 64BK4, incorporated 2010
- NASA, OSL and Commercial contracts completed and in process. June 2016 backlog over $5M.

Product Information:

- Aquila Multi-Manifest System supports both Multiple Auxiliary Payload and Dual Payload Configurations.
- All components compatible with ESPA, RUAG Separation Systems, Spacecraft Separation Systems and Cubesat Dispensers.
- Aquila Standard Adapter rated at 6,364 kg TRL 9
- Aquila Deck Adapter rated at 6,364 kg TRL 8
- Aquila Deck rated for 1000 kg. TRL 8
- APSU up to 32 individual separation events TRL 8
- APSU integrated battery flown on Missile systems
- ALS Mission Integration Services includes mission integration management, mission integration engineering, launch site engineering, range safety engineering, and launch site integration

bSpace Corp.

ARQ ISS **JEM-EF small satellite deployer and hosted payload platform**



Shown with arcsecond precision pointing platform

Heritage / Schedule Information:

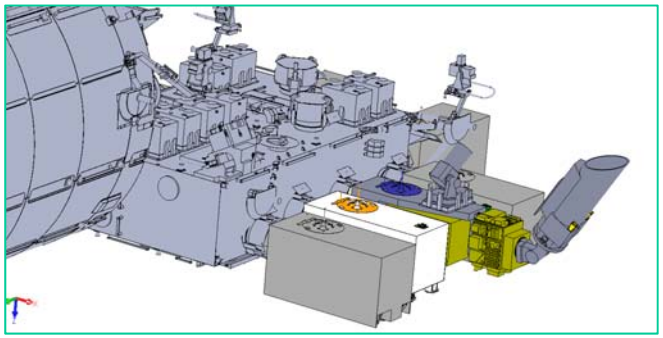
- *Experienced team of space hardware engineers and flight program managers with shuttle, station, & solar system heritage*
- *Now taking satellite & hosted payload customers*
- *First flight spring 2019*

Company Information:

- *POC Jason Budinoff*
- *208-559-7803 cell/txt*
- *jason@bsapcelaunch.com*
- *www.bsapcelaunch.com*
- *500 Yale Ave N, Suite 105, Seattle, WA 98103,*
- *CAGE Code 7PQ45*
- *DUNS 080244843*

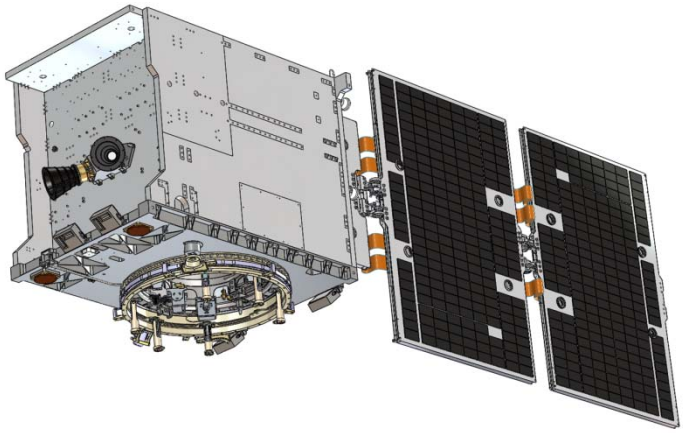
Product Information:

- *Affordable, Predictable, Available service with a minimum of 2 flights per year to ISS*
- *Deploy Satellites from 1U through ESPA including unique sizes and propulsion systems*



ARQ shown on JEM-EF

Surrey Satellite Technology US



Orbital Test Bed - X

Heritage / Schedule Information:

- *ESPA Grande 300kg class LEO spacecraft*
- *6 to be launched on falcon heavy for COSMIC-2/FORMOSAT-7 constellation*
- *Same dual redundant architecture used in all LEO satellites*

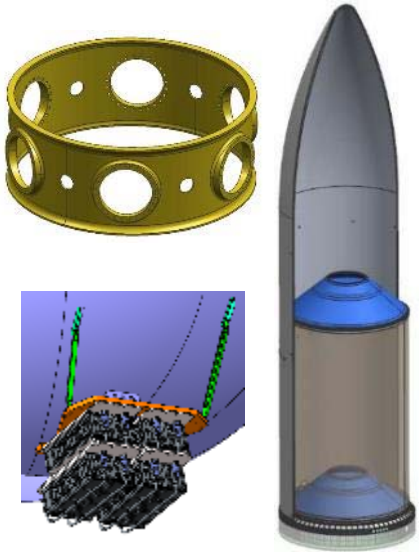
Company Information:

- *Will Thompson, wthompson@sst-us.com, 720-255-0909*
- *www.sst-us.com*
- *Surrey US established in 2008 in Englewood, CO. Facilities include offices, electronics lab, clean room for satellite integration and a Mission Operations Center, MOC. Capabilities include engineering and satellite subsystems.*

Product Information:

- *payload mass capacity ~100kg*
- *payload power ~300w OAP*
- *3 axis control, ideal for remote sensing applications*
- *7 year life*
- *1 Gbps downlink capacity*
- *launch 2021/22 Falcon SSO different LTDNs available, 500-600km*

UNITED LAUNCH ALLIANCE



Heritage / Schedule Information:

- *Averaging 1 launch per month since Dec 2006*
  - ***100%** mission success*
  - ***126** successful launches as of March 2018*
- ***11** ULA rideshare launches have delivered **73** small sats to space (including 67 CubeSats)*
  - *8 additional rideshare missions manifested*

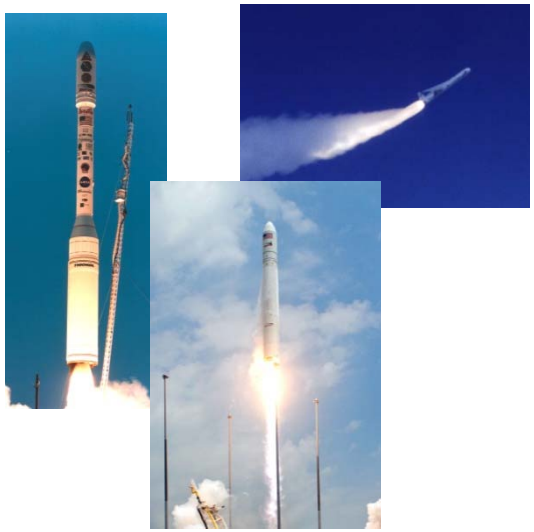
Company Information:

- Dan Adams, (303) 269-6520
  Daniel.D.Adams@ulalaunch.com
  www.ulalaunch.com
- Joint-venture; Boeing and Lockheed Martin; Est. Dec. 2006
- 3,000 employees across 6 sites
- Launch service contracts for USAF, NASA, NRO, and commercial customers

Product Information:

- *Launch Services*
  - *Atlas V, Delta II, Delta IV, Vulcan Centaur*
  - *Only service provider for all orbits: GEO, GTO, MEO, LEO, Interplanetary*
- *Rideshare Capabilities; 1kg to >5,000kg*
  - *Aft Bulkhead Carrier*
  - *ESPA, ESPA Grande*
  - *AQUILA*
  - *Dual Manifest*

Commercial Launch Options



Heritage / Schedule Information:

- *Pegasus has 43 launches, with the last 29 completely successful. It has one mission on manifest and has recently announced a partnership with Stratolaunch. Pegasus is available now for launches in 24 months.*
- *Minotaur-C has 10 launches with its last mission successful . It is available now for launches in 24 months.*
- *Antares has 7 launches, with the last two completely successful. There are 6 missions on manifest. It is available now for launches in 24 months.*

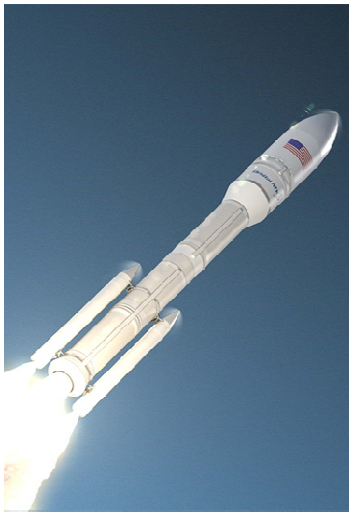
Company Information:

- *Warren Frick, 703-948-8192, warren.frick@orbitalatk.com*
- *OrbitalATK.com*
- *Orbital ATK is based out of Dulles, Virginia and has major operating locations in 17 states. It has more than 13,000 employees and was established in 2015 in the merger of Orbital Sciences Corporation and Alliant Techsystems. Orbital ATK's commercial launch vehicles are all available through the NLS-II contract as well as commercially.*

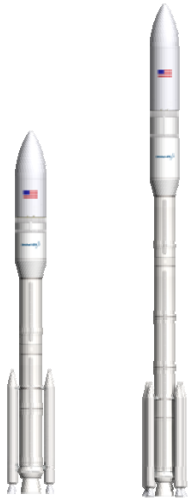
Product Information:

- *Pegasus has a performance up to 1000 lbs, and inclination range of 0 to very highly retrograde due to its mobile, air-launched nature*
- *Minotaur-C has a performance up to 3500 lbs and inclination range of 28.5 degrees to SSO*
- *Antares has a performance range from 1700 lbs to over 17000 lbs and inclination range of 38 to 60+ degrees and SSO.*

Orbital ATK: Future Launch Options



–Antares
–(for Comparison)



Heritage / Schedule Information:

- *Orbital ATK's Next Generation Launcher (NGL) is currently under development for the USAF EELV Program.*
- *NGL uses direct and derivative heritage parts from Orbital ATK's small and medium launch vehicles and the shuttle program as well as outside vendors.*
- *First Launch from Florida is planned for 2021*

Company Information:

- *John Steinmeyer, 949-344-4679, john.steinmeyer@orbitalatk.com*
- *OrbitalATK.com*
- *Orbital ATK is based out of Dulles, Virginia and has major operating locations in 17 states. It has more than 13,000 employees and was established in 2015 in the merger of Orbital Sciences Corporation and Alliant Techsystems. NGL will be available through USAF and NASA NLS-II contracts as well as commercially.*

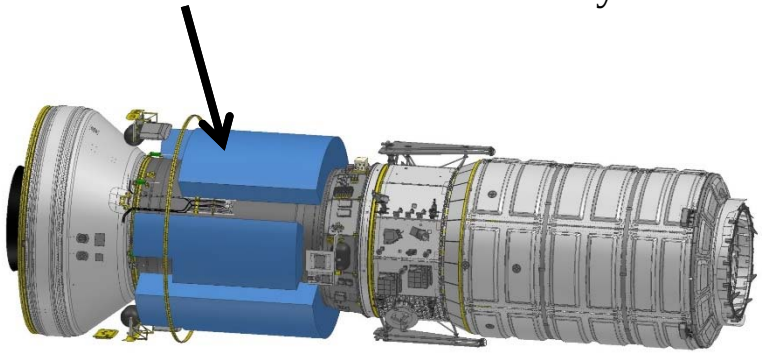
Product Information:

- *The smallest NGL configuration has performance over 18,000 lbs to 833 km SSO. The largest, over 47,000 lbs to that LEO orbit, and 17,000 lbs to GTO.*
- *The rocket is modular, and performance can be increased in segments by adding boosters and enlarging the core of the vehicle.*
- *Launch sites in Florida and California are planned to cover high and low inclination missions.*
- *Fairing size over 5m in diameter is planned to handle all payload sizes.*

Orbital ATK: Antares Secondary P/L

–ISS Resupply Mission

–Volume Available for Secondary



Heritage / Schedule Information:

- *Orbital ATK Commercial Resupply Missions launch several times each year. Four flights have successfully been completed and six more planned*
- *Orbit is ~185 x 300 km, Inclined 51.6 Degrees*
- *Current Launch Schedule:*
  - *1Q 2018, 3Q 2018, 2Q 2019*
- *Orbital ATK has been chosen for CRS-2 contract, with Launch Schedule mostly to be determined*
  - *3Q 2019, 1Q 2020, 2Q 2020*

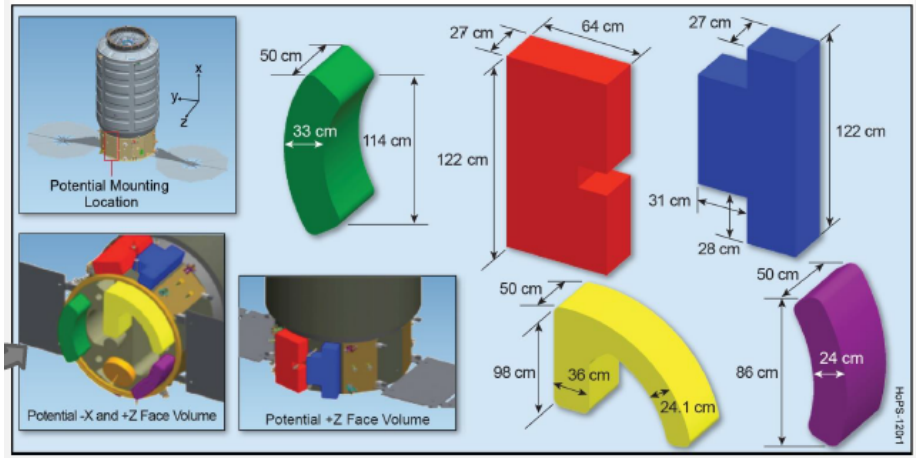
Company Information:

- *Warren Frick, 703-948-8192, warren.frick@orbitalatk.com*
- *OrbitalATK.com*
- *Orbital ATK is based out of Dulles, Virginia and has major operating locations in 17 states. It has more than 13,000 employees and was established in 2015 in the merger of Alliant Techsystems and Orbital Sciences Corporation. Orbital ATK's launch services are available through the NLS-II contract as well as commercially.*

Product Information:

- *The secondary capability on the Antares ISS Resupply Missions is mass-flexible. Each Mission has a mass commitment for ISS cargo, however the ISS program can re-allocate secondary mass as ISS cargo mass*
- *Secondary environments match Antares payload launch environments depending on mounting scheme used*
- *Orbital ATK can offer mass commercially if excess mass on the mission exists after fulfilling its ISS mass commitments.*

Orbital ATK: Cygnus Payloads



Heritage / Schedule Information:

- *Orbital ATK Commercial Resupply Services (CRS) missions launch several times each year. Six flights have successfully been completed and three more are planned under the CRS-1 contract*
- *Cygnus orbital nominal altitude is ~250 km, inclined 51.6, but altitude can be raised to ~400 km after ISS separation*
- *Current Launch Schedule:*
  - ***1**Q 2018, 3Q 2018, 2Q 2019*
- *Orbital ATK has been chosen for CRS-2 contract, with Launch Schedule mostly to be determined*
  - *3Q 2019, 1Q 2020, 2Q 2020*

Company Information:

- *Derek Hodgins, 703-406-6590, derek.Hodgins@orbitalatk.com*
- *OrbitalATK.com*
- *Orbital ATK is based out of Dulles, Virginia and has major operating locations in 17 states. It has more than 12,000 employees and was established in 2015 in the merger of Alliant Techsystems and Orbital Sciences Corporation. Orbital ATK's satellites are available through the GSFC RSDO contract and commercially.*

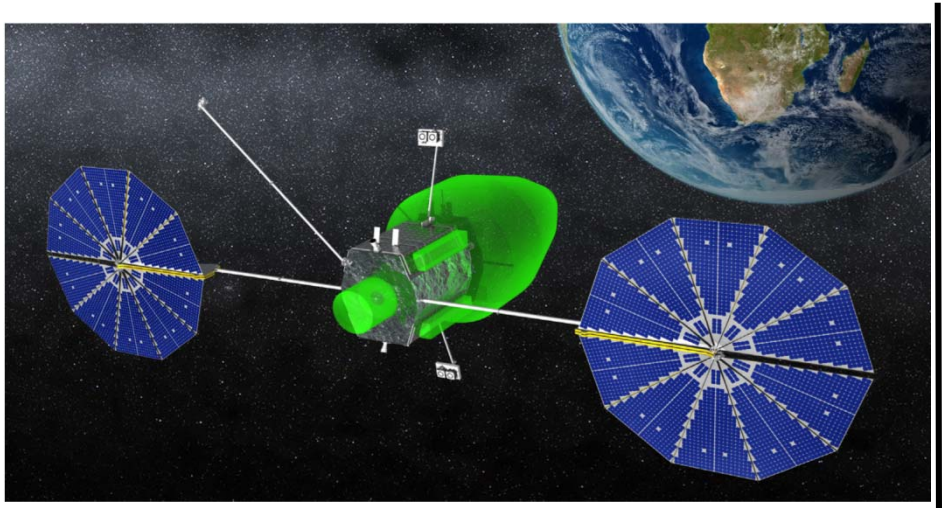
Product Information:

- *The total secondary mass capability on Cygnus for ISS Resupply Missions is mass-flexible depending on the mass of cargo for ISS resupply service. Each Mission has a mass commitment for ISS cargo, up to 3,500kg, however the ISS program can re-allocate unused mass*
- *Ride Share locations are primarily located on the Service Module, per figure above, or can be potentially accommodated on the Pressurized Cargo Module*

Orbital ATK: Rideshare Opportunities

- Antares (with Cygnus):
  - CubeSat Deployers
  - Payloads Smaller than ESPA (longer but skinnier), mass flexible
  - Orbit: 185 x 300 km, 51.6^0
  - Antares without Cygnus:
    - ESPA Payloads - shorter than standard ESPA P/L (due to 3.9 M faring v. 4.3 M diameter)
- Cygnus:
  - CubeSat Deployers
  - Payloads less than 50 kg, custom shapes – see quad chart
  - ISS Orbit: ~400 km, 51.6^0 (post ISS: slightly above/below & different inclination)
- Launch Opportunities
  - Antares and Cygnus will launch several times a year through 2022
  - 1Q and 3Q launches in 2018

Orbital ATK: GEO Hosted Payload



Heritage / Schedule Information:

- *Orbital ATK Mission Extension Vehicle (MEV) is planned for first flight in late 2018*
- *Orbit is GEO*
- *Lifetime is 15 years*
- *Mission: Rendezvous, Proximity Operations and Docking for commercial satellite servicing including:*
  - *Station keeping*
  - *Inclination reductions*
  - *Graveyarding*
  - *Flyby Inspections*

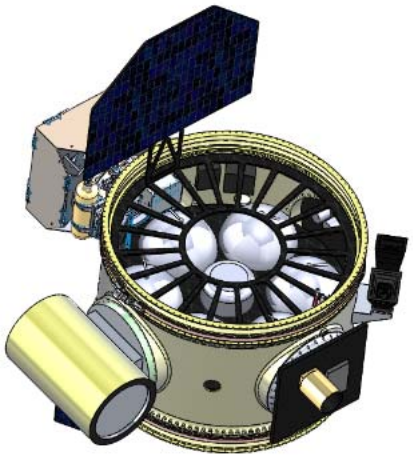
Company Information:

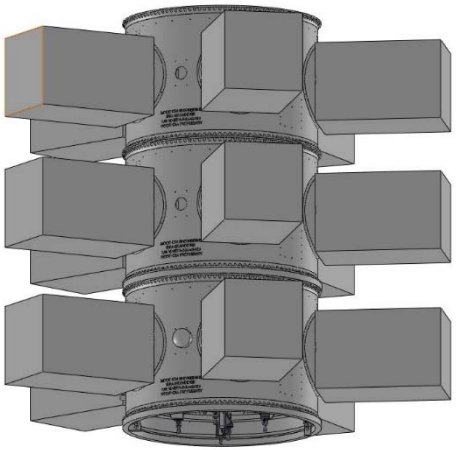
- *Joe Anderson, 703-948-8347, joseph.anderson@orbitalatk.com*
- *OrbitalATK.com*
- *Orbital ATK is based out of Dulles, Virginia and has major operating locations in 17 states. It has more than 12,000 employees and was established in 2015 in the merger of Alliant Techsystems and Orbital Sciences Corporation. The MEV is available through commercial contracting.*

Product Information:

- *Hosting information*
  - *Hosted payload capacity is up to 1000 kg*
  - *Hosted payload power is 2 kW*
  - *Various volumes available on Nadir, aft, or side panels*
  - *Ride-share to Geo with or without separation/deployment*
  - *HP can temporarily be the primary mission*
- *More detailed information on the MEV is available at:*
  - *http://www.orbitalatk.com/space-systems/human-space-advanced-systems/mission-extension-services/default.aspx*

Moog - OMV





Heritage / Schedule Information:

- *OMV based on flight heritage ESPA Ring (example LCROSS mission)*
- *All other elements (avionics, propulsion, power, comm, GNC) are TRL 9 and many sourced from within Moog reducing cost and schedule*
- *Modular and scalable architecture to meet mission needs from short life commercial LEO tug to 5 year Class C operational mission beyond Earth Orbit*
- *Targeting first flight to LEO in late 2018*

Company Information:

- *Christopher Loghry, cloghry@moog.com*
- *720-289-7041 or 818-734-3445*
- *www.moog.com/space*

- *Moog is a $2.5B company with 11,000 employees in locations in 27 countries*
- *Moog is headquartered in East Aurora, NY and has Space locations all over the US*
- *Moog was founded in 1951 and has supported nearly every single major space program including Apollo, Space Shuttle, EELV, and ISS*

Product Information:

- *Orbital Maneuvering Vehicle (OMV) leverages Rideshare for low-cost access to space*
- *OMV provides standalone power, propulsion, avionics, and communication as Free Flyer*
- *OMV can be used to achieve optimal orbits of spacecraft or other payloads including Beyond Earth Orbit*
- *OMV can also act as a hosted payload platform for payloads and be part of a system architecture (e.g. Comm Relay in Hub & Spoke system)*