

Novel Design Elements of the ST5 Spacecraft Mechanical System

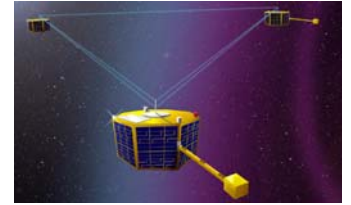
Peter Rossoni
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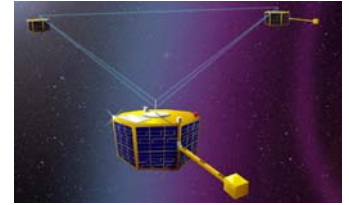
Agenda



- Mission Goals & Design Drivers
- “Frisbee” Deployer System
- “Card Cage” Electronics Housing
- Deployable Instrument Boom
- Streamlined Structural Analysis
- Conclusion



ST5 Mission Goals

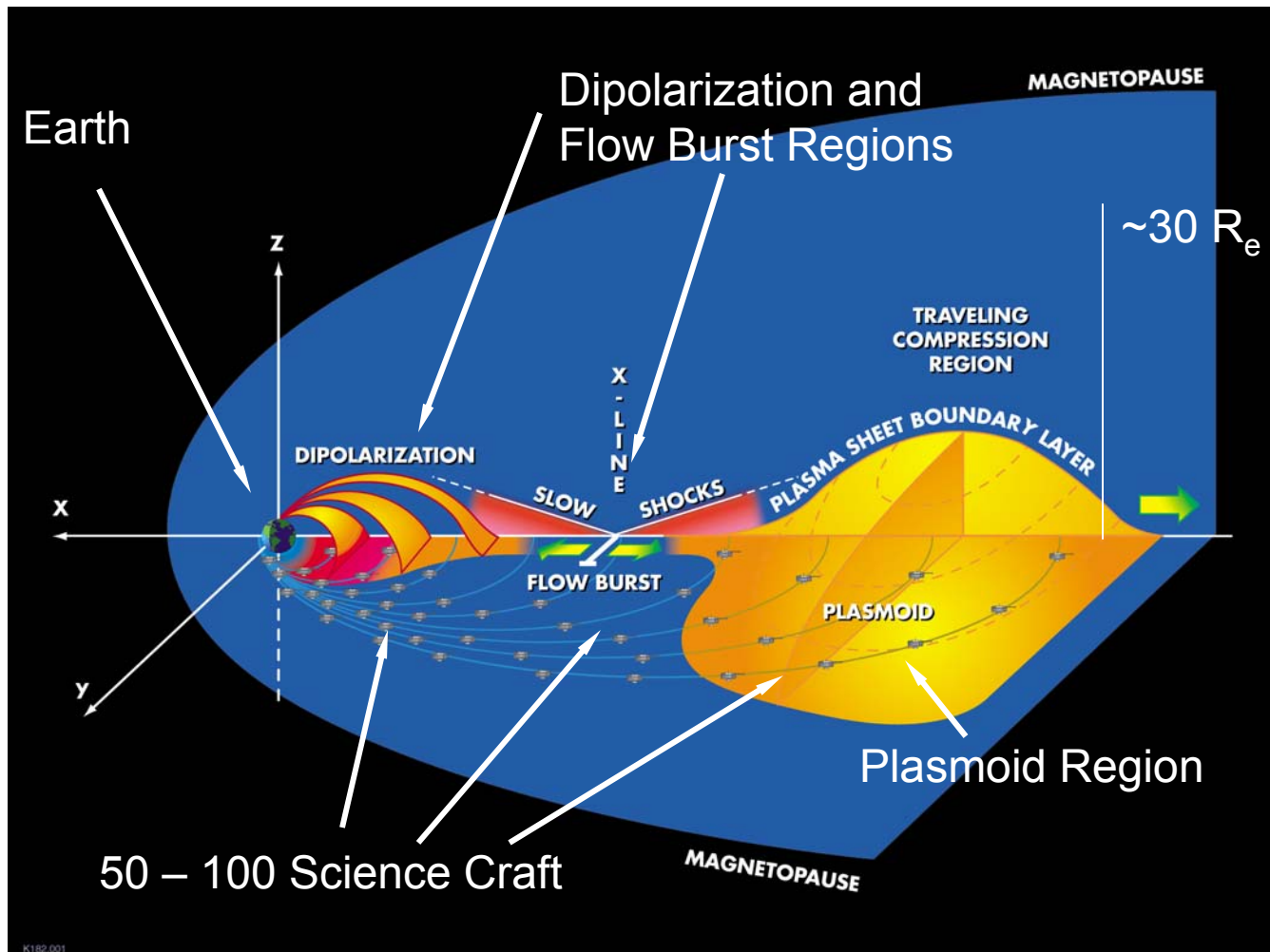
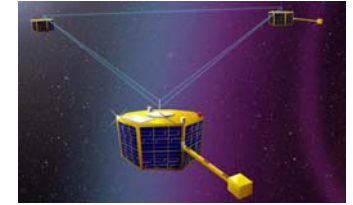


- The Space Technology 5 spacecraft (S/C) is a Trailblazer for constellation missions requiring up to 100 in-situ, simultaneous measurements in Earth's magnetosphere
 - Demonstrate miniaturized technology to enable these missions.
 - Demonstrate science-quality measurements can be achieved on a 20 kg-class spacecraft.



Future Mission Scenario

-Magnetospheric Mapping



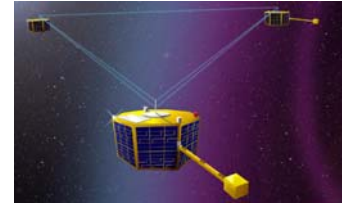
- 50 to 100 Magnetic Constellation Science Craft take
 - Magnetic field,
 - Energetic particle, and
 - Plasmareadings in these regions of interest
- All S/C launched on one Delta II
- Volume and mass constraints on each S/C

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ST5 Design Goals

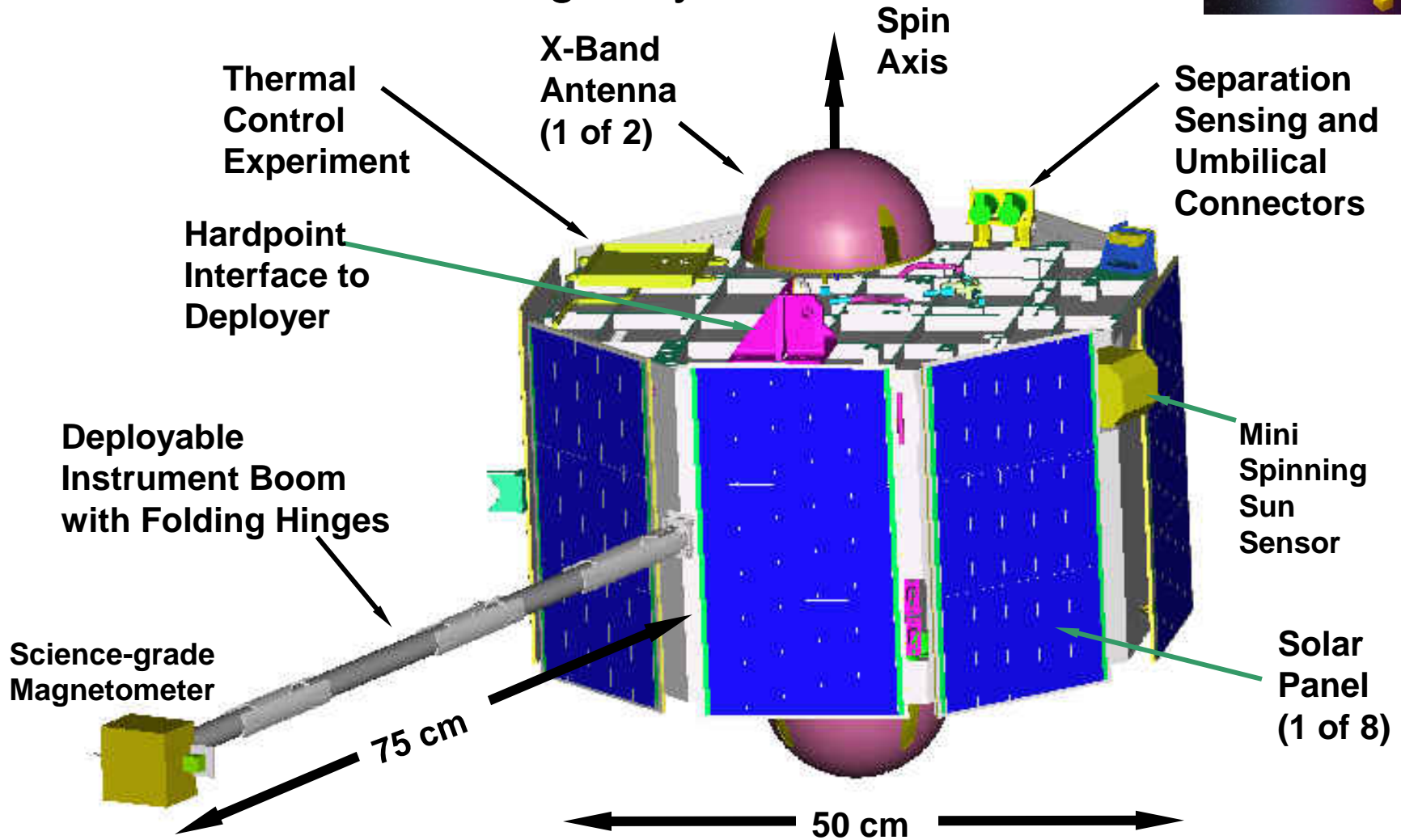
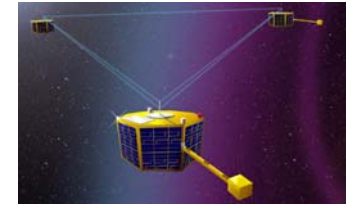


- Scale-reduction on the S/C system level is required to achieve Magnetospheric Mapping mission goals of fitting 50 – 100 buses on one launch vehicle
- Design Philosophy used the following principles in order to achieve these goals
 - Centralized electronics enclosure
 - S/C Interface at discrete kinematic hardpoints
 - Miniaturized components
 - Modular SC bus, mechanisms and actuators
 - “Ship & Shoot”
 - Bench-top Integration
 - Performance



ST5 Spacecraft

25 kg, fully functional



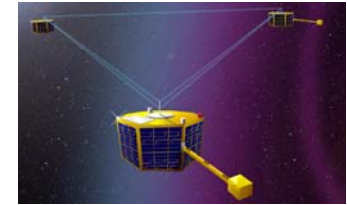
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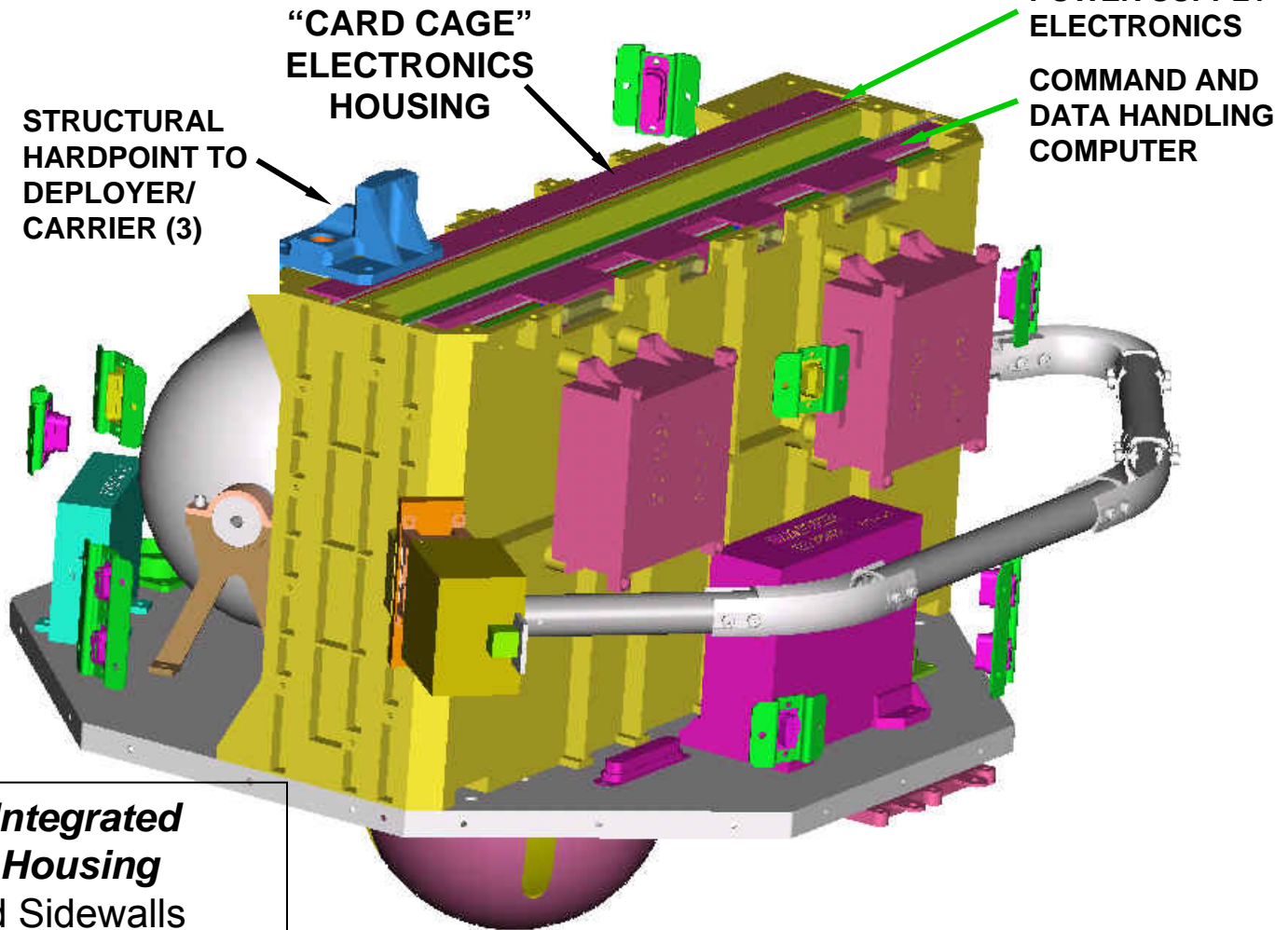


Card Cage

Multi-Functional Structure



- Monocoque Aluminum casting
- Serves as structural backbone
- Provides critical alignment for Deployer Mechanism

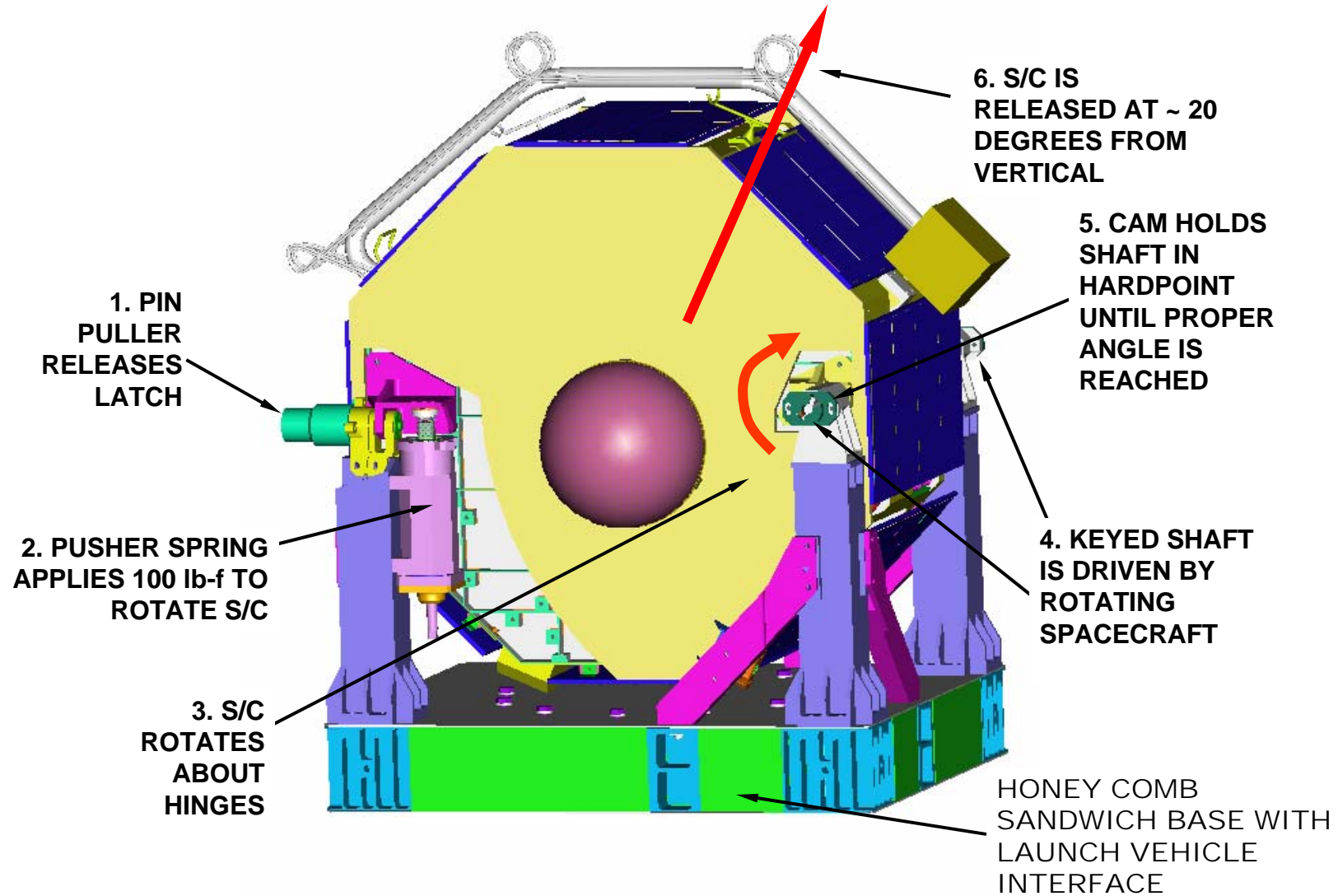
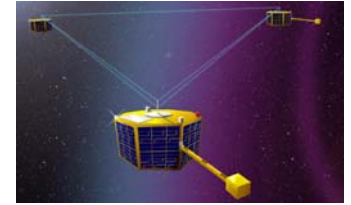


Structurally-Integrated Electronics Housing
-Top Deck and Sidewalls Removed



Deployer Structure

Imparts "Frisbee" spin

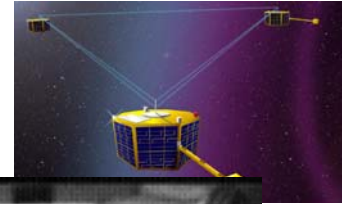


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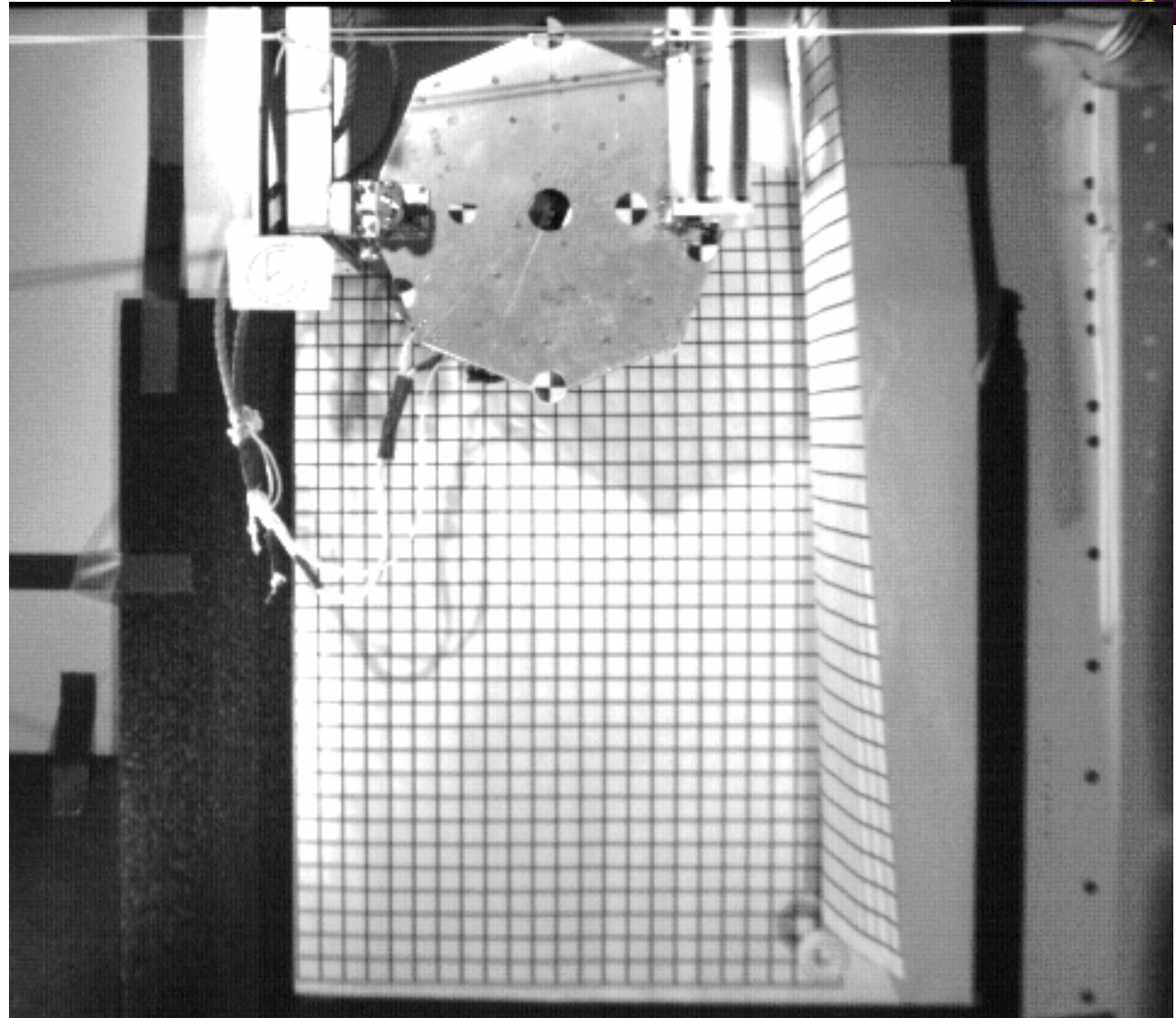
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Deployer Testing Video



- Video at 250 frames per second enabled spin rate and tip-off determination to within 2%
- Gravity effects subtracted analytically
- Subsequent thermal-vacuum testing deployed horizontally to cancel gravity effect

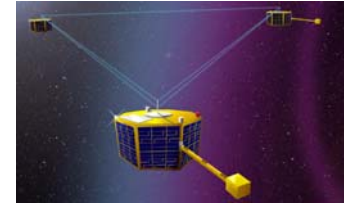


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Instrument Boom



- Integral BeCu Folding Hinges and $\varnothing 2$ cm graphite composite segments key to weight and volume reduction
- Alignment: $\varnothing 1$ cm and $\frac{1}{4}^\circ$ position holding requirements throughout mission
- Deployed natural frequency: 5 ± 3 Hz
- Incorporates Low shock Pinpuller
 - Shape Memory Alloy



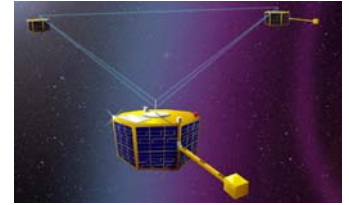
Boom Stowed in structural
mockup vibration fixture



Base Hinge Detail



Graphite Monolithic Boom

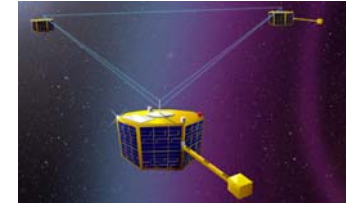


- Earlier proof-of-concept development effort produced monolithic graphite composite version
- $\varnothing 3.3\text{cm}$
- Met all constraints except diameter

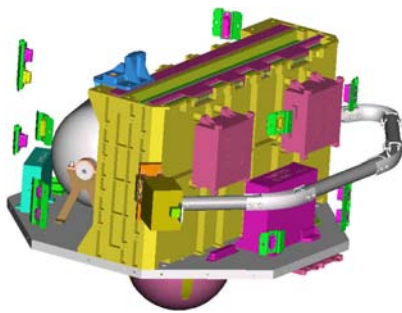




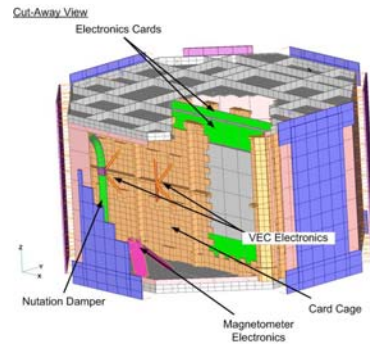
Analysis Tools



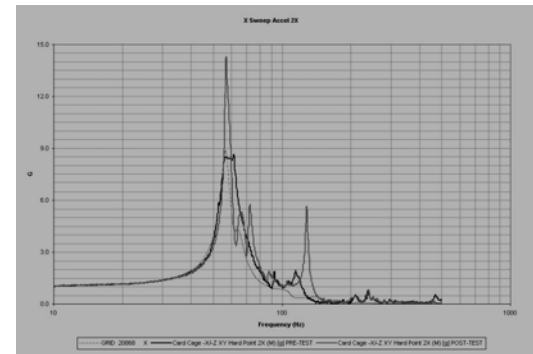
- “Paperless” analysis process allowed rapid turnaround parametric studies



– 3D design =>



FEA =>

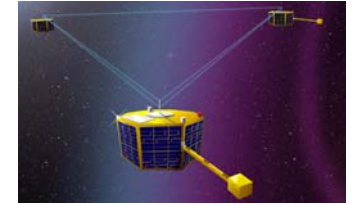


Automated Spreadsheets & Reports

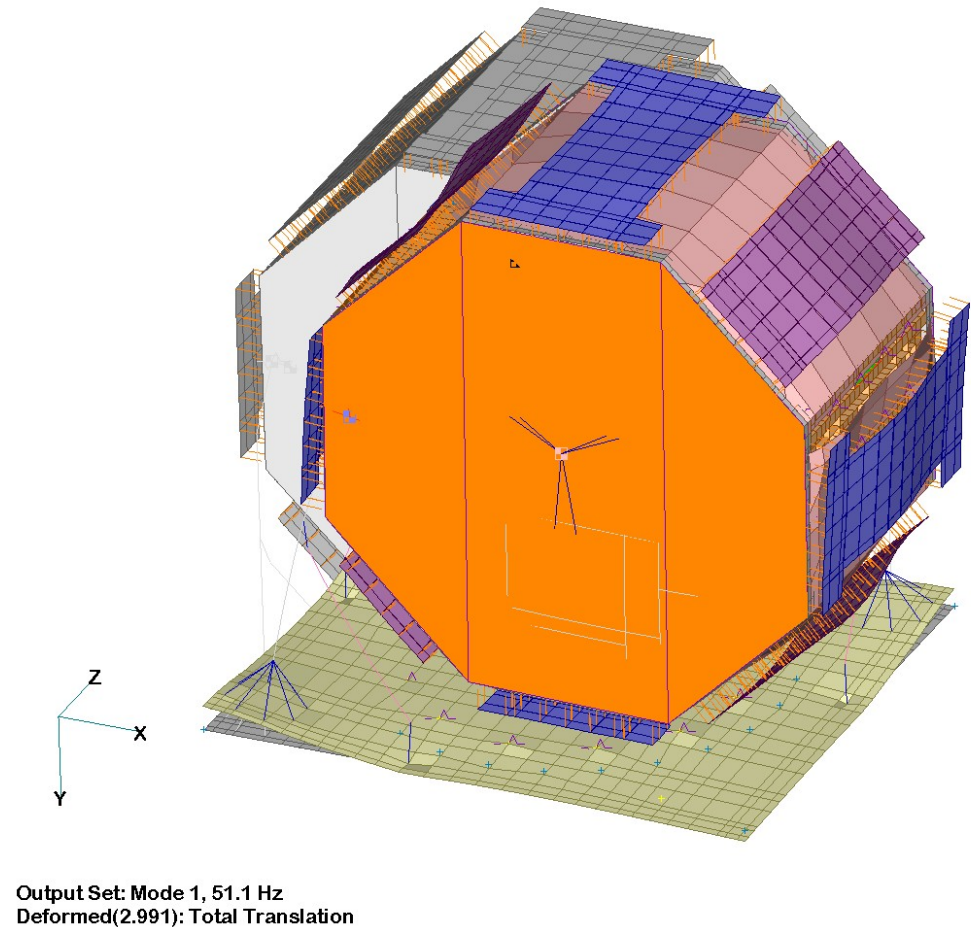
– Test Data



Structural Performance

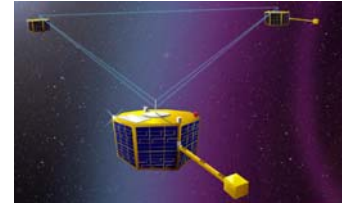


- S/C mass 25 kg
- Deployer mass ~12 kg (not optimized)
- First natural frequency 51 Hz
- Analysis covers worst-case launch environment
- Certain Elements (such as Card Cage) qualified by analysis





Conclusion



- Mechanical subsystem qualified with “ship & shoot” philosophy
- Design innovations implemented to enable scale-reduction of the S/C structural bus with unique mission needs in mind
 - Multi-functional card cage
 - Integral folding hinge boom
 - Frisbee deployer
- Schedule status: launch early ‘05