ESPAStar – Enabling Space Missions

SPRSA Conference

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What is an “ESPAStar”?

Historically, most launches have excess launch mass capability that is underutilized

Recognizing this, the Government developed an “ESPA ring” for hosting secondary payloads

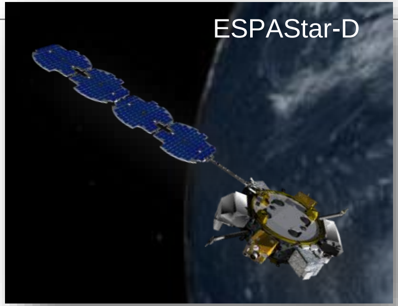
- ESPA = EELV Secondary Payload Adaptor

We have taken the ESPA ring concept and developed it into a fully functional space vehicle platform with six (6) “ports” available to host payloads

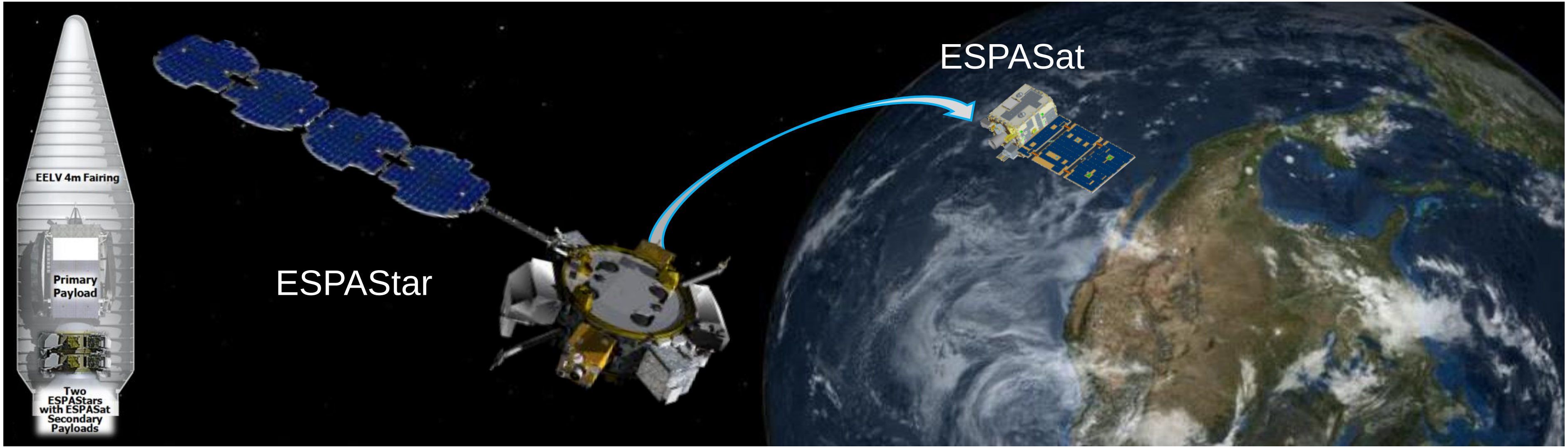
- Capable of hosting multiple payloads to GEO, LEO, and MEO
- Capable of stacked launch configurations as primary or secondary payloads
- Capable of hosting both separable and fixed (“hosted”) payloads
- Compatible with all future NSSL launch vehicles and fairings

Northrop Grumman’s first program was awarded in 2012. NG currently has 12 ESPAStar Missions on contract with more in the pipeline

ESPA Class Vehicles Are Our Fastest Growing Product Lines



ESPA Class Introduction



ESPAStar is An Affordable Rideshare Platform Capable of Hosting Multiple Payloads to GEO, LEO, and MEO
Capable of Stacked Launch Configurations as Primary or Secondary Payloads
Capable of Hosting Multiple Payloads Per Port – both Separable and Hosted
ESPAStar is an Ideal Host for ESPASat and ½ ESPA (ESPASat-L) Class Separables

ESPAStar Benefits

Commercial-like Production Line Reduces Cost, Schedule, and Risk

- Rolling inventory reduces time to launch
- Parts commonality across multiple spacecraft product lines
- Pre-planned Product Improvements & robust Supply Chain Management and Surveillance

Modular ESPA-based Design Provides Mission Flexibility

- Open and published standard payload interfaces
- Enhancements available to meet unique user needs

Designed to Maximize Opportunities for Launch

- Supports Variety of Payload Sizes (ESPA/Nano/CubeSat)
- Supports Combinations up to 6 Ports (multiple P/Ls per Port)
- Stackable Configurations

MMSOC 2.1/EGS Compliant

- NG internally developed TT&C and Mission Tools

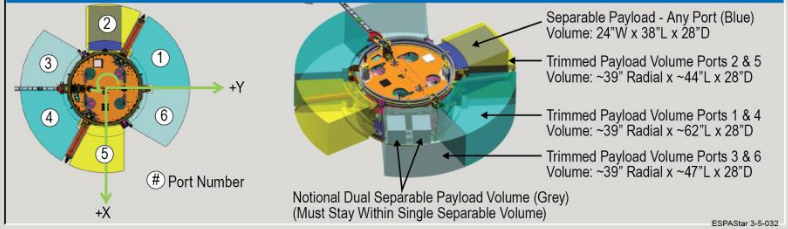
COMMON PRODUCT LINE COMPONENTS

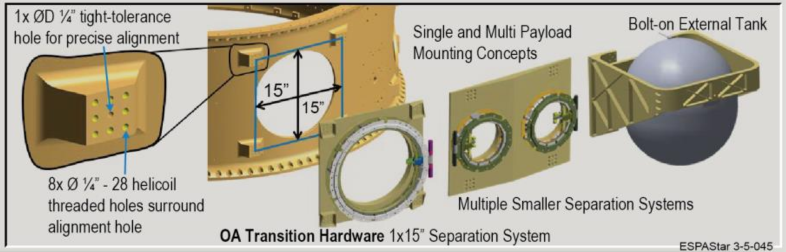
Component	ESPAStar	ESPASat	GEOStar	LEOStar	Cygnus
Battery	○	○			
Star Tracker	○	○		○	
Sun Sensor	○	○			
MIMU	○		○	○	
Reaction Wheel	○		○	○	
Reaction Engine	○	○	○	○	○
TT&C	○	○	○		
Software	○	△	△	△	

Key: ○ Same As ESPAStar △ SW Similar to ESPAStar,

ESPAStar 3-5-016r5

ESPAStar Architecture Allows for Single Non-Separable or Up to Two Separable Payloads at Any Port Location





Provides a flexible and scalable suite of capabilities to accommodate experiments, technology maturation, payload demonstrations, and operational missions

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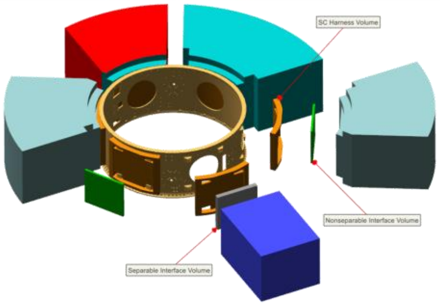
What Sets ESPAStar Apart

- Product Line Approach
  - Capabilities based approach - Recurring platform design reuse reduces cost, schedule, and permits bulk purchase of hardware
  - "Hot" inventory line means that we can flexibly respond to hardware failures with minimal or no impact to schedule
  - Highly capable, inexpensive, and less expensive bus offerings for demo and operational missions
- Dynamic Payload Environment
  - NG ESPAStar PPIRD the de-Facto Standard for GEO based Rideshare accommodation
  - Extremely mature, flexible, and capable set of interface definitions and satisfies extremely broad demands of payloads
  - Subject matter experts on hosted payload accommodation permits flexible payload deliveries – up to and including at launch site
  - Modular, build to print interfaces permits nearly ramp-on/ramp-off payload accommodation
  - Tailorable Mission assurance, and environmental testing environment to enhance or reduce testing levels
  - KG-505 Design will isolate and enable multi-level payload mission processing

Payload Power Switches

Switch Type	Total Quantity
1.2A	23
5.0 A	20
5.0 A (A/F)	6
5.0 A (A/F, Pulsed)	12

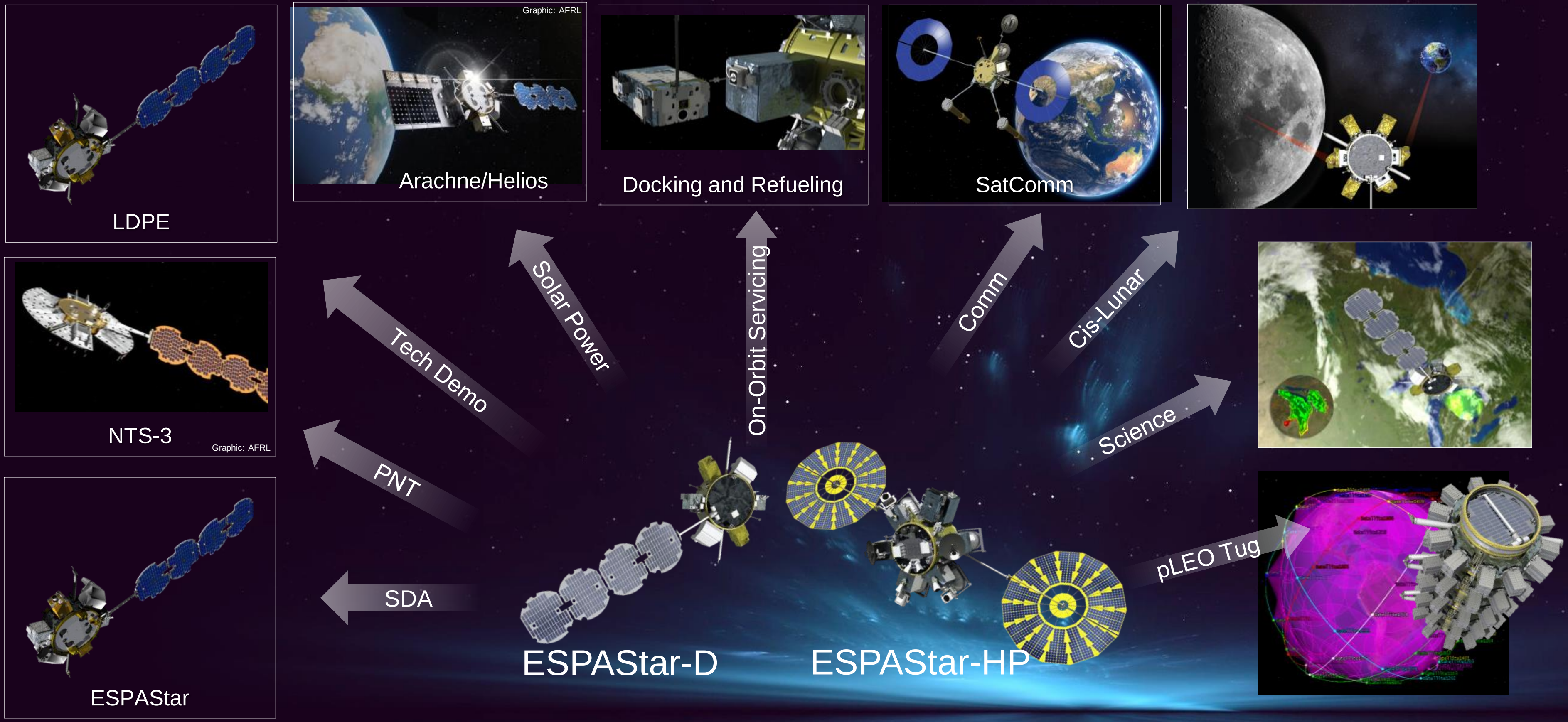
Payload MICD



Payload I/O

Interface Resources	Total Signal Allocations	Per Port Signal Allocations
Differential Transmitter (DCMD)	43	6
Synchronous Output	6	1
Asynchronous Output (UART)	15	2
Discrete Output	16	2
One PPS	6	1
Spacewire	6	1
Differential Receiver (DTLM)	49	7
Synchronous Input	6	1
Asynchronous Input (UART)	15	2
Discrete Input	22	3
Spacewire	6	1
RMII Ethernet	6	1
Discrete Bi-Level Input (BTLM)	41	6
Discrete Bi-Level Output (BCMD)	38	6
MIL-STD-1553 Data Bus Coupler	6	1
High Speed Data 3:21 SERDES	6	1
Analog Telemetry Input	47	7
PRT/Thermistor	4	Upon Request
AD590	60	10

ESPAStar: NG’s Multi-Mission Platform



Existing ESPAStar Programs

EAGLE

- Sponsored by AFRL and DoD Space Test Program
- Serves as ESPAStar prototype – basis of ESPAStar design
- Successfully launched in April 2018 and is operating nominally

ESPAStar-1, 2

- First and Second ESPAStars Built
- Incorporate lessons learned/enhancements over EAGLE, set baseline for current ESPAStar design, development, and production flow
- Both Ready to Launch

LDPE 1-3, 3A

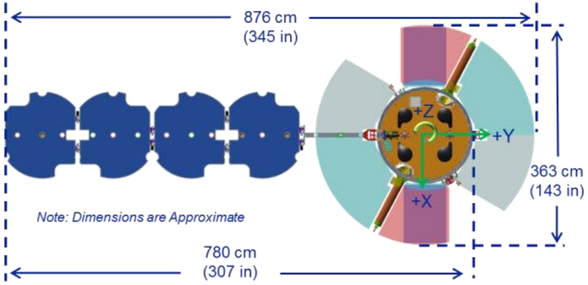
- Funded by SMC/AD – Four on contract
- Cost efficient build to print copy of ESPAStar-1
- LDPE-1&2 complete and ready to Launch, LDPE-3 Bus Delivered to AFRL for SSPIDR, -3A in Build

NTS-3

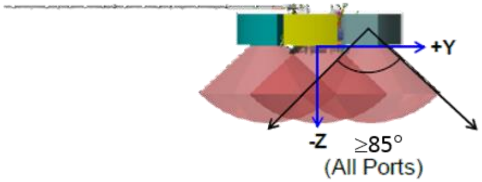
- AFRL’s Space Vehicles Directorate, Harris/L3 Prime, Experimental PNT satellite
- ESPAStar Bus Delivered.

Others – In Procurement and early I&T. ILC 2022 or beyond

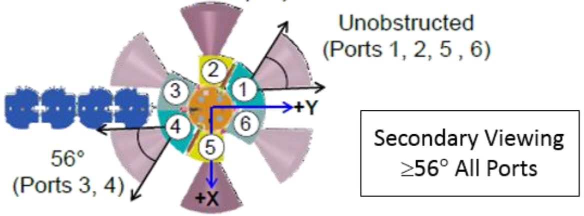
ESPAStar-D Performance



Primary Payload Viewing Direction (-Z)



Secondary Payload Viewing Direction (X/Y)

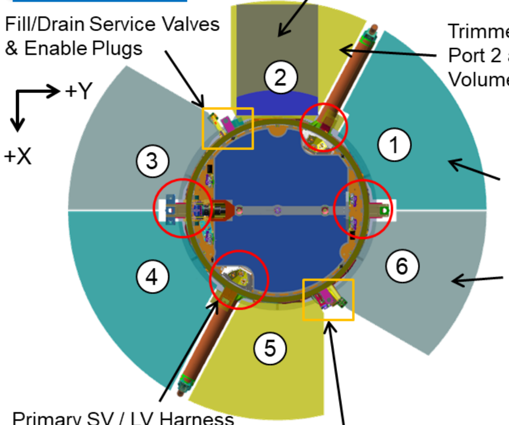


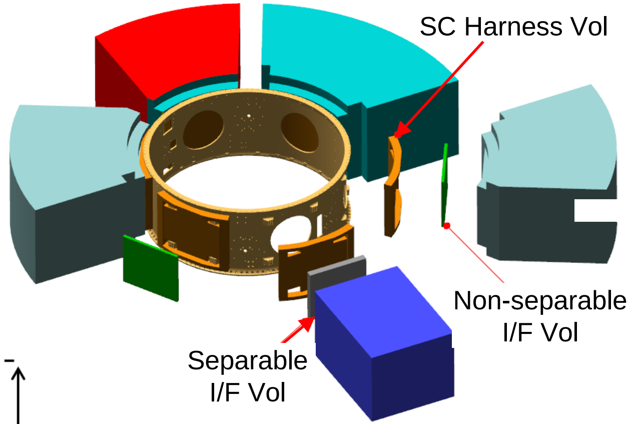
ESPAStar-D Platform Baseline Capabilities	
Bus Dry Mass (no P/Ls):	< 480 kg (Post Separation from LV)
Total P/L Mass:	1920 kg, ≥ 320 kg/port
Delta V:	400+ m/s (Manifest and DRM dependent)
GEO: Payload Power OAP:	800 W
LEO: Payload Power OAP:	250 W
Downlink Rate (via AFSCN):	256 kbps concurrent with non-separable P/L operation 1.6 Mbps in nadir pointing
Data Storage:	36 Gbytes non-TMR (24 Gbytes Payload-dedicated) 500 kbytes/day P/L SOH
Attitude Knowledge$^{\alpha}$:	< 245 μrad per axis (1σ) Normal Mode w/Solar Ephemeris attitude
Attitude Control$^{\alpha}$:	< 250 μrad per axis (1σ) Normal Mode w/Solar Ephemeris attitude
Jitter:	< 20 μrad RMS (1σ), > 0.1 Hz
Position Knowledge:	< 70 m (1σ)
Slew Rate	> 0.5 deg/sec

$^{\alpha}$ Attitude knowledge and control can be improved on-orbit using additional STA sensors and/or data from payloads, depending on the manifest

ESPAStar-D Payload Accommodation (1/2)

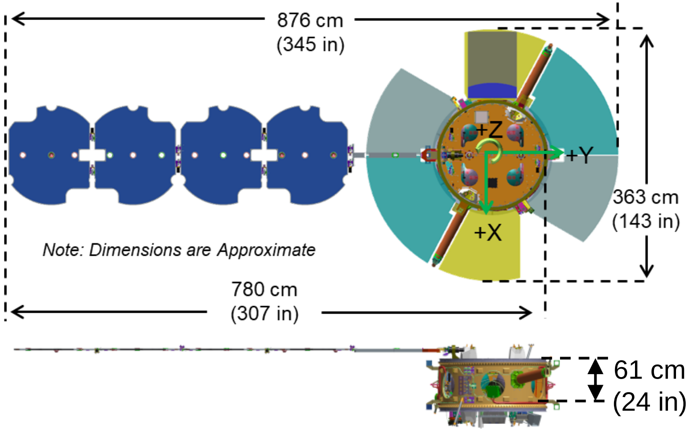
Solar Array Stowed





4m Fairing Payload Volumes Depicted

Solar Array Deployed



ESPAStar-D Payload Accommodation (2/2)

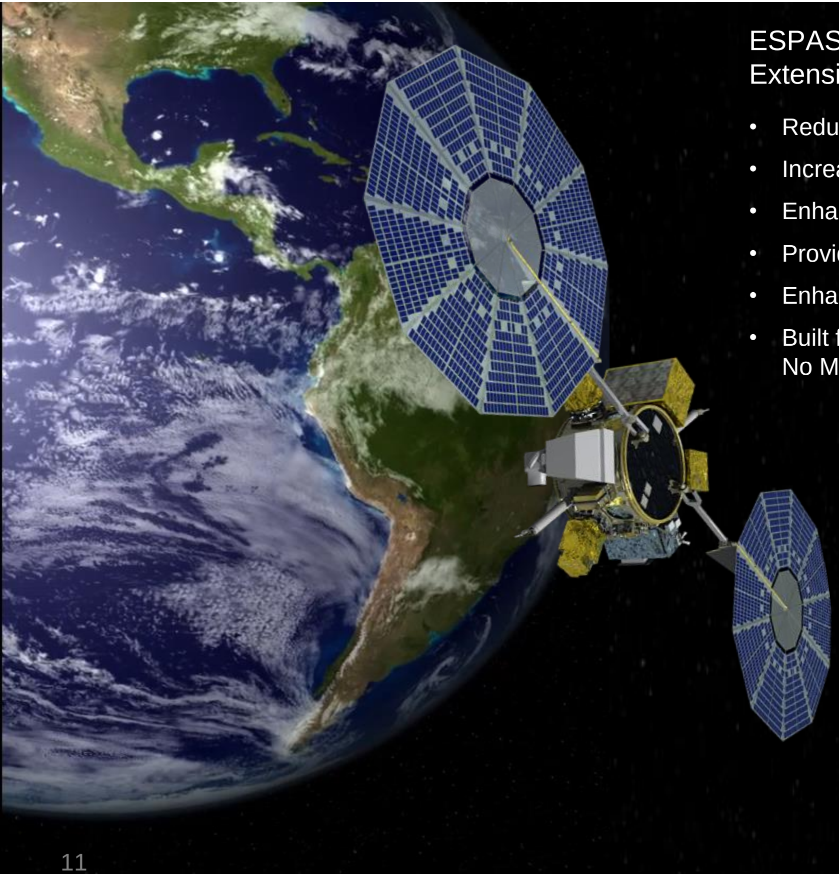
Platform to Payload ICD (PPICD), ES01231000R3, defines and controls generic interfaces between Payloads and ESPAStar-D Platform

- Details form, fit, and functional interfaces required to achieve installation, checkout, and preliminary mission objectives
  - Mechanical (mass, volume, mounting, alignments)
  - Thermal (thermal hardware, mounting interface, thermal exchange)
  - Electrical (Connections, power reqts, EMI/EMC, signals, pin-outs)
  - C&DH (data, memory, command and telemetry, fault mgmt)
  - Model exchange requirements (CAD, thermal, finite-element, reduced-numerical)
  - Software (commands, telemetry, CRC definition, error checking)
- Individual payload ICD appendices supplement main ICD
  - Allows for common interface controls to be documented and released as an unclassified document
  - Separate appendices can be held at higher levels as appropriate and may have additional signatories

ESPAStar-D Signal Allocations (Each Port)

Interface Resources
Differential Transmitter (DCMD)
Synchronous Output
Asynchronous Output (UART)
Discrete Output
One PPS
Spacewire
Differential Receiver (DTLM)
Synchronous Input
Asynchronous Input (UART)
Discrete Input
Spacewire
RMII Ethernet
Discrete Bi-Level Input (BTLM)
Discrete Bi-Level Output (BCMD)
MIL-STD-1553 Data Bus Coupler
High Speed Data 3:21 SERDES
Analog Telemetry Input
PRT/Thermistor
AD590

ESPAStar-HP: The Evolution of ESPAStar



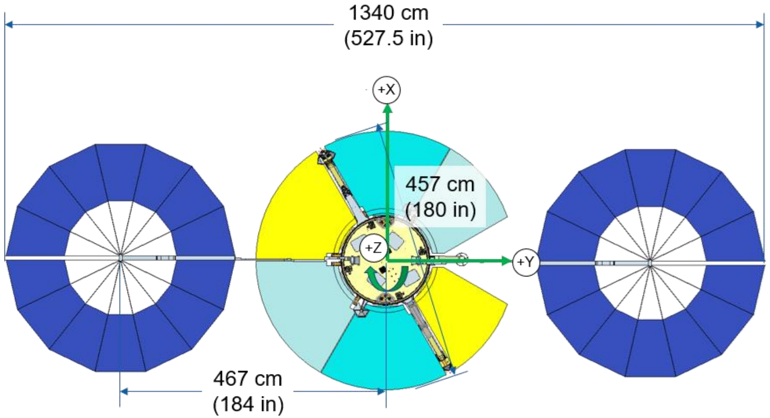
ESPAStar-HP Meets Customer Objectives, Providing the Nation with an Affordable, Extensible Platform Enhanced for Operation over a Wide Range of Orbits

- Redundant Architecture Provides > 5 yr Mission Life
- Increased Payload Volume, Power and I/O Capabilities Facilitated by Innovative, Modular Architecture
- Enhanced Communications Capability, Including USB and Crosslinks
- Provides Hosting Capability for Effective, Post-Primary Mission Technologies
- Enhanced Propulsion System Supporting Increased Delta-V and Small Satellite Refueling Capability
- Built for GEO Environment, but Enhanced Shielding is Incorporated for Extended Operation at MEO – No Major Architecture Changes Required. LEO capable.

ESPAStar HP Platform Baseline	Capability
Bus Dry Mass (No P/Ls)	< 900 kg (post-separation from launch vehicle)
Total P/L Mass	≥ 1920 kg total, > 320 kg/port
Delta V	470 m/s to 1060 m/s (Manifest and DRM dependent)
Payload power OAP/Peak	GEO: 3000 W / 4000 W (30 mins). LEO: 2000 W OAP
Downlink Rate (via AFSCN)	400 kbps on Omnis, 6 Mbps on HGA in nadir pointing
Data Storage	48 GB non-TMR, 4 GB per port
Attitude Knowledge[α]	< 245 μrad/axis (1σ) in Solar Ephemeris mode
Attitude Control[α]	< 250 μrad/axis (1σ) in Solar Ephemeris mode
Jitter	< 20 μrad/axis RMS, > 0.1 Hz
Position Knowledge	< 25 m (1σ), < 5 m typical
Slew Rate	> 0.5 deg/sec (manifest dependent)

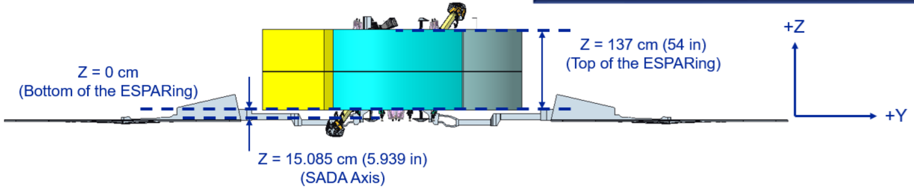
[α] Attitude knowledge and control can be improved on-orbit using additional star tracker cameras and/or payload data

(U) ESPAStar-HP Platform Configuration



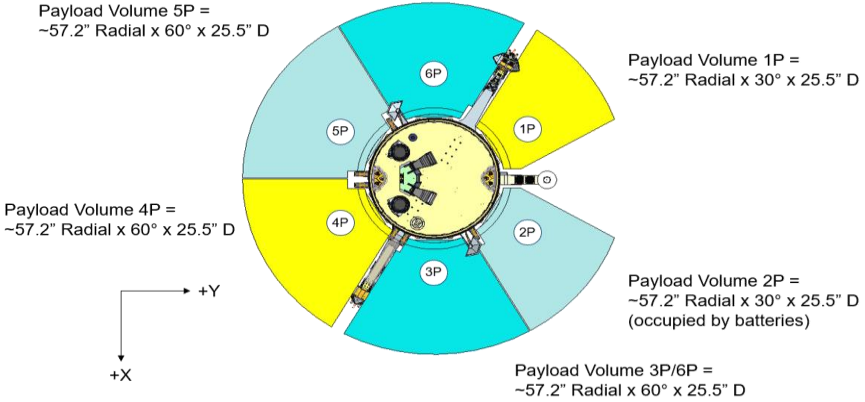
Note: Dimensions are approximate

Overall Dimensions

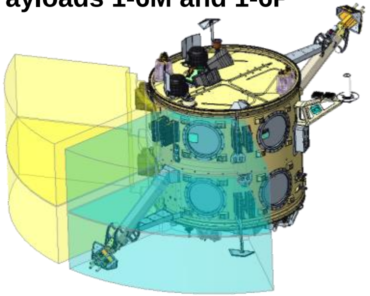


Payload Volume Dimensions

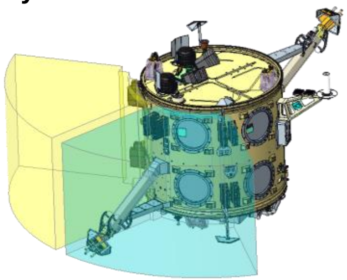
Payload Volumes 1-6P



Payloads 1-6M and 1-6P



Payloads 1-6C



Satellite Manufacturing Facility (SMF) – Gilbert, AZ
Integration & Test (I&T) w/ Manufacturing

- Complete Space System End-to-End Integration & Test Under One Roof
- Accommodates All Tactical Space Systems LEO, GEO, Cis-Lunar and Deep Space Platforms
- Single Level Direct Access Between Integration and Test Areas
- 100K/10K Clean Rooms w/ Overhead Bridge Crane Accessibility
- Avionics Assembly, MLI Fabrication, and Harness Manufacturing
- Battery Storage, Hi/Low Voltage Test Lab & Machine Shop
- Large Transition Bay For Ease of Ingress & Egress
- Full Suite of Environmental Testing for All Launch & Space Environments:
  - EMI/EMC
  - Dynamics / Mass Properties / Static Testing
  - Thermal Cycling / Thermal Vacuum Testing / Bake-out

Vibration & Acoustics Cell

EMI/EMC Chamber

TVAC Chamber

Gilbert Main Campus

Satellite Manufacturing Facility

Headquarters & Engineering Building

Satellite Engineering Building

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