Efforts to Increase Rideshare Initiatives: Current Technical Challenges and Initiatives Underway

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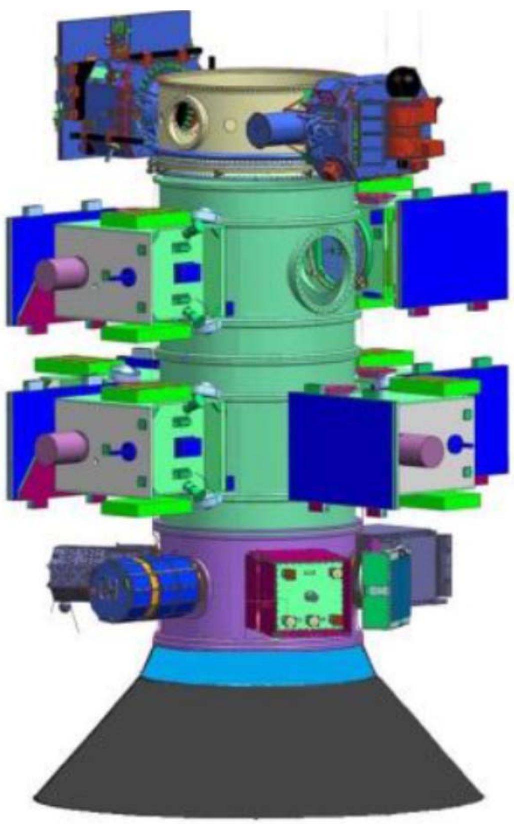
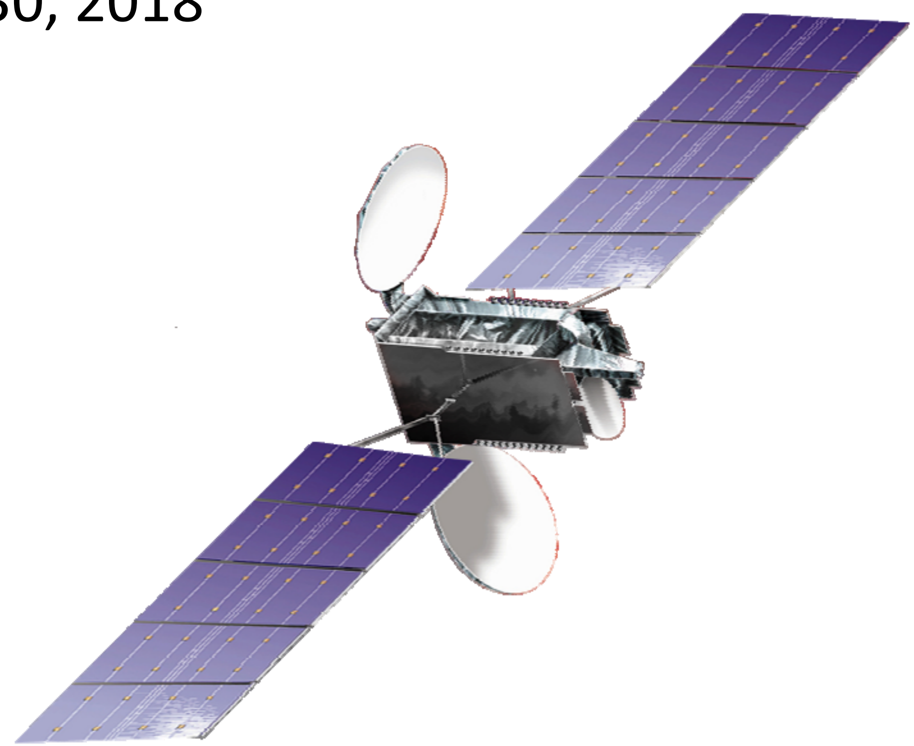
May 30, 2018



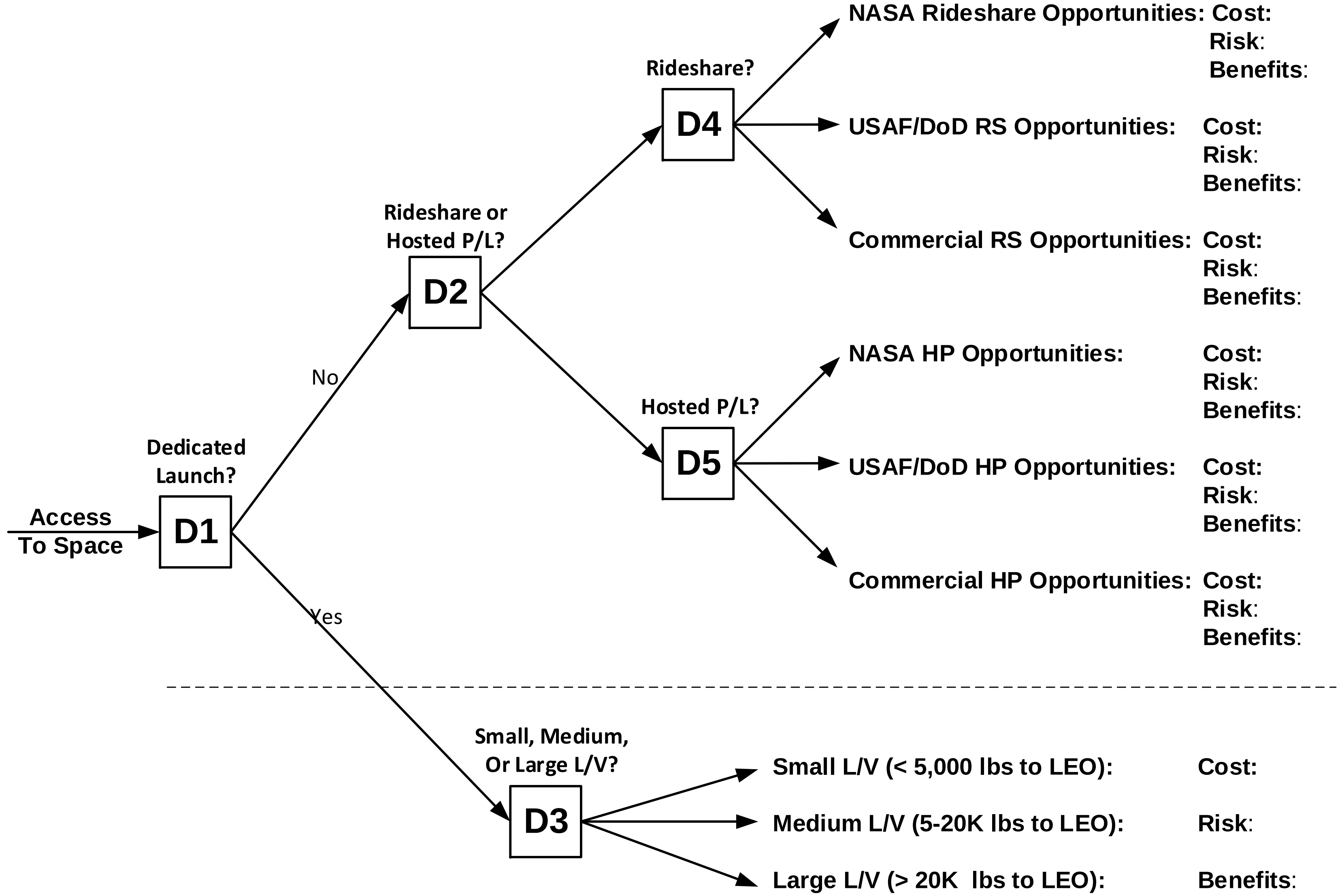
Air Force Rideshare (STP-2)



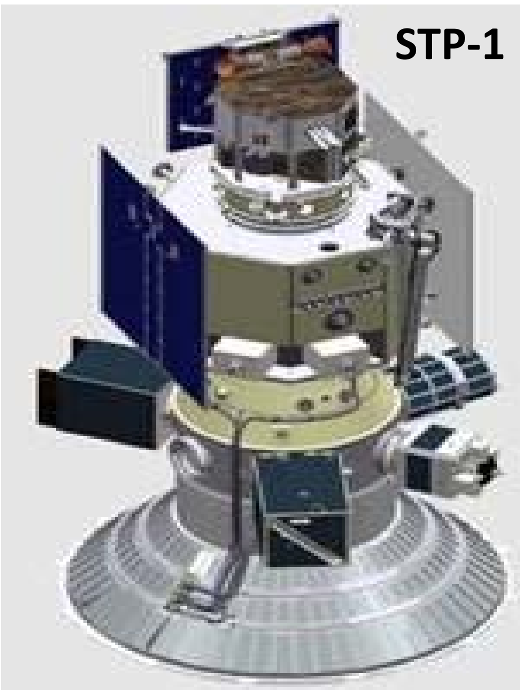
Commercial HP (SES/GOLD)

Access to Space (ATS) Options

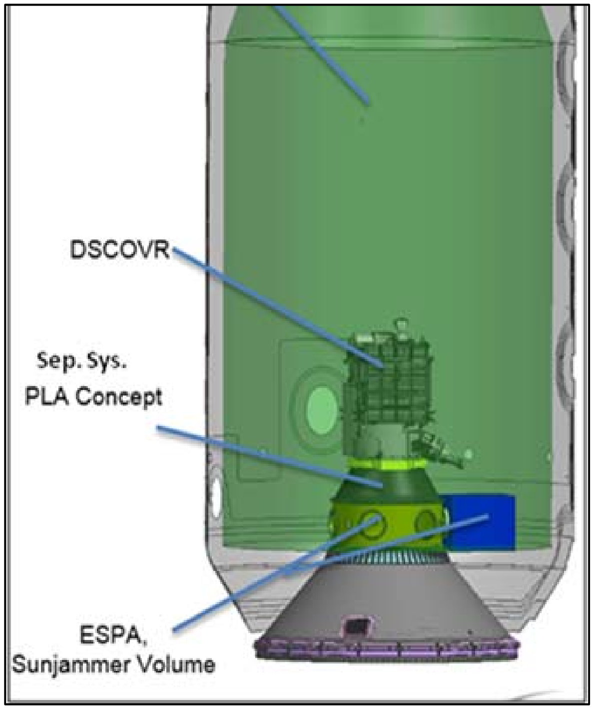
Access to Space (ATS) Decision Tree



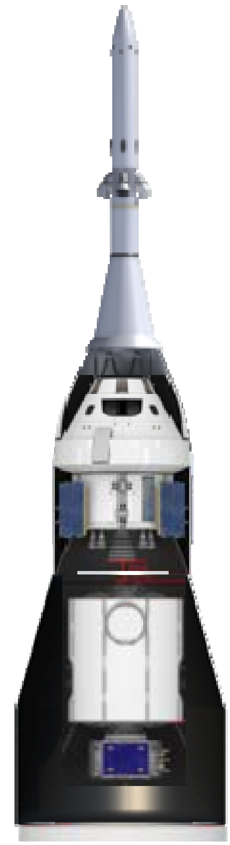
Government & Commercial Rideshare



Air Force / DoD



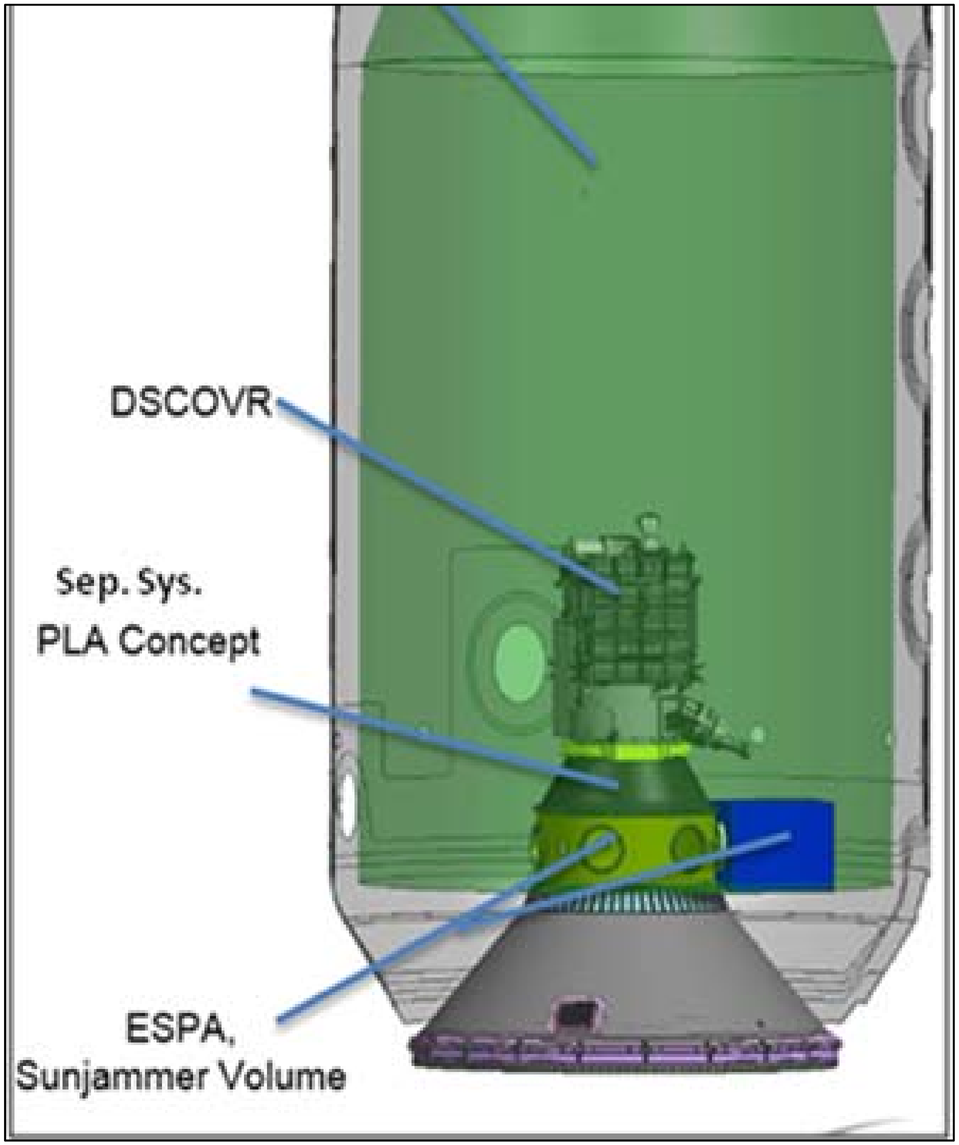
NASA / EELV



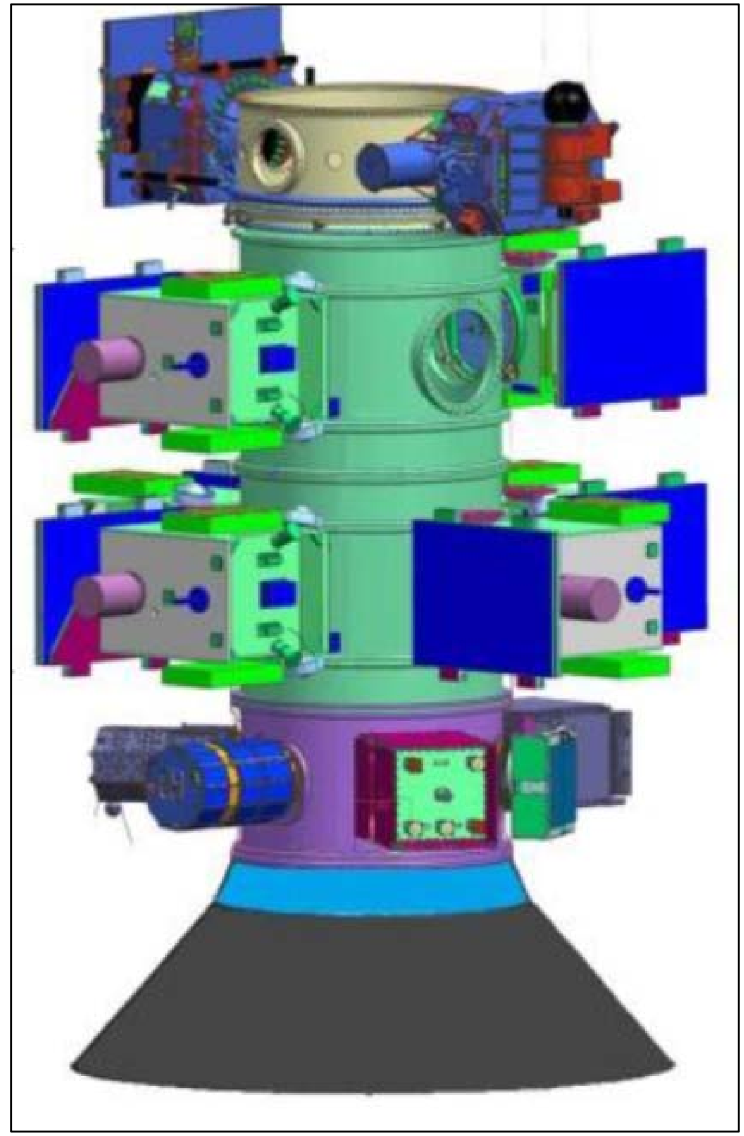
NASA / SLS

Commercial

Government Rideshare: Past, Present & Future



Past Missions (DSCOVR)



Future Multi-missions (STP-2)

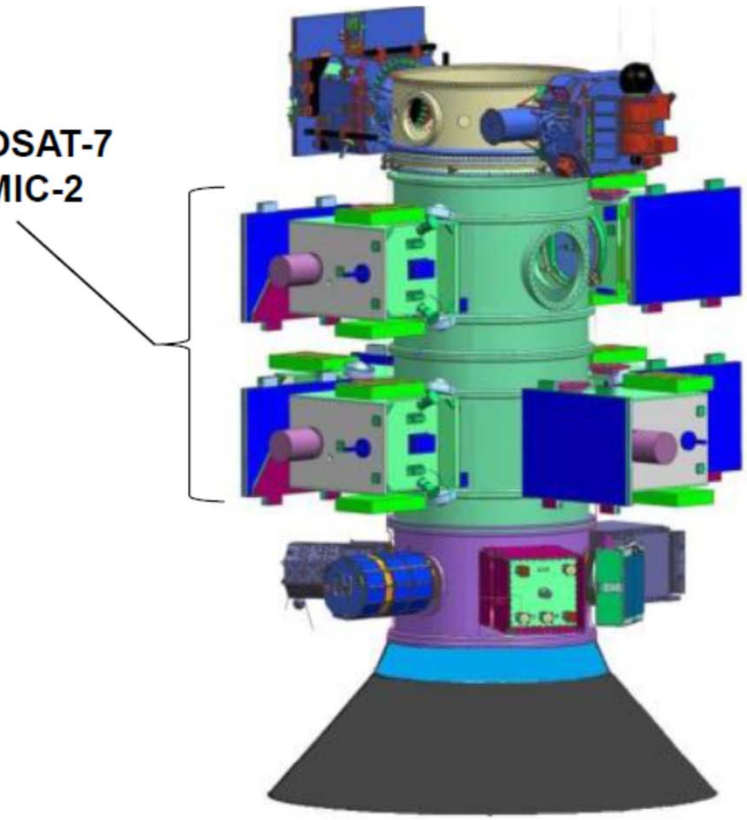
Government HP & Rideshare on STP-2: OTB-1 & C2A

(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**

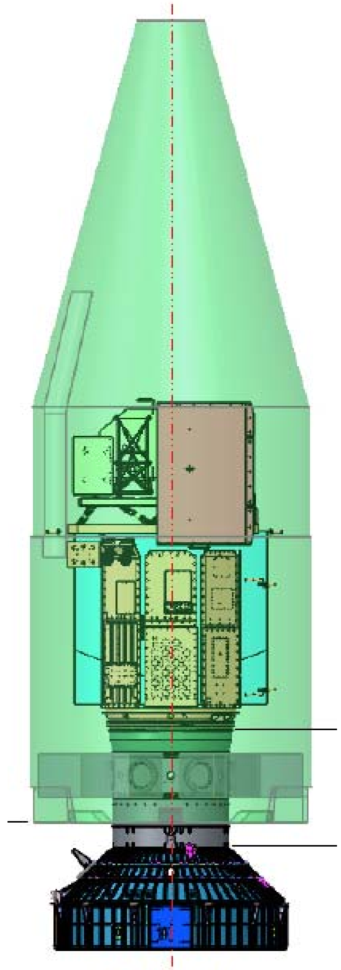


Concept of Falcon Heavy from Launch Comlex-39A CCAFS

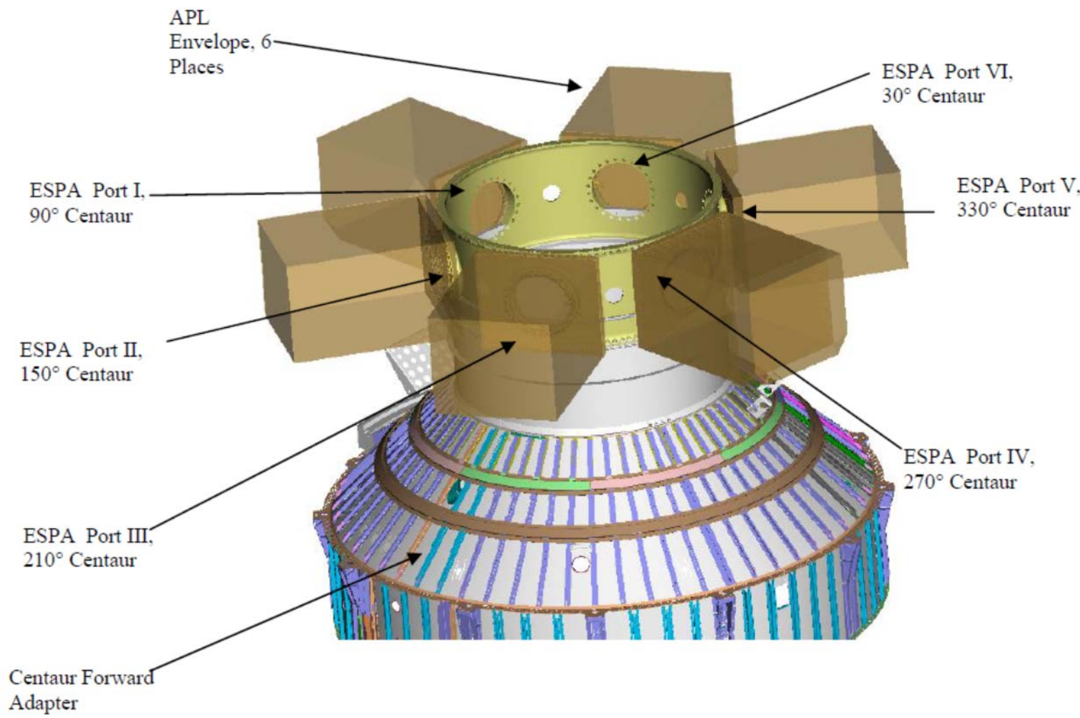
STP-2: multiple payloads, multiple orbits

- 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

Government Rideshare on Landsat-9

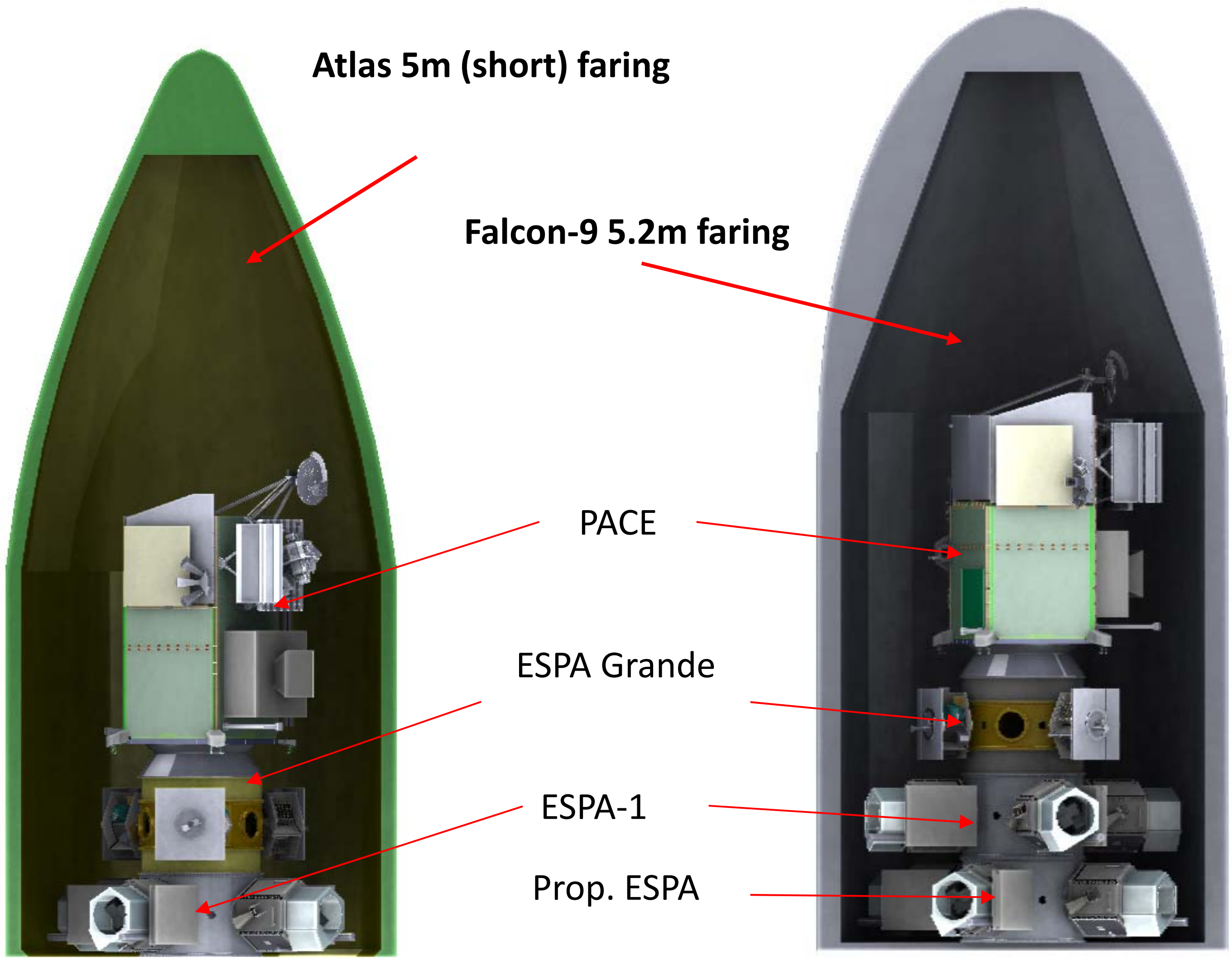


Landsat 9 with an ESPA Ring



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

A Notional Government Rideshare



NASA & Air Force Rideshare Opportunities

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

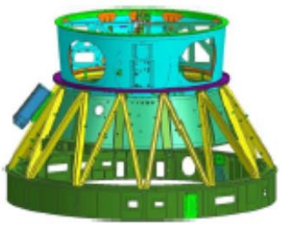
Key: **Air Force Missions (bold)** & NASA (non-bold)

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)

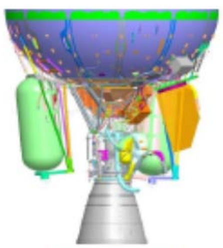
AL - Adaptive Launch Solutions
ET - Electron
NR - NanoRacks
OA - OrbitalATK
SF - SpaceFlight
TS - TriSept
TV - Tyvcak

Rideshare Adaptor Options:



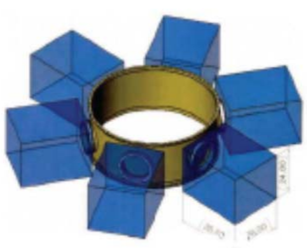
P-POD

10 kg



ABC

80 kg



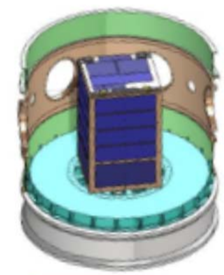
ESPA

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

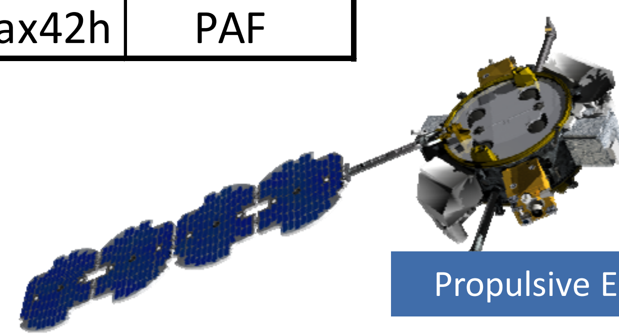
ESPA Grande

~350 kg



A-Deck / Aquila

~1,000 kg



Propulsive ESPA

~1,500 kg

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 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

Rideshare Spacecraft RFI Overview

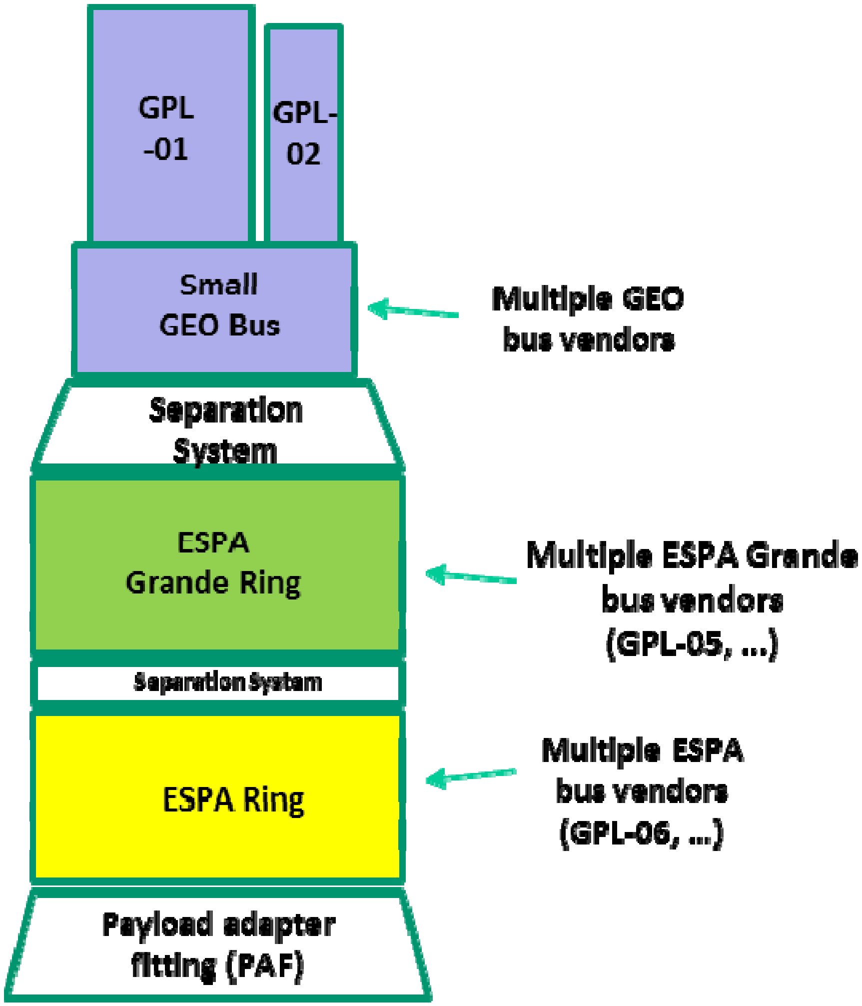
1. Rideshare Spacecraft RFI Stakeholders:
   a) Mission Design Lab (MDL) – to use the results in future design studies
   b) Next Gen Earth Relay (NGER) – to use the results in concept studies
   c) Project #1-3 – Internal Project's in the Concept Development phase
   d) Rapid S/C Development Office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

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

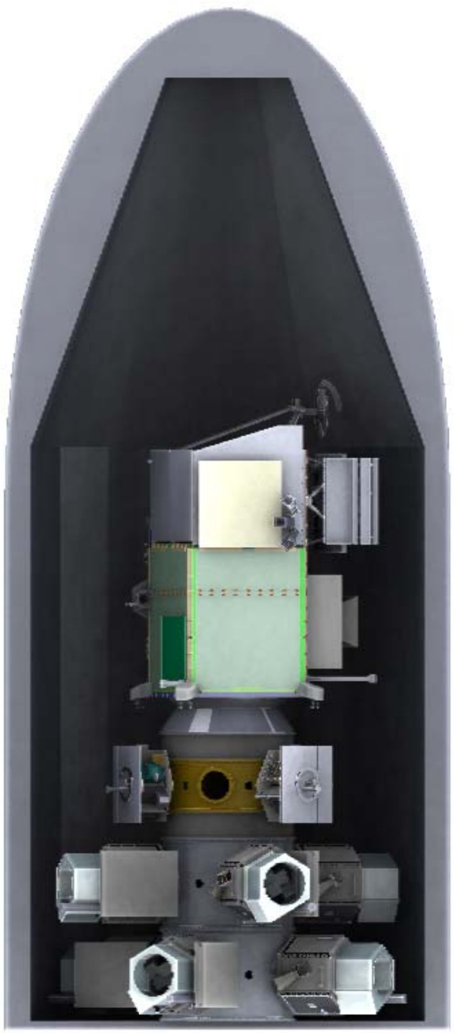
3. Elements of the Rideshare S/C RFI:
   a) Rideshare Document Review
   b) Survey Industry's Rideshare Spacecraft Capabilities
   c) Survey Industry's Science Instrument Accommodation Capabilities
   d) Survey Industry's Communication P/L Accommodation Capabilities

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

RFI #3: Potential Rideshare Configuration of Science Instruments



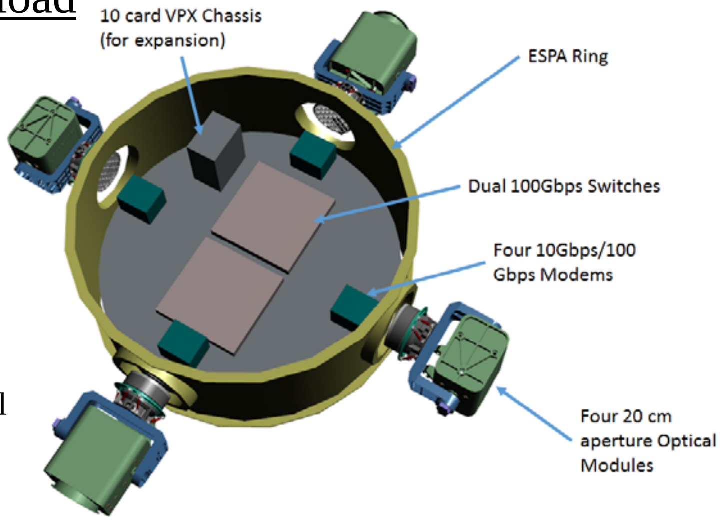
MDL Rideshare Example

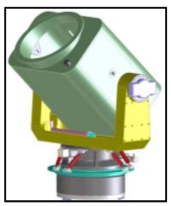


PACE Rideshare Example

RFI #4: Next Generation Earth Relay Concept

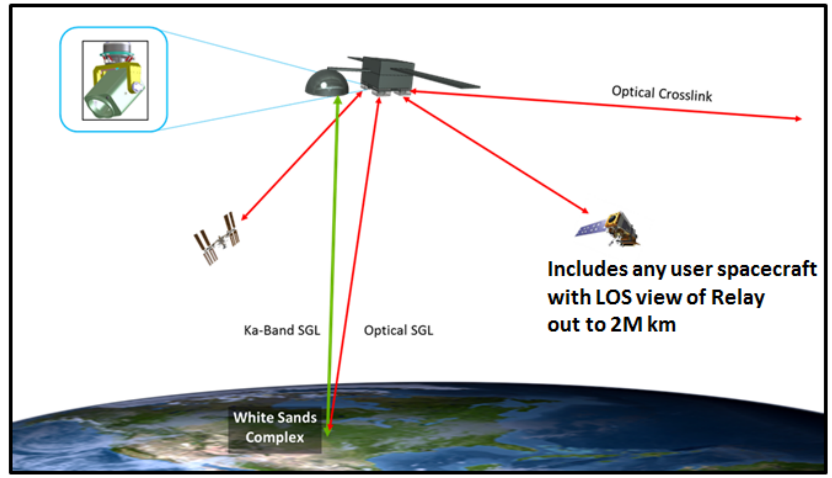
Basic Payload





20 cm Optical Module

Notional view of Relay Node operations



Payload Characteristics

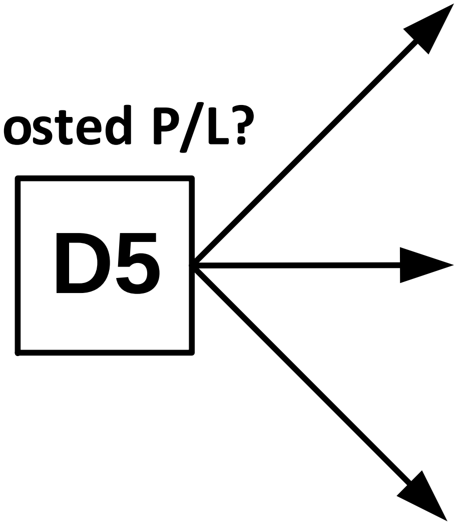
	Mass/ Unit, kg	Number Units	Total Mass, kg	Power, W	Total Power, W	Dimensions per Unit, cm
Space Switching Unit (SSU)	9	2	18	342*	342	4.3 X 44.0 X 44.47
Optical Module (OM)	41.3	4	165			71.2 X 55.9 X 33.1
Modem & Controller	9	4	36	157	628	17.8 X 12.7 X 15***
Harness plus miscellaneous hardware (estimate)	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

Hosted Payload ATS Options

Hosted P/L?



NASA HP Opportunities:

Cost:
Risk:
Benefits:

USAF/DoD HP Opportunities:

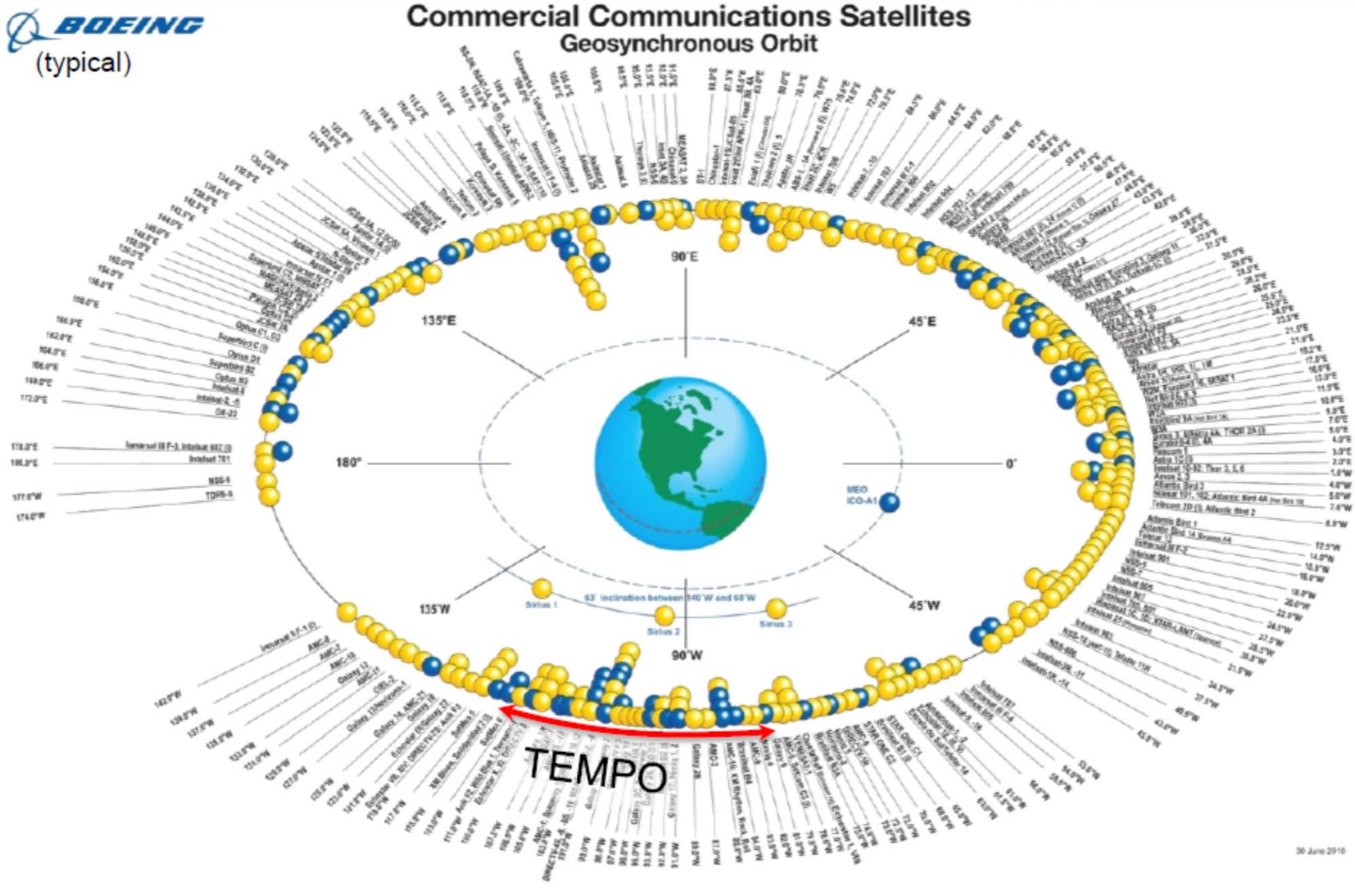
Cost:
Risk:
Benefits:

Commercial HP Opportunities:

Cost:
Risk:
Benefits:

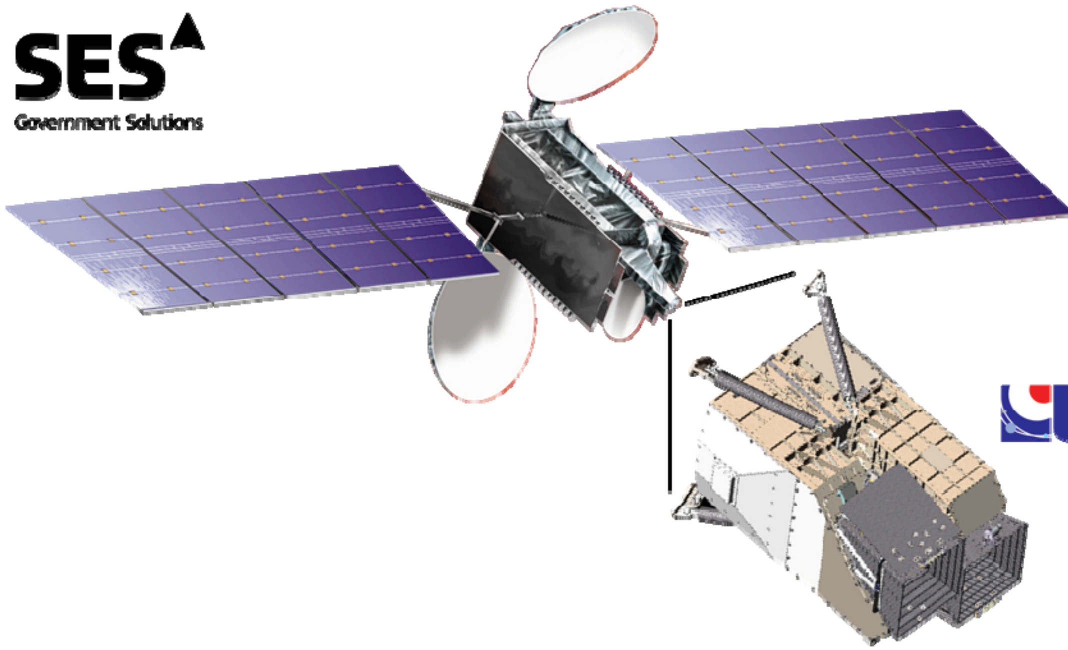
Capturing the cost, risk, and benefits of hosted payload implementation options

Geostationary Orbit Opportunities



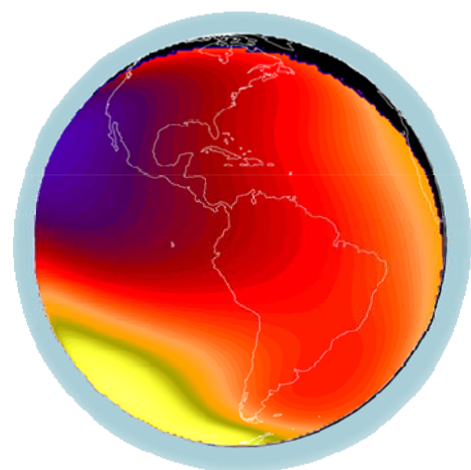
GOLD: NASA HP on a Commercial Bus

SES Government Solutions

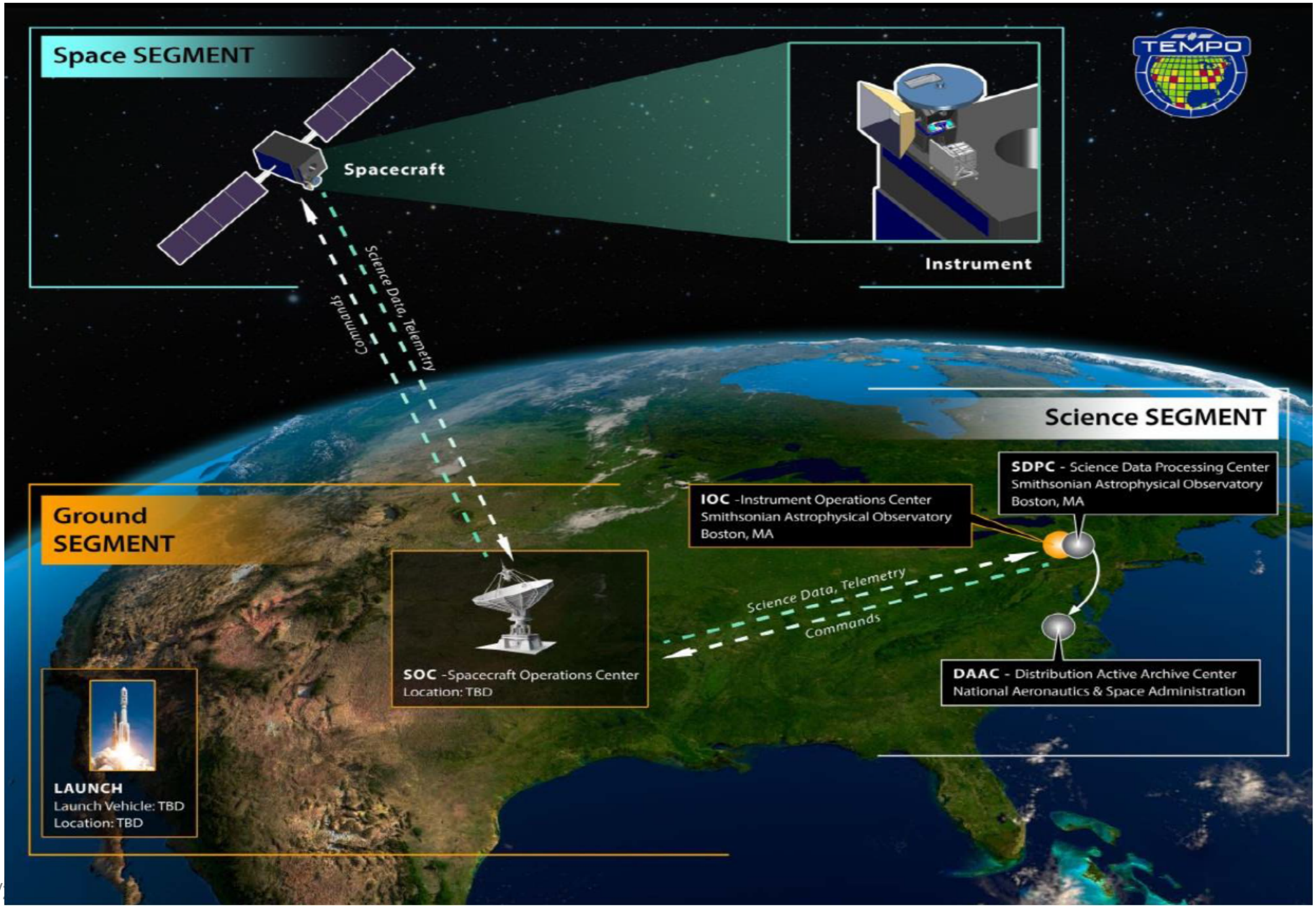


LASP

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



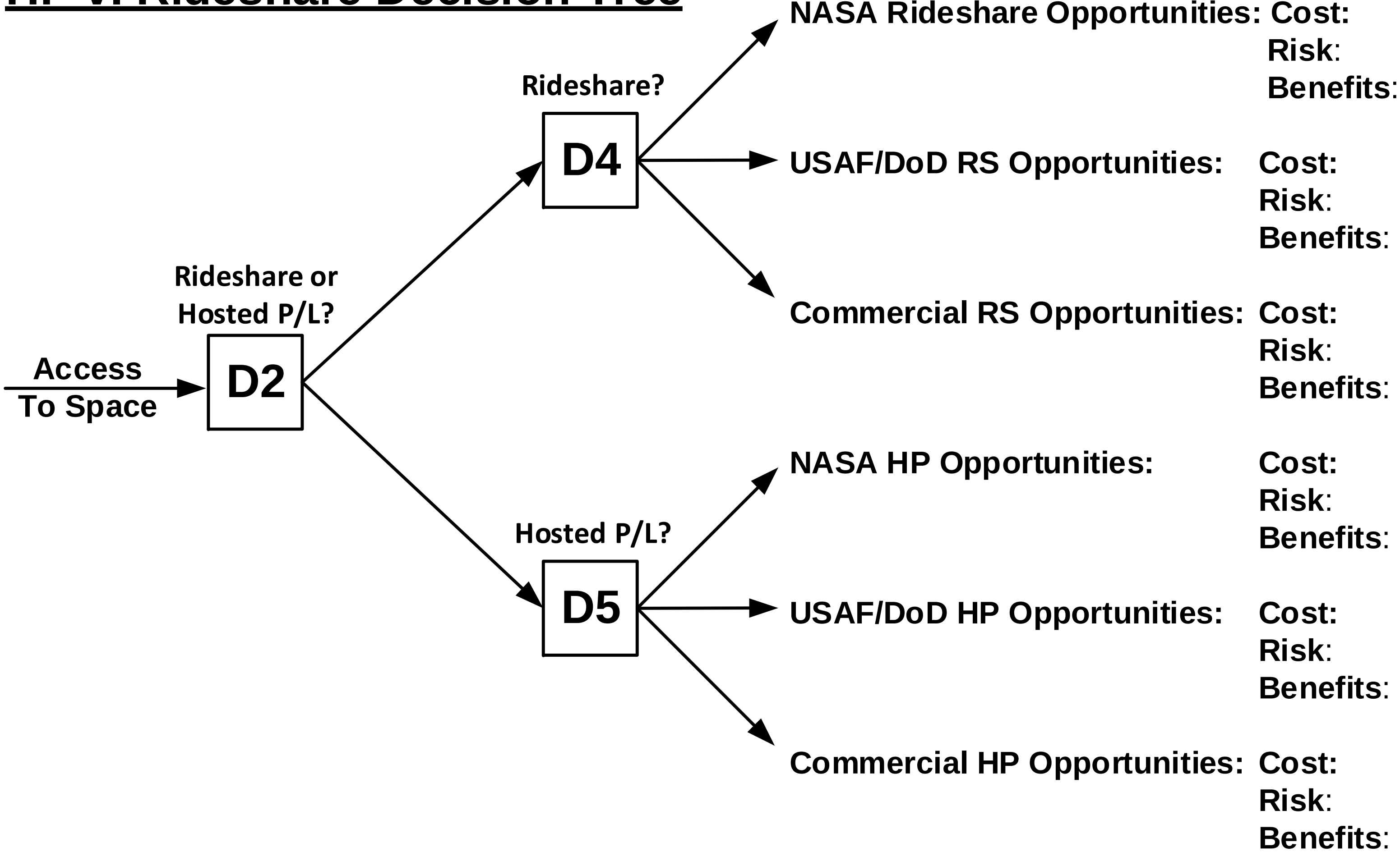
TEMPO: NASA HP on a Commercial Bus (w/HoPS)



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

Rideshare & Hosted Payload Options

HP v. Rideshare Decision Tree

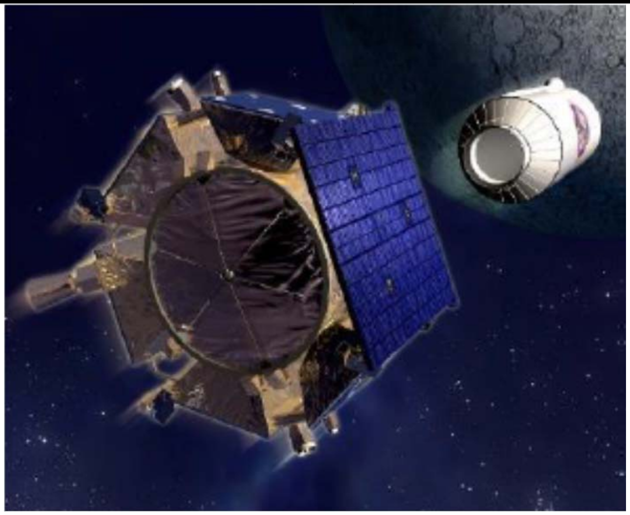


Capturing the cost, risk, and benefits of the rideshare & hosted payload implementation options

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

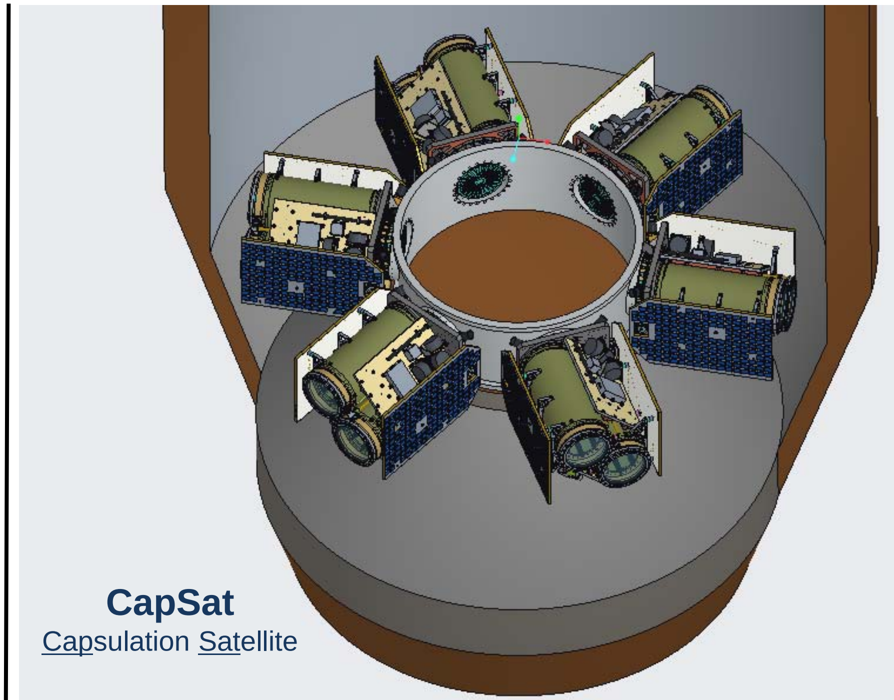
OG2-2

CapSat-Capsulation Satellite

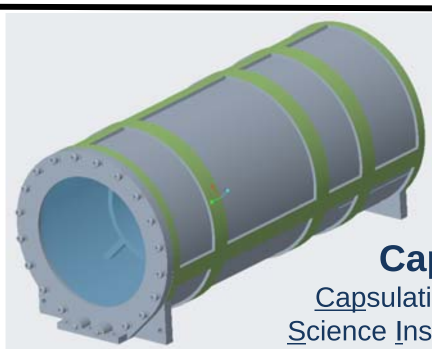
ESPA Class Spacecraft taking advantage of unused launch vehicle mass to orbit

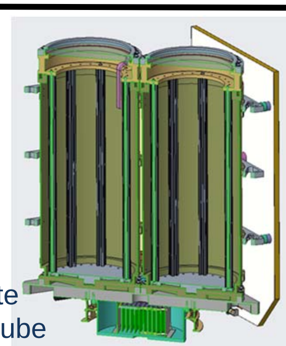
- **Mission Description:**

- Capsulation Satellite or CapSat is a low cost, 3 axis stabilized, modularized and standardized spacecraft, based on using pressurized volumes which allow ruggedized COTS hardware to be flown reliably in space in a manner similar to the NASA Hitchhiker-Get Away Special or GAS Can Program.
- The Capsulation Satellite Science Instrument Tube or CapSIT is a standardized interface allowing independent development of multiple instruments/technology demonstrations that can be integrated quickly into the bus.
- CapSIT is fully qualified for flight independent of the CapSat spacecraft and maybe fully pressurized or not as desired.



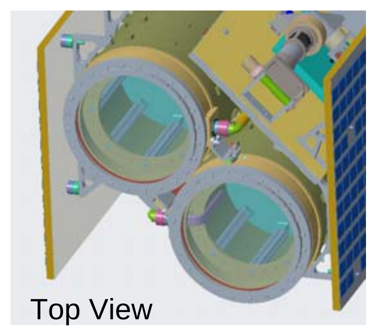
CapSat
Capsulation Satellite



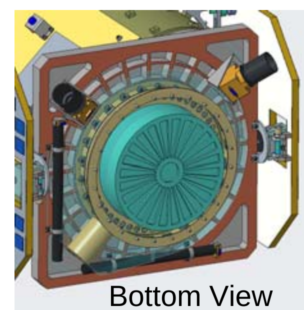


CapSIT
Capsulation Satellite
Science Instrument Tube

Cutaway view

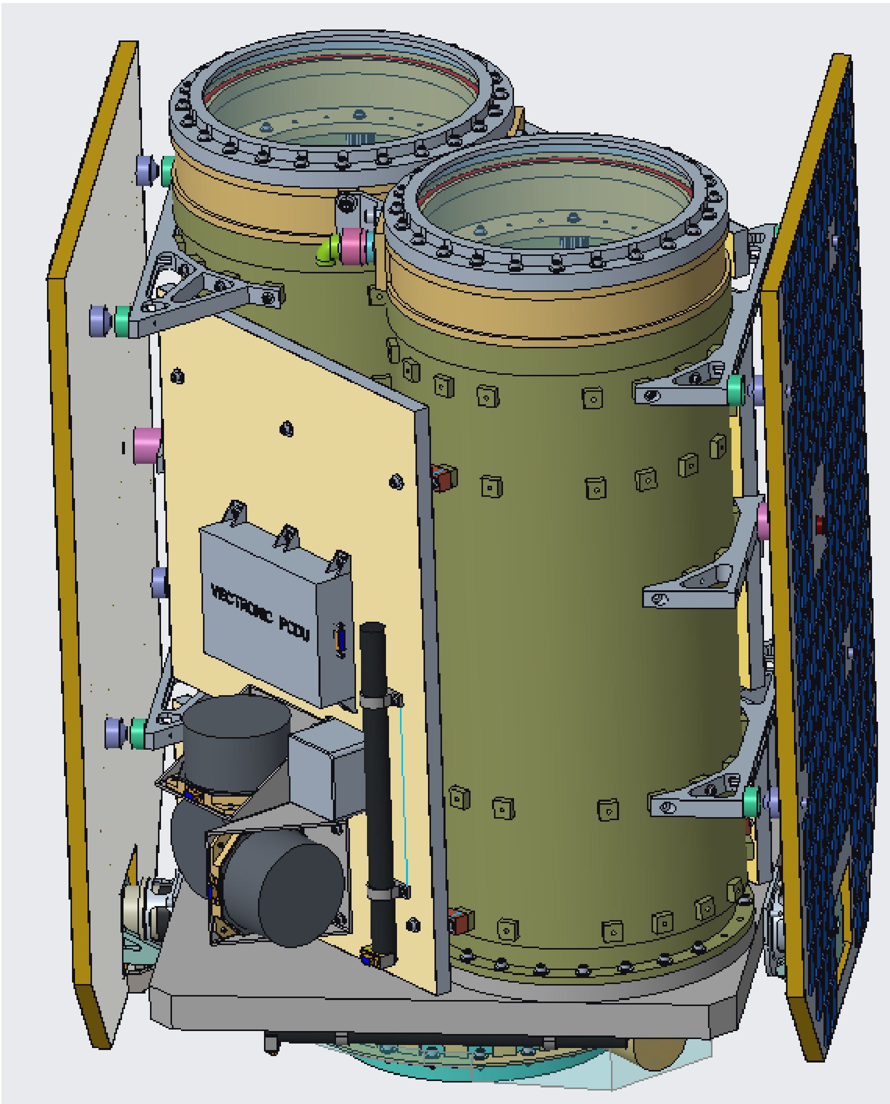


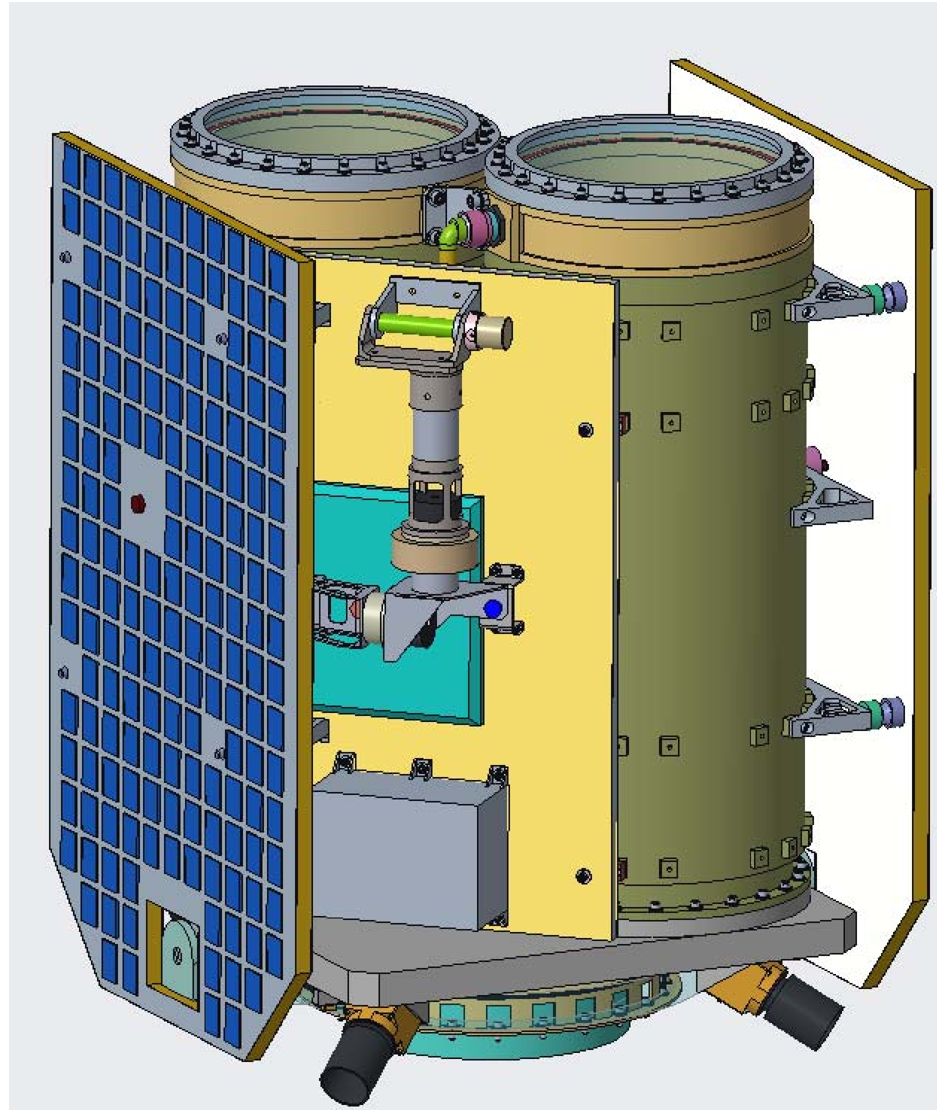
Top View



Bottom View

Capsat isometric stowed views



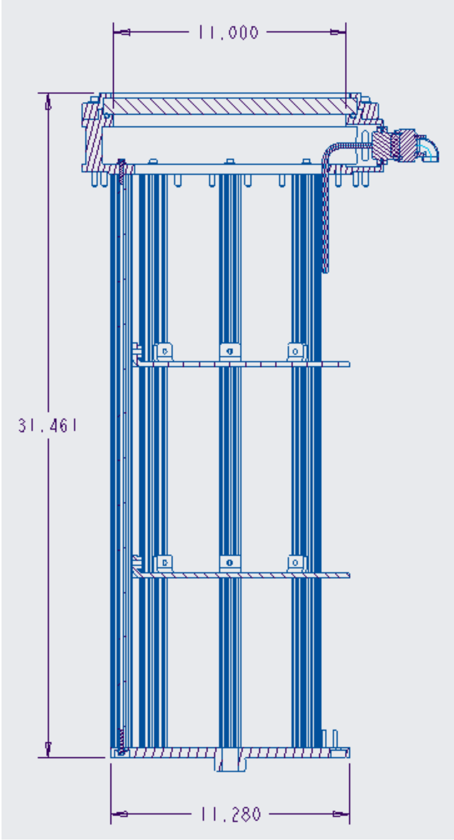


Component Panel A View

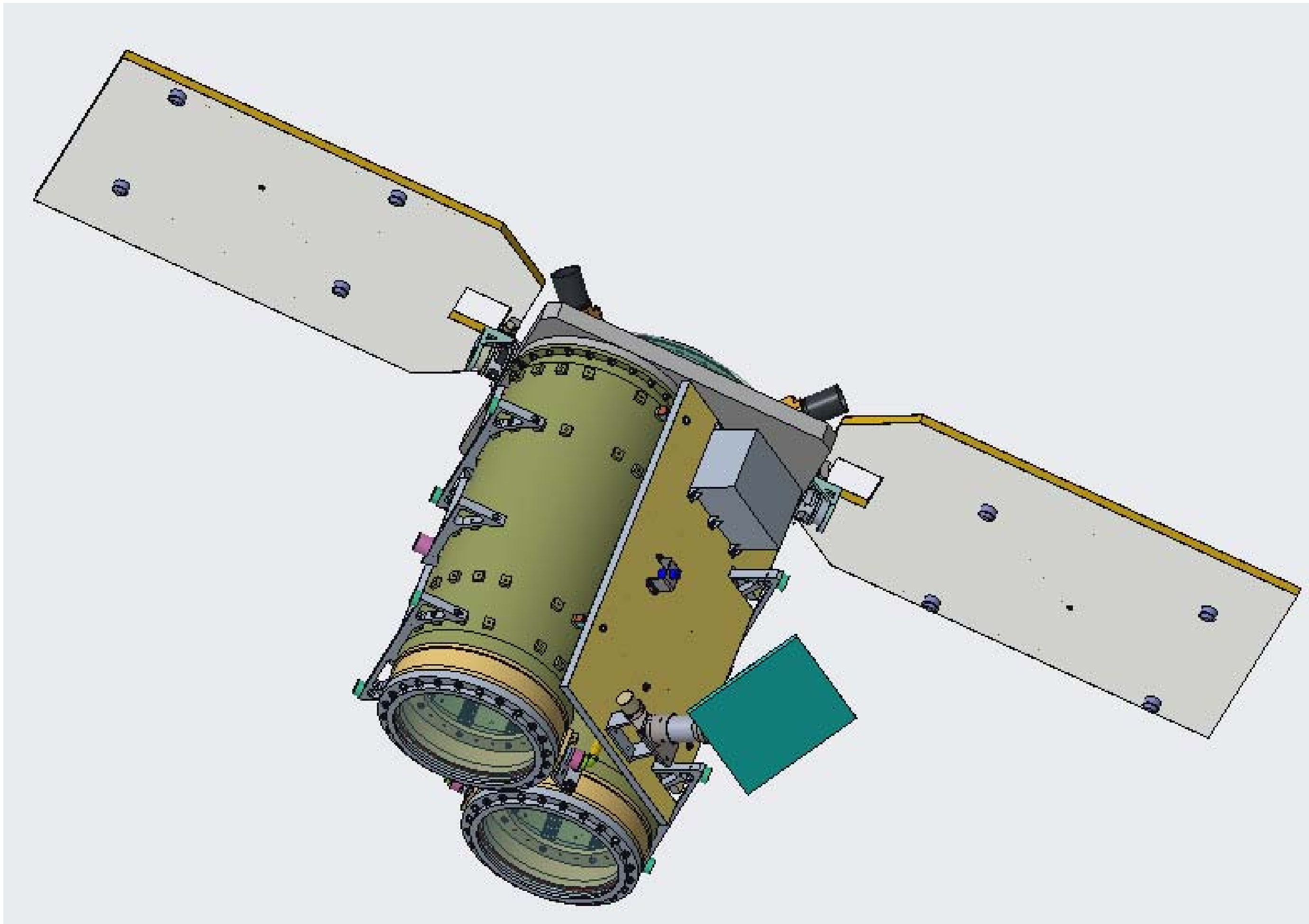
Component Panel B View

CapSIT: "If it fits it flies"

- CapSIT Tubes are roughly 1 ft x 2.5 ft
- They provide an instrument volume equal to ~53U per tube or 106U for a pair
- They are designed with a standard interface for rapid interchangeability
- The Tubes are designed to contain 17.5 kg and provide 20+ Watts of power
- They are intended to use this entire mass, adding weight if needed in order to maintain direct interchangeability without affecting coupled loads
- Tubes will be delivered to an instrument developer in a kit form
- The Kit will include software to allow testing through commercial standard data interfaces
- The mechanical ICD will specify the CG location & frequency response
- The electrical ICD will include EMI/EMC and inrush current requirements
- There is a design for an all-in-one tester that could be delivered to the instrument building institution for a complete mechanical, thermal, EMI/EMC/ and data flow verification.
- Qualified tubes can be delivered or swapped out very late in the I&T flow
  - Possibly up to the last minutes if there is an appropriately placed fairing door
  - This is intended for certain biological experiments but allows for maximum flexibility and quick response to space that other payloads could take advantage of
- Tubes can be flown pressurized or unpressurized.
- A single instrument can span two tubes buy placing electronics in one tube and detectors/optics/etc. in the other, both of which can be pressurized or not independently.
- Standard tubes can also be flow on other host spacecraft. Simplifying interfaces, coupled loads, lead times, contracts, and cost.



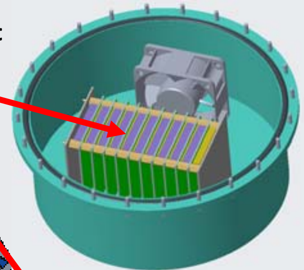
Capsat isometric deployed

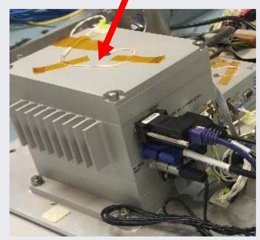


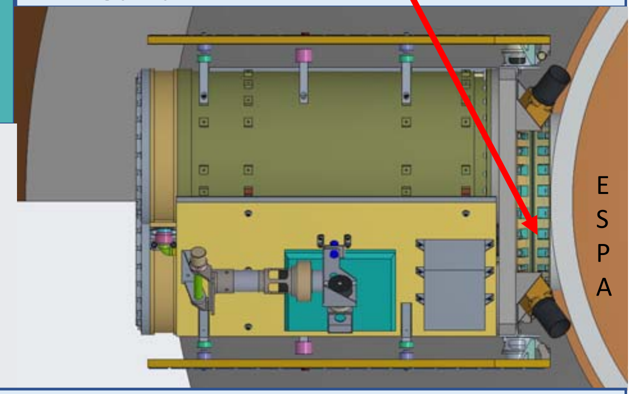
CapSat builds on NASA's tradition of Hitchhicker Get Away Special-GAS Cans that flew on the shuttle. Hitchhiker flew over 200 missions over 2 decades managed out of Goddard Space Flight Center. CapSIT allows independent development of instruments and spacecraft decoupling funding, contracts and science. "If it fits, it flies!" and when its ready it can go. Interchangeable tubes allow slipping and leapfrogging of instruments and substitution to a dummy mass if needed to insure no impacts to the primary mission launch date.

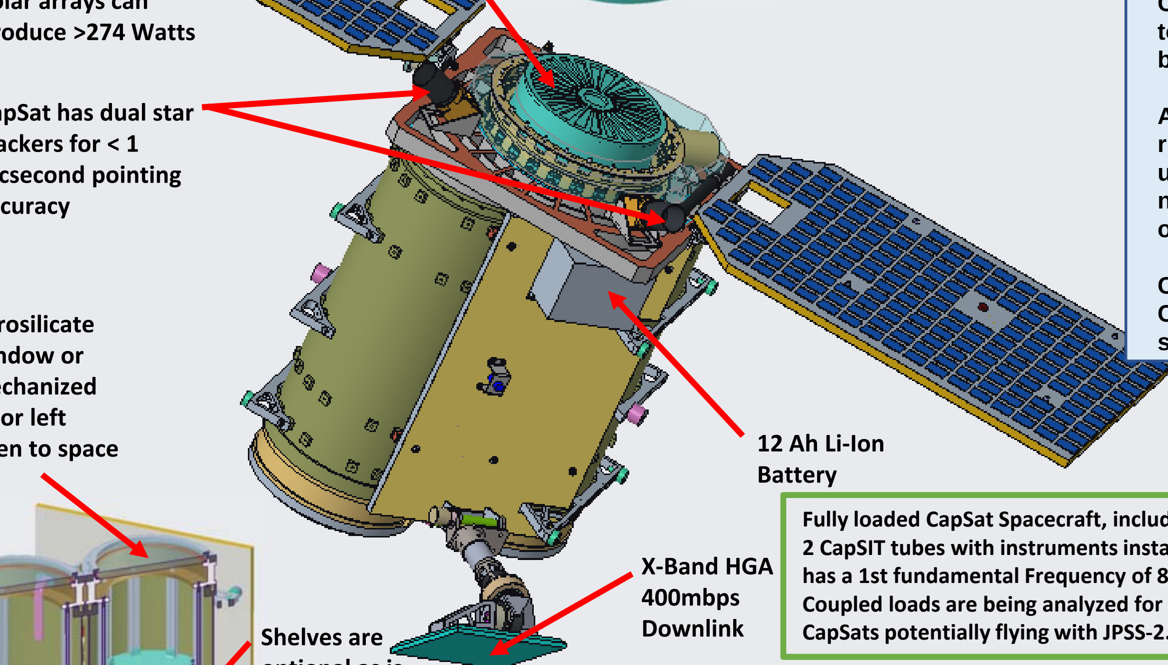
CapSat Flight software uses NASA's open source core flight executive cFE; developed with decades of Goddard heritage and now approved for Class A human rated use. A version of Microsoft Windows was successfully run on a CapSat C&DH within the cFS to demonstrate plug and play instrument software integration for a new type of Landsat Thermal Imaging Sensor instrument in 2016.

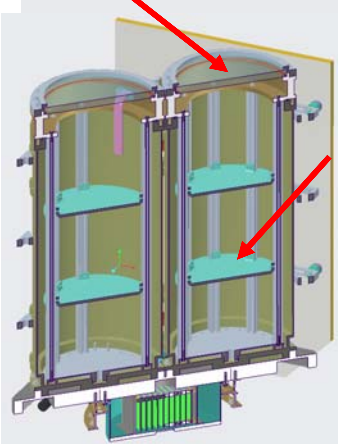
CapSat supports Motorized Lightband-MLB attachment to a standard 6 port ESPA with 180 kg per port.









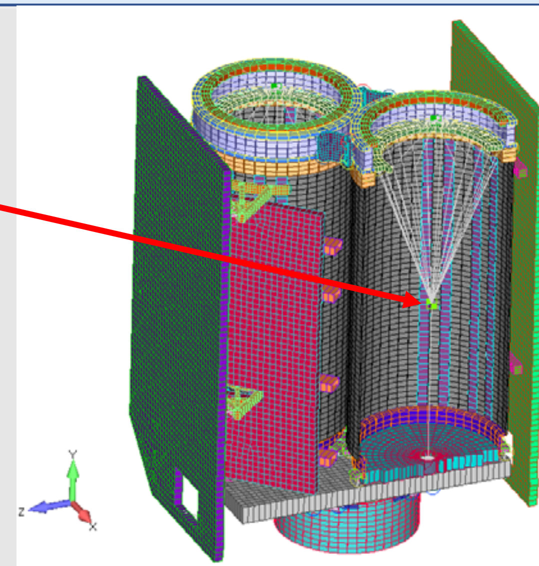


CapSat takes advantage of unused launch vehicle mass to orbit capabilities via the USAF Ride Share program; being specifically designed to mate to an ESPA Ring.

Almost all future NASA missions will be providing rideshare opportunities. This capacity typically goes unused largely do to cost. Typical CubeSat's are still nearly $1M/kg. A single CapSat can provide 180kg of on-orbit mass at a cost >20 times cheaper.

CapSat achieves this by leveraging proven SmallSat and CubeSat hardware combined with decades of GSFC software heritage.

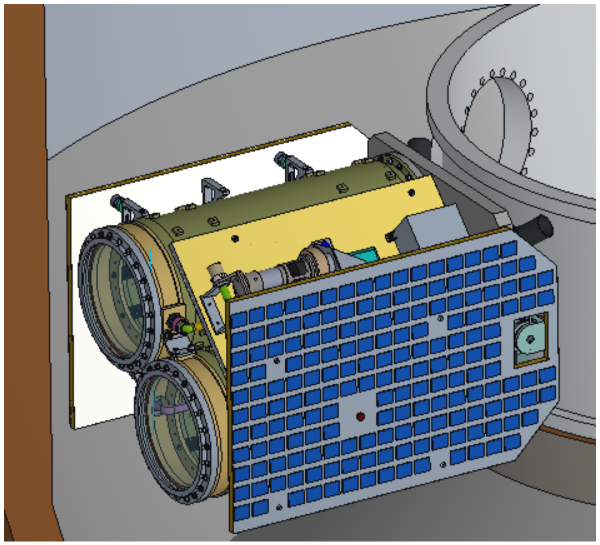
Fully loaded CapSat Spacecraft, including 2 CapSIT tubes with instruments installed, has a 1st fundamental Frequency of 88hz. Coupled loads are being analyzed for 6 CapSats potentially flying with JPSS-2.

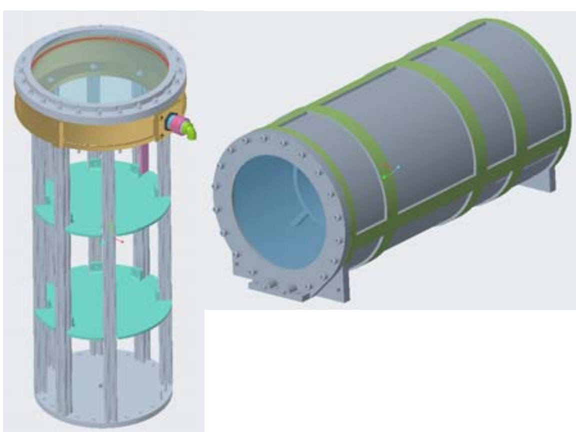


CapSat ground systems will use ITOS-Integrated Test & Operations System. Developed at Goddard in 1990 and available as a commercial product since 2000. ITOS has flown on missions like; Landsat , LRO, DSCOVR, Fermi(GLAST), LADEE, NuSTAR, upcoming ICESAT-2, ICON. ITOS supports instrument and spacecraft development as well as full observatory on orbit operations.

CapSat

Capsulation Satellite or CapSat is a low cost, 3 axis stabilized, modular, standardized spacecraft, based on a pressurized volume allowing ruggedized COTS hardware to be flown reliably in space at a cost per Kg 20 times cheaper than the average Cube Sat.





"IF IT FITS, IT FLIES!"

Paper presented at the 2017 IEEE Aerospace Conference

"Capsulation Satellite or CapSat: A Low Cost Reliable Rapid Response Spacecraft Platform"

September 27, 2016: CapSat article makes top page of www.nasa.gov and www.nasa.gov/goddard

October 2016 CapSat inputs approved for next edition of NASA Technology Innovation Magazine

https://viewer.aemmobile.adobe.com/index.html#project/20151817-e5ce-4721-aff0-65bc38c9679b/view/ti.17.3/article/17.3.Space.for.Everyone

July 2016 CapSat article makes the cover of Cutting Edge

https://gsfctechnology.gsfc.nasa.gov/newsletter/Summer16Current.pdf

https://www.nasa.gov/feature/goddard/2016/nasa-develops-satellite-concept-to-exploit-rideshare-opportunities

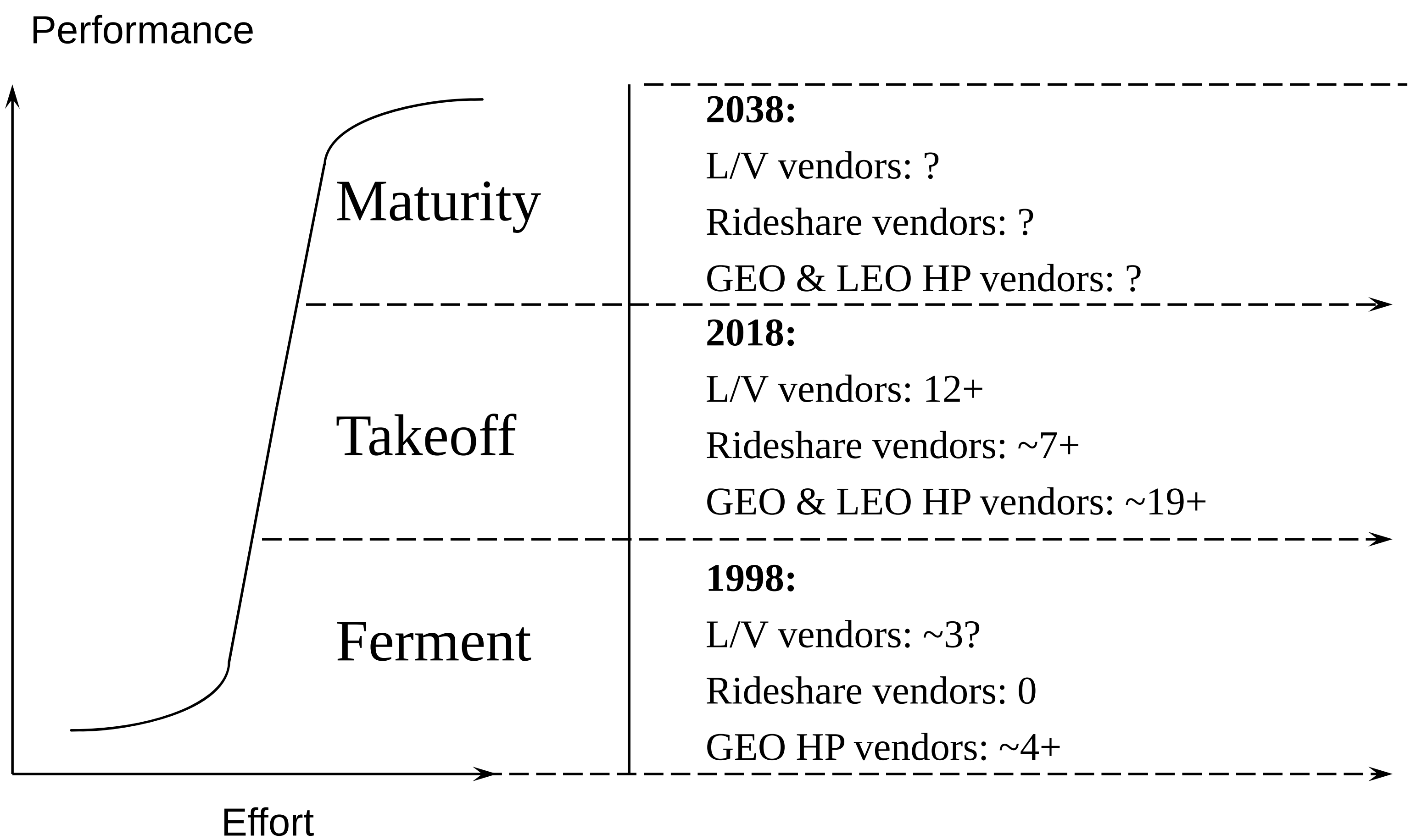
CapSat is currently in Patent pending status with the US Patent Office:

PATENT PENDING

For more information
Contact JOE.BURT@NASA.GOV
301-286-2217

Backup charts …

Access to Space and the S-curve

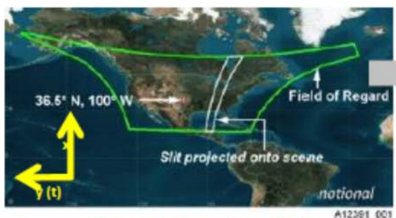


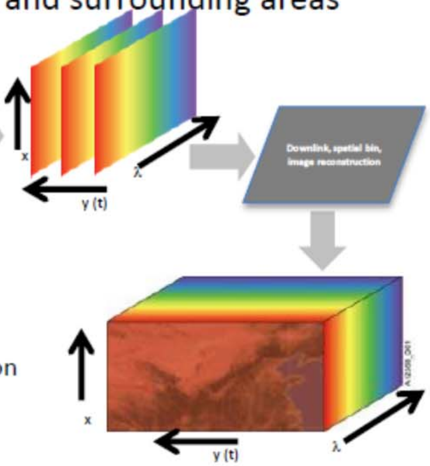
Notes on the S-Curve

- 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

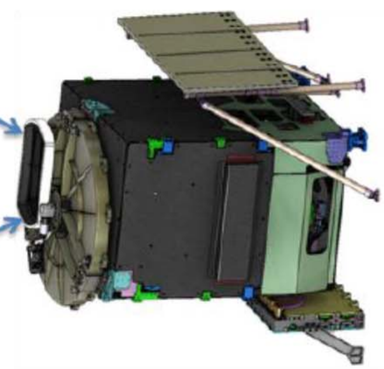
TEMPO: Is a scanning ultraviolet/visible spectrometer to measure chemical species critical to air quality and climate over Greater North America and surrounding areas

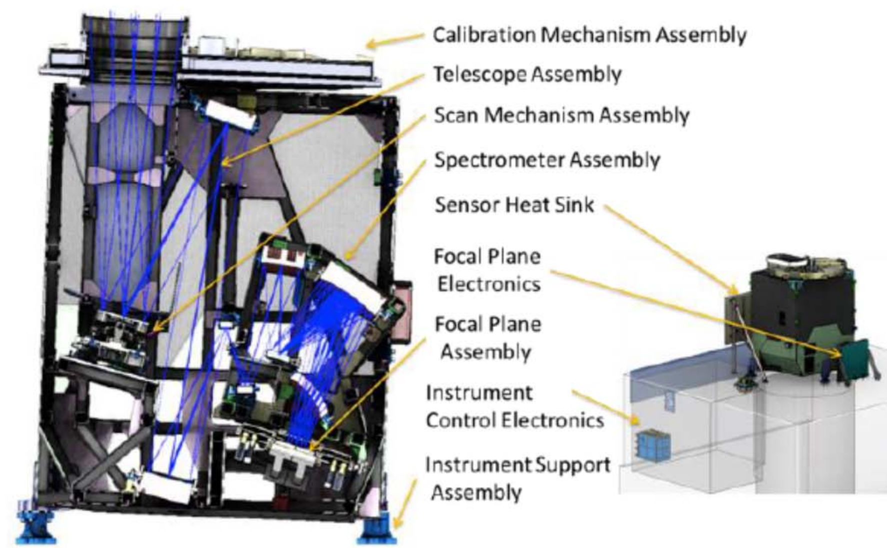




- Geostationary orbit
- Resolution will allow tracking pollution at sub-urban scales on an hourly basis
- NASA Class C

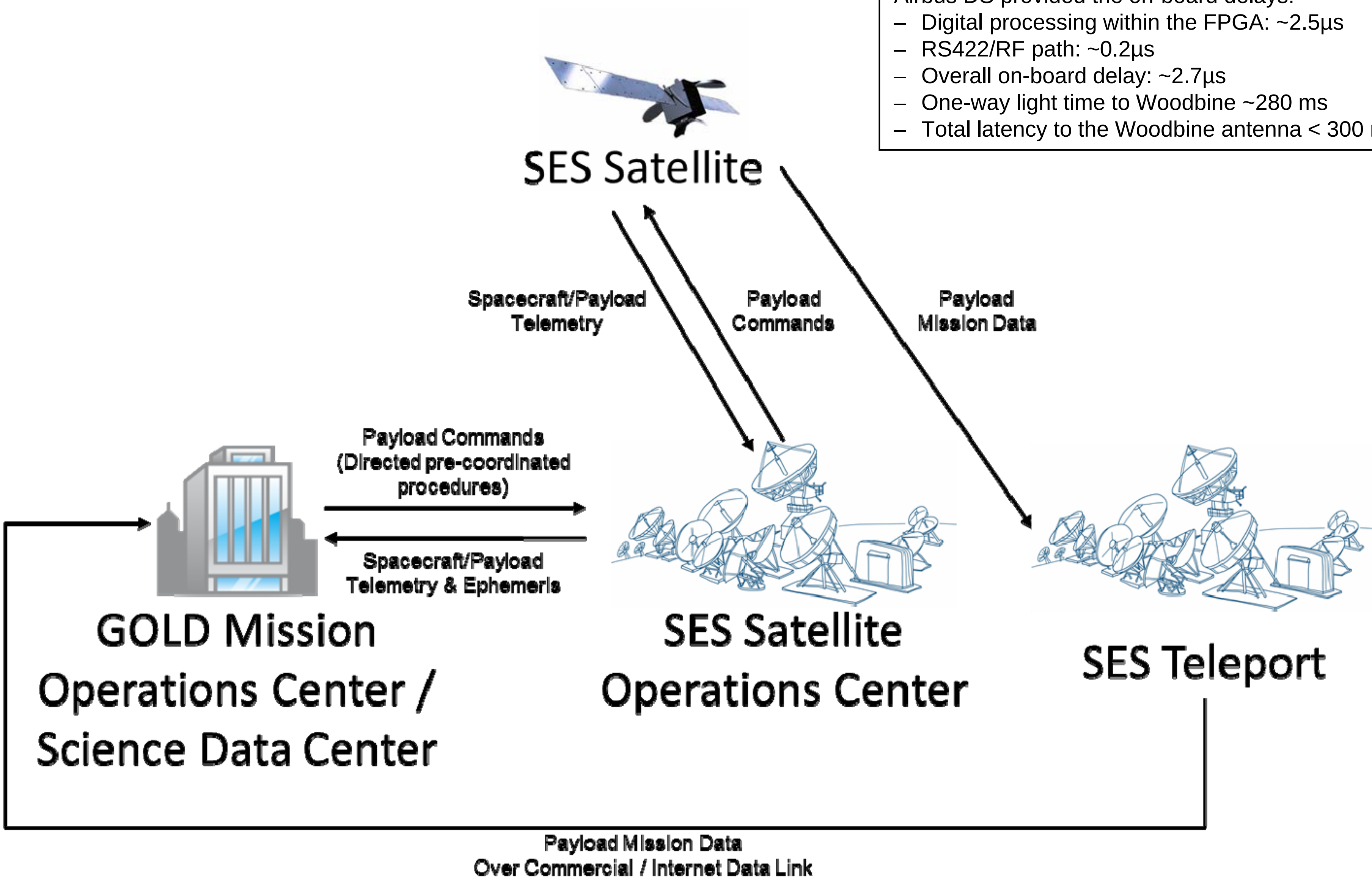
- Wavelength range = 290 – 490 nm and 540 – 740 nm
- Two 2048 (spatial) x 1024 (spectral) pixel CCD detectors
- Step/stare 2-axis scan mechanism
- 60 minute E→W scans performed approximately 2 hours on either side of full sunlight
- Composite M55J truss structure
- Calibration wheel with transmissive 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

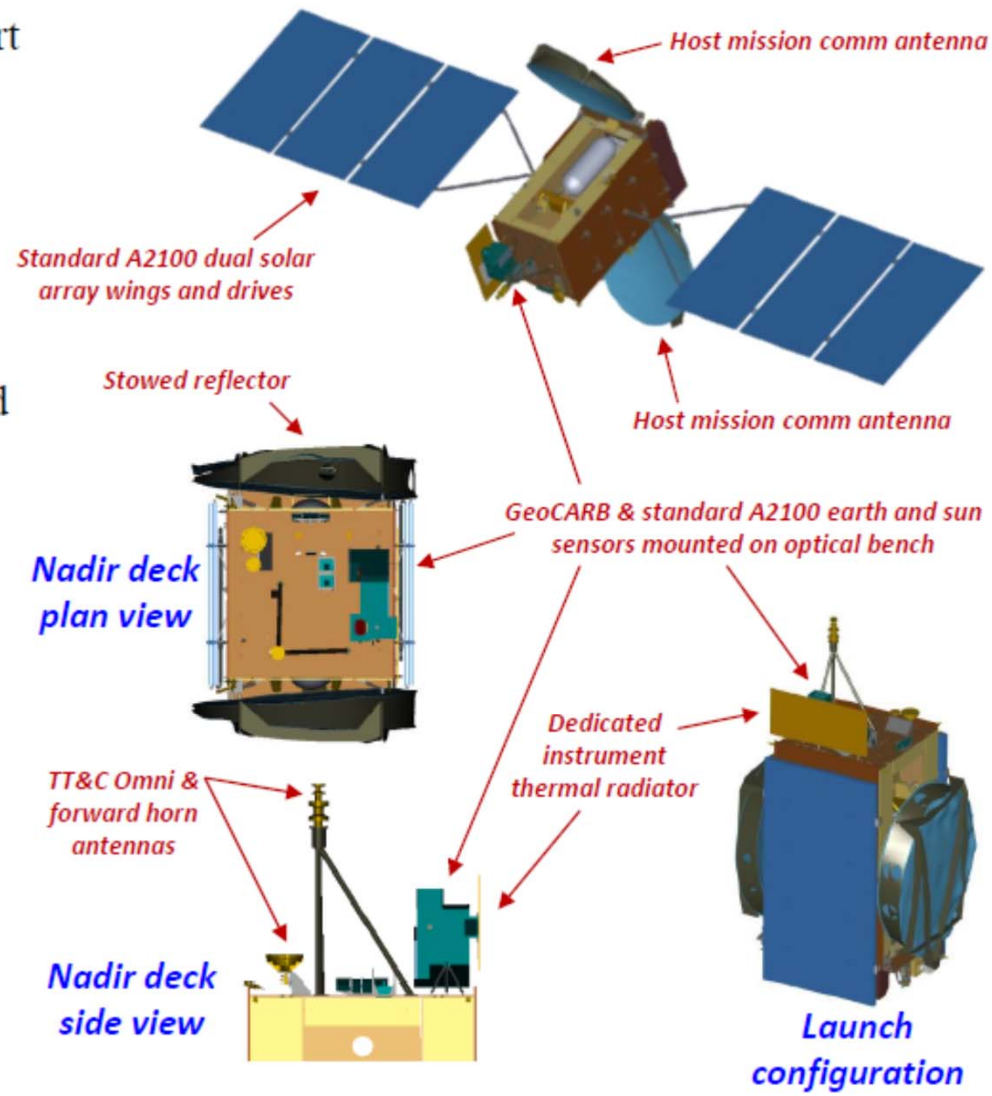
Airbus DS provided the on-board delays:
- Digital processing within the FPGA: ~2.5µs
- RS422/RF path: ~0.2µs
- Overall on-board delay: ~2.7µs
- One-way light time to Woodbine ~280 ms
- Total latency to the Woodbine antenna < 300 ms



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

GeoCARB hosted on typical geo-satellite, deployed view



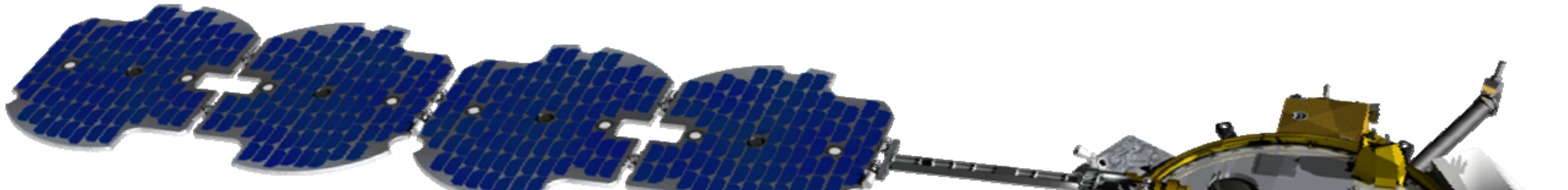
NASA Missions w/Rideshare

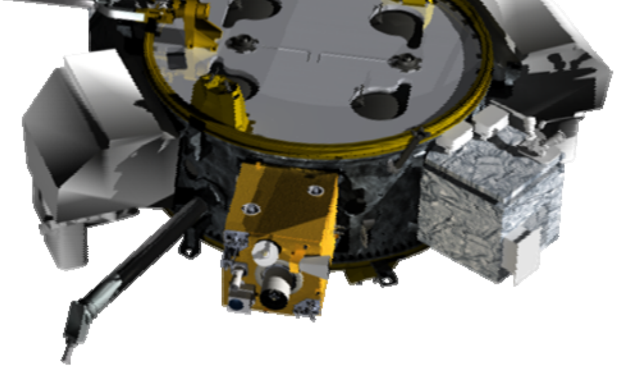
Candidate Primary Mission	Launch Date	Orbit	Apogee (km)	Perigee (km)	Inclination (deg)	Rideshare Adapter
Sentinel-6 (JPL)	11/2020	Polar, Cir.	1336km	1336km	66 deg	ESPA Option
Restore-L	11/2020	Polar	670km	670km	98.2°	ESPA Option
Landsat-9	12/2020	Polar	700km	700km	98.2°	ESPA Option
SWOT (JPL)	4/2021	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

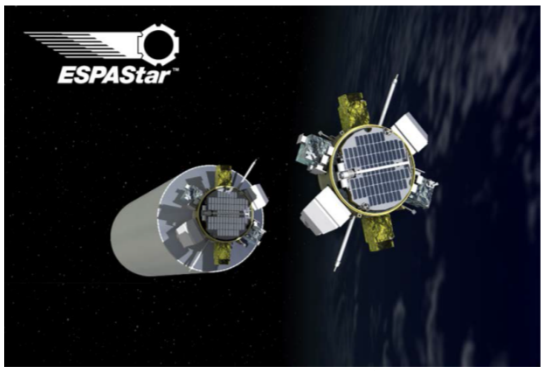
L/V Upper-stage Restart may be an Option for Rideshare Missions

- 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

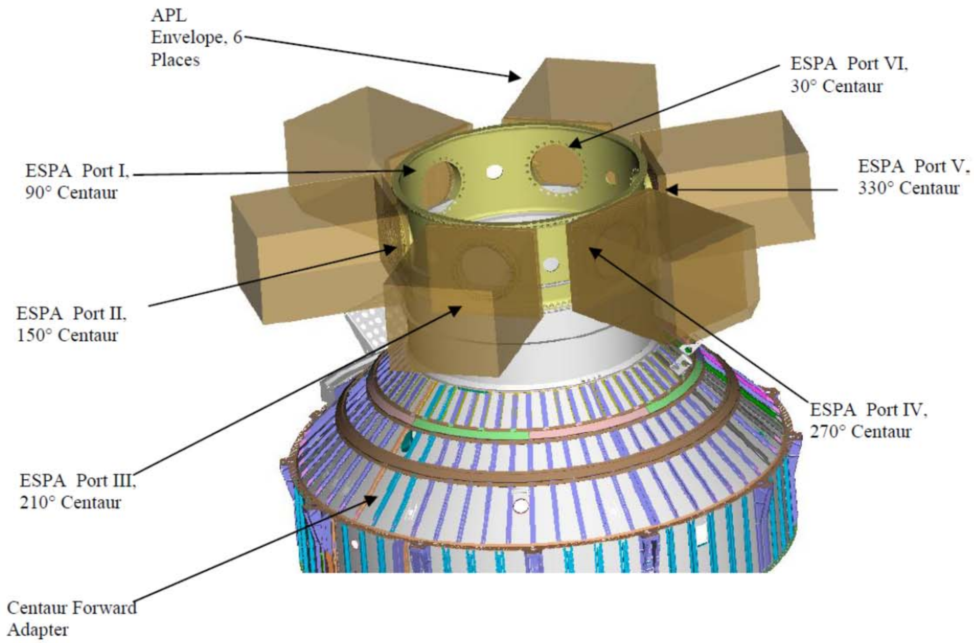


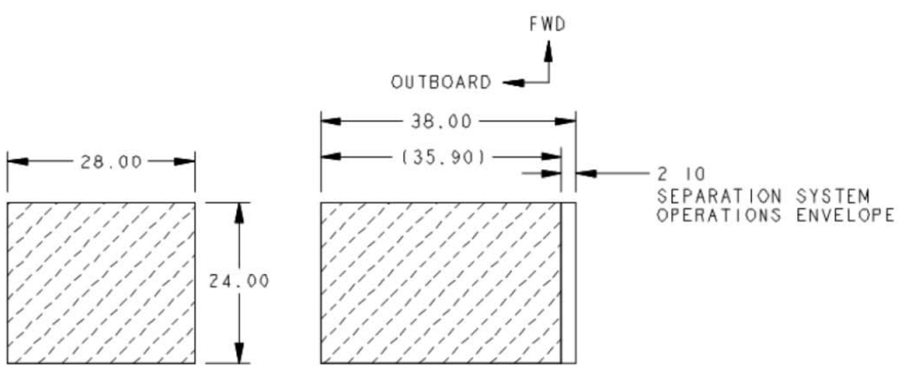


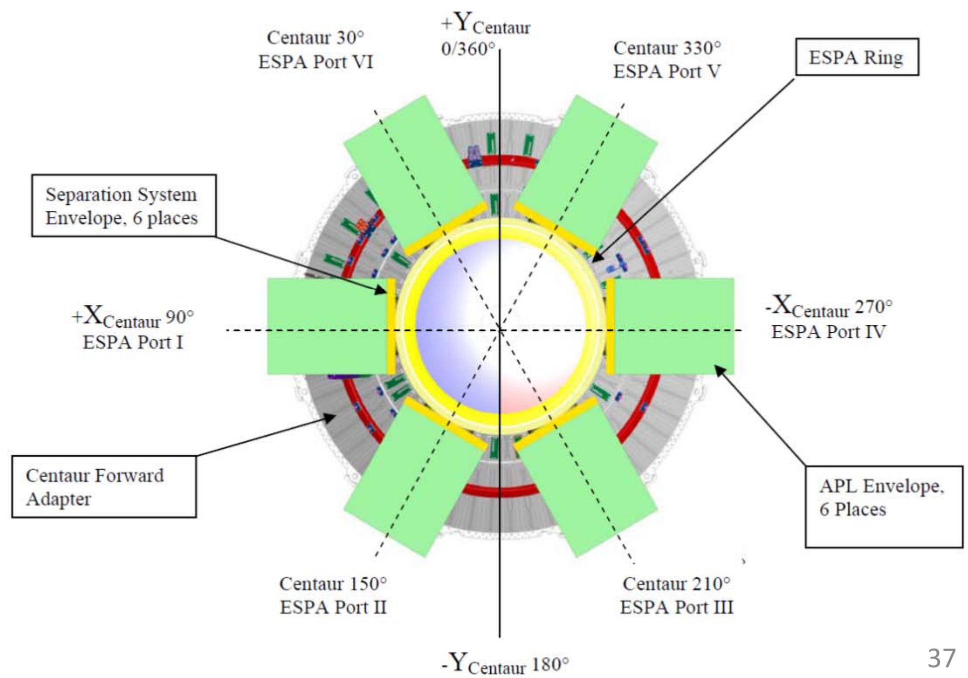


Attribute	ESPAStar
Payload Capacity	6 fixed or up to 12 separable
Payload Mass	1086 kg (181 kg per port)
Mission Duration	5 Years
Downlink	1.6 Mbps, AFSCN-compatible, Type 1 encryption
Attitude Knowledge	< 10 µrad, 1 Sigma
Positional Knowledge	<10 m w/GPS
Jitter	<10 µrad, 1 Sigma, <0.1Hz
Delta V	400 – 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

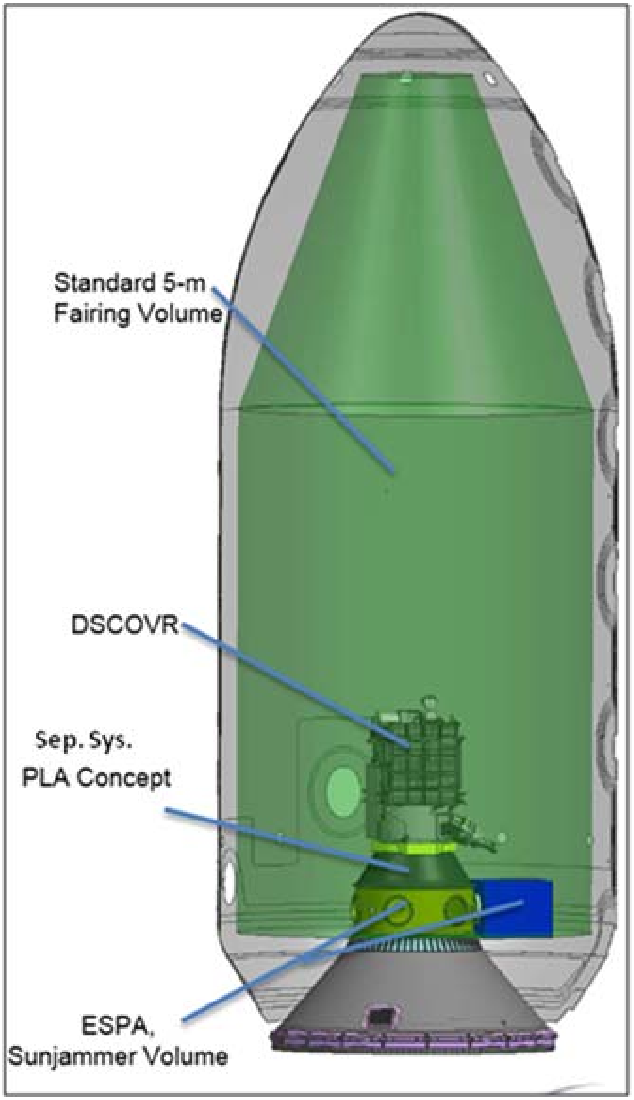
Air Force RUG: ESPA Mechanical Data







Rideshare Poster-child: DSCOVR & TESS

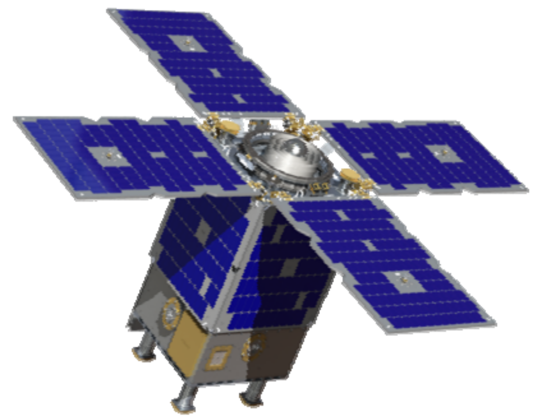


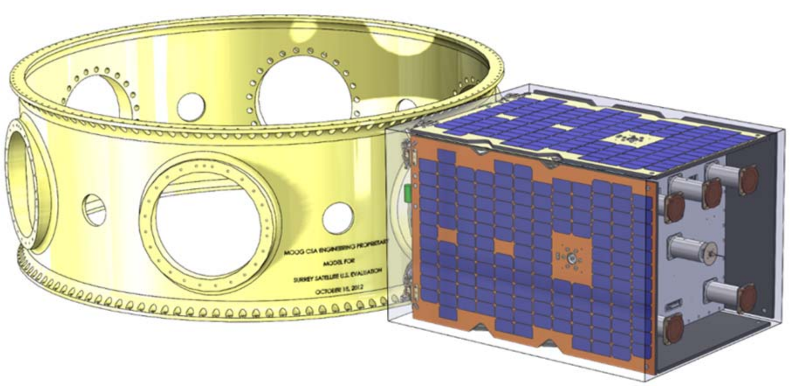
DSCOVR: Feb 2015
2500 kg of unused mass went to L-1

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]