STAR TRACKER ON CHIP

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(2) Azmerit Ltd.
## Satellite Classification

<table>
<thead>
<tr>
<th>Size</th>
<th>Weight Range</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>&gt;1000 kg</td>
<td>Hubble, GLONASS</td>
</tr>
<tr>
<td>Medium</td>
<td>500-1000 kg</td>
<td>Spitzer, GPS II</td>
</tr>
<tr>
<td>Small</td>
<td>100-500 kg</td>
<td>Galex</td>
</tr>
<tr>
<td>Micro</td>
<td>10-100 kg</td>
<td>Sputnik-1, TabletSat</td>
</tr>
<tr>
<td>Nano</td>
<td>1-10 kg</td>
<td>CubeSat</td>
</tr>
<tr>
<td>Pico</td>
<td>0.1-1 kg</td>
<td>PhoneSat-1.0</td>
</tr>
</tbody>
</table>

**Visual Display of Small to Pico Satellite Scale**

- Small Satellite (100-500 kg)
- Micorsatellite (10-100 kg)
- Nanosatellite (1-10 kg)
- Picosatellite (<1 kg)
Small Satellite Examples

Communications
HAMSAT
Mass: 46 kg

Remote Sensing
WNISAT
Mass: 10 kg

Scientific Research
UNISAT
Mass: 1.5 kg

Biological Experiments
O/OREOS
Mass: 5.5 kg

Technology Demonstration
FalconSat 1
Mass: 50 kg

Military Application
SMDC-One
Mass: 4 kg

Academic Training
AAUSAT 2
Mass: 1 kg
Small Satellite Series

CubeSat

1U:
- 10×10×10cm
- up to 1.33 kg

Bus 6U:
- 34×23×10cm
- up to 8 kg

TabletSat

Bus 1U:
- up to 12 kg
- power 3W

Bus 4U:
- up to 50 kg
- power 10W

~ 3 years lifetime
Market Size

Large Satellites

Small Satellites

Global Number of Satellites Ordered and Launched

Source: NSR
Known Micro Star Trackers

Sinclair Interplanetary (Canada)

Berlin Space Technologies (Germany)

University of Kentucky

NOTE

- All 3 Star Trackers Based on 5Mpxl Aptina CMOS sensor MT9P031 (2592×1944, pixel size 2.2×2.2μm)
- Attitude accuracy ~30″–60″
- First flight: spring 2013
### ASTC-1
(Autonomous Star Tracker on Chip v.1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMOS Format</td>
<td>128×128 px</td>
</tr>
<tr>
<td>Pixel Size</td>
<td>20×20 μm (6.4'×6.4')</td>
</tr>
<tr>
<td>Field of View</td>
<td>13.7°×13.7° (193 sq. degree)</td>
</tr>
<tr>
<td>Lens (f, D/f)</td>
<td>10.55 mm, 1:1.2</td>
</tr>
<tr>
<td>Size, Weight</td>
<td>56×40×55 mm, 90 g</td>
</tr>
<tr>
<td>Power Supply</td>
<td>0.2 W (w/o Peltier Cooler)</td>
</tr>
<tr>
<td>Stellar Catalogue</td>
<td>1800 stars up to 5ᵐ</td>
</tr>
<tr>
<td>Attitude Accuracy (σₓᵧ / σᶻ)</td>
<td>5&quot; / 60&quot; (ω&lt;10°/s)</td>
</tr>
<tr>
<td>Update Rate</td>
<td>10 Hz</td>
</tr>
</tbody>
</table>
High Attitude Accuracy:
- 5" (1σ) in 90% of the sky
  (Such accuracy will allow ASTC-1 replace “large” star trackers)

On-Orbit Calibration
ASTC-1 Construction
ASTC-1 Assembling

Peltier cooler
ASTC-1 Assembling

128×128 CMOS
ASTC-1 Assembling

Shutter’s solenoid

128×128 CMOS

Shutter’s solenoid

Shutter
ASTC-1 Assembling

Lens (w/o case)
ASTC-1 Assembling

CPU

Flash

SDRAM
ASTC-1 Assembling
ASTC-1 Assembling

Fasteners

Lens case

Case

RS 485
ASTC-1 Assembling

- Lens hood
- Cover
- Case
- RS 485
High Attitude Accuracy

1. “Defocused” Stellar Images
2. Multiple Stars in Field of View
3. Systematical Errors Correction
“Defocused” Stellar Images

\[ \Delta_{x,y} = \frac{P}{SNR} \]
Systematical Errors Correction

List of taking into account systematical errors:
1. Individual Pixel Sensitivity
2. Individual Pixel Dark Currents
3. CMOS Parameters Thermal Dependencies
4. Lens Aberrations (Chromatic and Achromatic)

Most Important Errors are # 2 and # 4.
Individual Pixel Dark Currents

More detailed see Tuchin et al. (SSC13-I-10)
On-Orbit Calibration

Why is it necessary?
Dark Current Changes with Total Irradiation Dose

High Accuracy Star Tracker (HAS) Version 2 CMOS Active Pixel image Sensor (CMOS APS)

Dark Current increases by 100 times in ½ year in radiation belt

Source: HAS2 Detailed Specification - ICD
On-Orbit Calibration

1. Dark currents map changes drastically under the effect of radiation belt.
2. This map should be updated for attitude accuracy maintaining during long missions.
3. Map building is impossible while the lens is open because of those stars which are fainter than the observation threshold. The shutter is designed for carrying out the calibration.
Conclusions

We hope to produce the first example of ASTC-1 by the end of 2014