SOLAR CUBE
A Heliogyro Propulsion System for CubeSats

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Solar Cube
Solar Cube

• Technology Demonstration Mission
• 6U CubeSat Form Factor
• Heliogyro Subsystem ~2.5 kg
• Four Blades, Each 150m x .25m x 5μ
• Characteristic Thrust: 1.2 mN
• Descendent of Four Major Development Efforts
  – MacNeal, ca. 1967 (Original Concept)
  – JPL, ca. 1978 (Halley’s Comet Rendezvous)
  – MIT, ca. 1990 (Solid-State)
  – Solar Blade, CMU, ca. 2000’s
Solar Cube Heritage - Original

- Two-blade Heliogyro
  - Blades 5700m x 1.5m x 6μm
  - 250 kg
    - 160 kg Sail Mass
    - 90 kg Non-Sail Mass
  - Rotational Period: 6 min.
  - Characteristic Acceleration: 0.6mm/s²
  - Bedrock of Conceptual Development

Solar Cube Heritage - JPL

- **Halley’s Comet Rendezvous**
  - Two Counter-Rotating Tiers of 6 Blades
    - 7500m x 8m blades
    - Redundant Edge Stiffeners Attached to Battens, to smooth out stress wrinkles in blades
    - Blade Tensioners to Damp Out-of-Plane Motion
    - Counter-rotation would eliminate gyroscopic stiffness as well as remove nutation and other disturbances
  - 3800 kg Non-Sail Mass
  - Massive Blades were Required for Massive Payload

Solar Cube Heritage - MIT

- **Solid-State Heliogyro**
  - 8 Blades, 100m x 1.5m x 7.62μ
  - 18 kg S/C Mass
  - 0.6 mm/s² Characteristic Acceleration

- **Design Study Conducted for Optimizing Earth Escape**

Solar Cube Heritage - MIT

- Deployment Study Also Conducted
  - Free Deployment
  - Stop-Start Deployment
  - Controlled Feed Rate
    - Blade Roll at Tip
      - Unroll and Eject
    - Blade Roll at Root


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Solar Cube Heritage – Solar Blade


Blade Dynamics/Deformation Analysis
Technology Demo Effort Begun

Stowage and Deployment Design
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https://www.youtube.com/watch?v=Lw56RL6Q9i4
Solar Cube Heritage – Solar Blade
Latest Generation Heliogyro
Solar Cube -- Configuration
Solar Cube – Stowage and Deployment

1. 6U, Stowed

2. Release Blades, Point Toward Sun, Spin Up

3. Feed Out Blades In a Controlled Manner

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Solar Cube – Control

Cyclic Pitch
Provides in-plane thrust

Collective Pitch
Changes spin rate

Collective-Cyclic Pitch
Changes spin rate and precesses the spin vector

Half-P Pitch
Precesses spin vector
Solar Cube – Hardware Fabrication and Testing
Solar Cube – Development Path

• Terrestrial Deployment/Actuation Test at Plum Brook Station Vacuum Chamber
• Three Blade Assemblies Mounted on Vertical Spinning Shaft
• Spin Rate is Sufficient to Counteract Gravity, Which Acts as Solar Pressure Analog
• Photogrammetry Used to Determine Blade Shape
• Blade Deformation Compared to Blade Models
• Successful Test Means TRL 6 for the Blades
Solar Cube – Development Path