Outline

• Star trackers for nanosatellites
  – Challenges
  – Solutions

• Using star trackers only
  – Challenges
  – Potential Solutions
Mission Enablers

• Nanosatellite star trackers enable:
  – Astronomy payloads
  – High resolution Earth observation
  – Interplanetary probes

• Star tracker only approach involves:
  – Elimination of ancillary attitude sensors:
    • Sun sensors, magnetometers, Earth sensors, gyros, etc.
  – Reduction of onboard complexity
    • Fewer modes and fault cases

• Hypothesis: A star tracker only approach may reduce mission cost, even when very accurate pointing knowledge is not required.
# Nanosatellite Star Tracker

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solution</th>
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<tbody>
<tr>
<td>Short baffle forces narrow FoV</td>
<td>Use faint stars</td>
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<td></td>
<td>Carry very large catalog</td>
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<tr>
<td>Small aperture limits incoming photons</td>
<td>CMOS active-pixel sensor with $\sim 4$ e⁻ noise</td>
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<td>Restricted electronics volume</td>
<td>Combine processor with camera head.</td>
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<td>Embrace stacked-BGA technology.</td>
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S3S Star Tracker

- 59 x 56 x 32.5 mm
- 90 g
- 0.5 W average
Performance

- Observing Ursa Major
- RMS $0.002^\circ$ declination, $0.018^\circ$ roll
Setup allows for both piston and tip/tilt adjustments.

8-10 pixels
Images

S3S Images

Star Map

August 12 2010

SSC10-X-3
Electronics Volume

- Cray-2, 1985 (Image from NASA)
  - 1.9 GFlops, 256 MWords RAM
  - Foreground and background processors
- S3S Electronics assembly, 2010
  - 5000 MIPS, 256 MB RAM
  - Auxiliary supervisory processor
Radiation Tolerance

Image Noise vs Temperature
Beginning of life, and after 9 krad of 105 MeV protons
# Star Tracker Only

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<td>Large and unknown body rates cause image shear</td>
<td>Differential image analysis to estimate rate and de-shear</td>
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<tr>
<td>Earth and sun-pointing safe-hold modes require orbit and/or ephemeris data</td>
<td>Robust mission clock or GPS</td>
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<tr>
<td>Obstruction and stray-light from sun, Earth and moon</td>
<td>Multiple star trackers required</td>
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CMOS active pixel sensor have electronic rolling shutter
Row exposures staggered in time.

Double images used to estimate body rates

Under motion, this causes geometric distortion

Sequential Images

Must operate at maximum tip-off rates
Star Tracker Only Safe/Hold

• Star tracker gives inertial attitude data
• Safe/Hold targets are never inertial
• Sun-pointing Safe/Hold
  – Need to know time of year to determine sun direction
  – Clock requirements are not strict
• Earth-pointing Safe/Hold
  – Need to know time and orbit accurately
  – GPS, or faith in launcher
• Passive Safe/Hold remains least complex
Obstruction and Stray Light

- Star trackers very vulnerable to stray light from sun, Earth and moon
- 3-axis attitude data available from Earth and moon
  - Crescent moon tracking has been tested
  - Track Earth based on terrain, cloud maps, known city lights, etc?
- Sun does not damage optics
  - Saturates detector even at fastest exposure
- Dead zone when bright object is outside FoV, but stray light obscures stars
- Multiple star trackers required for 100% availability
  - Specific missions may be able to use only one
Upcoming Flights

• CanX-4/5
  – Launch in late 2011
  – Star tracker as secondary payload
  – Use as experimental platform after end of primary mission

• BRITE-Poland
  – Launch in 2012
  – Star tracker used to support astronomical payload