

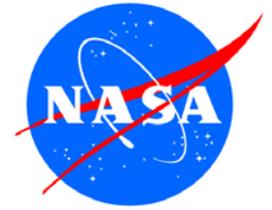
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# **Solar Sail Assembly/Deployment in Earth Orbit: An Enabling Capability for an Enabling Capability**

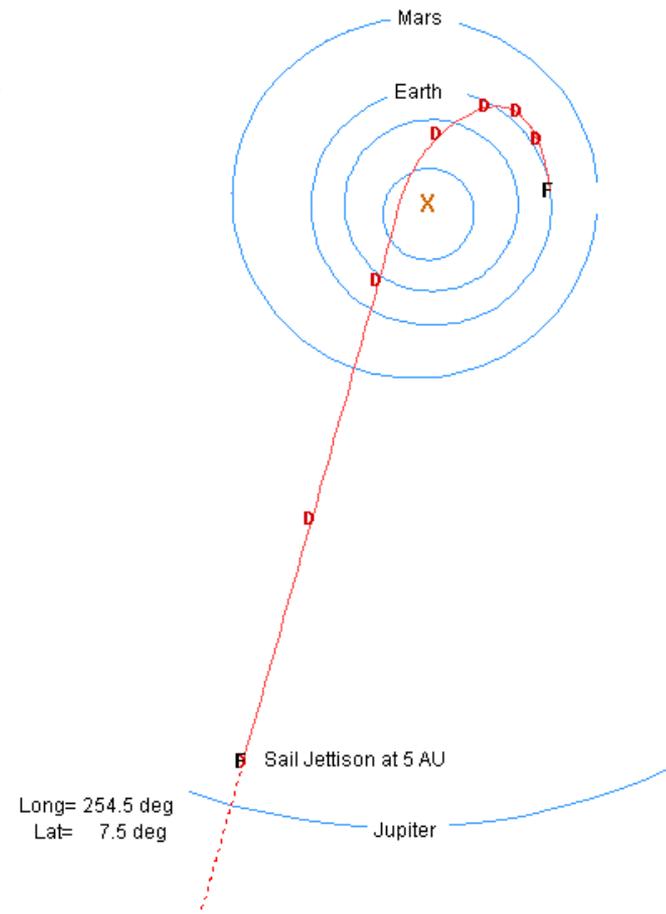
**International Workshop on  
On-Orbit Satellite Servicing  
Adelphi, Maryland, USA  
24-26 March, 2010**

**Bruce Campbell  
Tim Van Sant  
NASA/GSFC**

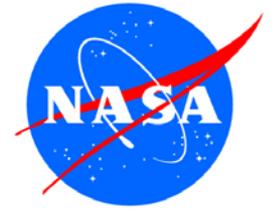
# What's a Solar Sail?



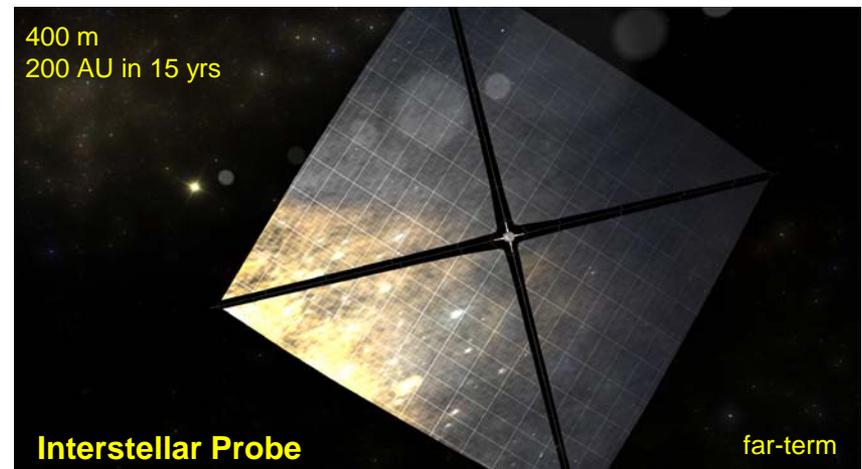
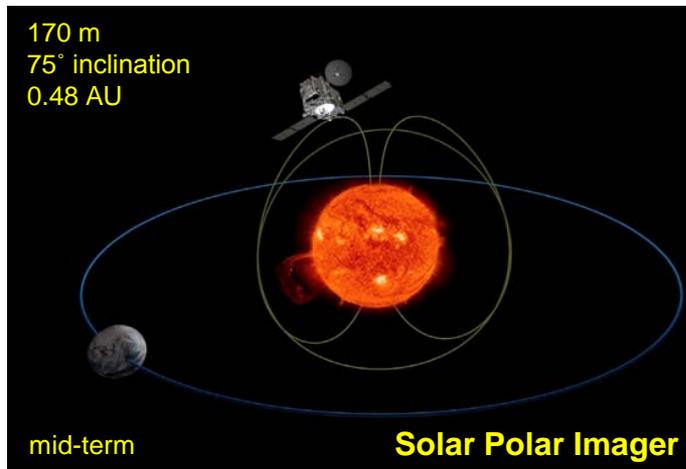
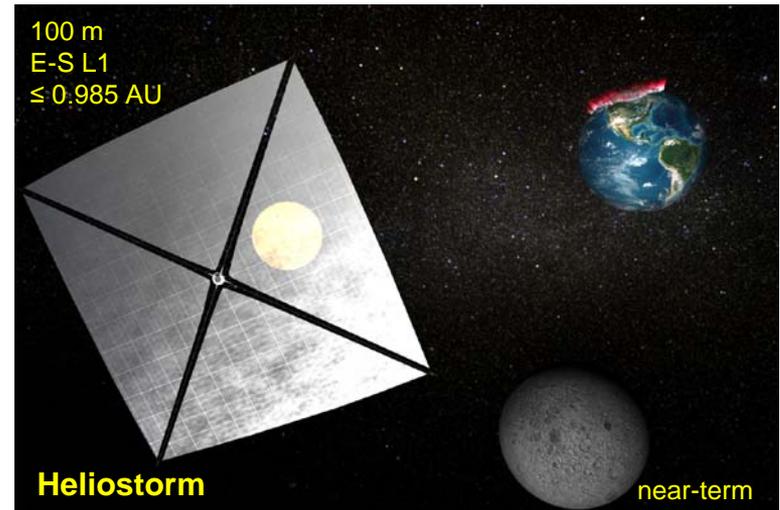
- Unique form of in-space propulsion that uses the reflection of photons of light from the Sun to produce thrust
- Potentially **continuous thrust** from solar radiation
  - Allows some orbits unobtainable by other forms of propulsion
- Potentially **unlimited delta-v**
  - Allows some performance unobtainable by other forms of propulsion



# Solar Sail Strategic Missions



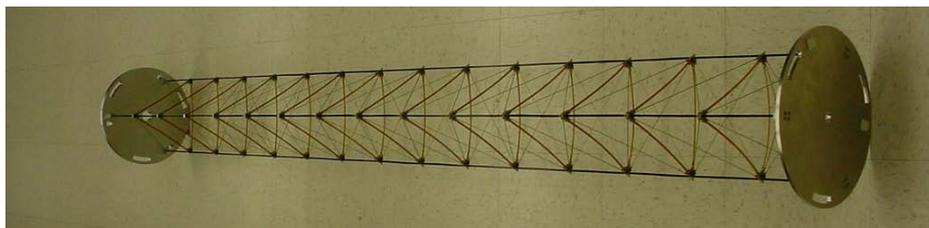
- Three strategic missions in earlier Heliophysics Roadmaps require solar sail propulsion.
  - Heliostorm
  - Solar Polar Imager
  - Interstellar Probe
- The sail dimensions, orbital parameters, and notional timeframe are shown



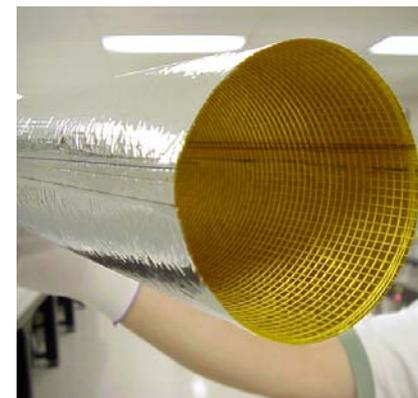
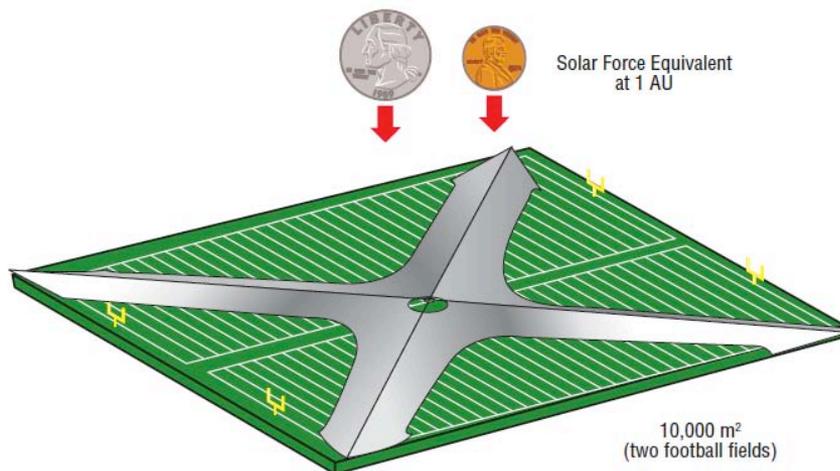
# Solar Sail Characteristics



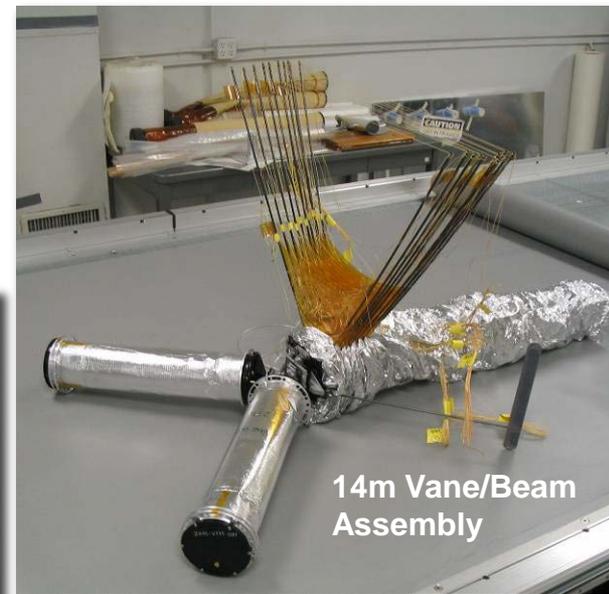
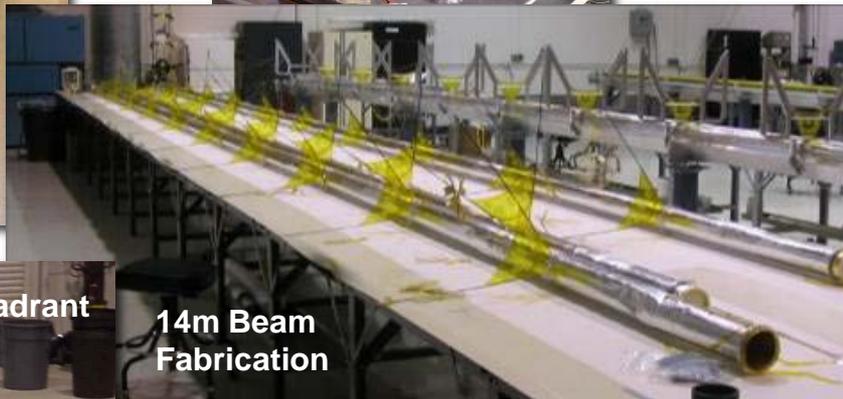
- Lightweight reflective material for sail
  - 1 micron, silver coating
- Lightweight booms/support



- Low thrust



# Solar Sail Technology – TRL 6-ish

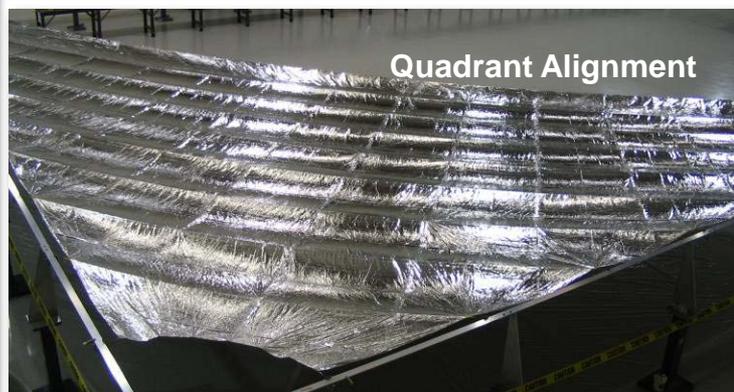


14m Vane/Beam Assembly

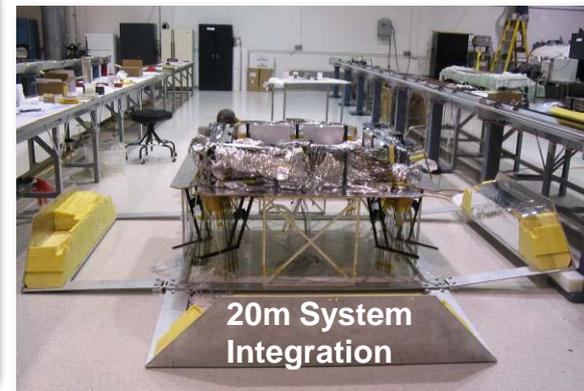


Membrane Quadrant Fabrication

14m Beam Fabrication

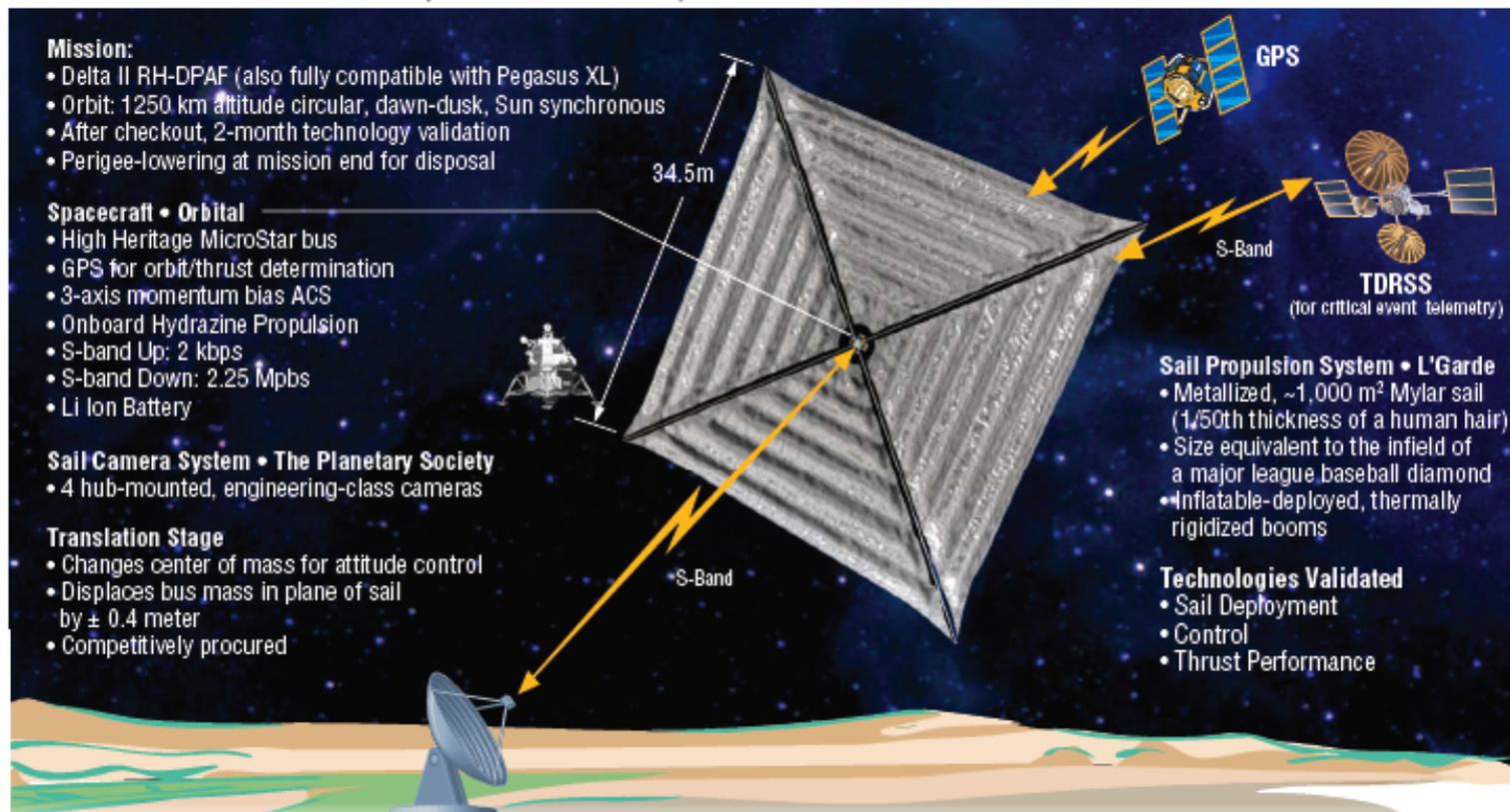


Quadrant Alignment



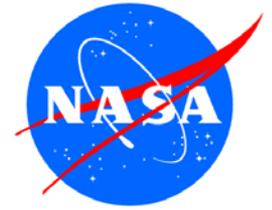
20m System Integration

# ST9 Proposal – Ready for Validation

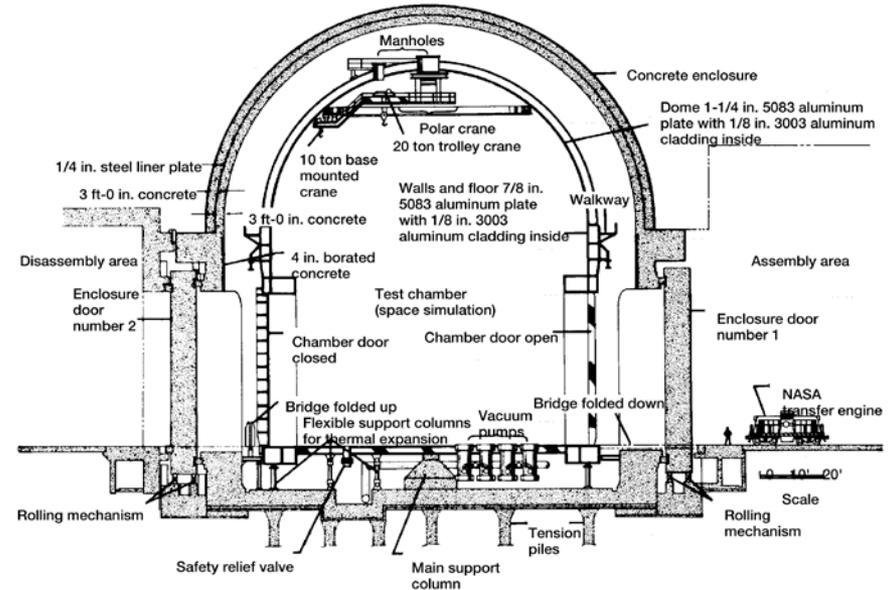
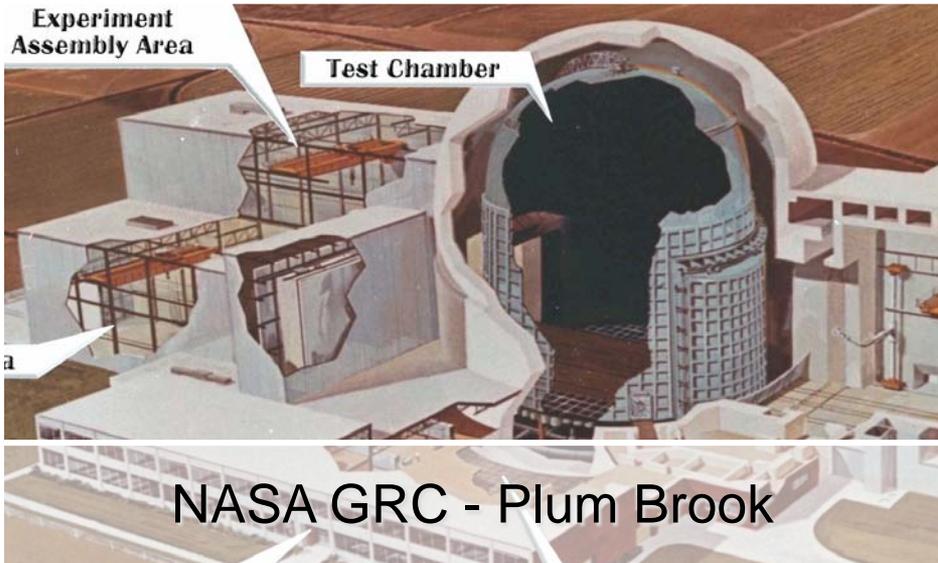


L'Garde	Orbital	Goddard Space Flight Center	Jet Propulsion Laboratory	In-Space Propulsion Technologies Project	The Planetary Society
<b>Tustin, CA</b> <ul style="list-style-type: none"> <li>• Solar Sail</li> <li>• Sail Electronics and Structure</li> </ul>	<b>OSC Mission Operations Center Dulles, VA</b> <ul style="list-style-type: none"> <li>• Spacecraft Bus</li> <li>• System Integration and Test</li> <li>• Mission Operations</li> </ul>	<b>NASA Ground Network</b> <ul style="list-style-type: none"> <li>• 11 m Dishes                             <ul style="list-style-type: none"> <li>- Alaska</li> <li>- Wallops</li> </ul> </li> </ul>	<b>Greenbelt, MD</b> <ul style="list-style-type: none"> <li>• Project Management</li> <li>• Systems Engineering</li> <li>• Mission Assurance</li> <li>• Technology Validation</li> <li>• Education/Public Outreach</li> </ul>	<b>Pasadena, CA</b> <ul style="list-style-type: none"> <li>• Thrust Estimation</li> <li>• Inflation/Deployment Modeling</li> </ul>	<b>LaRC Hampton, VA</b> <ul style="list-style-type: none"> <li>• Structural Modeling</li> </ul>
				<b>MSFC Huntsville, AL</b> <ul style="list-style-type: none"> <li>• Control Modeling</li> <li>• Design Validation and Test</li> <li>• Space Environment Test</li> </ul>	<b>Pasadena, CA</b> <ul style="list-style-type: none"> <li>• Sail Camera System</li> <li>• Education/Public Outreach</li> </ul>

# Greatest Challenges to Solar Sail Mission Development

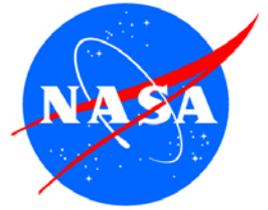


- Ground testing
  - Accommodation of large sail sizes
  - Gravity



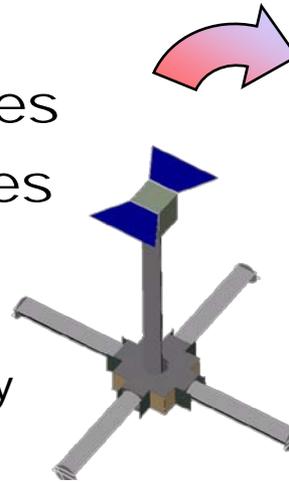
Cutaway view of test chamber.

# Greatest Challenges to Solar Sail Mission Development (cont.)

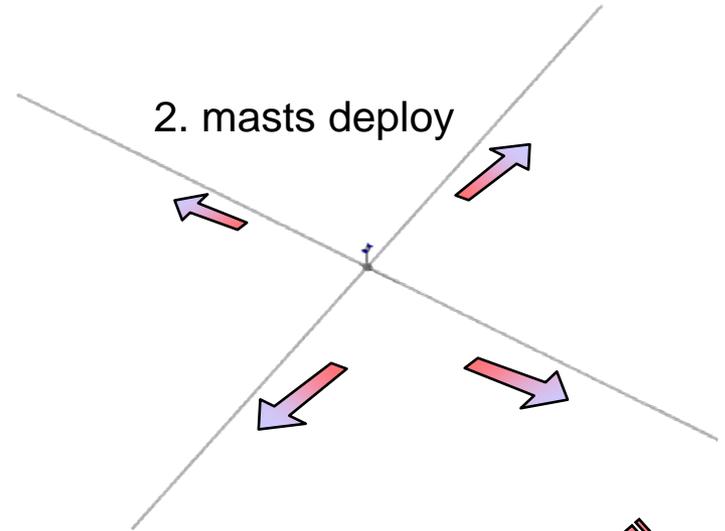


- On-orbit Deployment
  - Gossamer structures
  - Thin sail membranes

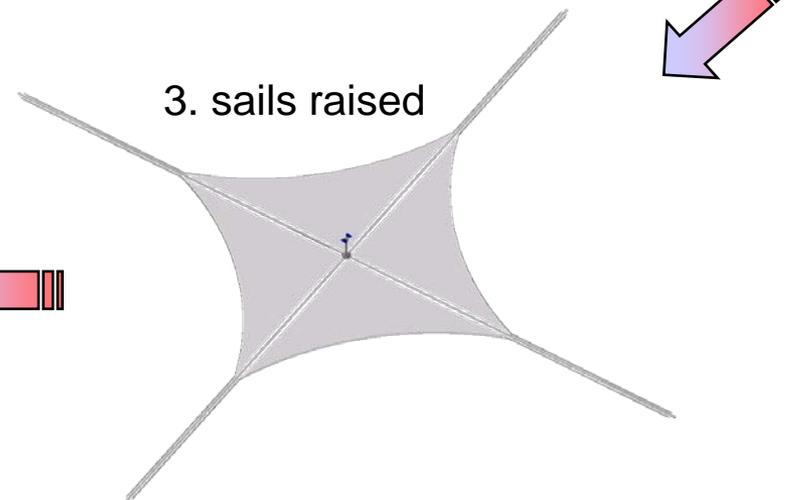
1. spacecraft ready to deploy



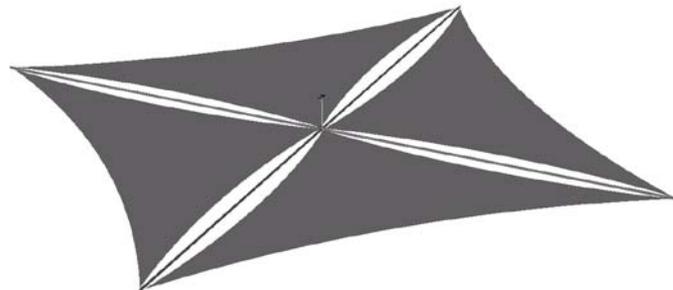
2. masts deploy



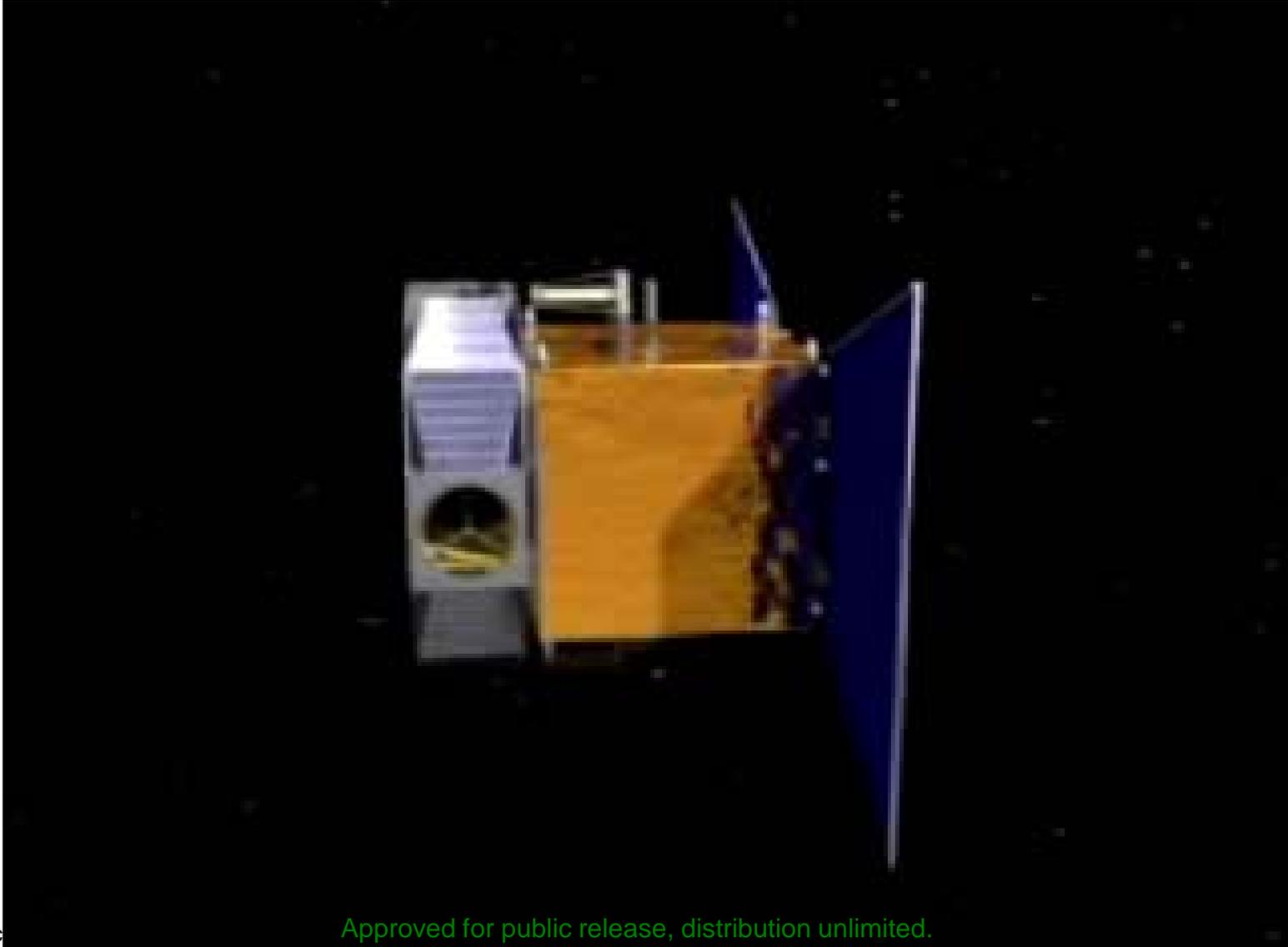
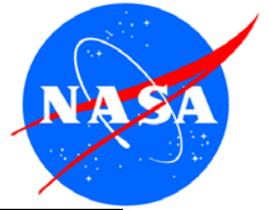
3. sails raised



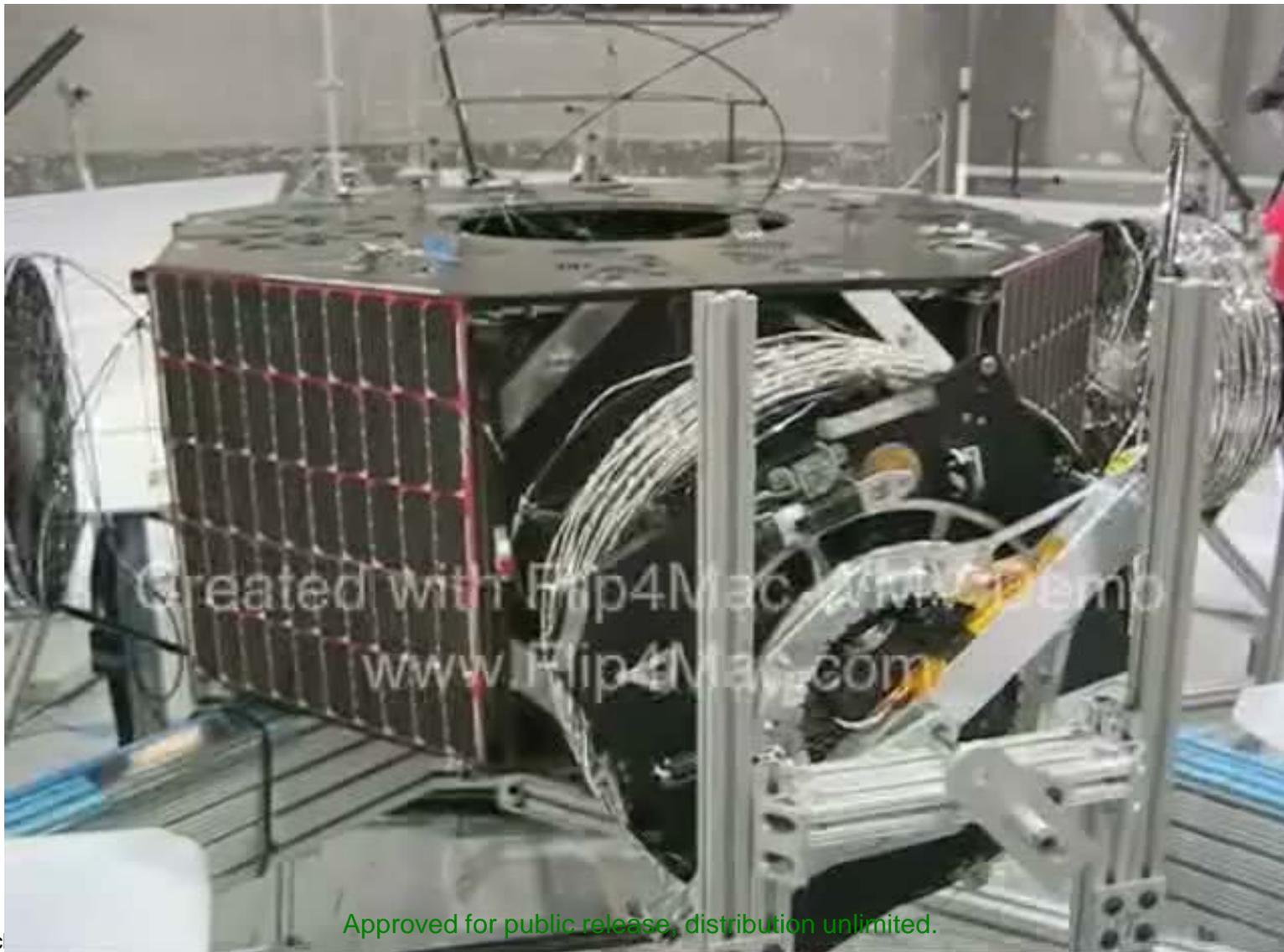
4. sailcraft operational



# Very Nice Deployment Video



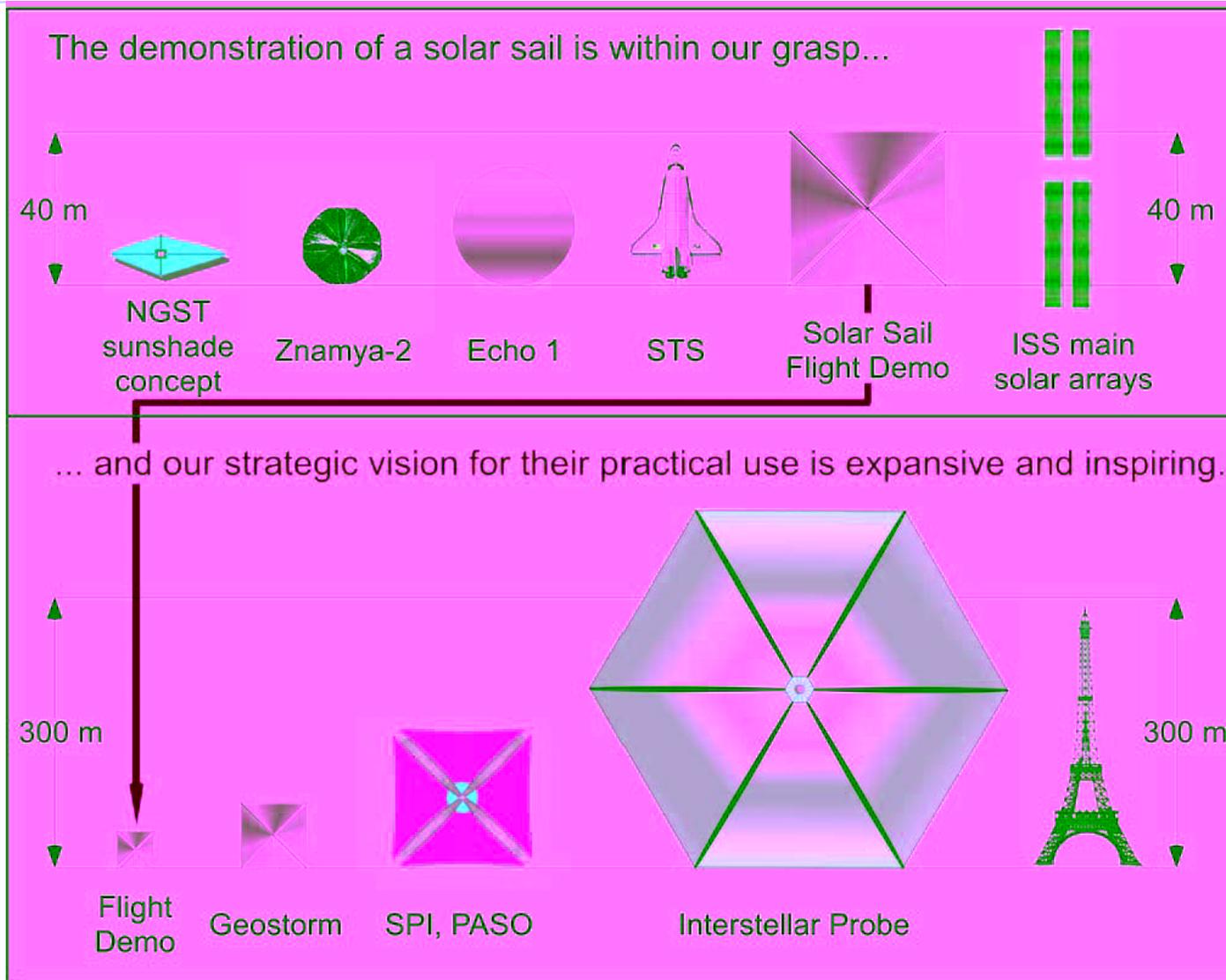
# REAL Ground Deployment Video



**20 – meter (on a side) square solar sail.  
Largest possible for ground deployment and testing under  
environmental conditions ...**

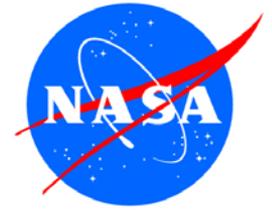
**... not quite big enough for missions currently envisioned.**

# Solar Sail Mission Size Comparison



# In-Space Deployment/Assembly Benefits

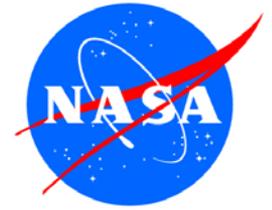
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- Tended Deployment:
  - Stable platform from which to deploy
    - No thrust/attitude control complications
  - On-site monitoring and control
    - Start, stop, reverse as needed
  - Intervention and assistance during deployment
    - Sticky boom or sail material, mechanisms
  - Post-deployment repairs
    - Rips/tears
  - Complete system check-out
    - Payload as well as sail system
  - Positive mission launch

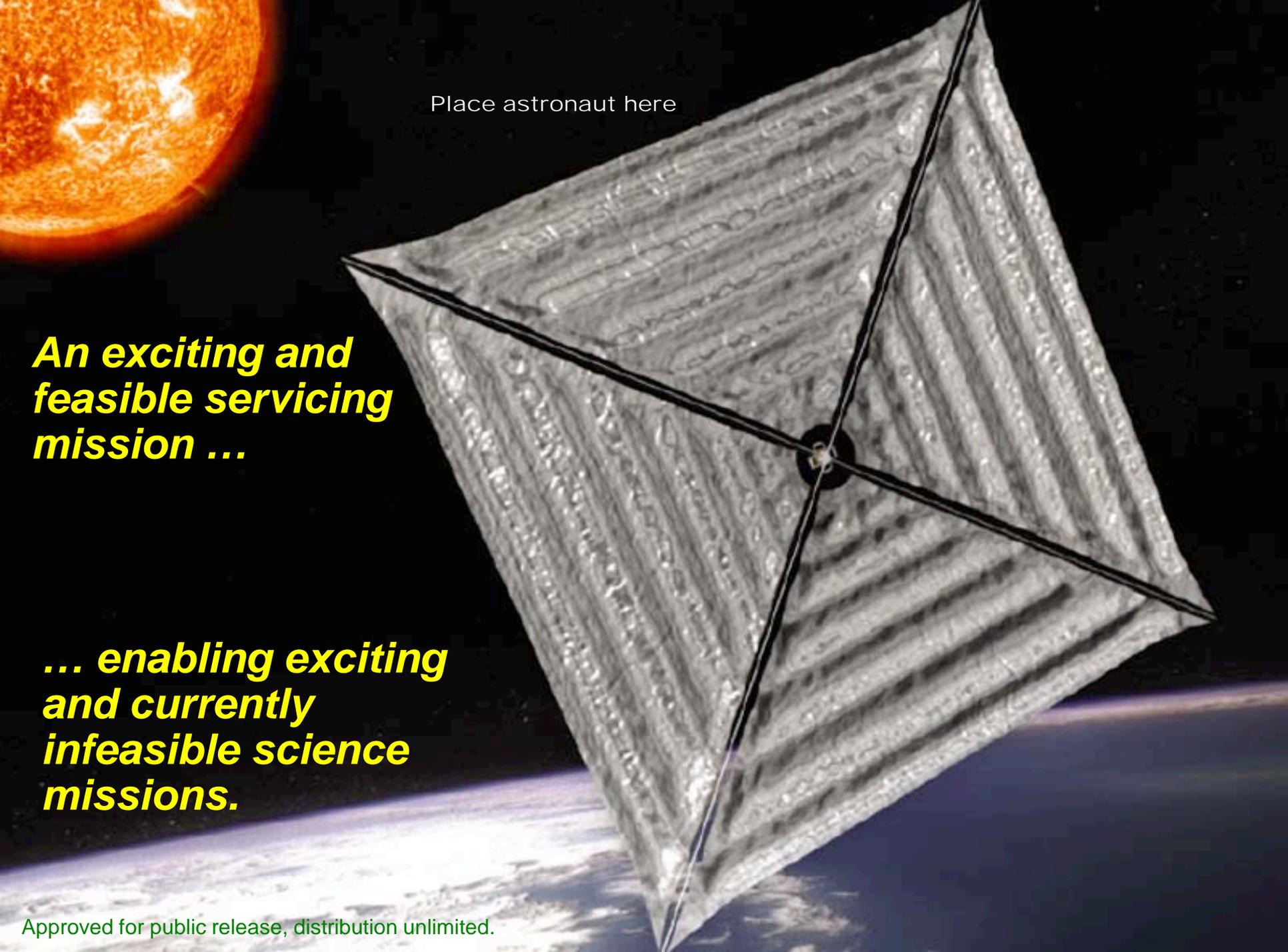
# In-Space Deployment/Assembly Benefits (cont.)

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- In-Space Assembly:
  - Same benefits as Tended Deployment, PLUS:
  - Larger sail sizes possible
    - Modular components assembled to large size
    - More mission capability (bigger is better)
  - NOT designed for gravity loads
    - Lighter booms and sail materials
  - NOT designed for deployment
    - As above, lighter, more efficient booms and sails designed only for in-space performance
    - Packaged for transport & assembly
  - No need for deployment-associated systems

In-space assembly would enable design and use of solar sail systems capable of performing game-changing science missions.



Place astronaut here

***An exciting and  
feasible servicing  
mission ...***

***... enabling exciting  
and currently  
infeasible science  
missions.***