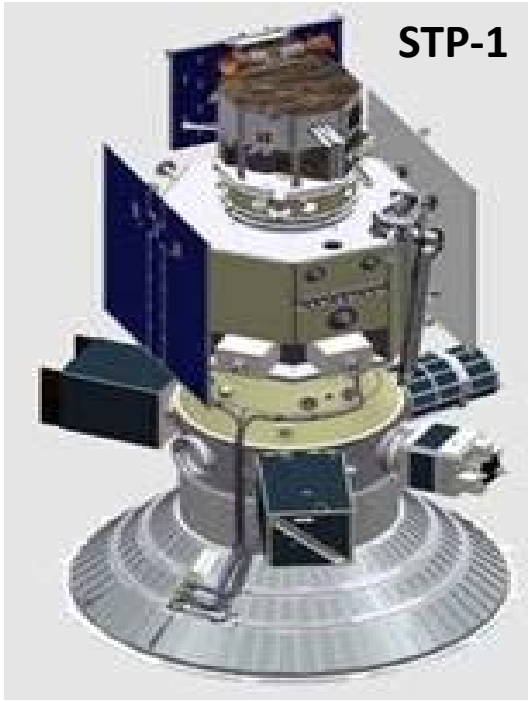
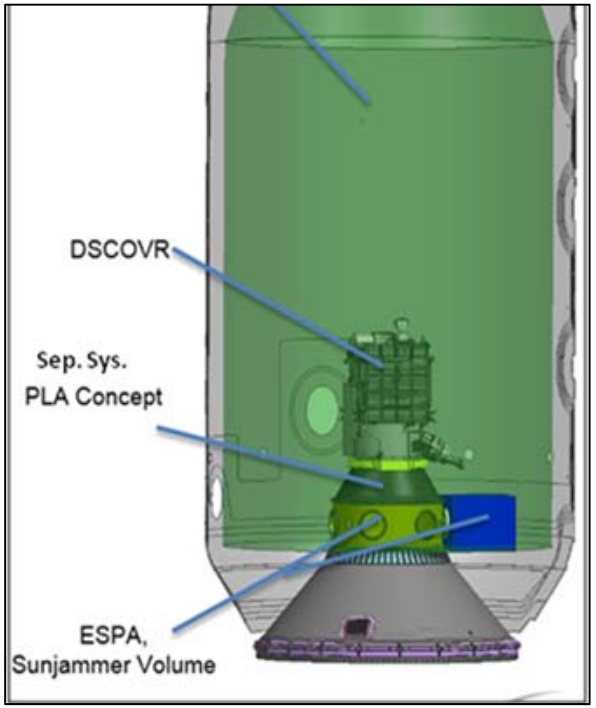
# Rideshare/Multi-Manifest Payload Overview

Bob Caffrey
robert.t.caffrey@nasa.gov, 301-286-0846

June 2019




Air Force

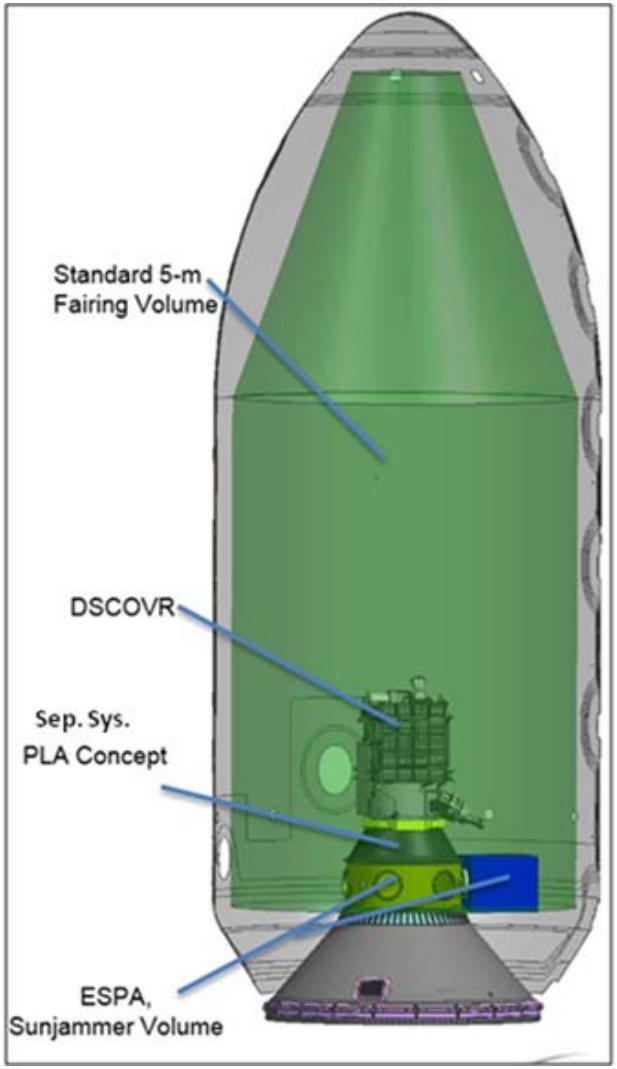



NASA / EELV

NASA / SLS

Commercial

# Rideshare Poster-child: DSCOVR & TESS



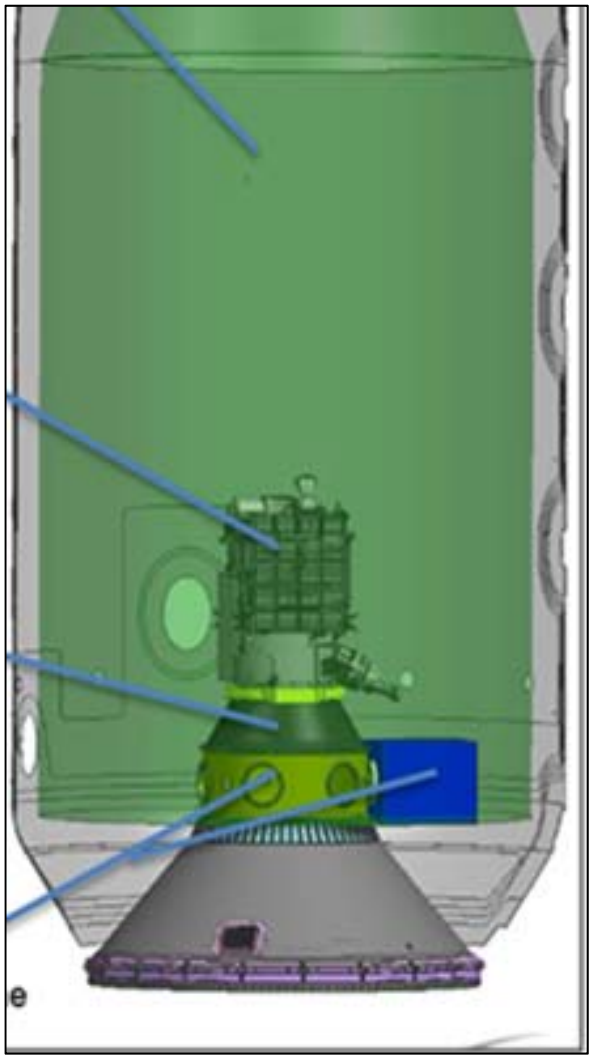

***DSCOVR: Feb 2015***

*2500 kg of unused mass went to L-1*

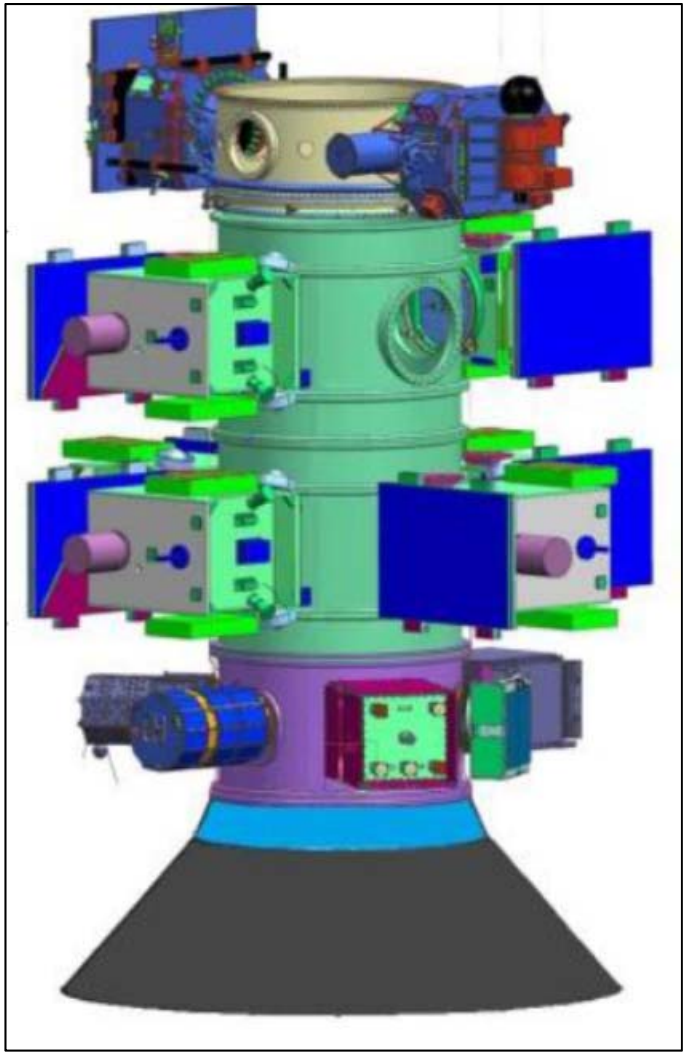
***TESS: April 2018***

*~300kg S/C and ~3000 kg excess on a TLI orbit*

# Government Rideshare: Past, Present & Future



Past Missions (DSCOVR)



Present Missions (STP-2)

Future Missions (PACE?)

# NASA Competitive Opportunities:

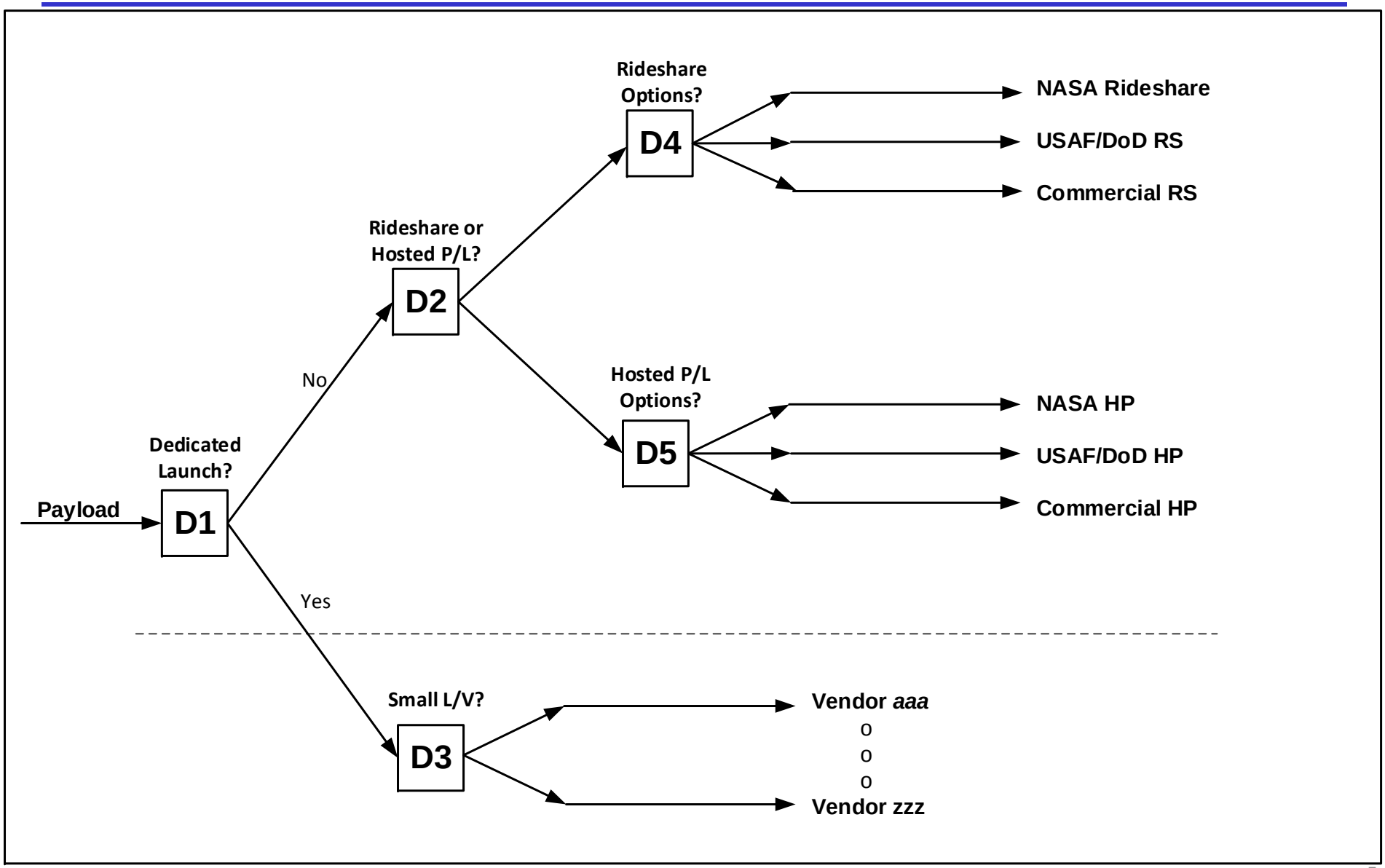
(https://soma.larc.nasa.gov/standardao/pdf_files/Planning%20List%20for%20SMD%20Solicitations%2020190403-final.pdf)

| NASA Science Opportunity | Planned AO Release Date | AO Required Launch Window |
|---|---|---|
| Astrophysics Explorers MOO | 3-MAR-2019 | AO + ~6.5 years |
| Astrophysics SMEX | 3-Apr-2019 | AO + ~6.5 years |
| Discovery AO | 1-Apr-2020 | AO + ~6.5 years |
| Heliophysics MIDEX AO | Q3 FY 2019 | AO + ~6.5 years |
| Earth Venture Mission-3 AO | Q4 FY 2019 | AO + ~6.5 years |
| Earth Venture Ins-6 AO | Q3 FY 2020 | AO + ~6.5 years |
| Astrophysics MIDEX & MOO | Q4 FY 2021 | AO + ~6.5 years |

photo credit ORBCOMM, SpaceX, SNC

# Multi-Manifest Payload Launch Options

(Exploring each option's cost, schedule, risk, & performance)



# NASA & Air Force Rideshare Options

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

| Year | LEO (mid inc) | LEO (hi inc) | MEO | GEO/GTO | Other / TLI |
|---|---|---|---|---|---|
| **2019** | **STP-2**<br>**RALI (~3)** | | **USAF** | **STP-3** | |
| **2020** | | Landsat-9 | **USAF** | GOES-T | EM-1 |
| **2021** | | **STP-S28** | **USAF** | **USAF (GTO)** | LUCY |
| **2022** | | JPSS-2<br>PACE | **USAF** | **USAF** | PSYCHE |
| **2023** | **STP-S29** | **USAF** | **USAF** | **USAF (3+)** | EM-2 |
| **2024** | | | **USAF** | **USAF (2+)**<br>GOES-U | IMAP<br>New Front-4<br>EM-3 |
| **2025** | | JPSS-3<br>**USAF** | **USAF** | **USAF (3 ea)** | GDC<br>EM-4 |
| **2026** | | Sentinel-6b<br>Landsat-10 | **USAF** | **USAF (3+)** | Discovery 15<br>EM-5 |

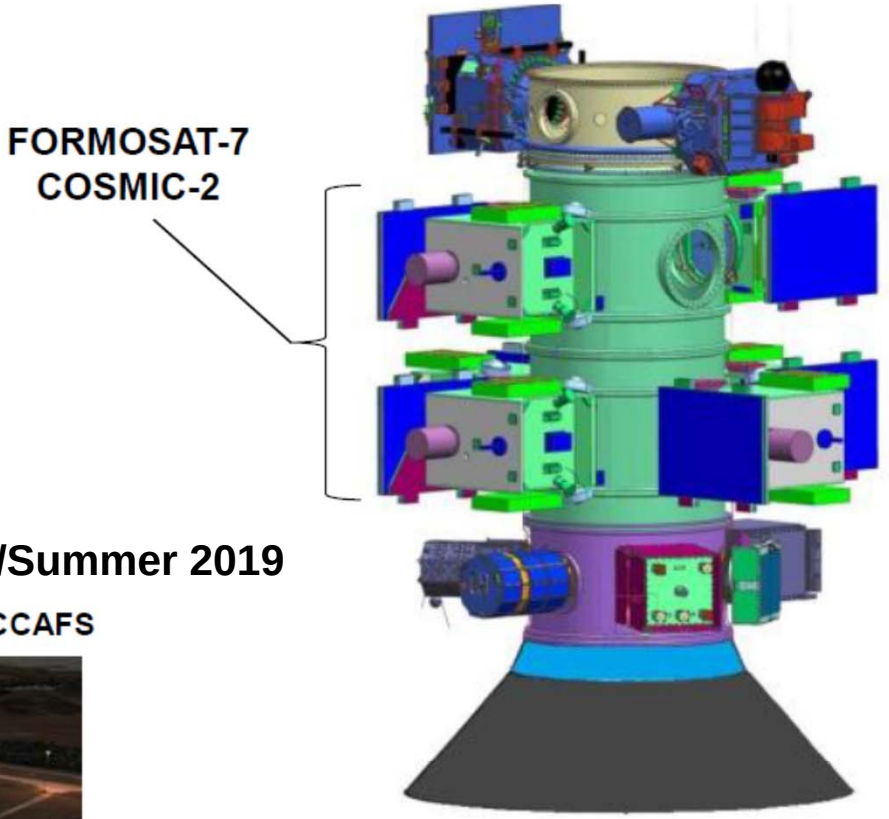
# USAF Rideshare Example: STP-2

(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 launch

  **February 6th, 2018**
- COSMIC-2 launch planned for **Spring/Summer 2019**

**Concept of Falcon Heavy from Launch Comlex-39A CCAFS**

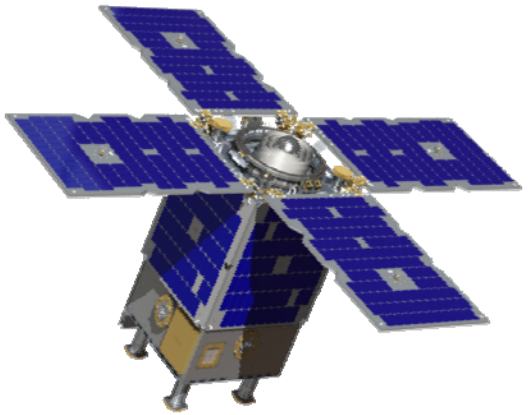


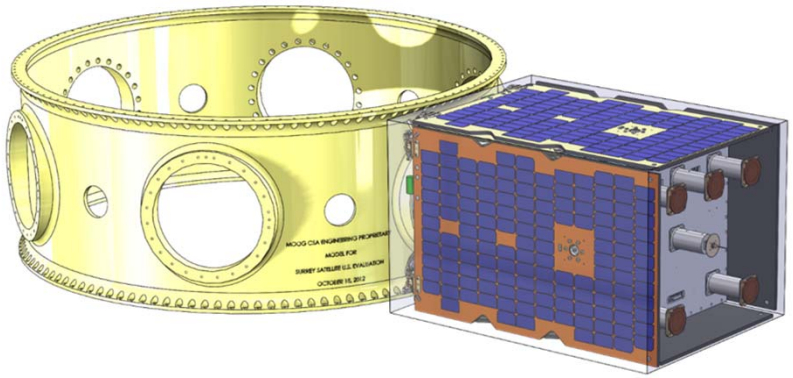

**STP-2: multiple payloads, multiple orbits**

- 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

# USAF Rideshare & Hosted Payload 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

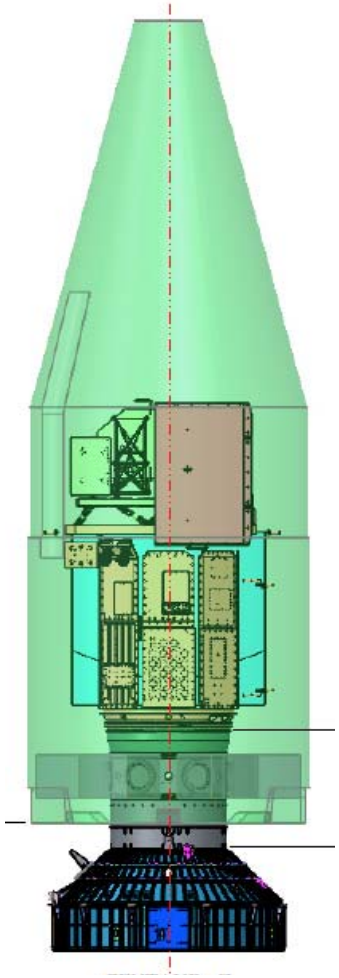




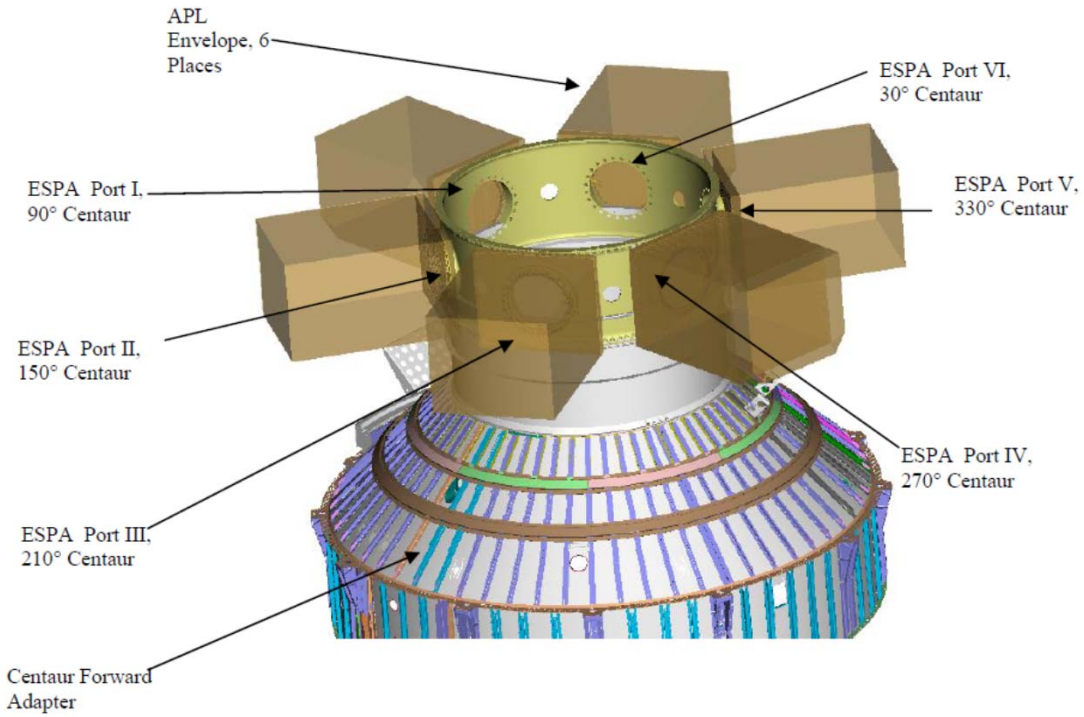
- OTB payload suite: evaluation, demonstration, heritage
  - FlexRX: programmable receiver
  - RadMon: radiation effects monitor
  - CUSP: University of Colorado collaboration, off-the-shelf components
  - High-efficiency solar cell experiment: performance characterization
  - Electronic Test Bed: new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

# NASA Rideshare Example: ESPA on Landsat-9

(A four burn mission delivering rideshare payloads to a 550km SSO orbit)



**Landsat 9 with an ESPA Ring**




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

# Notional Commercial Rideshare Opportunities

*(contact vendors for details, vendor provided quad charts in backup)*

| Year | LEO (Low Inc.) | Polar (Hi Inc.) | GEO | Other |
|---|---|---|---|---|
| **2018** | NR, TS, TV | SF, TS, TV | SF, NR, TV, MX | SF, TV (GTO) |
| **2019** | SF, TV, NR | SF, TS, TV | SF, NR, TV | SF, TV (GTO), TV (EE) |
| **2020** | SF, TV, NR | SF, TV | SF, TV | SF, TV (GTO) |
| **2021** | SF, TV, NR, MX | SF, TV, MX | SF, TV | SF, TV (GTO) |
| **2022** | TV, NR | SF, TV | SF, TV | SF, TV (GTO) |
| **2023** | TV, NR | SF, TV | SF, TV | SF, TV (GTO) |

SF - SpaceFlight TS - TriSept NR - NanoRacks TV - Tyvcak
MX – Maxar (Loral)

*Note: This data is the result of a market survey and not an endorsement*

# Commercial Rideshare Example: SpaceFlight SSO-A

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

SPACEFLIGHT INDUSTRIES

# Past and Future Launch Metrics

- Spacecraft launched: 224
  - Mass ranging from 1U's to 900kg
  - 19 Missions to LEO, GTO (Lunar), & GSO
- 17 Missions scheduled for 2019
- USG Customers:
  - NASA: ARC, JPL
  - DoD: AF Space Test Program, ORS Office, AF Academy, AF Research Laboratory, US SOCOM, DHS, Intel, SPAWAR, DARPA
- Spaceflight has another 70+ spacecraft manifested ranging from 1U to 1250kg
- Launch Vehicle and hardware agnostic
  - Established agreements with current and new entrant providers

| **Percent** | **Type** |
|---|---|
| 69.00% | Commercial |
| 31.00% | Government |
| 84.50% | Domestic |
| 15.50% | International |

**Dedicated Rideshare Mission F9 (SSOA): Dec 18**

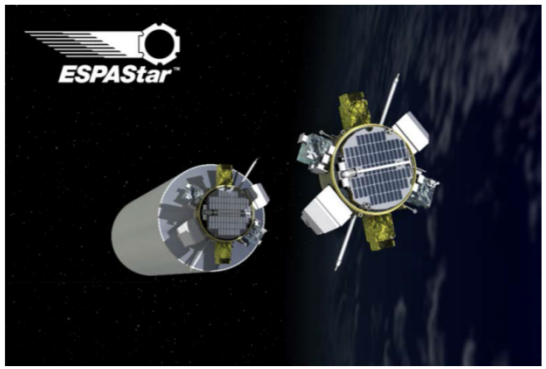
Most spacecraft on single mission: 64 s/c, 18 countries, & 35 customers represented

**GTO/GSO Rideshare: Feb 19**

Space IL: Lunar Mission

USG: GSO Mission

# Commercial Rideshare Example: NGC ESPAStar

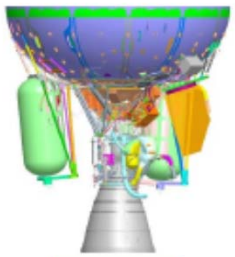


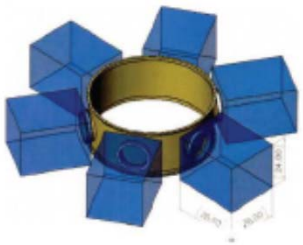



| Attribute | ESPAStar |
|---|---|
| Payload Capacity | 6 fixed or up to 12 separable |
| Payload Mass | 1086 kg (181 kg per port) |
| Mission Duration | 5 Years |
| Downlink | 1.6 Mbps, AFSCN-compatible, Type 1 encryption |
| Attitude Knowledge | < 10 µrad, 1 Sigma |
| Positional Knowledge | <10 m w/GPS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

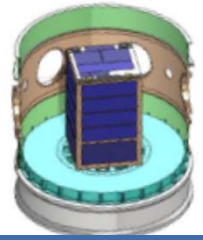
# Rideshare ESPA Spacecraft Options Defined by USAF RUG & ESPA Users Guide

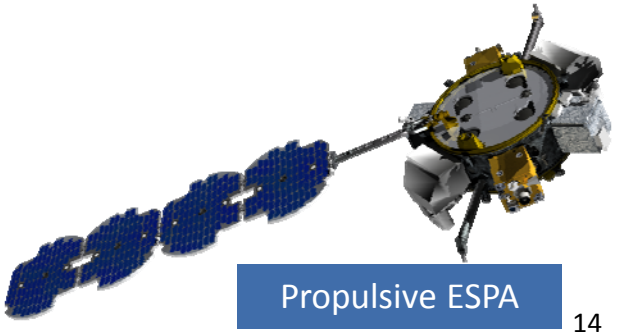
| Rideshare Carrier | Max S/C Mass | Volume Available | S/C Interface | Fastener Size | Comments |
|---|---|---|---|---|---|
| ABC | 80kg | 34"x20"x20" | 8/15" cir. | | APC Operational |
| ESPA (1 of 6 ports) | 257kg | 24"x28"x38" | 8/15" cir. & 15" squ. | 1/4" | ESPA Operational |
| ESPA Heavy (1 of 6 ports) | 450kg | | | 5/16" | |
| ESPA Grande (1 - 4 ports) | 700kg | 42"x46"x56" 42"x46"x38" | 15/24" cir. & 24" squ. | 1/4" | ESPA Grande Operational (5m and 4m faring) |
| ESPA Grande Heavy (1-4) | 700kg | | | 5/16" | |
| Aquila (A-Deck) | ~1,000 | 56-diax60"h | 24/38" cir. | | Aquila (dual-P/L adaptor) qualified |
| Propulsive ESPA S/C | ~2,800 | 4m-diax24"h | 62" dia | | Ports for Rideshare P/L or Hosted P/L |
| Propulsive ESPA Grande | ~4,400 | 5m-diax42"h | 62" dia | | Ports for Rideshare P/L or Hosted P/L |


ABC


ESPA

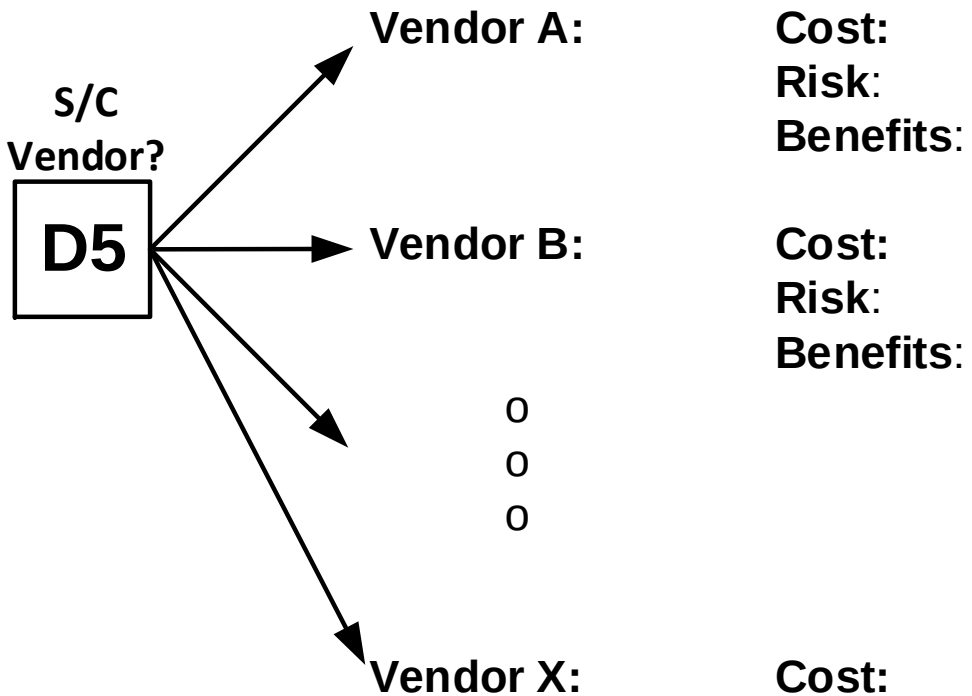

ESPA Grande


A-Deck / Aquila


Propulsive ESPA

# Rideshare Spacecraft Options

## Rideshare Spacecraft (RSC) Decision Tree




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

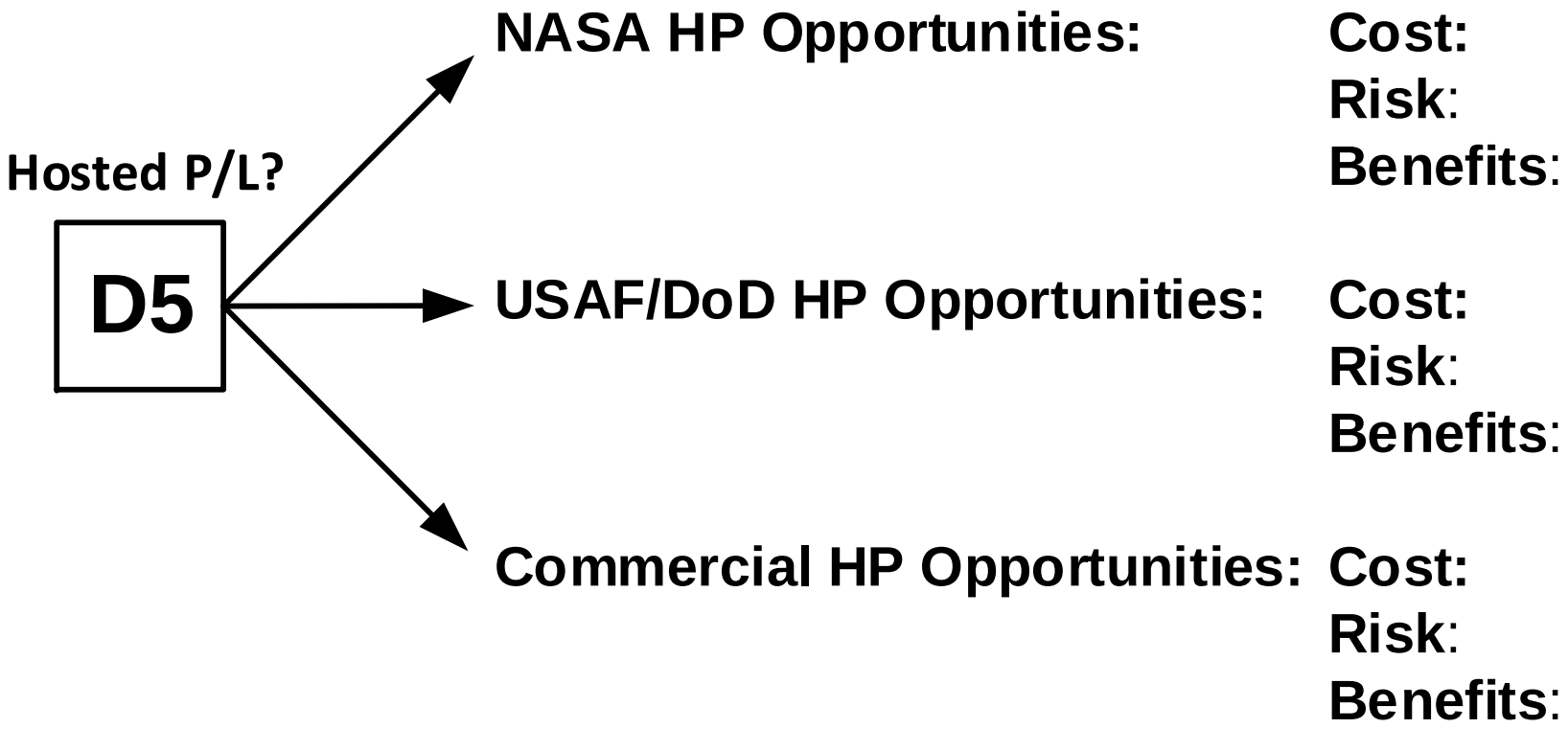
# Commercial Rideshare Spacecraft Options

*(contact vendors for details, vendor provided quad charts in backup)*

| Rideshare Adaptor/Carrier | Ball Aerospace | Boeing / SMS | GA (Surrey US) | Millennium Space Sys. | Moog Space & Def. | NGIS (Orbital-ATK) | Sierra Nevada Corp. (SNC) |
|---|---|---|---|---|---|---|---|
| ESPA Class S/C | BCP Small | Boeing/502XS | SSTL-150 ESPA | RED-EYE (ALTAIR-G2) | --- | NGIS ESPASat | SN-30L, SN-30G, & SN-50L |
| ESPA Grande Class S/C | BCP Small | Boeing/502S | SSTL-300 | RED-EYE (ALTAIR-G2) | --- | NGIS ESPASat | SN-100L, SN-200L, & SN-200G |
| A-Deck Class S/C | BCP Large | Boeing/502M | SSTL-600 | WFOV (AQUILA M8) | --- | GEOStar-1 | --- |
| Propulsive ESPA S/C | BCP Small | --- | SSTL-600 | WFOV (AQUILA M8) | COMET | ESPAStar | SN-1000 |
| Propulsive ESPA Grande | BCP Large | --- | SSTL-600 | Millennium/ OMS | METEOR | ESPAStar (1) | SN-1000+ |

*Note: This data is the result of an open RFI/market survey and not an endorsement*

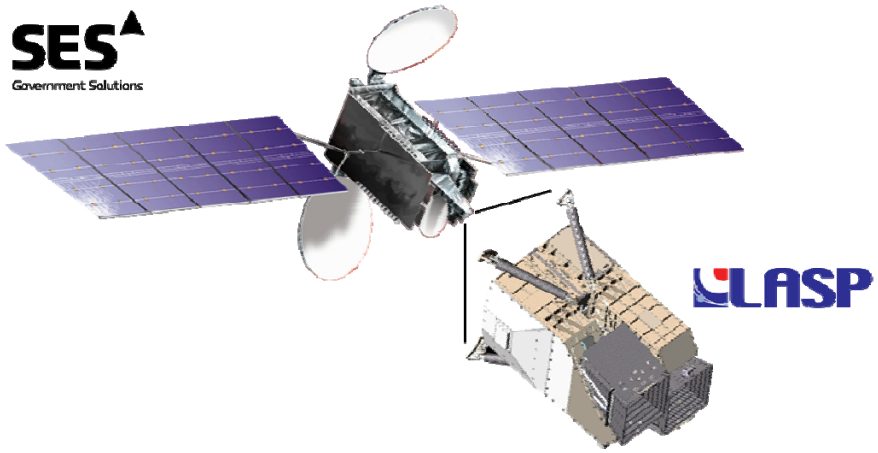
# Hosted Payload Options




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

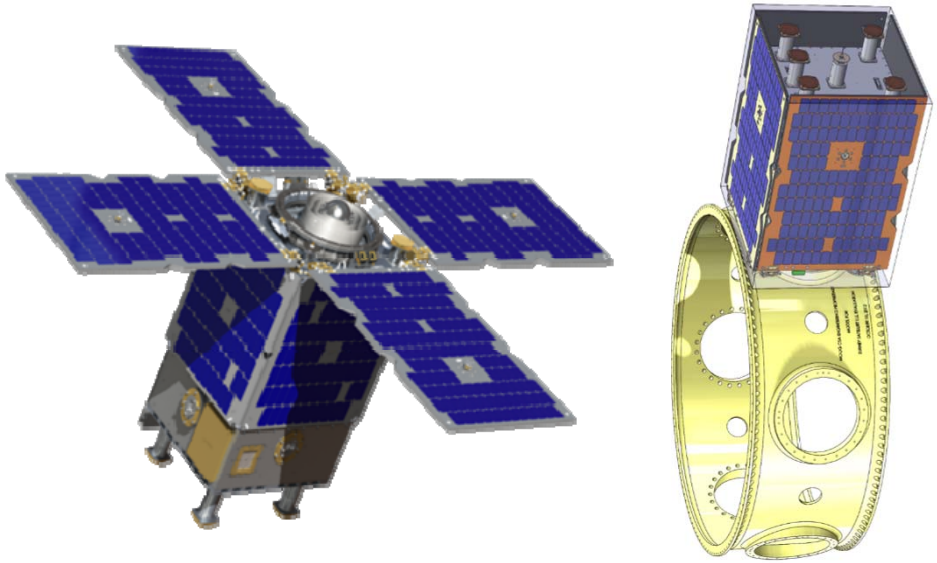
# What is a Hosted Payload (HPL)?

## A Payload integrated on someone else's S/C

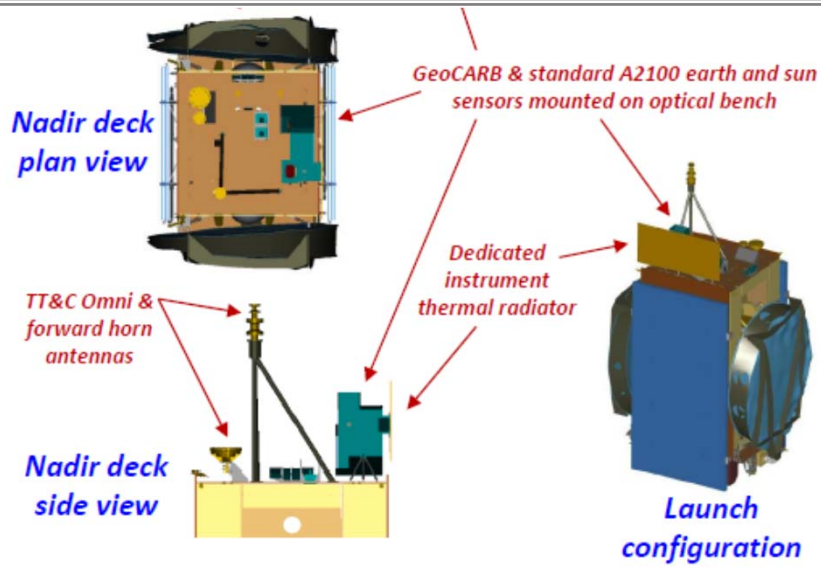



NASA's GOLD HP on a Commercial Bus

NASA's Laser HP on a USAF Bus



NASA & USAF HP's on a Commercial Bus

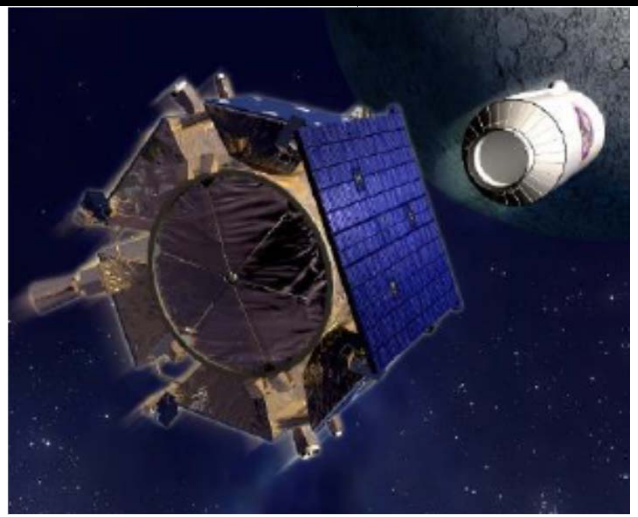



NASA's GeoCarb HP on a Commercial Bus

# 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

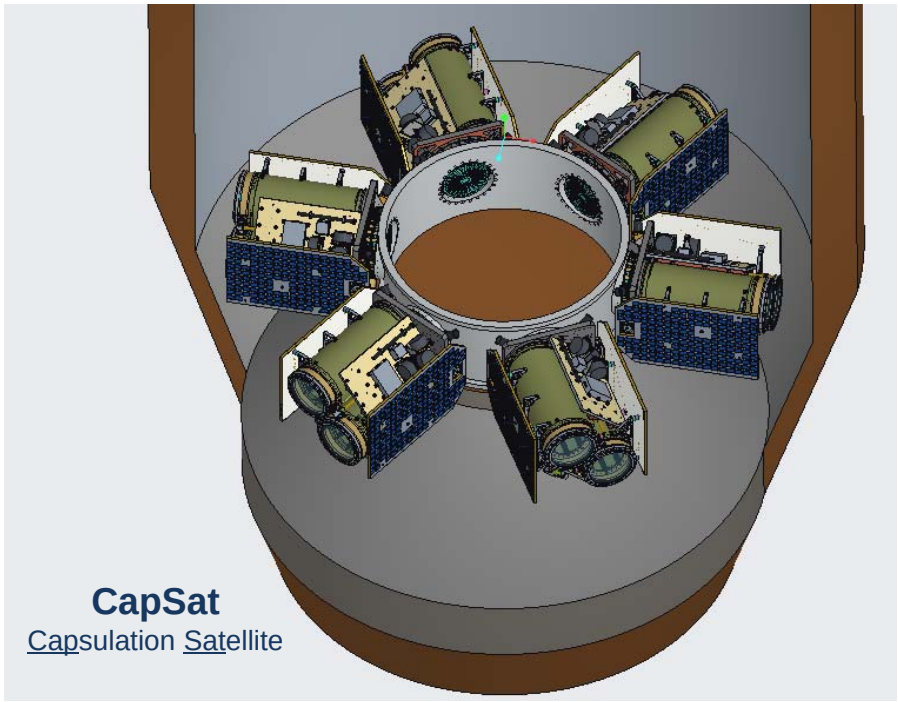

OG2-2

# CapSat-Capsulation Satellite: *The New GAS Can*

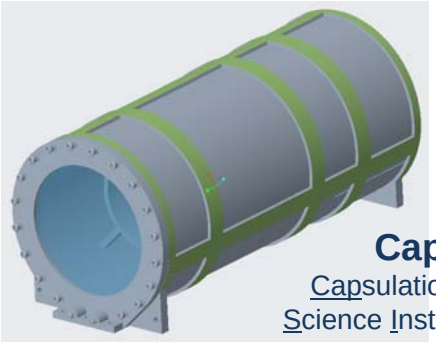
***ESPA Class Spacecraft taking advantage of unused launch vehicle mass to orbit***

- Mission Description:

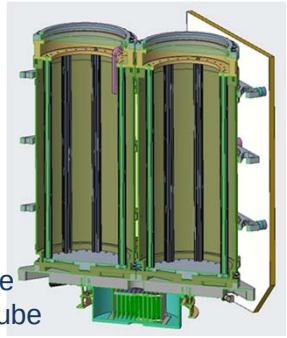
- Capsulation Satellite or CapSat is a low cost, 3 axis stabilized, modularized and standardized spacecraft, based on using pressurized volumes which allow ruggedized COTS hardware to be flown reliably in space in a manner similar to the NASA Hitchhiker-Get Away Special or GAS Can Program.
- The Capsulation 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.



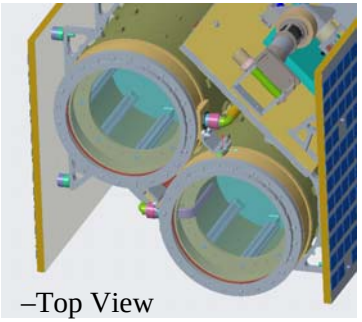
**CapSat**
Capsulation Satellite



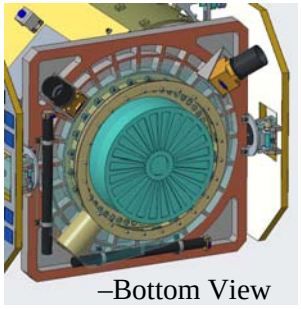
**CapSIT**
Capsulation Satellite
Science Instrument Tube



–Cutaway view



–Top View



–Bottom View

# NASA Rideshare Info: S³VI Website

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


Jointly Sponsored by the Space Technology Mission Directorate (STMD) and the Science Mission Directorate (SMD)


# *Backup charts …*

MOOG
SPACE AND DEFENSE GROUP

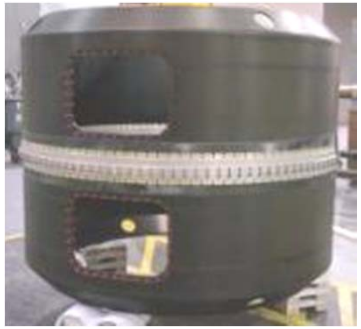
# Example ESPA Configurations


| Name | ESPA P/N | # of Ports | Ø of Ports | ESPA Height | Port Payload | ESPA Mass | Notes |
|---|---|---|---|---|---|---|---|
| Standard ESPA | 6-15-24 | 6 | 15” | 24” | 181 kg | 136 kg | ¼” Bolts |
| ESPA Heavy | 6-15-24 | 6 | 15” | 24” | 322 kg | 136 kg | 5/16” Bolts |
| EAGLE | 2-15-24-4PT | 2 | 15” | 24” | 181 kg | 136 kg | 4x 4 Point Mounts |
| | 12-11.7-24 | 12 | 11.7” | 24” | ~85 kg | 136 kg | “1/2 ESPA” |
| | 4-24-32 | 4 | 24” | 32” | 320 kg | 170 kg | 24” Port Min Height |
| | 4-24-42-SP | 4 | 24” | 42” | 320 kg | 173 kg | ¼” Bolts, Lightweight |
| ESPA Grande | 4-24-42 | 4 | 24” | 42” | 320 kg | 211 kg | ¼” Bolts |
| Grande Heavy | 4-24-42 | 4 | 24” | 42” | 454 kg | 211 kg | 5/16” Bolts |
| “SHERPA” | 5-24-42 | 5 | 24” | 42” | 320 kg | 212 kg | |
| | 4-24-48 | 4 | 24” | 48” | 454 kg | 238 kg | 5/16” Bolts |
| Long ESPA | 4-24-60 | 4 | 24” | 60” | 320 kg | 286 kg | ¼” Bolts |
| Long ESPA | 4-24-60 | 4 | 24” | 60” | 454 kg | 286 kg | 5/16” Bolts |

# Secondary Payload Adapters

ESPA

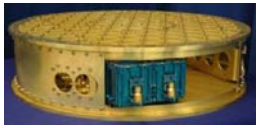
Flat Plate Adapters



CASPAR

ESPA SUM

Wafer Adapters

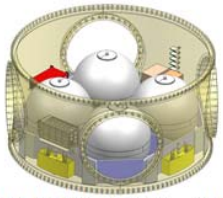


ESPA 6-15-24 LCROSS

SL ESPA 15

SL ESPA 24

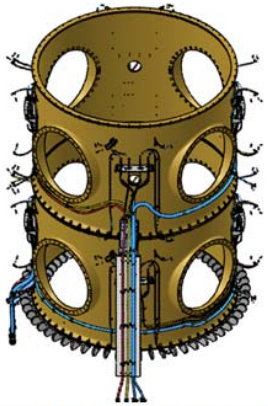
ESPA 4-15-24 DSX



ESPA 4-24-32 SPECIAL OMEGA

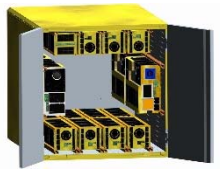
ESPA 2-15-24-4PT EAGLE

ESPA 5-24-42 SHERPA

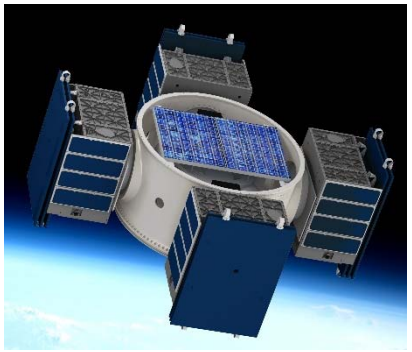


2x ESPA 4-24-42 ORBCOMM

**ESPA n-d-h**
**n=number of ports, d=port diameter (inches), h=ring height (inches)**



FANTM-RiDE



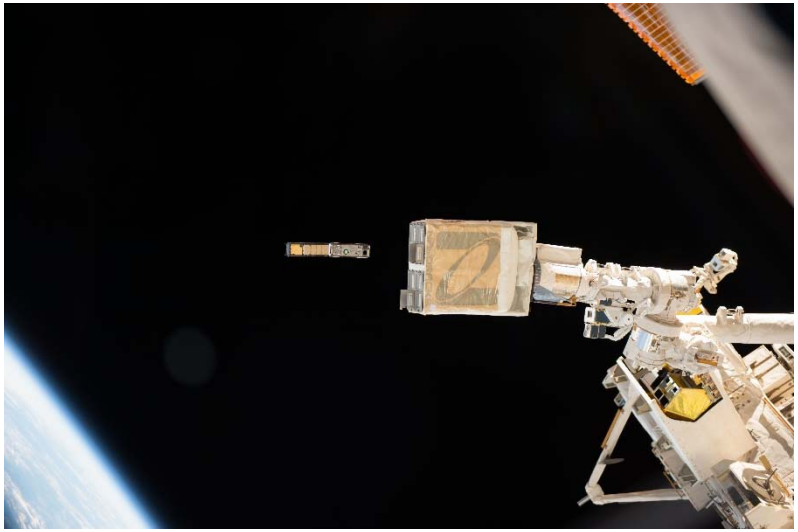
OMV (Ø62”)

Small Launch Adapter and SL-OMV (Ø24” to Ø38”)

# *Rideshare Broker Quad-charts …*

***Note: This data is the result of a market survey and not an endorsement***

# NANORACKS



## Heritage / Schedule Information:

*•Commercial ISS Satellite Deployments (CubeSats and MicroSats up to ~90kg)*
*•External Cygnus CubeSat Deployments Above ISS*
*•Additional Expendable Launch Vehicle Opportunities Available (i.e. PSLV)*
*•231 SmallSats deployed to date (19 launches)*
*•Quarterly flights to ISS*
*•ISS External Platform Hosting on JEM External Facility*
*•NanoRacks Bishop Commercial Airlock launching on SpaceX CRS-21 with additional SmallSat deployment and hosted payload capabilities*

## Company Information:

- *NanoRacks, LLC*
  - *Established 2009 (~50 employees)*
  - *Primary Offices in Houston and Washington, DC*
  - *http://nanoracks.com/*
- *Point of Contact:*
  - *Technical: Conor Brown or Henry Martin*
    - *cbrown@nanoracks.com, (703)973-6821*
    - *hbmartin@nanoracks.com, ((859) 559-7322*
  - *Sales: Allen Herbert*
    - *aherbert@nanoracks.com, (703) 677-4857*
  - *General Inquiries:*
    - *info@nanoracks.com*
- *Contract Mechanisms*
  - *Flexible Commercial Contracting*
  - *GSA Contract #: 47QRAA18D004R*
  - *Contracting with NASA Centers and other USG entities via standardized JSC Services Contract*

## Product Information:

- *CubeSat Deployment from ISS*
  - *51.6° inclination, ~400-420km circular orbit*
- *MicroSat Deployment from ISS*
  - *51.6° inclination, ~400-420km SMA*
  - *Up to ~90kg to date (larger capacity available in 2021 upon launch of NanoRacks Airlock module to ISS)*
- *CubeSat Deployment from Cygnus ISS Ressupply Vehicle*
  - *51.6° inclination, ~445-500km circular orbit*
- *SmallSat and MicroSat Deployment from PSLV*
  - *Polar Orbit (~98° inclination), 450-600km*
  - *Mid-Inclination Orbit (40-50° inclination), 450-600km*
- *Additional Brokerage Services for ELVs*
  - *Launch brokerage and mission management services for nearly any expendable launch vehicle on the market*

SPACEFLIGHT

## One Stop Integration & Launch Services


- Spaceflight is a next-generation, integrated space services and solutions company that is changing how small satellites are built, launched and operated to improve access to space and enable persistent global awareness
- Business Sectors
  - Launch & Integration Services
  - Small Space Systems Development
  - Integrated Data Analytics Platform

- Small Business with ~ 155 employees
- Providing Launch Services since 2010
  - 247 payloads launched to date; 150+ to come
- 5-Year: GSA Contract: GS-00F-036DA
- Other commercial and USG contracts

Valerie@spaceflight.com: Director of Government Business

Scott@spaceflight.com: Chief Engineer & Sr Mission Mgr

sales@spaceflight.com
www.spaceflight.com

1505 Westlake Ave, Ste 600
Seattle, WA 98109 USA

Products/Services:

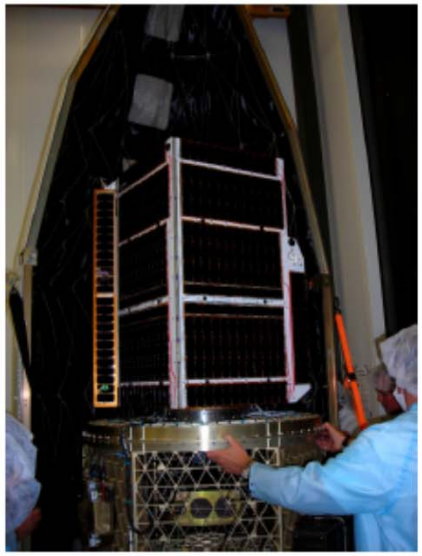
- On-line pricing & payment schedules for standard missions
- Rideshare/Annual Dedicated Rideshare Missions to LEO, GSO, & GTO
- Experienced staff & in-house integration facility to provide
  - Documentation, ICDs, MA, MSPSP, Master schedule, shipping, fit-check
  - Adapters, Separation Systems, dispensers

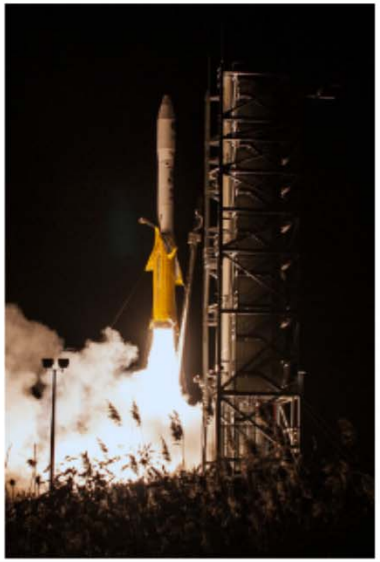
SPACEFLIGHT

# Rideshare Pricing

- On line pricing and quotes at: www.spaceflight.com
- USG Contracts:
  - NASA/Ames: Task Ordering IDIQ
  - NASA/KSC: Cubesat launch and integration
  - GSA: Launch and Integration Services
    - On-boarding more rates to include 150kgs+ and GTO/GSO


# 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*

# Tyvak Nano-Satellite Systems Inc.

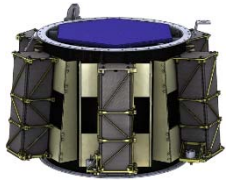
3U P-POD

3U Rail-POD

6U NLAS

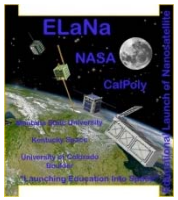
12U NLAS

MicroAMPP
Launch Vehicle Avionics



Orbital Maneuvering Vehicle
With Moog

**Supporting USG SmallSat Enablers**




NASA ELaNa and CSLI

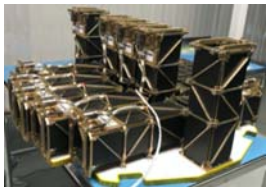
DoD, USAF, NRO

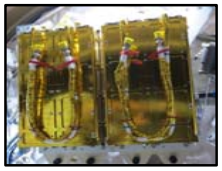
## Flight Heritage with Cal Poly:

**Launch Vehicles**
- Arianespace Soyuz
- Arianespace Vega
- Eurockot Rockot
- ISRO PSLV
- Kosmotras Dnepr
- Orbital Sciences Minotaur C
- Orbital Sciences Minotaur 1
- Orbital Sciences Minotaur 4
- Orbital Sciences Taurus XL
- SpaceX Falcon 1
- SpaceX Falcon 9
- ULA Atlas V
- ULA Delta II
- NASA SLS (in work)

**Space Ports**
- Vandenberg AFB, USA
- Cape Canaveral AFS, USA
- NASA Wallops, USA
- Reagan Test Site, Kwajalein
- Guiana Space Center, Kourou
- Baikonur Cosmodrome, KZ
- Yasny Launch Base, Russia
- Plesetsk Cosmodrome, Russia
- Satish Dhawan Space Centre, India

**Customers**
- NASA LSP
- NASA MSFC
- NASA JPL
- NRO
- DoD
- ESA
- ULA
- RocketLab
- Various US Commercial
- Various US Universities
- Foreign Govt./Comm./Univ.





## Company Information:

- ***VP, Commercial Space and Launch***
  David Caponio
  David.Caponio@tyvak.com
  310-923-3611
- 15330 Barranca Parkway, Irvine CA, 92618
- Formed in 2011, 90+ engineers, 35,000 sqft facility including secured office and lab space
- Tyvak provides turnkey launch services from rapid 2 month call up from ATP to launch on commercial, DoD, and NASA missions
- Launch hardware consisting of dispensers with 80% vibration reduction (6U/12U), to avionics to control a LV, and a maneuverable upper stage partnered with Moog.

## Tyvak SmallSat Launch Process:

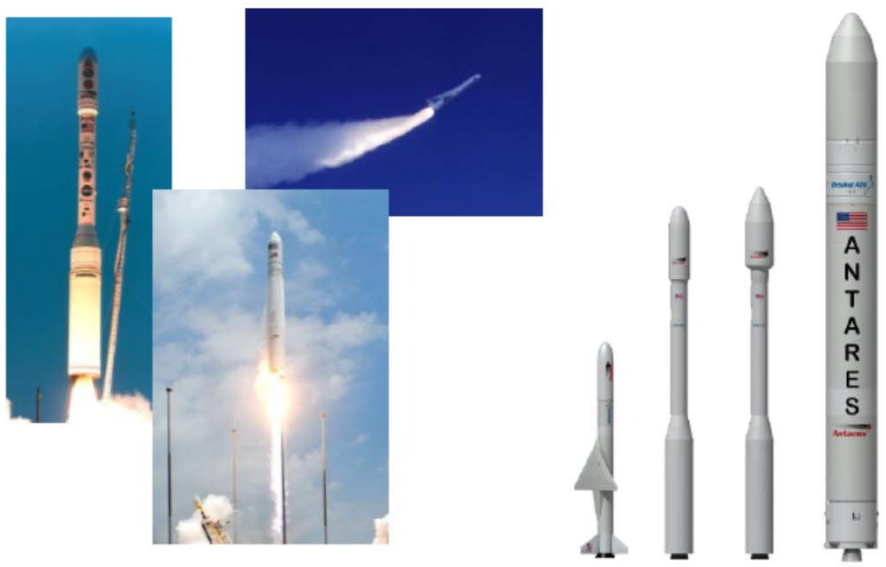
**Tyvak Responsible For**

- 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

# Northrop Grumman Rideshare Support




## Heritage / Schedule Information:

- *Pegasus has 43 launches, with the last 29 completely successful. It has one mission on manifest. 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 10 launches, with the last 5 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@ngc.com*
- *NGC.com*
- *Northrop Grumman is a leader in space, providing world-class end-to-end capabilities across all domains. From cyber to ground systems, payloads, innovative in-space logistics, spacecraft and the launch vehicles that propel them to space, we provide our customers with agile and resilient full mission sets. We are innovators in the commercial satellite market with the ability to design, build and deliver innovative products to orbit for a variety of commercial and government customers.*

## Product Information:

- *Pegasus has a performance up to 400 kg, and inclination range of 0 to very highly retrograde due to its mobile, air-launched nature*
- *Minotaur-C has a performance up to 1590 kg and inclination range of 28.5 degrees to SSO*
- *Antares has a performance range from 800 lbs to over 8000 kg and inclination range of 38 to 60+ degrees and SSO.*

# Northrop Grumman: Rideshare Opportunities

- Antares (with Cygnus):
  - CubeSats Deployers
  - Payloads Smaller than ESPA (longer but skinnier), mass flexible
  - Orbit: 185x300 km, 51.6°
  - Antares without Cygnus:
    - ESPA Payloads - shorter than standard ESPA P/L (due to 3.9 M faring v. 4.3 M diameter)
- Cygnus:
  - CubeSats Deployers
  - Payloads less than 50 kg, custom shapes – see quad chart
  - ISS Orbit: ~400 km, 51.6° (post ISS: slightly above/below & different inclination)
- Launch Opportunities
  - Antares and Cygnus will launch several times a year through 2022 (3 possible launches in 2017).

# *Rideshare Spacecraft Quad-charts …*

***Note: This data is the result of a market survey and not an endorsement***

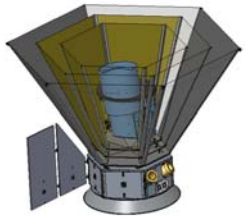
# Ball Configurable Platform (BCP) For Rideshare


STPSat-2


STPSat-3


GPIM


IXPE


SPHEREx

## Heritage / Schedule Information:

- *STPSat-2, Launched Nov 2010, 2 payloads*
- *STPSat-3, Launched Nov 2013, assembled in 47 days, 6 payloads*
- *GPIM, planned launch summer 2019, green propellant propulsion system prime payload, 3 secondary payloads; contract start to spacecraft bus complete – 24 months; Launch June 2019*
- *IXPE, in development, Mission CDR June 2019; launch planned April 2021*
- *SPHEREx, in development, phase B start May 2019, launch planned November 2022*

## Company Information:

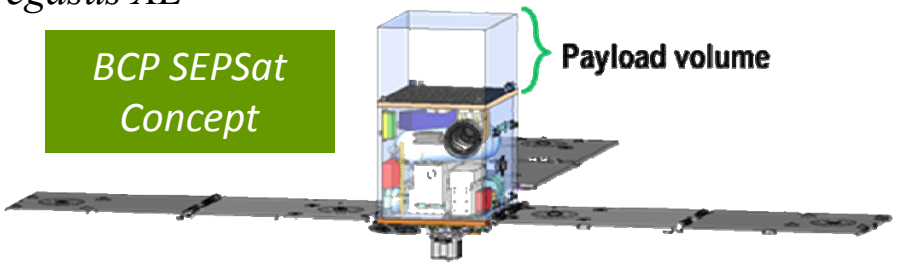

- *Dr. W D Deininger*
- *303.939.5314*
- *wdeining@ball.com*
- *Dr. J. Weinberg*
- *303.939.4215*
- *jweinber@ball.com*


- *www.ball.com*
- *Boulder & Broomfield, Colorado, USA,*
- *~4000 employees,*
- *Active SmallSat Projects Include: STPSat-2, STPSat-3, GPIM, IXPE, NeoWISE (WISE), SPHEREx*

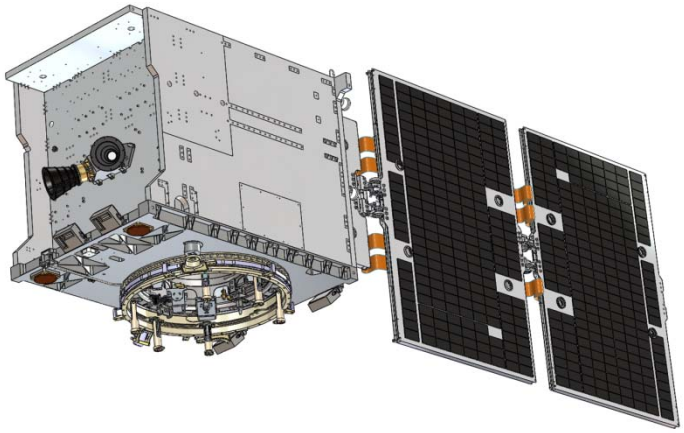
## Small BCP Product Information:

- *Orbit; 400 km to 1200 km*
- *Inclination: 0 deg to sun-synchronous*
- *Stabilization: 3-axis, zero net momentum*
- *Attitude knowledge: 0.02° 3σ each axis*
- *LV Compatibility: ESPA, ESPA Grande, Minotaur, Pegasus XL*

BCP SEPSat Concept



# General Atomics Electromagnetic Systems



**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:**

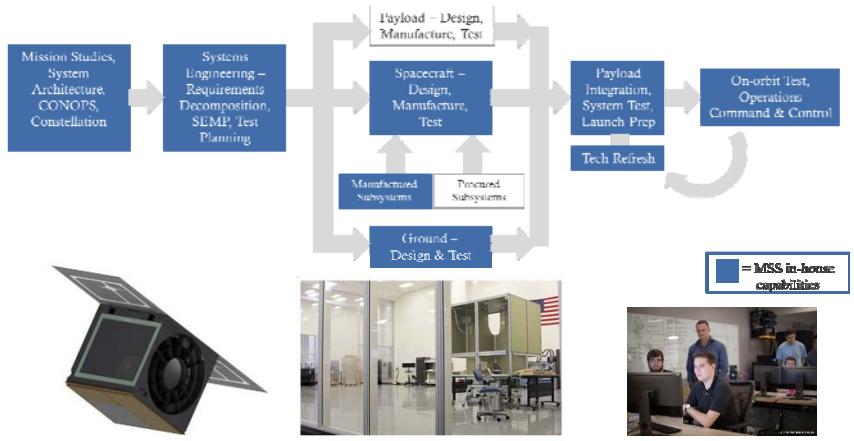
- *Dave Robie, David.Robie@ga.com, 858-860-6708*
- *Capabilities include engineering and satellite subsystems.*

**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*

# Millennium Space Systems

## Vertically Integrated, End-to-end Spacecraft Mission Prime System Integrator




## Heritage / Schedule Information:

- *Flight heritage AQUILA-M1 spacecraft launched on 06 Feb 2011 hosting multiple payloads*
- *Flight heritage ALTAIR Pathfinder spacecraft commercially deployed off of ISS on 17 May 2017 hosting numerous technology components*
- *Flight heritage ALTAIR-E1 spacecraft launched on 04 May 2019 to ISS and to be deployed in Jun 2019*
- *Space-qualified AQUILA-M8 spacecraft manifested on 2020 launch, dedicated payload*
- *Several more ALTAIR follow-on spacecraft with planned launches in 2019 through 2020*
- *Several RWA-1000s and processors on-orbit*

## Organization Information:

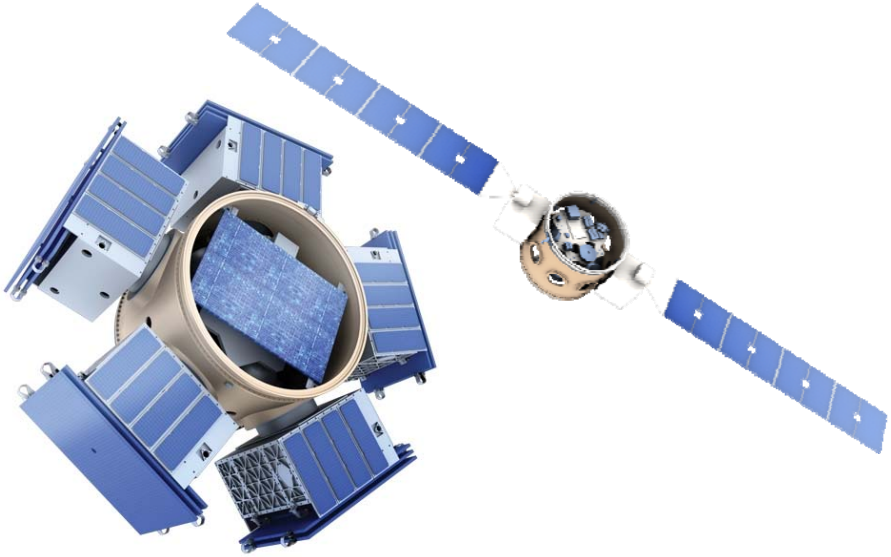
- *Jason Kim, Vice President of Strategic Planning*
- *☎ (310) 683-5884*
- *✉ Jason.kim@millennium-space.com*
- *Website: www.millennium-space.com*
- *Location: El Segundo, CA (150,000 sq-ft factory)*
- *No. Employees: 350+ and growing*
- *Founded: in Nov 2001 (>18 years in business)*
- *Acquired by The Boeing Company in Sep 2018, operating as a non fully-integrated wholly owned subsidiary*
- *Customers: DoD, IC, NASA, Commercial*
- *GSA Schedule: RWA-1000 and more to come*

## Product / Service Information:

| AQUILA™ Spacecraft bus | ALTAIR™ Spacecraft bus | RAPTOR Spacecraft bus | Products Subsystems |
|---|---|---|---|
| • Longer life<br>• Higher performance<br>• Selective to full redundancy<br>• Moderate to high power<br>• Small to medium launch rideshare | • Shorter life<br>• High performance, tech refresh<br>• <ESPA class<br>• Single string, selective redundancy<br>• Small to moderate power | • Miniaturized cutting edge technology in 6U to 12U compact form factor<br>• 100s of space vehicles launched off dedicated or rideshare | • RWAs & CMGs<br>• Star trackers<br>• Batteries<br>• IMUs<br>• Software Defined Radios<br>• Antennas<br>• Processors<br>• SADAs<br>• And more |

†In addition to spacecraft bus and subsystems products, we provide SEIT, rapid prototyping, launch integration, launch support, and mission operations services

# Moog - OMV



## Heritage / Schedule Information:

- *OMV based on flight heritage ESPA Ring (example EAGLE and 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*
- *CDR level, flight readiness at ATP + 24 months*

## 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 25 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)*

# Northrop Grumman Innovation Systems


## Heritage / Schedule Information:

- ESPAStar is Northrop Grumman's Innovative ESPA-Based Propulsive Satellite Platform
  - Design Based on Fight Proven AFRL's EAGLE Program
- Six ESPA Payload Slots Provide for Combinations of Hosted and/or Separable Payloads
- GEO Orbit Baseline
  - GTO, MEO, and LEO Variants
- Provides Standardized Interfaces, C3, Onboard Processing
- Compatible with All ESPA-Capable Launch Vehicles

## Organization Information:

Carol Welsch
Senior Director of Business Development
Carol.welsch@ngc.com
(571) 342 0100
-Or-
Tim Rumford, P.E.
ESPAStar Program Director
Timothy.rumford@ngc.com
(571) 447 6173

## Product / Service Information:

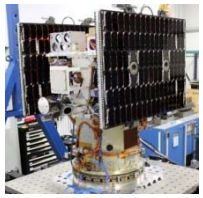
- Commercial-like production line reduces cost, schedule, and risk
  - Rolling inventory enables 22 month ATP to ILC schedule
  - Parts commonality across multiple spacecraft product lines
- Modular ESPA-based Design Provides Mission Flexibility
  - Open and published standard payload interfaces
  - Enhancements available to meet unique user needs
  - Mature ICD and User's Guide
- Designed to Maximize Opportunities for Launch
  - Supports Variety of Payload Sizes (ESPA/Nano/CubeSat)
  - Supports Combinations up to 12 Separating Payloads or 6 Hosted Payloads
  - Stackable Configurations
- MMSOC 2.1/EGS Compliant
  - Northrop Grumman's Maestro TT&C

SIERRA NEVADA CORPORATION

TacSat-2

OG2


STPSat-5



DSX

## Heritage / Schedule Information:

- *TacSat-2, Launched December 2006, 0.5m GEOINT mission, low jitter, high-performance*
- *Orbcomm Generation 2 (OG2), Launched 2014 & 2015, stacked ESPA, 17 satellites, production line rate 1 satellite / month, ultra quiet EMI/EMC*
- *STPSat-5, Launched December 2018, green propellant, 5 payloads, common payload interface*
- *Deployable Structures Experiment (DSX), free flying ESPA ring spacecraft, investigate persistent smallsats for C³ISR in MEO, Launched Summer 19*

## Company Information:

- *Tim Flora*
- *(720) 407-3247 Ext: 173247*
- *Tim.Flora@sncorp.com*
- *https://www.sncorp.com/*
- *Louisville, Colorado, USA*
- *~800 Space Systems Group employees*
- *Established in 1963*
- *Prime Integrator and Spacecraft Bus provider*
- *Active SmallSat Projects Include: Orbcomm Generation 2, STPSat-5, DSX, SN-50, Other*

## Product Information:

- *Orbit: LEO, MEO, GEO, or deep space*
- *Inclination: As required by mission*
- *Stabilization: 3-axis, zero net momentum*
- *Attitude Knowledge: 0.01° or 0.001°*
- *LV Compatibility: ½ ESPA, ESPA, ESPA Grande, Minotaur 1/4, Falcon 9*
- *Bus & P/L Example:*
  - *SN-50 ESPA*
  - *STPSat-5 (LEO)*