A Flexible Rideshare Adapter System to Increase Space Access for "Express" Class 20-50 kg Small Satellite Missions

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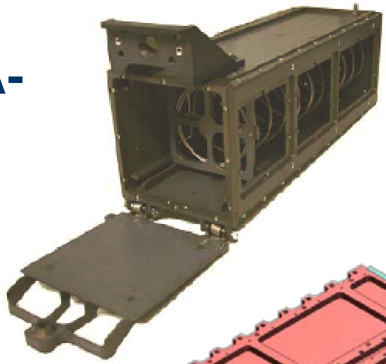
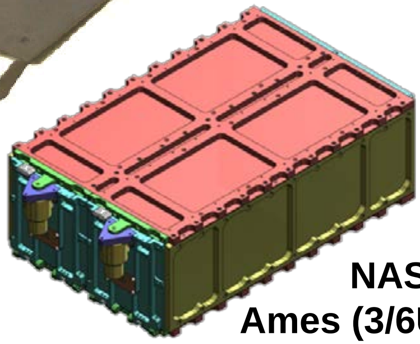
The Need

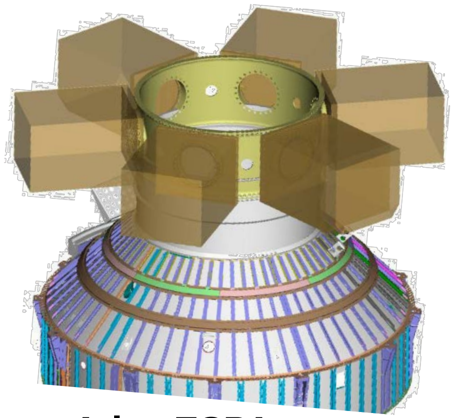
- **Many missions cannot be fulfilled by 3U/6U CubeSats (up to 12 kg) but do not require an ESPA-class (181 kg).**
- **Need an intermediate spacecraft (nanosatellite) with a standardized LV interface, like CubeSats but not containerized, like ESPA.**
- **Rideshare compatibility helps reduce the total cost of missions using these small satellites.**
- **Intermediate size spacecraft needs to use available secondary launch mass and volume efficiently.**
  - **The N*U scaling paradigm replaced by an enveloping analysis of LV secondary accommodation, volume and mass.**
  - **Needs an inexpensive hard-point separation system that can be used on virtually any launch vehicle.**
- **Result: The *Express-class* space vehicle, and LV interface, to enable 20-50 kg rideshare missions.**
  - **More capable than CubeSats; Less expensive than ESPA.**



Poly-Picosat Orbital Deployer (P-POD)



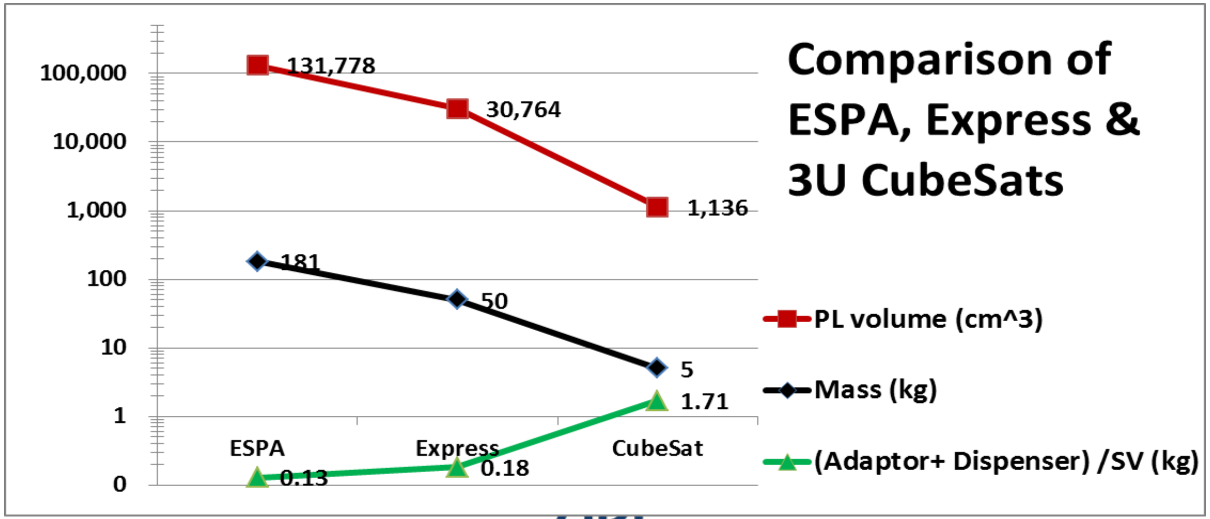
NASA Ames (3/6U) NLAS Dispenser



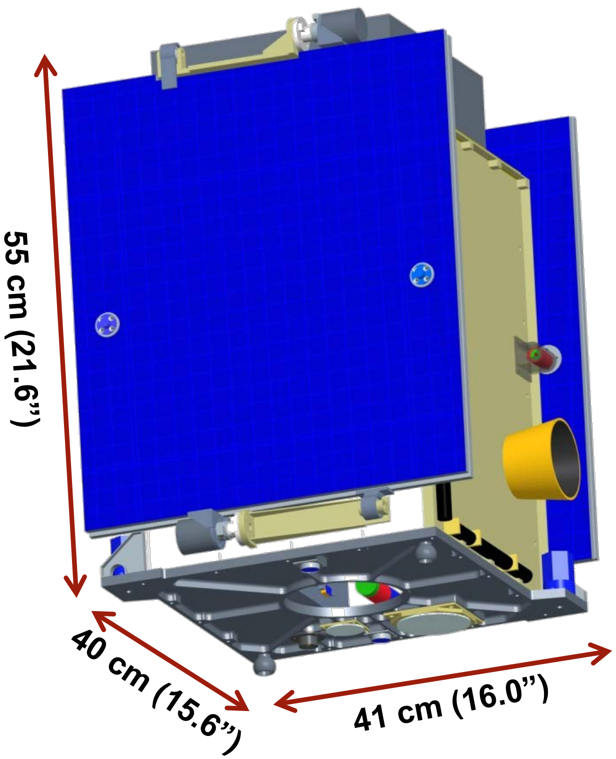
Atlas ESPA Configuration

Motivation for Investigation

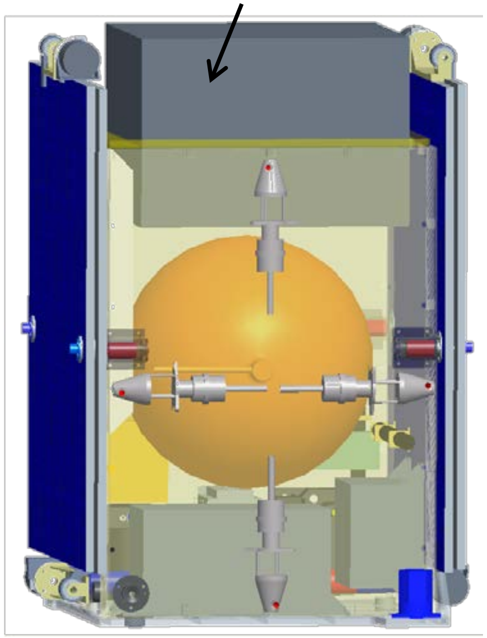
- **An intermediary mission class standard is needed between ESPA (181 kg) and 3/6U CubeSat (~4-12 kg), to:**
  - **More optimally utilize excess LV secondary payload rideshare accommodation capability.**
  - **Enable lower cost missions when ESPA-class not needed.**
  - **Provide for more flexible and capable space vehicles than possible within the 3U CubeSat constraints (e.g. mass, volume, form factor).**
    - ***Key examples: Larger payloads, greater power generation, propulsion***
  - **Permit more ready-use of COTS components and technologies.**



Express Class: Reference Nanosatellite Design



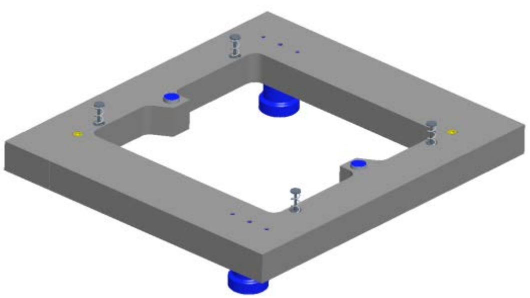
25 x 25 x 18 cm payload volume
with propulsion (10 x 10 x 7 in)

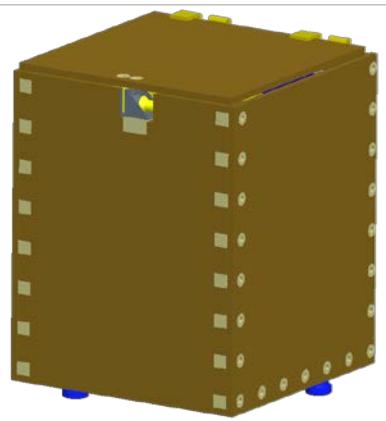


- Provides a standard, flexible spacecraft interface compatible with multiple LVs:
  - For secondary manifest:
    - Space-X Falcon 1e/9/9H
    - OSC Minotaur I/IV/V, Antares,Taurus XL
    - ULA Atlas V, Delta IV
    - LM/ATK Athena IIc
  - For primary manifest:
    - ORS Super-Strypi
    - SMDC SWORDS*
    - DARPA ALASA*
- Bridges gap between 3U/6U and ESPA

* To be investigated as data becomes available

Simple, Low-Cost Separation System





- Optional shroud alleviates concerns of primary PL damage
- Protects/conceals contents from:
  - Visual inspection
  - Physical access and tampering
  - Aero-heating, thruster plume thermal
  - Acoustics and contamination
  - EMI/EMC

Express Features and Benefits

FEATURE	BENEFITS
Configurations with or without propulsion.	> 225 m/s ΔV propulsion allows rideshare flexibility; enables formation flying and constellations. Non-propulsion is lower cost and accommodates larger payloads within standard volume.
Adapter is a plate with release nuts.	Simple, proven, low cost, allows axial or radial deployment, easily adapted to any LV.
Available shroud.	Provides protected environment, prevents visual inspection, tamper-resistance prevents access.
Size, shape and mass less constraining than CubeSats.	Allows more use of COTS components, can still benefit from use of CubeSat components, appendages can protrude if necessary,
Multiple PL interfaces.	Allows (min) two independent payloads.
Large payload volume.	Propulsion: 6,500 cm^3 (400 in^3) Propulsion Extended: 35,000 cm^3 (2100 in^3) Non-propulsion: 20,000 cm^3 (1200 in^3)

Applicability of *Express* to SERB* Payload List

*Space Experiments Review Board

2010 SERB Matrix

Experiment		Experiment Type	Flight Ready Date	Mission Duration (Months)	Orbit Regime	Apogee (km)	Perigee (km)	Inclination(deg)	Power (W)	Dimensions (cm)	Volume (cm3)	Mass (kg)
Aerodynamic Drag Environment Sensor	ADES	Payload - Hosted	Jan-13	12	LEO	500 2000	150 - 400	75 - 105	2	10 x 10 x 10	1000	1
Active Thermal Tile	ATT	Payload - Hosted	Mar-12	12	Any	Any Any	Any - Any	Any - Any	10	10 x 10 x 0.5	50	0.1
Active Track Target Illumination Augmentation	ATTILA	Payload - Hosted	Dec-11	12	LEO	400 650	400 - 650	40 - 65	10	63 x 8.7 x 8.7	4768	4
Chip Dosimeter and Telescope Testbed	CDTT	Payload - Hosted	Jan-12	24	GTO	24000 37000	400 - 1400	-20 - 20	2	10.2 x 10.2 x 7.62	793	1.5
Cerberus	Cerberus	Payload - Hosted	Mar-13	12	LEO	500 700	300 - 500	0 - 98	1.5	30 x 30 x 10	9000	1
Debris-Resistive / Acoustic Grid Orbital Navy Sensor	DRAGONS	Payload - Hosted	Apr-12	12	LEO	600 800	400 - 600	45 - 98	2	100 x 100 x 0.5	5000	3
Global Awarness Data-exfiltration International Satellite	GLADIS	Payload - Hosted	Oct-11	12	LEO	300 570	300 - 570	80 - 100	10	25.14 x 20.11 x 22.63	11441	10
Geostationary Radio Beacon	GRAB	Payload - Hosted	Dec-11	12	GEO	29366 29466	29366 - 29466	-3 - 3	20	10 x 8 x 5	400	2
GPS Radio Occulation and Ultraviolet Photometer on a CubeSat	GROUP-C	Full Spacecraft - CubeSat	Nov-11	12	LEO	400 1100	400 - 1100	40 - 98	10	10 x 10 x 30	3000	4
Integrated Miniaturized Electrostatic Analyzer-Reflight	iMESA-R	Payload - Hosted	Jan-10	12	LEO	200 1000	200 - 1000	0 - 90	0	5 x 5 x 2	50	0.15
Iso-grid, Structural-Thermal Panel	Iso-Therm	Payload - Hosted	Mar-12	12	Any	Any Any	Any - Any	Any - Any	10	40 x 40 x 10	16000	15
Limb-imaging Ionospheric and Thermospheric Extreme-ultraviolet Spectrographs	LITES	Payload - Hosted	Jun-11	12	LEO	400 900	400 - 900	Any - Any	7.5	17.8 x 14 x 33.7 8.9 x 3.8 x 2.5 25.4 x 33 x 15.3	8398 84.6 12824.5	10
Optimal Autonomous Orbit Maneuver	OAOM	Payload - Flight Software	Feb-13	36	LEO	300 1000	300 - 1000	45 - 95	5	20 x 10 x 10	2000	5
Payload Alert Cueing System	PACS	Payload - Hosted	Jan-12	12	LEO	400 1200	400 - 1200	0 - 100	1	2.3 x 1.2 x 0.6	2	1
Spacecraft Plasma Diagnostic Suite	SPADE (data TBD)	Payload - Hosted	Sep-14	12	LEO	Any Any	Any - Any	Any - Any	2	20 x 20 x 7 10 x 15 x 3	--	2
Supra Thermal Electron, Ion, Neutron Experiment	STEIN	Payload - Hosted	Jan-13	12	LEO	600 1200	500 - 900	50 - 100	0.6	10 x 10 x 10	1000	1
Small Wind And Temperature Spectrometer	SWATS	Payload - Hosted	Dec-10	12	LEO	300 550	300 - 550	20 - 98	2	7.62 x 6.56 x 7.62	381	1
Wireless Telemetry System	WiTS	Payload - Hosted	Aug-12	6	Any	300 1000	300 - 1000	45 - 130	6	15 x 22.5 x 2	675	2

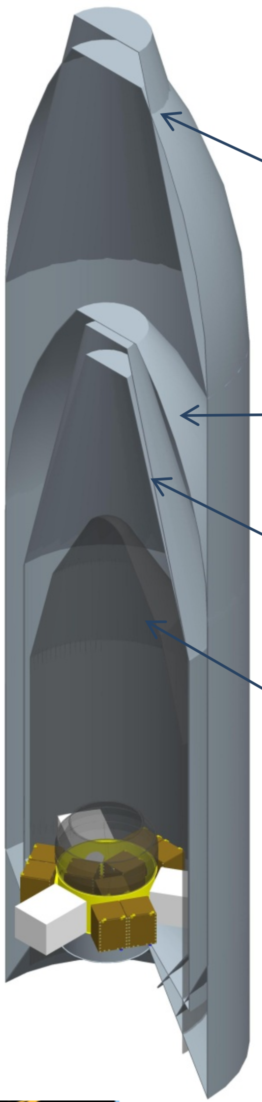
Criteria:

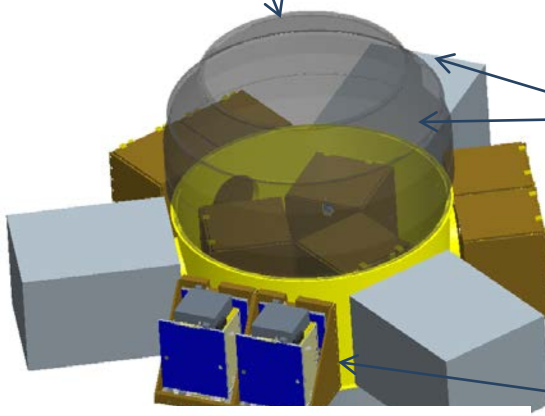
- V < 20,000 cm^3 (w/o prop.)
- P < 30 watts
- M < 15 kg

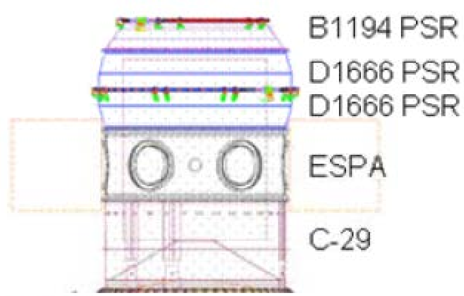
Results:

Suitable for 18 of 73 (25%) of candidate payloads from 2010 SERB list

EELV, F-9/Heavy, Antares Accommodation: ESPA

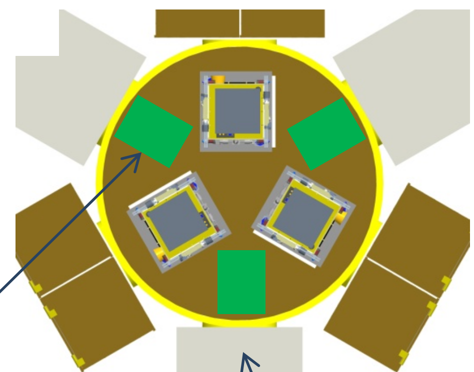


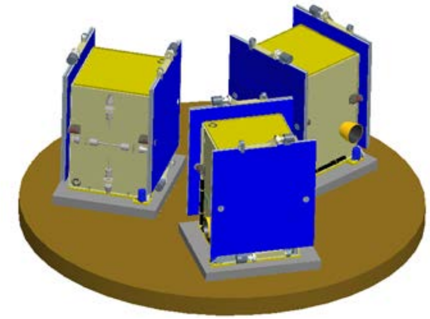




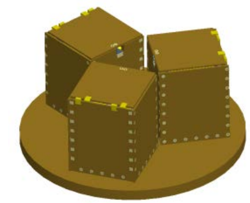
(Figure courtesy of ULA)

(Figure courtesy of Moog CSA)

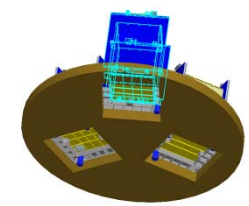




CSA Flat Plate Adaptor & 3 SVs

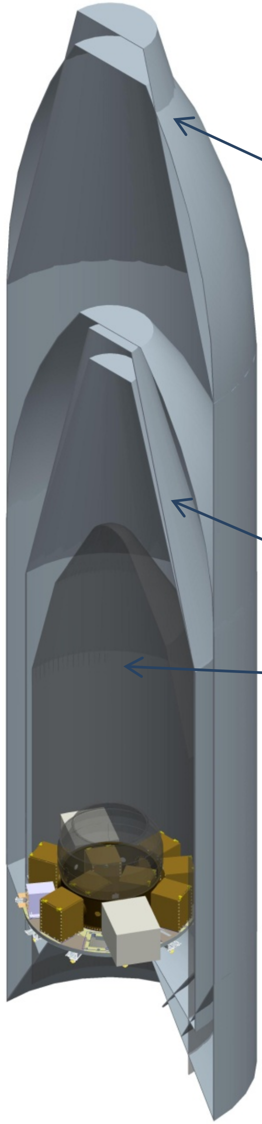


Shrouded Option



Clearance for Antennas, etc.

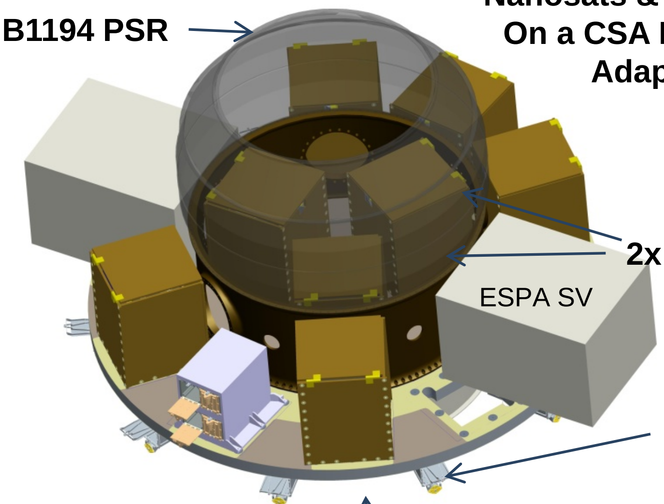
EELV, F-9/Heavy, Antares Accommodation: ESPA + FPA



Atlas V
Delta IV
Falcon 9
5-m fairings

Atlas V
Delta IV
4-m fairings

Antares



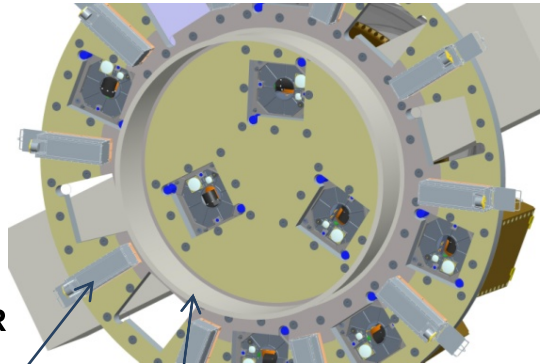
B1194 PSR

Nanosats & ESPA SVs
On a CSA Flat Plate
Adaptor

2x D1666 PSR

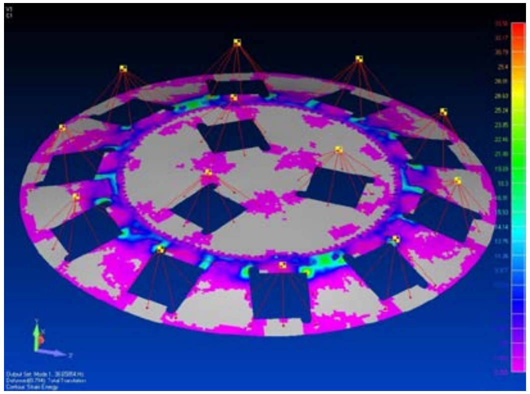
CubeSats (10)

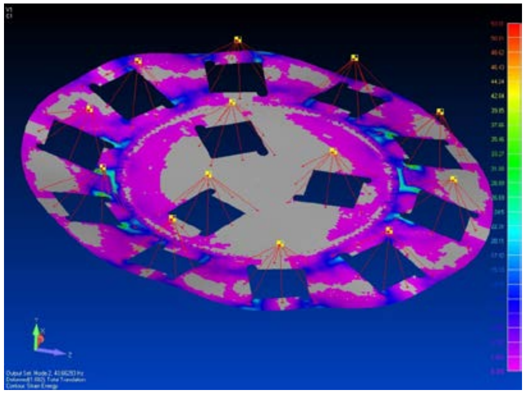
CSA Flat Plate Adaptor



Bottom View

C-13 Adaptor (between Centaur forward cone and CSA Flat Plate Adaptor)

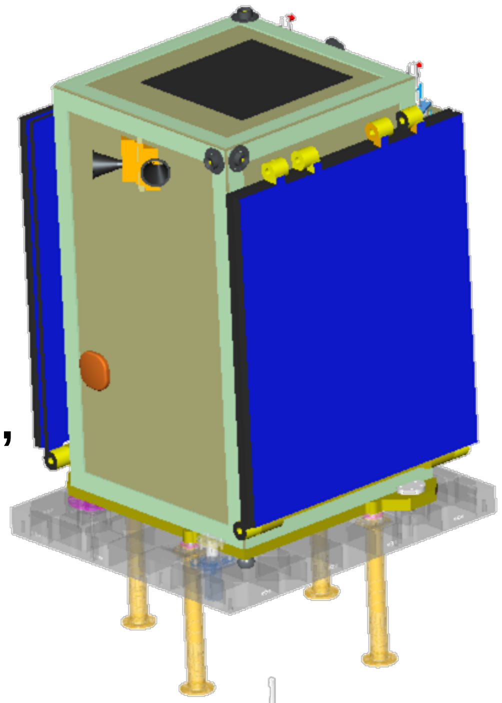


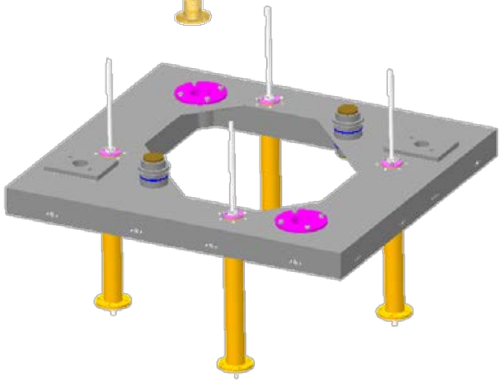


(Figures courtesy of Moog CSA)

Adapter System

- **Provides common SV mounting interface,**
  Independent of launch vehicle
- **Hard points on one end of SV; not canisterized**
  - **Simple and reliable**
  - **SV secure during launch; no rattle**
  - **Mounting maintains cantilevered frequency ≥ 35 Hz**
  - **Allows solar arrays, deployable and fixed appendages, instruments, to be mounted externally to the bus envelope**
- **Tunable deployment velocity (1-2 m/s nominal)**
- **Optional shroud to:**
  - **Protect/conceal sensitive spacecraft; tamper resistant**
  - **Acoustics, EMI/EMC, contamination protection**
  - **Thruster plume thermal protection**
  - **Alleviate concerns of primary payload damage**
  - **Shroud mass can be traded for SV mass**

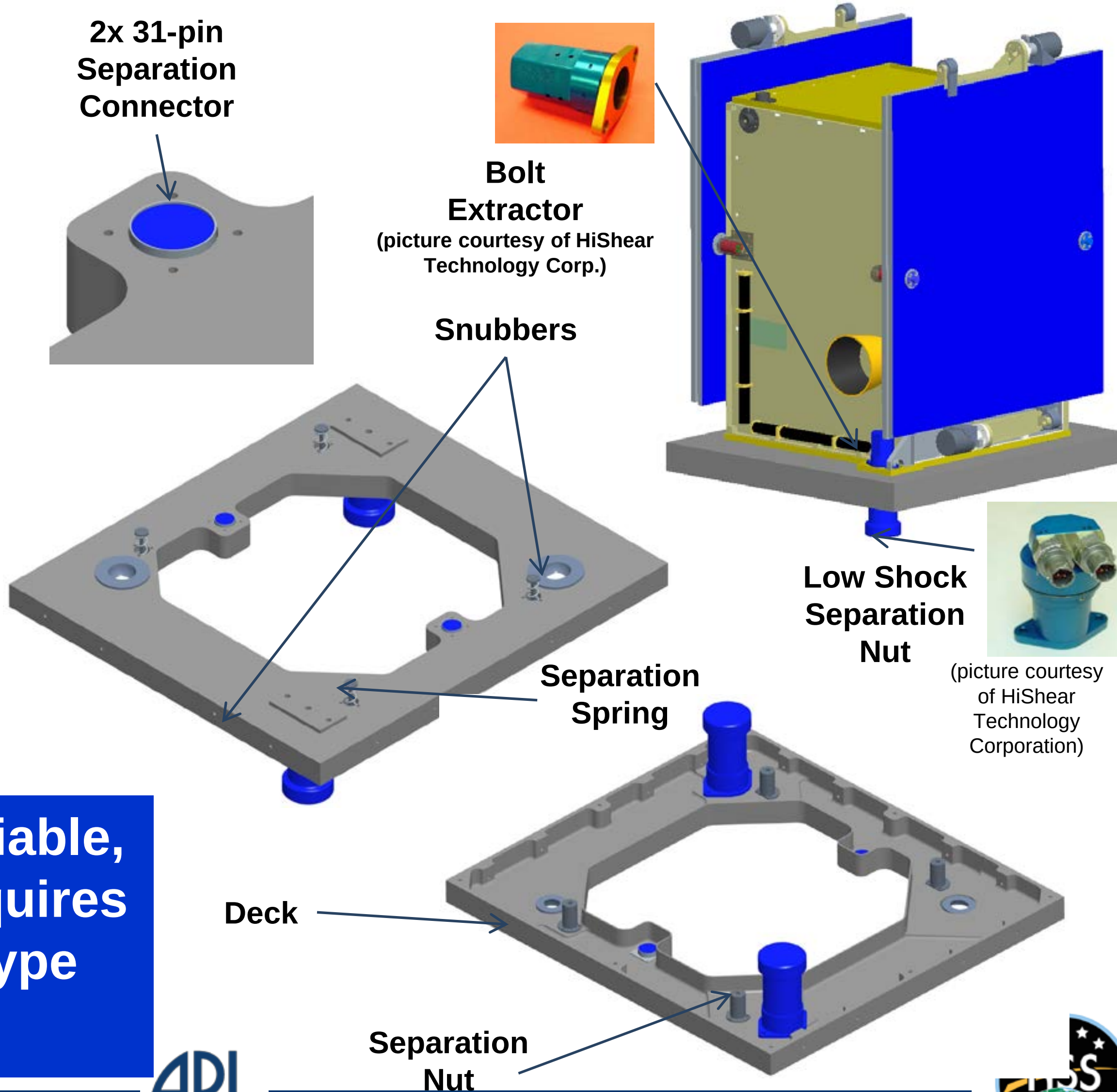




Adapter System Mechanism Concept

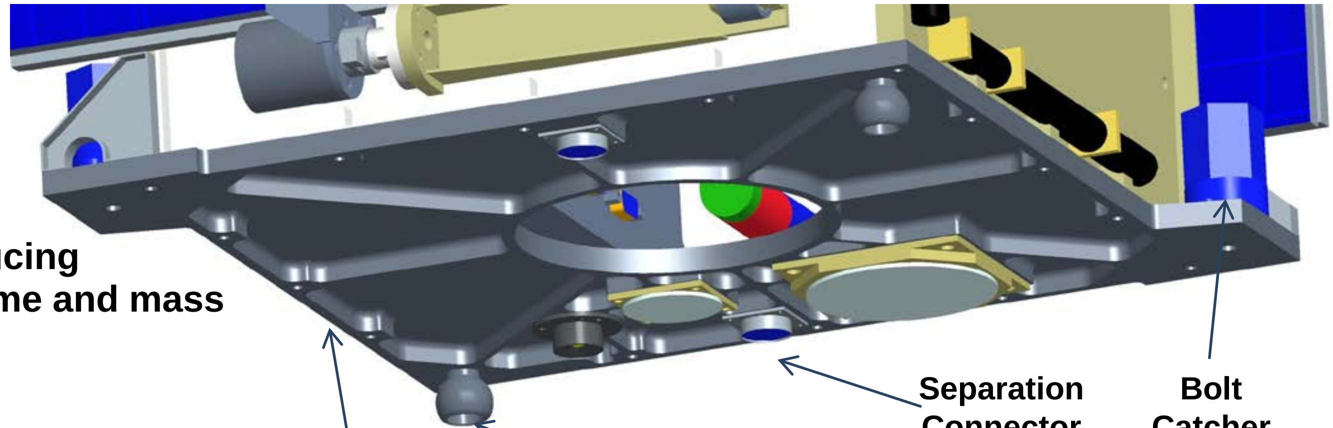
- **Simple and reliable**
  - **Single machined deck from flat plate**
  - **Two separation nuts**
  - **Two spherical snubbers**
- **Separation nuts are:**
  - **Simultaneous with low shock**
  - **Reliable with heritage**
  - **Nonexplosive actuators are available**
- **Integral separation connectors**
- **Same dispenser mechanism for:**
  - **Shrouded or un-shrouded**
  - **With an ESPA, flat plate (or ABC)**
  - **All compatible launch vehicles**

Design is simpler, more reliable, more cost effective and requires less volume than a ring type separation system.



Space Vehicle Interfaces to Adapter System

- **Simple and reliable**
  - Single machined deck from flat plate
  - Separation system features integrated into bottom deck of SV, reducing separation system volume and mass
  - Two spherical snubbers
  - Two bolt catchers
- **Spherical snubbers:**
  - Are adjustable in plane
  - Are preloaded to eliminate gapping during launch
  - Allow alignment flexibility
  - Allow for interface thermal gradients
- **Integral separation connectors**
  - Redundant break-wire separation indication
  - Battery charging

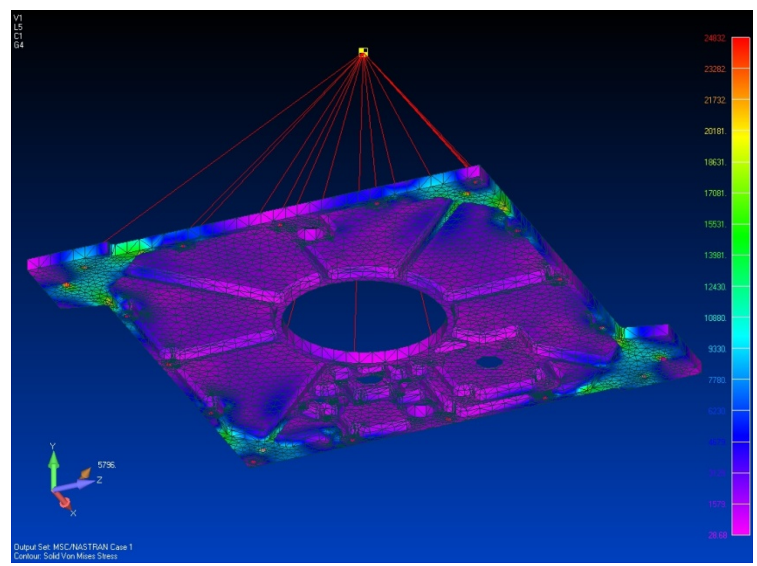


Separation Connector

Bolt Catcher

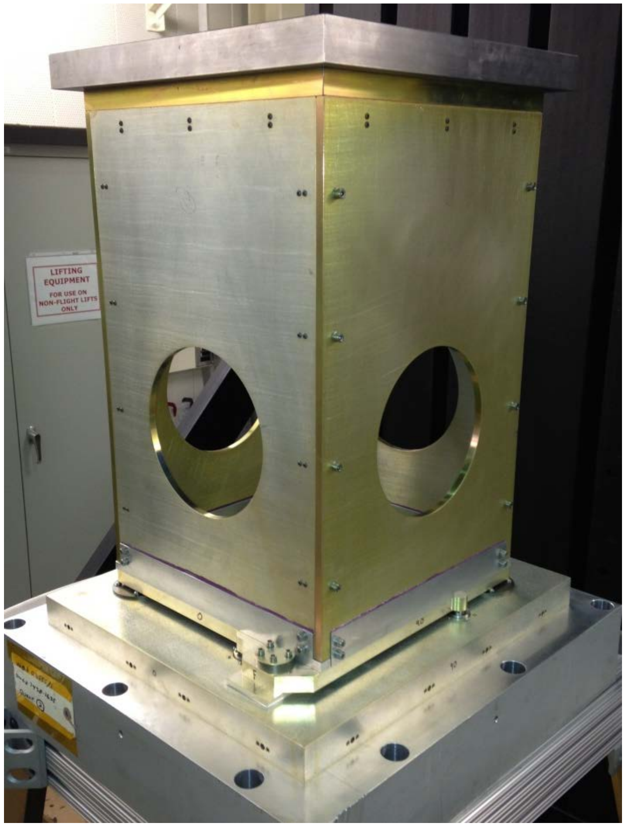
Deck:
3/8” AL 7075-T73

Spherical Snubber:
Adjustable in-plane and out (with shims)



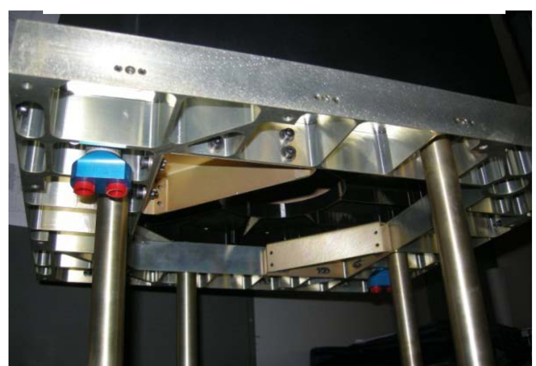
Express Adapter Prototype Hardware

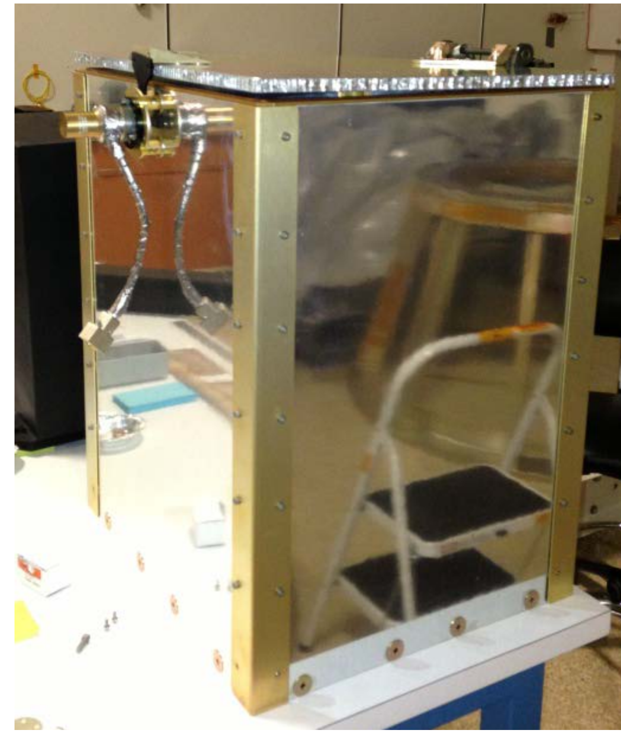
Design characterization and full environmental qualification in process



System with Mass Model

Adapter Deployment H/W

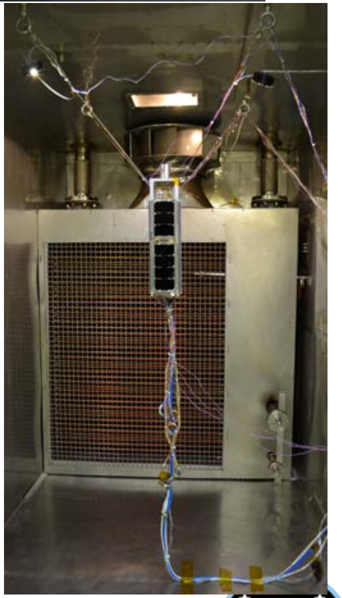




Shroud Assembly

Prototype Flight Qualification Testing

- **Pre-Environment deployments**
  - **Instrumented for shock measurement**
- **Vibration testing to enveloped LV environments**
  - **Test level in each axis:**
    - ***Pre-test Sine Sweep (0.25g)***
    - ***Sine Vibration, 15g***
    - ***Random vibration, 14.1grms (GEVS)***
    - ***Post-test Sine Sweep***
- **Thermal testing to ± 65° C to envelope Earth-orbiting and interplanetary missions**
- **Deployment testing: separation and tip-off rate measurement (future)**



Summary and Next Steps

- **Summary**
  - Community need exits for an intermediary 20-50 kg space vehicle class standard for rideshare (and primary) missions: ***Express***
  - APL has designed and developed the enabling adaptor, separation system and optional shroud
  - Prototype hardware fabrication and assembly complete
  - Testing will be conducted in September 2013
- **Next Steps**
  - Perform testing results analysis, model correlation, documentation
  - Develop draft Users Guide
    - *To include: interfaces, test requirements, and key design specifications*
  - Continue coordination with launch vehicle community
  - Pursue Express mission concepts as a consumer of the capability
  - Continue engagement with industry technology transition partners

Questions?

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