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Vibration Suppression – Precision Motion Control

MOOG

ESPA as Base Vehicle for Servicing Missions

NASA Goddard Space Flight Center
International Workshop on On-Orbit Satellite Servicing
UMUC Conference Center, Adelphi, Maryland

26 March 2010

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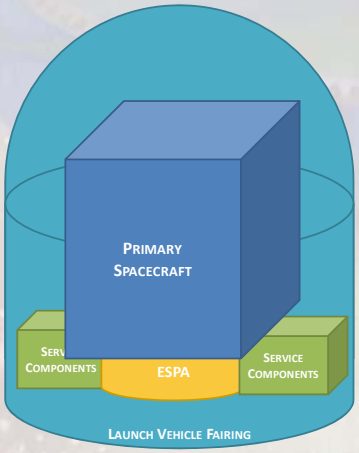

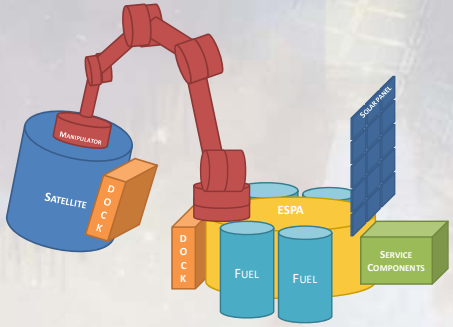

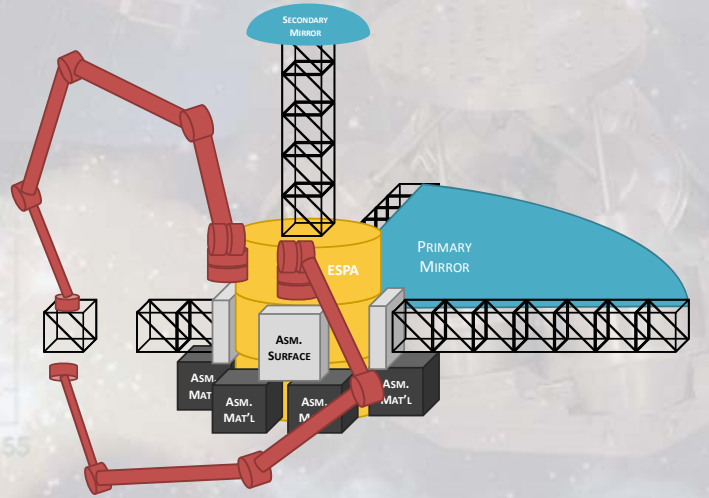

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Outline

- EELV Secondary Payload Adapter background
- ESPA structure
- ESPA modularity
  - NASA and LRO secondary payload
- ESPA orbital maneuvering vehicles
- ESPA variations
- ESPA as base vehicle for servicing missions

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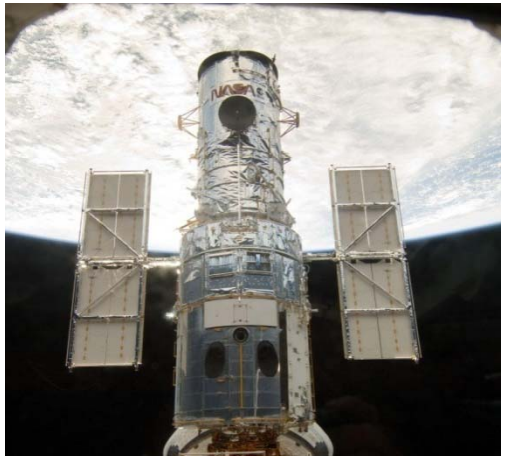
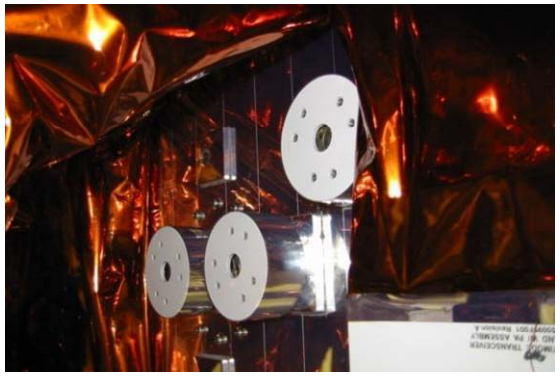
CSA Engineering Relevant Programs

Axial Carrier M-Strut isolators



Solar array dampers

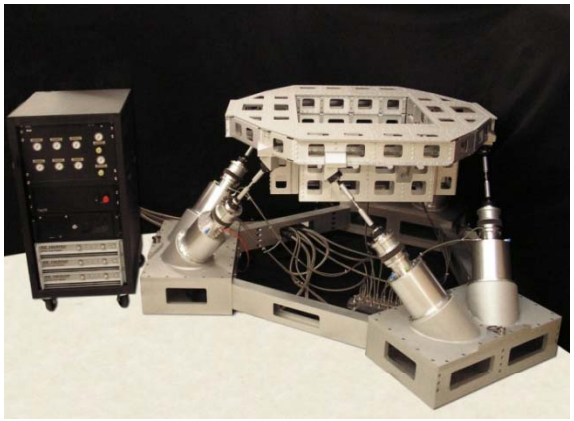


GLAST tuned mass dampers

Ground Test: JWST Six-axis positioner

Electromagnetic actuators

SoftRide



Flight motion and jitter simulators

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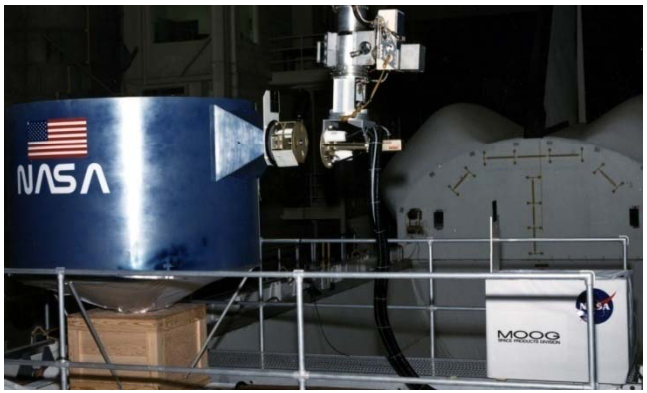
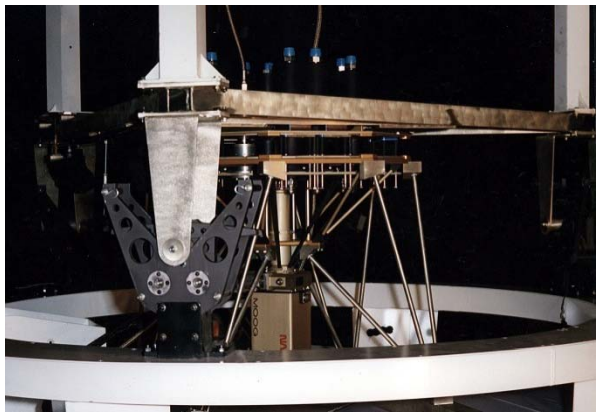
Moog Relevant Programs



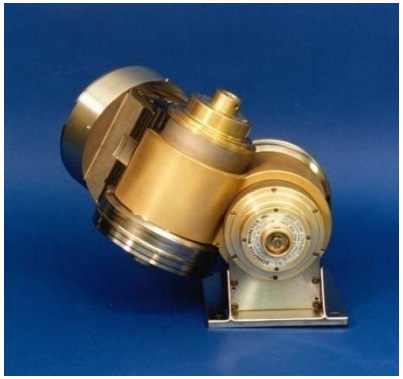
Automated Umbilical Connector Testing at JSC



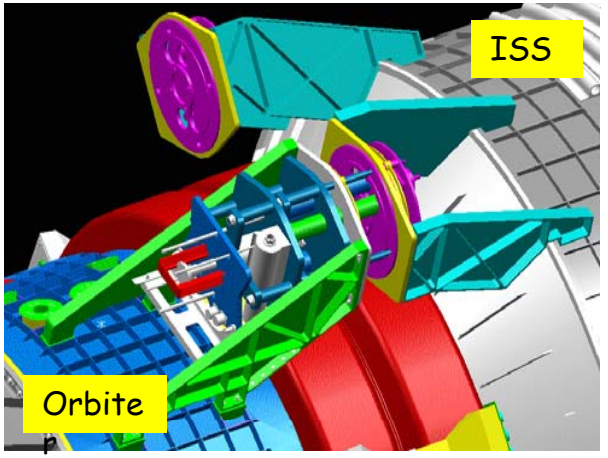
Automated Fluid Interface Testing at MSFC

Universal Refueling Interface

ISS Thermal System Fluid Disconnect



ISS Flight Telerobotic Servicer - 7DOF Joints



ISS Orbital Fluid Transfer System PDR Design

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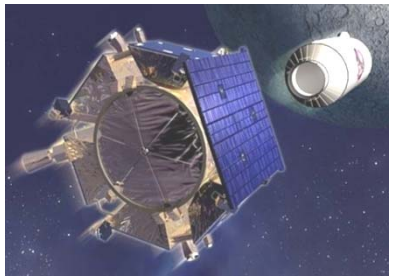
ESPA as Mission Enabler

- In 2006, NASA moved Lunar Reconnaissance Orbiter (LRO) Mission from Delta II to Atlas V, creating excess lift capacity
- 19 proposals from NASA Centers were submitted for secondary payload mission
  - All viable mission scenarios used ESPA as payload adapter
- Ames Research Center's LCROSS won competition; Northrop Grumman built spacecraft around ESPA
  - Spacecraft directed Centaur upper stage to impact lunar surface
    - » Propellant tank mounted on Ring interior
  - Launch from Cape June 18, 2009
    - » Lunar impact October 9
  - Northrop Grumman and NASA stated that ESPA was essential to mission success



NASA/Northrop Grumman LCROSS satellite integrated with LRO

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EELV Secondary Payload Adapter

- ESPA accommodates six 400-lb satellites as secondaries on EELV Medium launches
- ESPA installed between primary spacecraft and launch vehicle at 62-inch interface
  - Six ESPA "ports" with 15-inch interface for secondary spacecraft
  - Stiffness-driven structure achieves ESPA design mandate

No added risk for primary payload

- ESPA Standard Service in development at ULA to implement policy directive from Secretary of Air Force
  - ESPA Rings on all Air Force EELVs with excess capacity
- ESPA use for applications other than original design objective has been demonstrated
  - Dedicated secondary mission, e.g., LCROSS
  - ESPA Orbital Maneuvering Vehicles in development
  - ESPA structure variations developed under NASA funding

ESPA Ring Structure

- **Satellite adapter designed for Atlas V and Delta IV**
  - **United Launch Alliance medium EELVs**
  - **Qualified for 15,000-lb primary and six 400-lb secondary spacecraft**
  - **Compatible with SpaceX Falcon 9**
    - » **Same diameter interface as EELV**
- **Structural hub for free-flyer spacecraft and orbital maneuvering vehicles**
- **Building block for modular mission configurations**
- **Stiffness driven design and high strength margins**

STP-1 Atlas V launch stack March 2007

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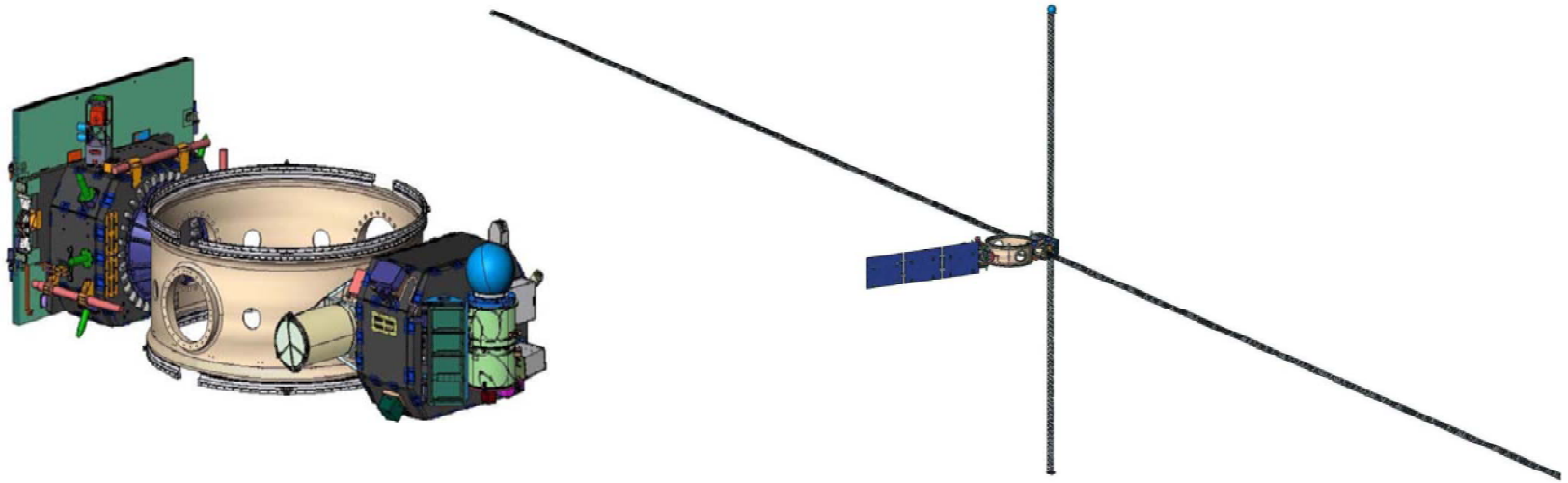
ESPA as Satellite Structure

Demonstration and Science Experiments (DSX)

- Air Force Research Lab mission uses 4-port Ring
  - Experiments require 3-axis-stabilized spacecraft bus (but no propulsion), suite of radiation sensors, and extended duration in MEO
- Thirteen payloads in 3 research areas with common requirements
  - Wave Particle Interaction Experiment (WPIx): investigate electromagnetic wave-particle interaction in MEO
  - Space Weather Experiment (SWx): collect space weather data
  - Space Environmental Effects (SFx): collect data on degradation in MEO
- Target launch co-manifest with operational DoD satellite in 2012



Launch and Flight Configurations

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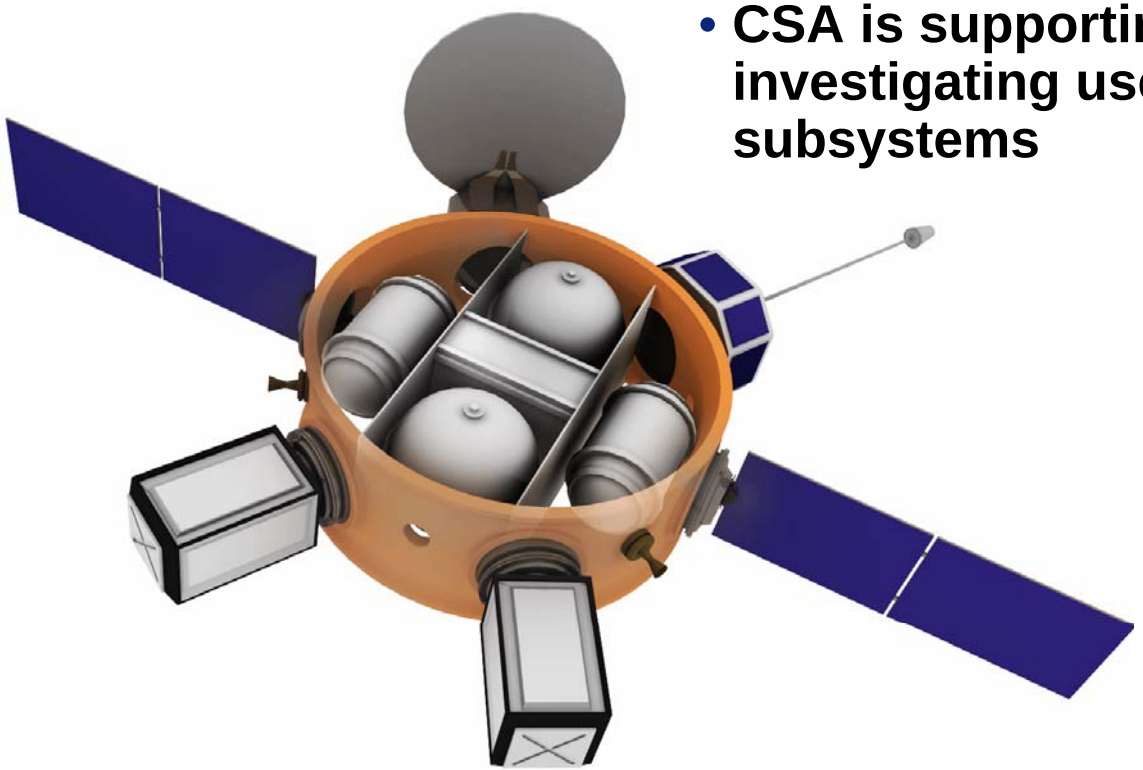
ESPA as Orbital Maneuvering Vehicle

Adapter is launch vehicle final stage or hub of free-flyer

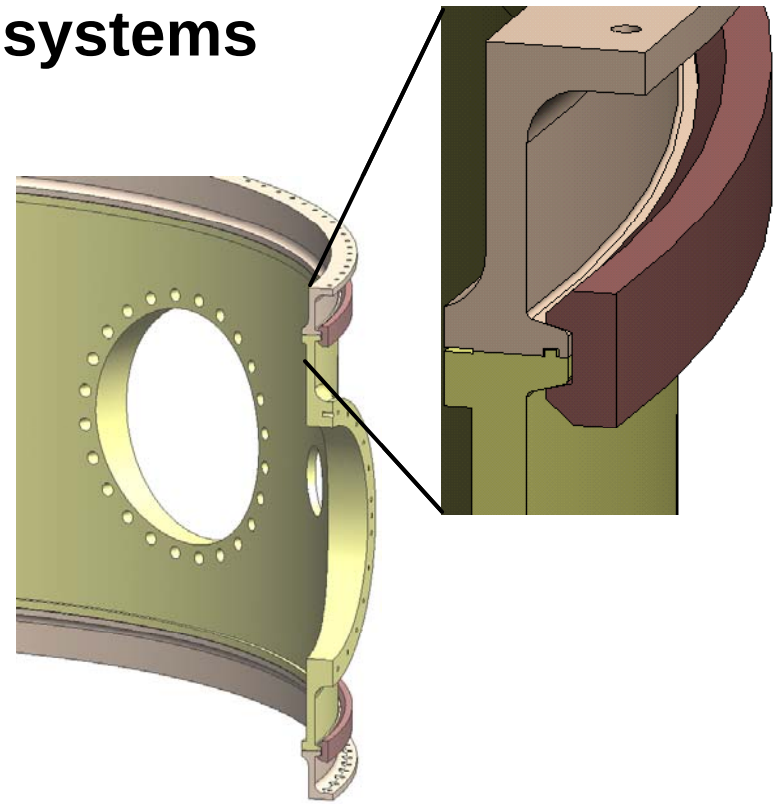
- On-board propulsion provides enhanced capability
- AFRL and STP are funding development of ESPA Orbital Maneuvering Systems
- CSA is supporting teams and investigating use of Moog components in subsystems



ESPA Variation
Integral Separation Systems

- **Low-shock separation system built into Ring**
  - **Primary interface modified to share sep system function**
  - **Elimination of bolted interface reduces stack height and weight**
- **Designs developed for two systems**
  - **Ruag Space AB (formerly Saab Space)**
  - **Planetary Systems Corp.**

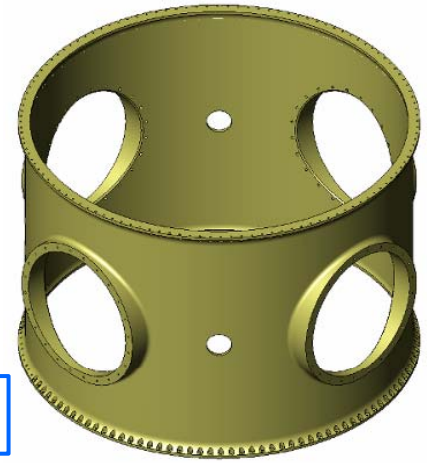
Developed to PDR level under NASA SBIR



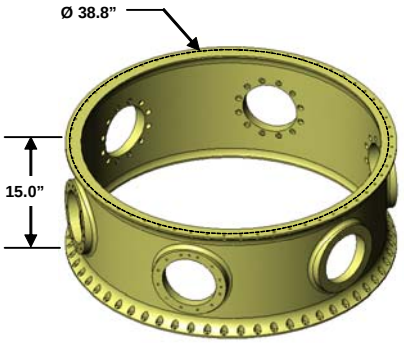
ESPA Variations
Larger and Smaller Rings

- **ESPA Grande**
  - Standard ESPA 62-inch diameter
  - Ring height variable up to 60 inches
  - 23.25-inch secondary ports
  - 660-lb secondary spacecraft
- **Small Launch ESPA**
  - 38.8-inch interface compatible with Minotaur, Falcon, Taurus, Delta II
  - 15-inch Ring, 8-inch ports
  - 24-inch Ring, 15-inch ports

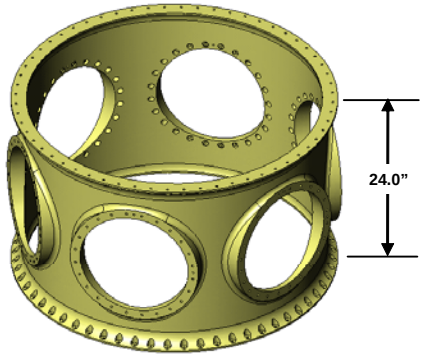
Developed to PDR level under NASA SBIR



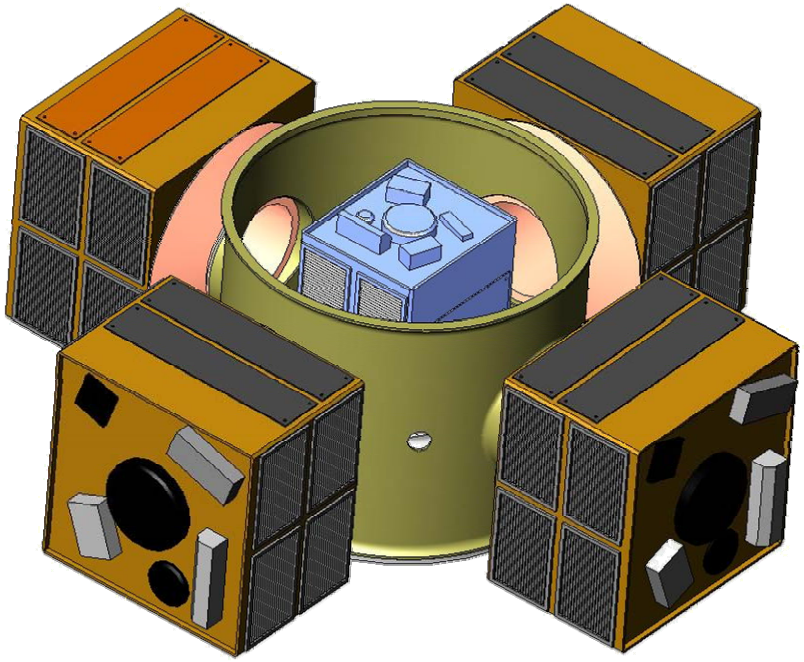
ESPA Grande



SL-ESPA-15



SL-ESPA-24



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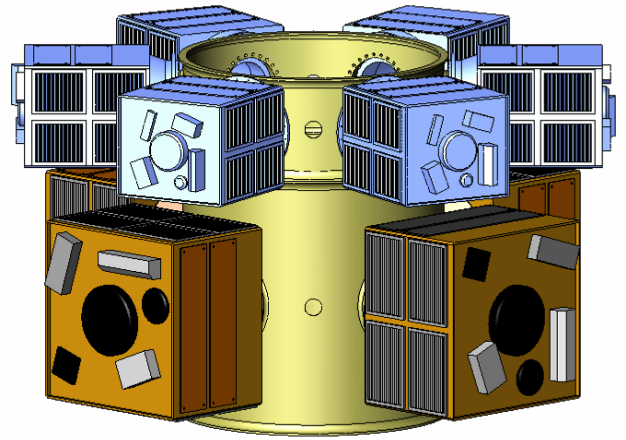
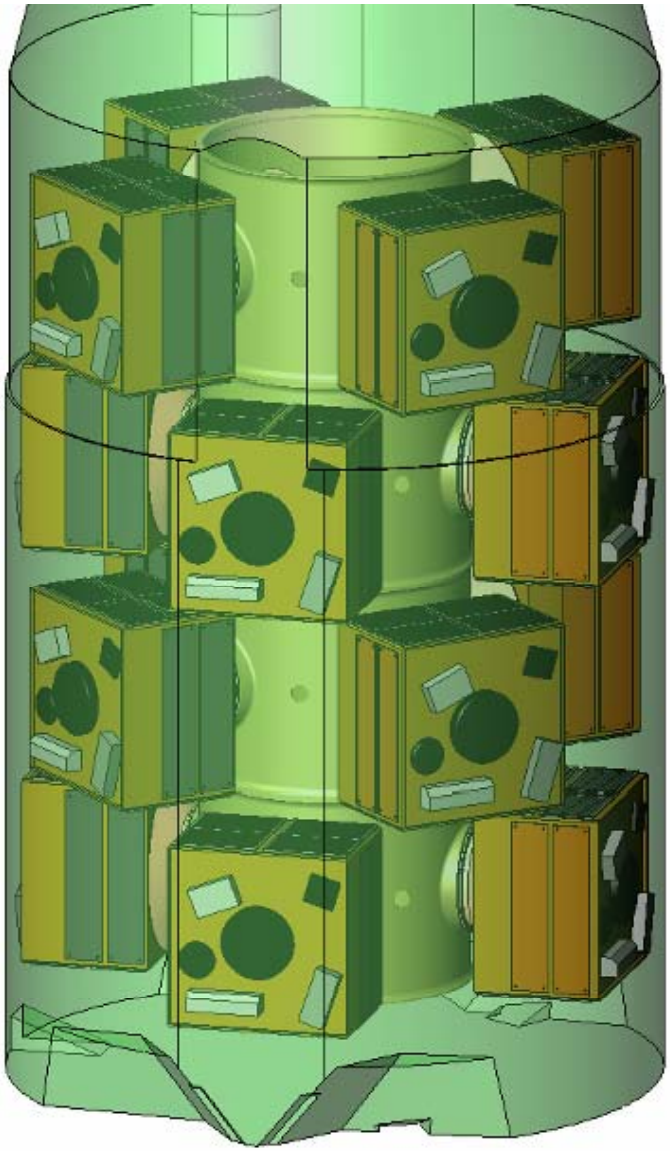
Stacking of ESPA Rings

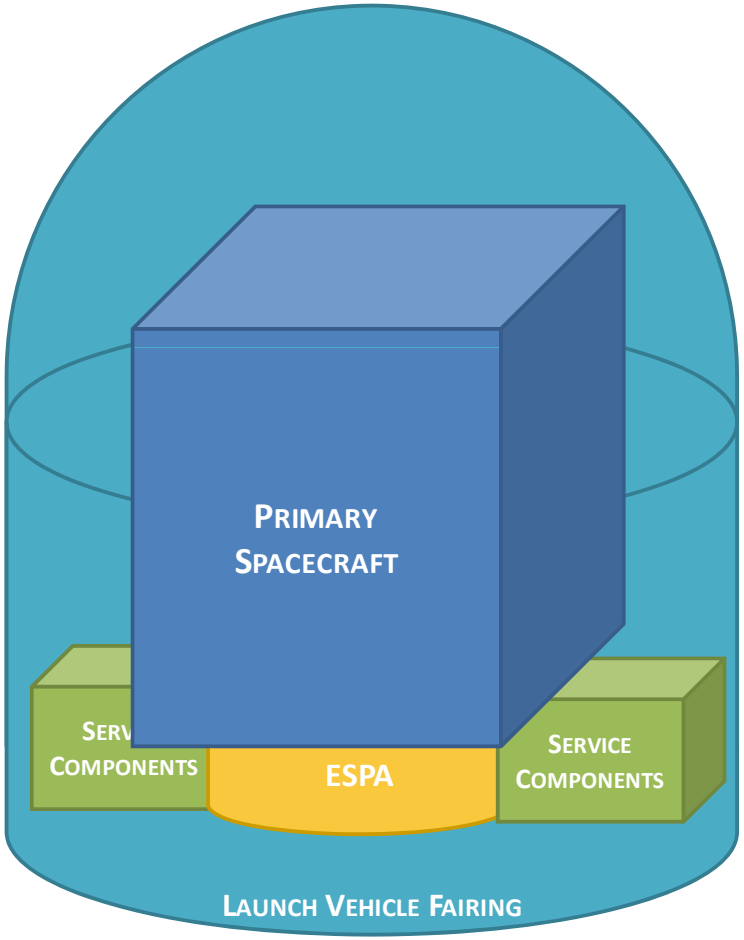
Satellite constellations deployed on single launch employing multiple Rings

- Up to thirty-six 400-lb spacecraft on six stacked (standard) ESPAs
- Up to sixteen 660-lb spacecraft on stack of four ESPA Grande Rings



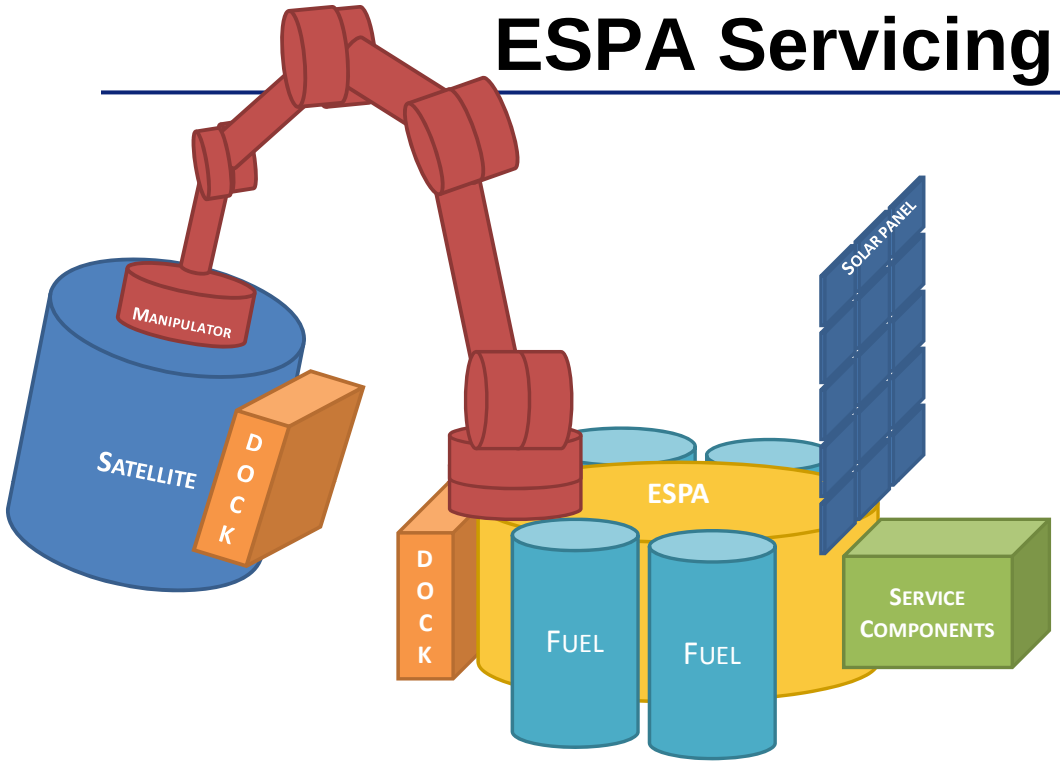


On-Orbit Servicing: ESPA as Component Launch System



- **Flight qualified adapters**
  - **Transparent to primary mission**
  - **Technical Readiness Level 9 (TRL9)**
- **ESPA launches components or spacecraft segments for later use in servicing or assembly by another spacecraft**
  - **ESPA inserted into mission with minimal impact to launch**
  - **After launch, servicing spacecraft docks with ESPA, removes/ replaces components on failed system**

On-Orbit Servicing: ESPA Servicing Vehicle

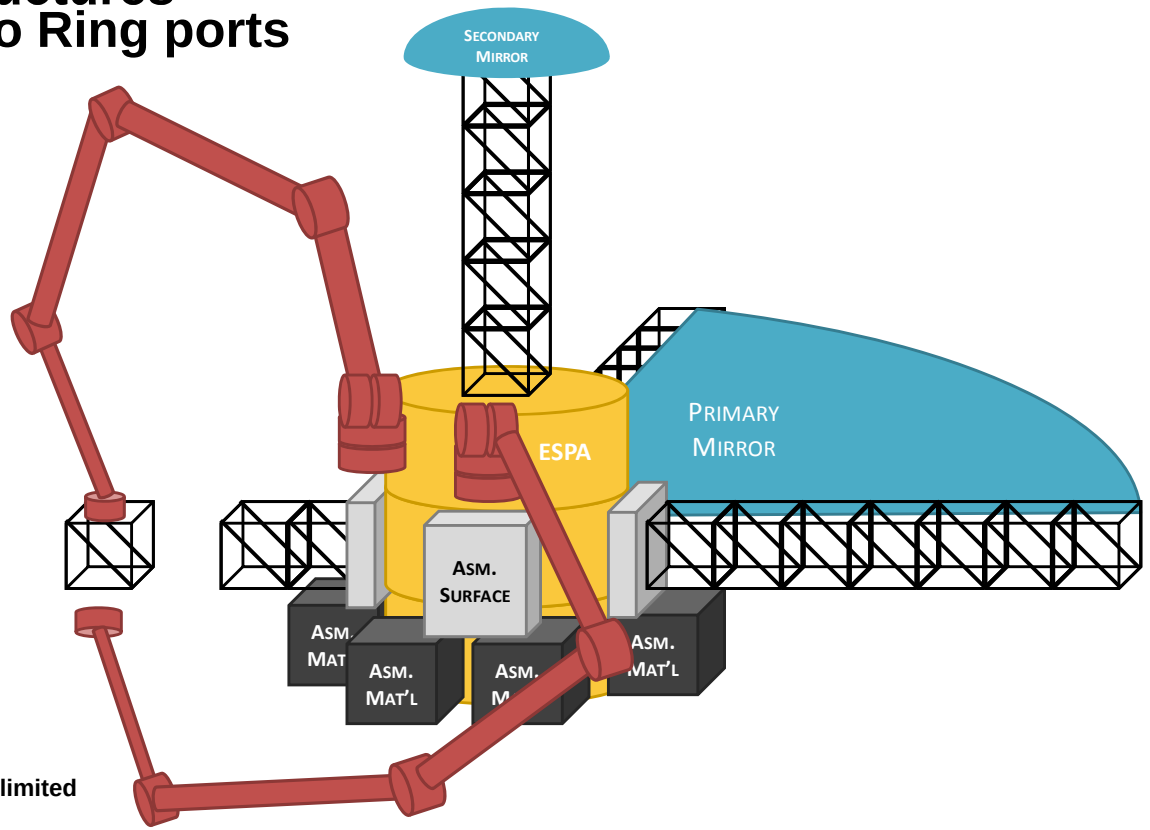


- Standard ESPA structure augmented with robotics, avionics, propulsion, servicing modules
  - Modules selected per servicing mission need
  - Inserted on launch as available
  - Transparent to primary spacecraft

- On orbit rendezvous with target satellite
  - Inspection
  - Docking
  - Exchange of cryogens, fuel, components, payloads
- On mission completion, ESPA de-orbits itself and/or non-functional spacecraft

On-Orbit Servicing: ESPA as Assembly Hub

- **Ring(s) launched with construction elements and dexterous manipulators**
  - On-orbit base for structure assembly
  - Extended structures mounted onto Ring ports
- **Launch as single Ring or ESPA stack**
  - Within fairing limitations
  - Additional rings jettisoned after extracting components
  - Alternative use as mast for stability



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ESPA Provides a Running Start

- **ESPA modularity, ESPA variations, other adapters → opportunities for mission flexibility**
  - **Stacking of Rings**
  - **Separable interface**
  - **ESPA Grande**
  - **CSA adapters for Delta II, Minotaur IV, Falcon 1e**
  - **Moog fluid transfer systems and mechanisms**
- **Robust adapter structure → multiple configurations of servicing base vehicle**
  - **Robotic arms or other components mounted to secondary ports or to Ring cylinder**
  - **Structure serves as launch interface, on-orbit bus, mission building block**
- **ESPA can be combined with CSA's SoftRide whole-spacecraft isolation systems and other adapters**
  - **www.moog.com/products/spacecraft-payload-interfaces**
  - **www.csaengineering.com/oos**