STAR TRACKER ON CHIP

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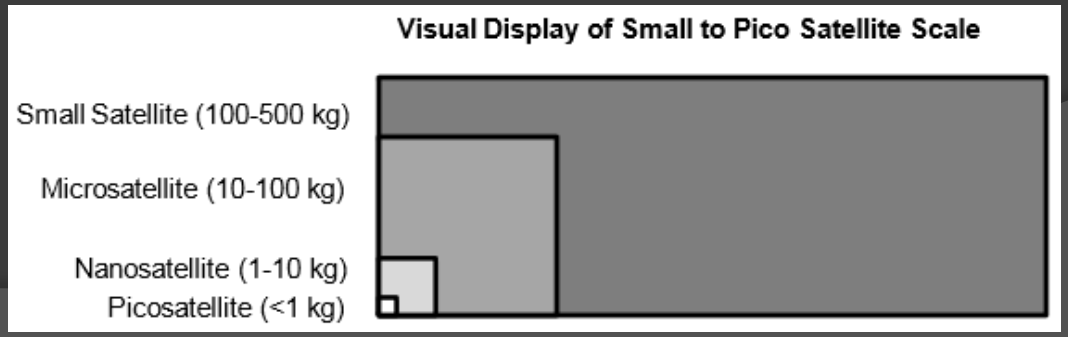
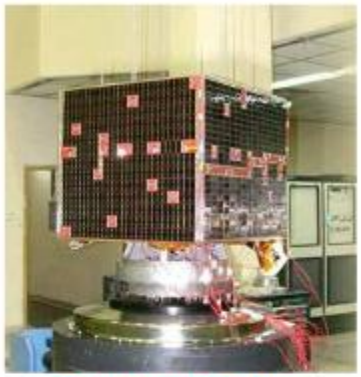
Satellite Classification

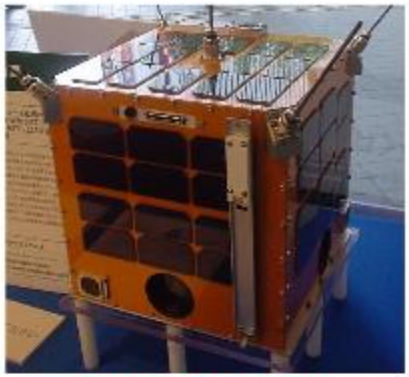
Large	>1000 kg	Hubble, GLONASS
Medium	500-1000 kg	Spitzer, GPS II
Small	100-500 kg	Galex
Micro	10-100 kg	Sputnik-1, TabletSat
Nano	1-10 kg	CubeSat
Pico	0.1-1 kg	PhoneSat-1.0



Small Satellite Examples

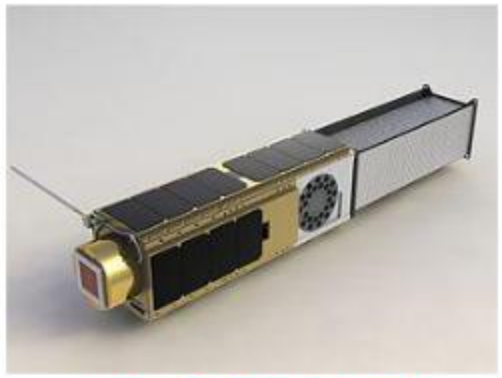


Communications
HAMSAT
Mass: 46 kg

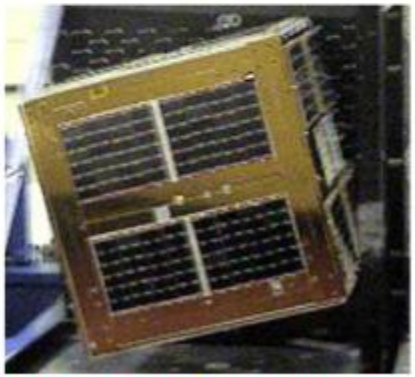


Remote Sensing
WNISAT
Mass: 10 kg

Scientific Research
UNISAT
Mass: 1.5 kg

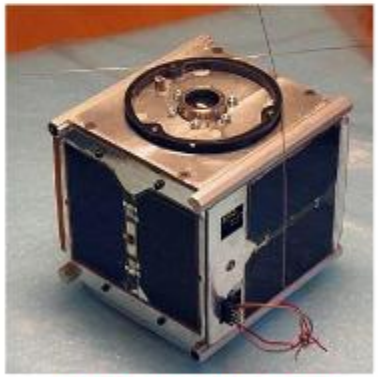


Biological Experiments
O/OREOS
Mass: 5.5 kg



Technology Demonstration
FalconSat 1
Mass: 50 kg

: **Military Application**
SMDC-One
Mass: 4 kg



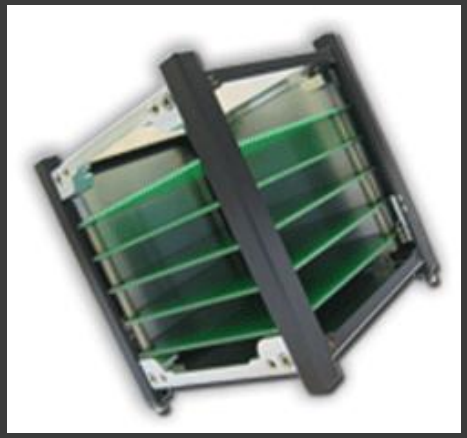
Academic Training
AAUSAT 2
Mass: 1 kg

Small Satellite Series

CubeSat

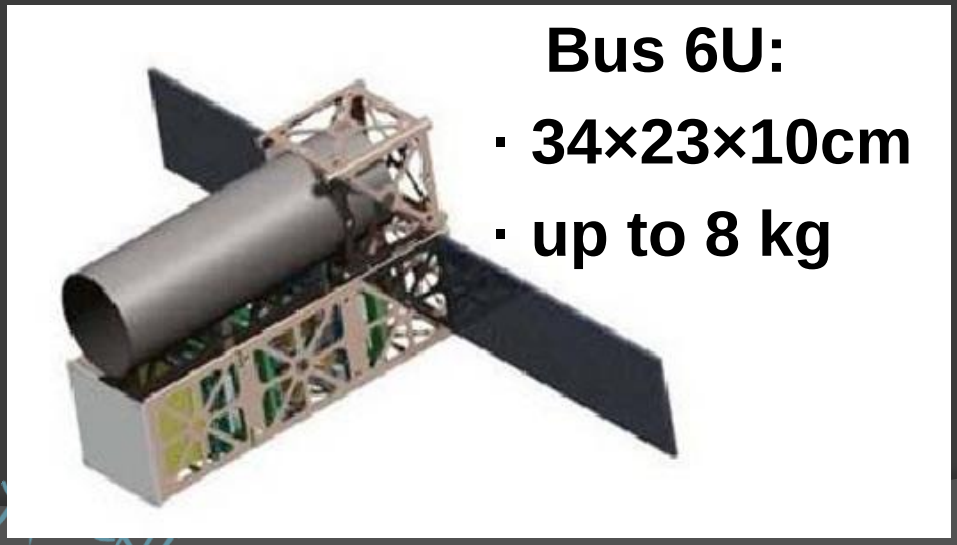
1U:

- **10×10×10cm**
- **up to 1.33 kg**



Bus 6U:

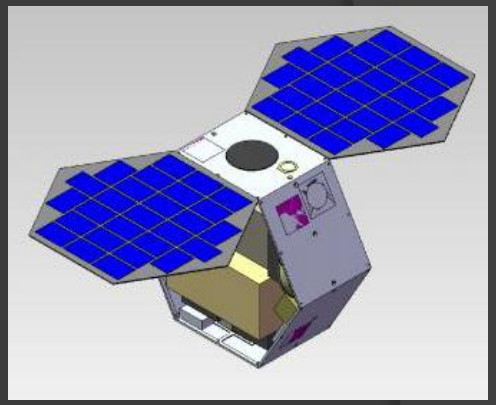
- **34×23×10cm**
- **up to 8 kg**

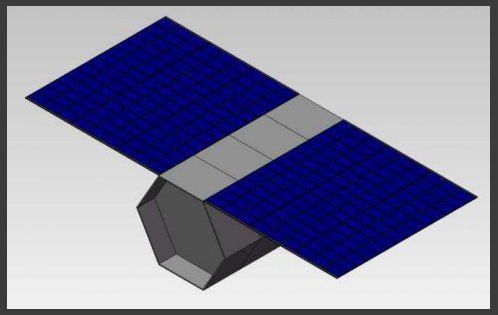


TabletSat

Bus 1U:

- **up to 12 kg**
- **power 3W**





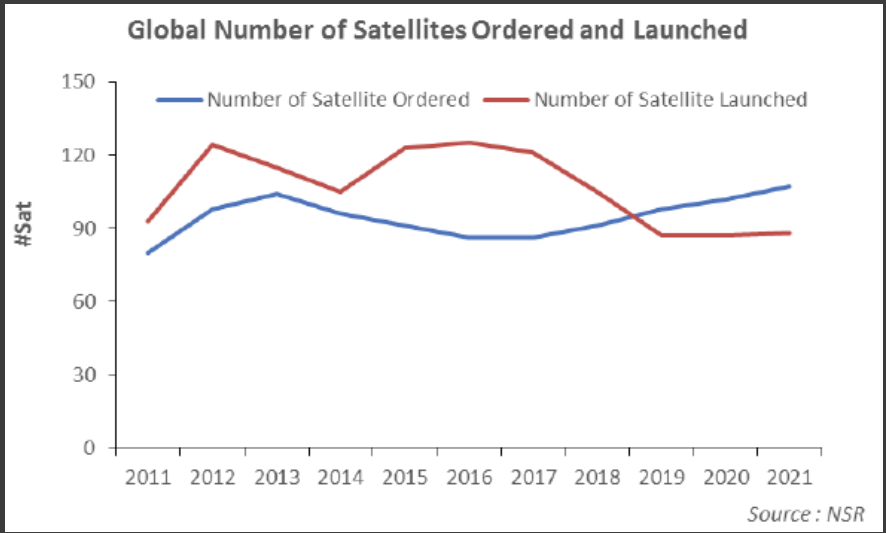
Bus 4U:

- **up to 50 kg**
- **power 10W**

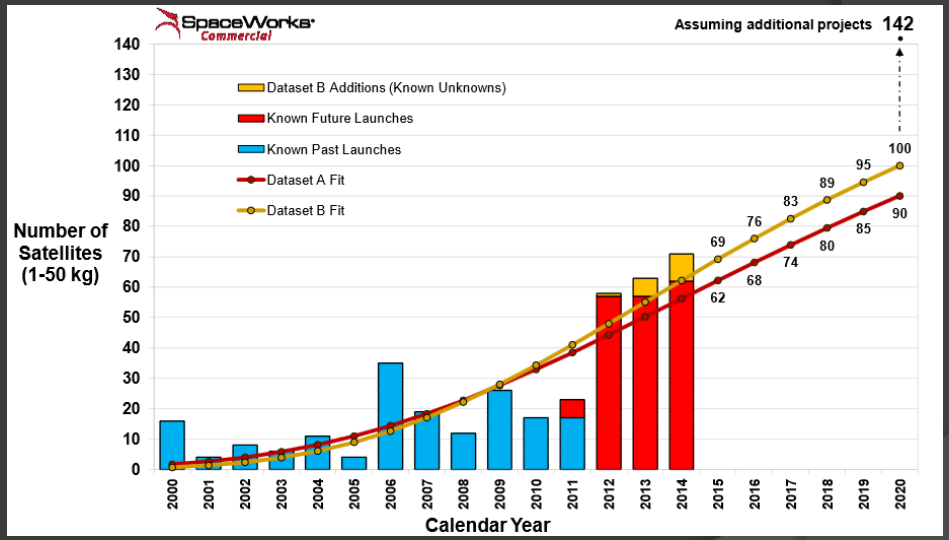
~ 3 years lifetime

Market Size

Large Satellites



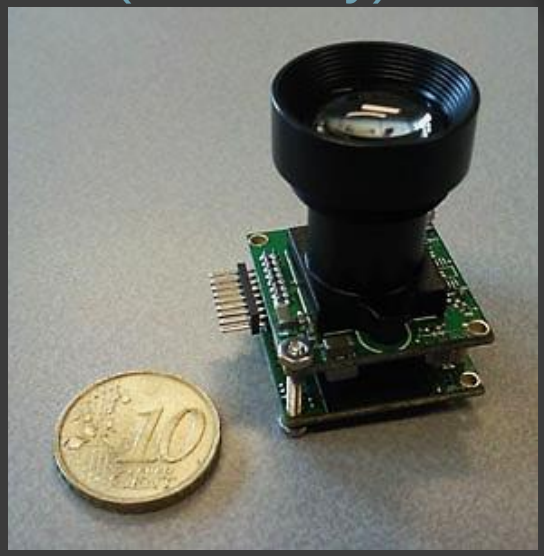
Small Satellites



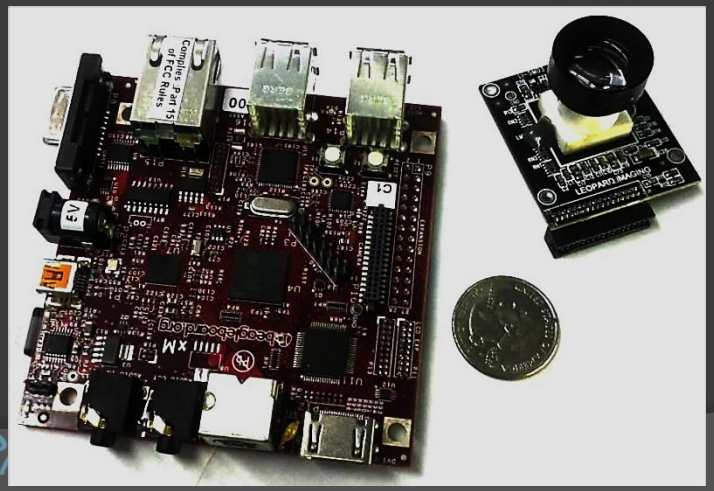
Known Micro Star Trackers

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)

Parameter	Value
CMOS Format	128×128 px
Pixel Size	20×20 μm (6.4'×6.4')
Field of View	13.7°×13.7° (193 sq. degree)
Lens (f, D/f)	10.55 mm, 1:1.2
Size, Weight	56×40×55 mm, 90 g
Power Supply	0.2 W (w/o Peltier Cooler)
Stellar Catalogue	1800 stars up to 5^m
Attitude Accuracy (σ_{xy} / σ_z)	5" / 60" (ω<10°/s)
Update Rate	10 Hz

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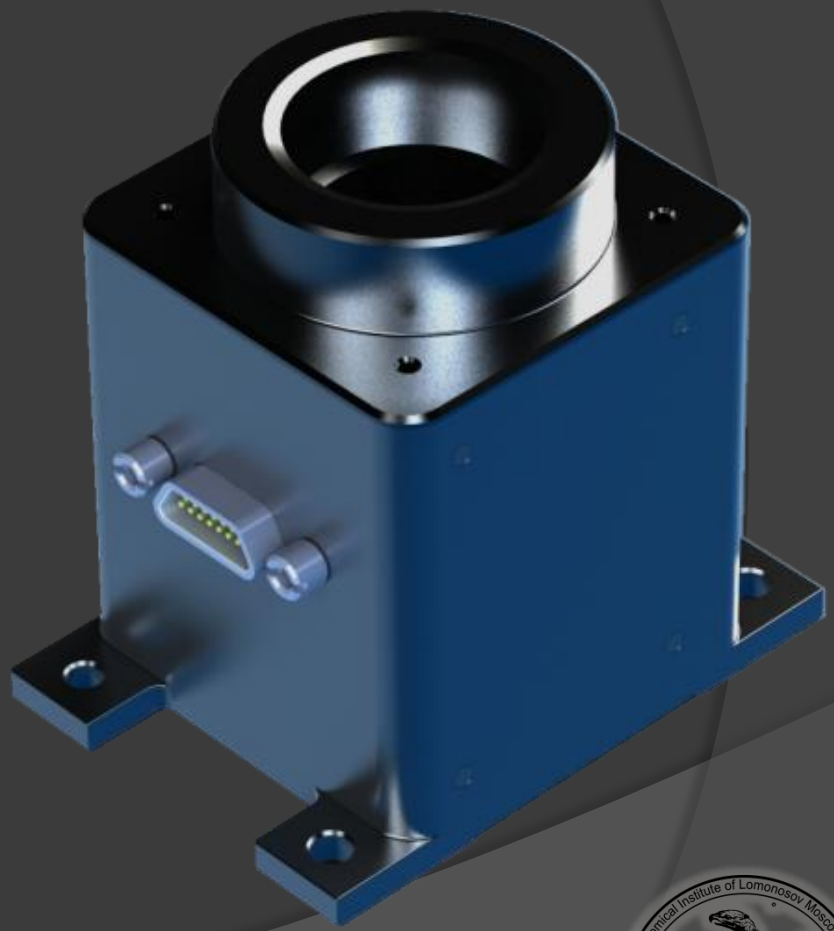
ASTC-1 Features

- High Attitude Accuracy:
  - 5" (1σ) in 90% of the sky

    (Such accuracy will allow ASTC-1 replace “large” star trackers)
- On-Orbit Calibration



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ASTC-1 Construction

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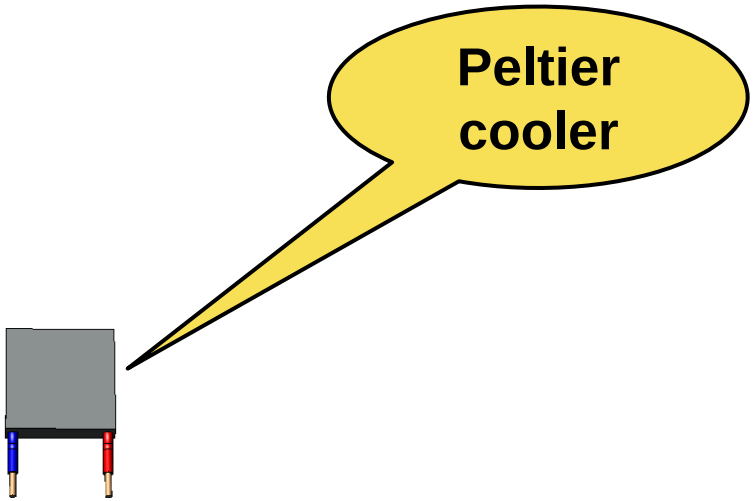
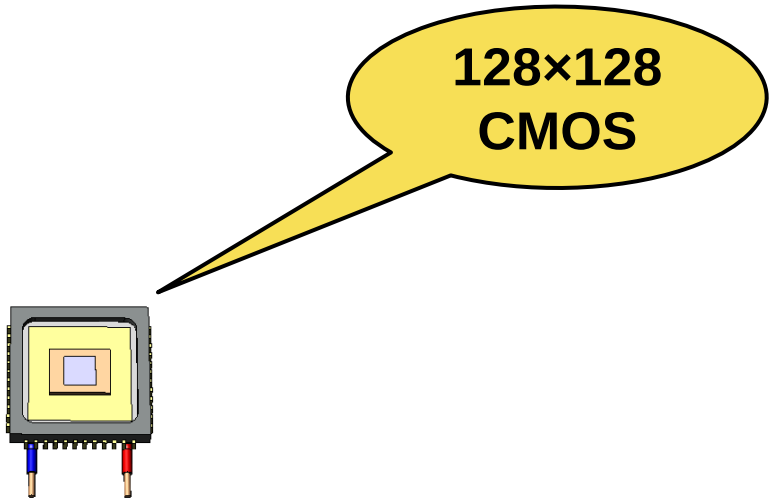
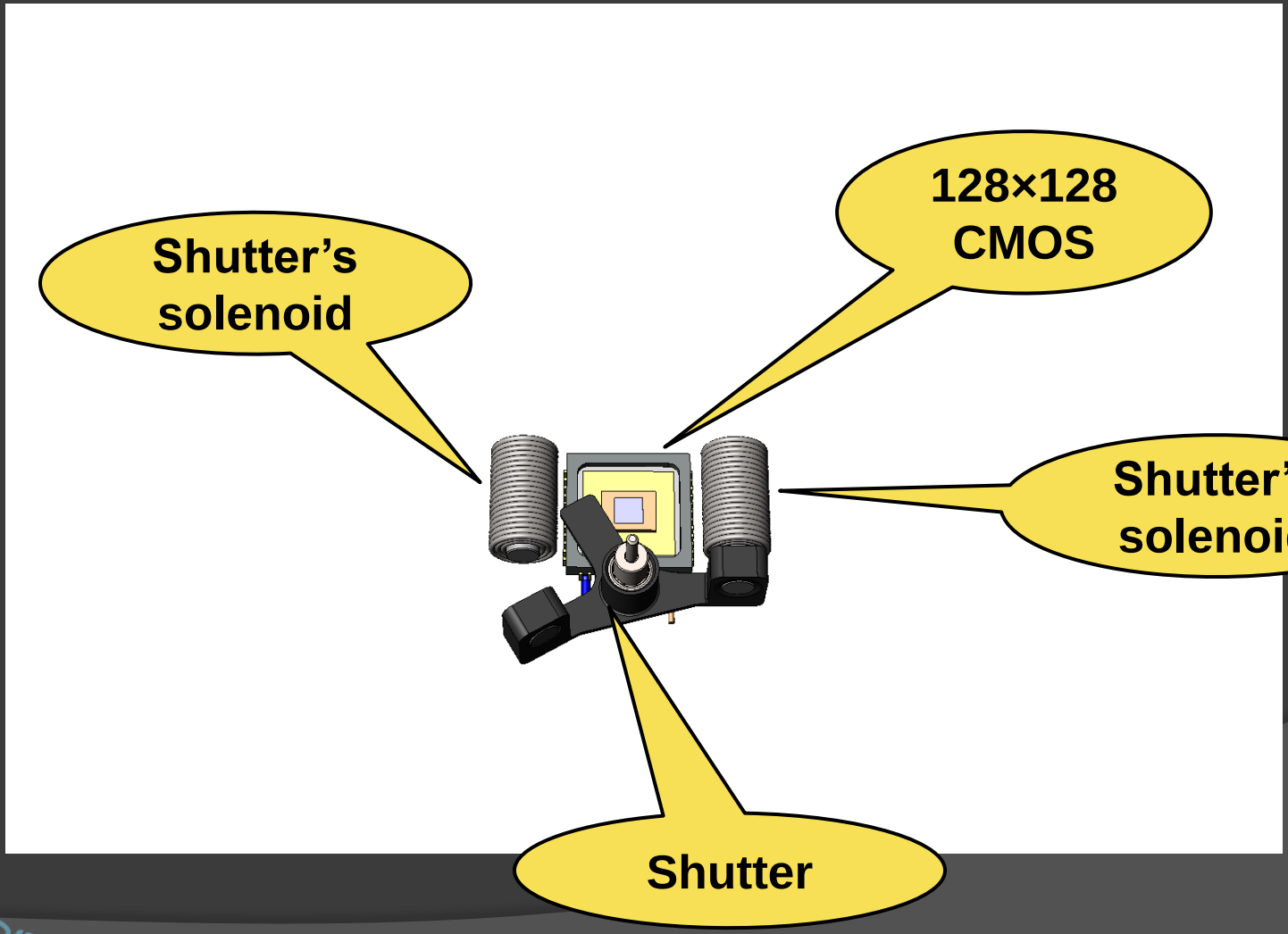
ASTC-1 Assembling



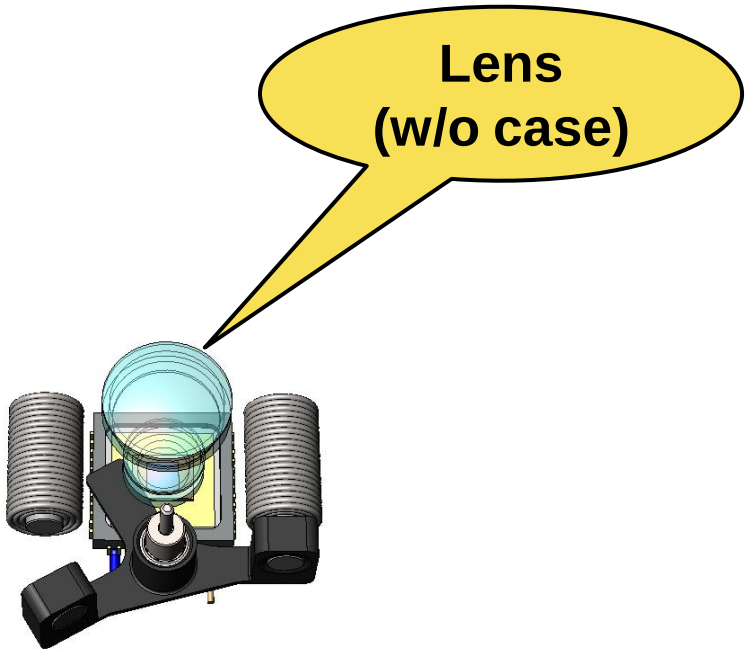
ASTC-1 Assembling



ASTC-1 Assembling



ASTC-1 Assembling



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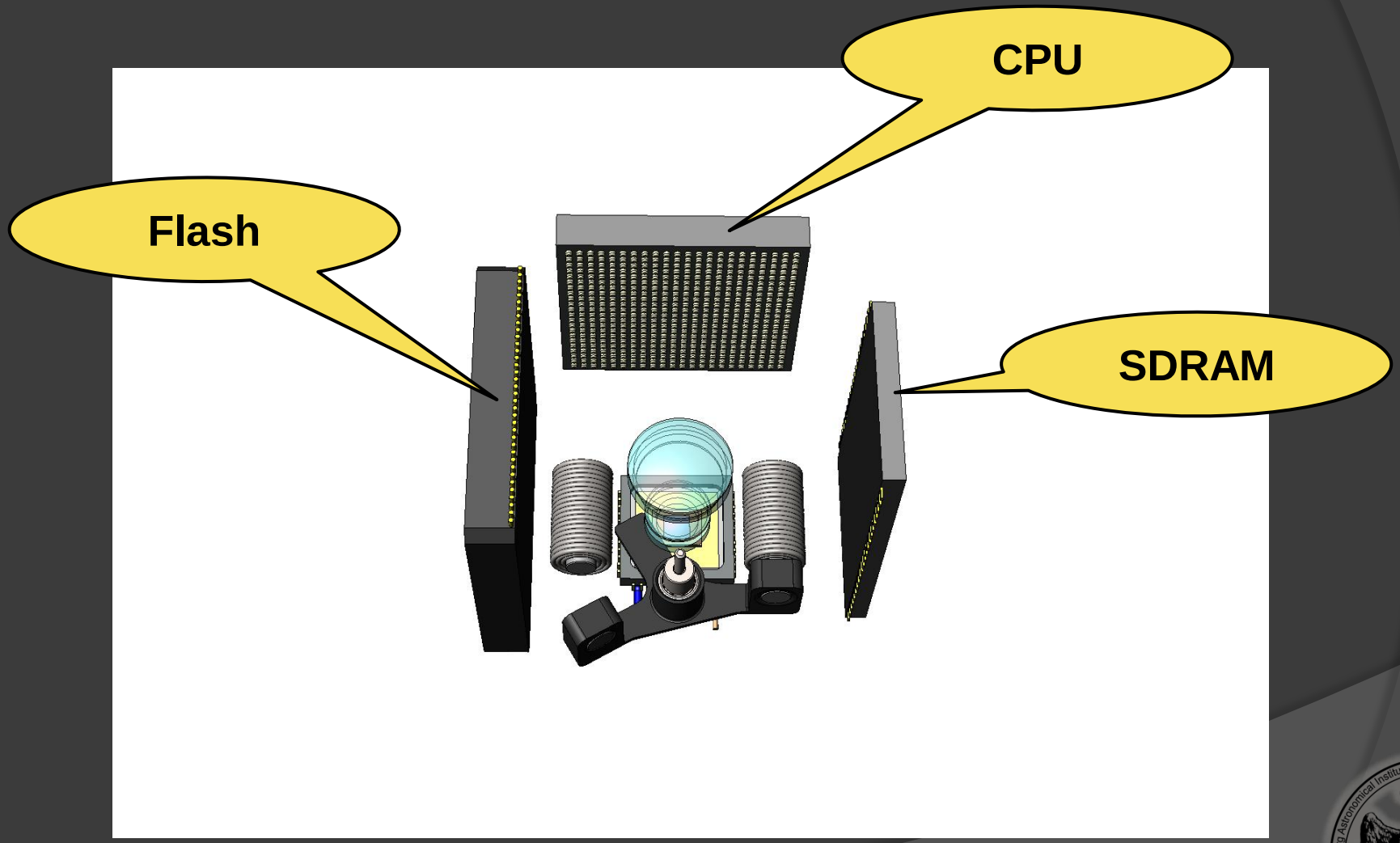

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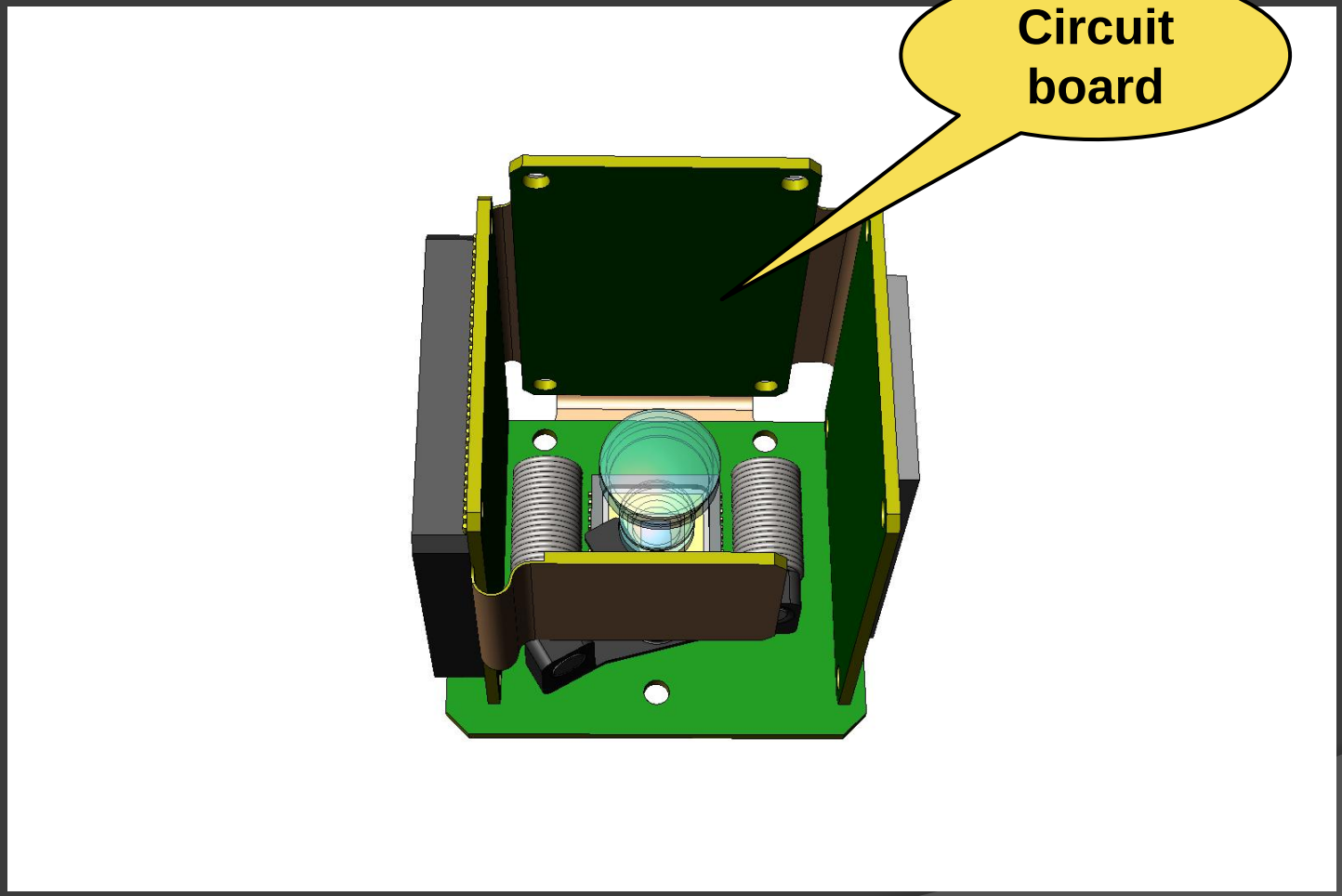
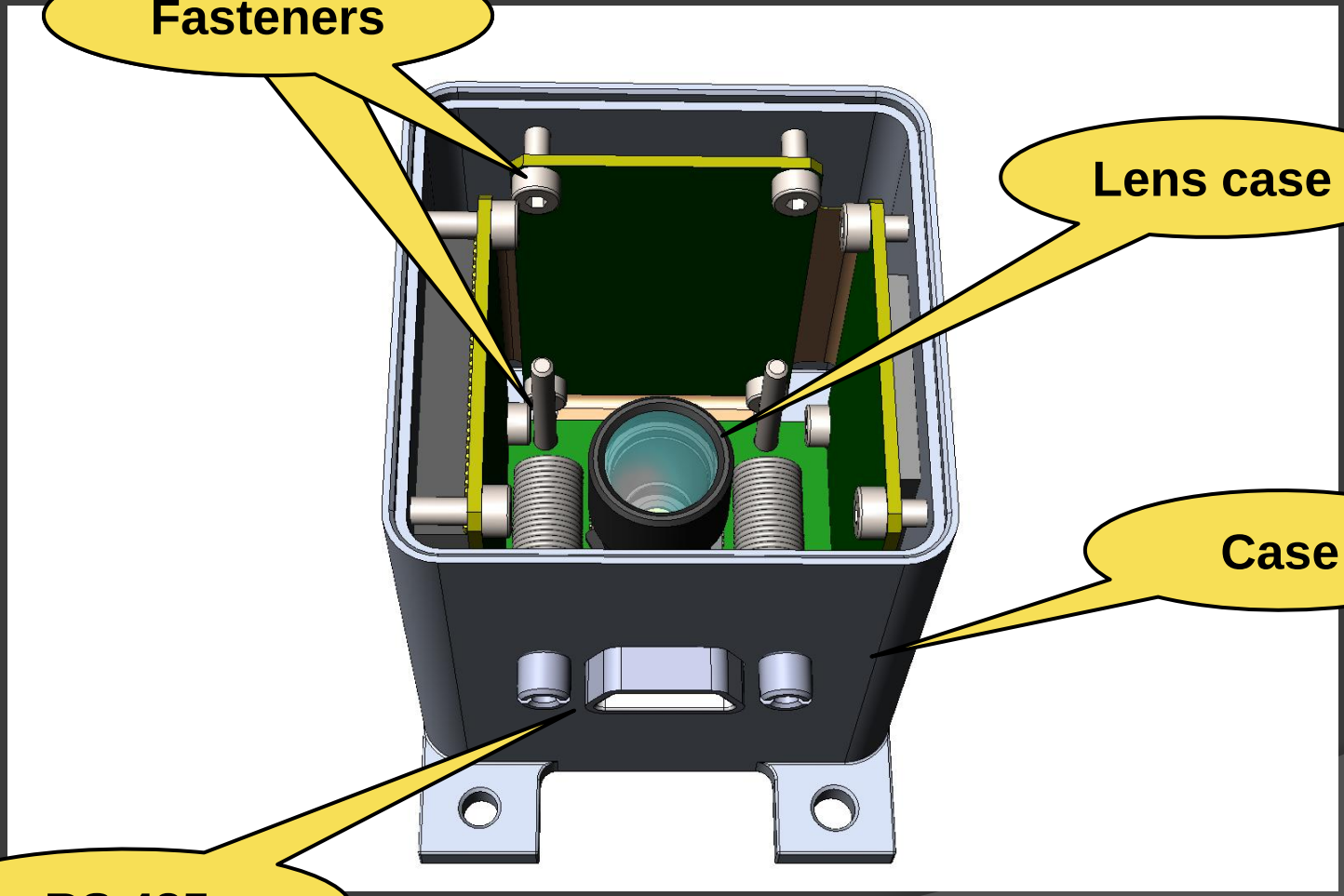
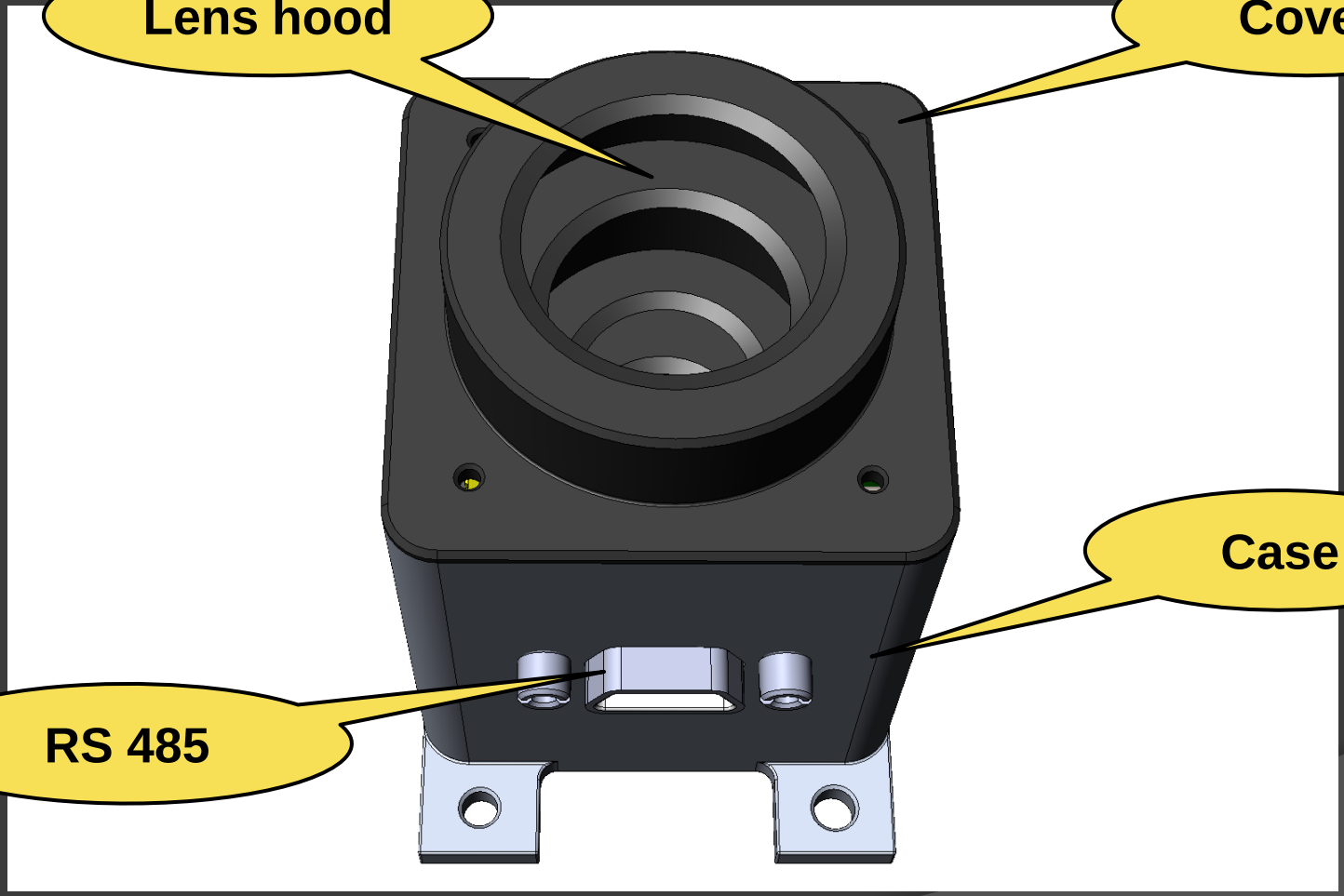


ASTC-1 Assembling



ASTC-1 Assembling



High Attitude Accuracy

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

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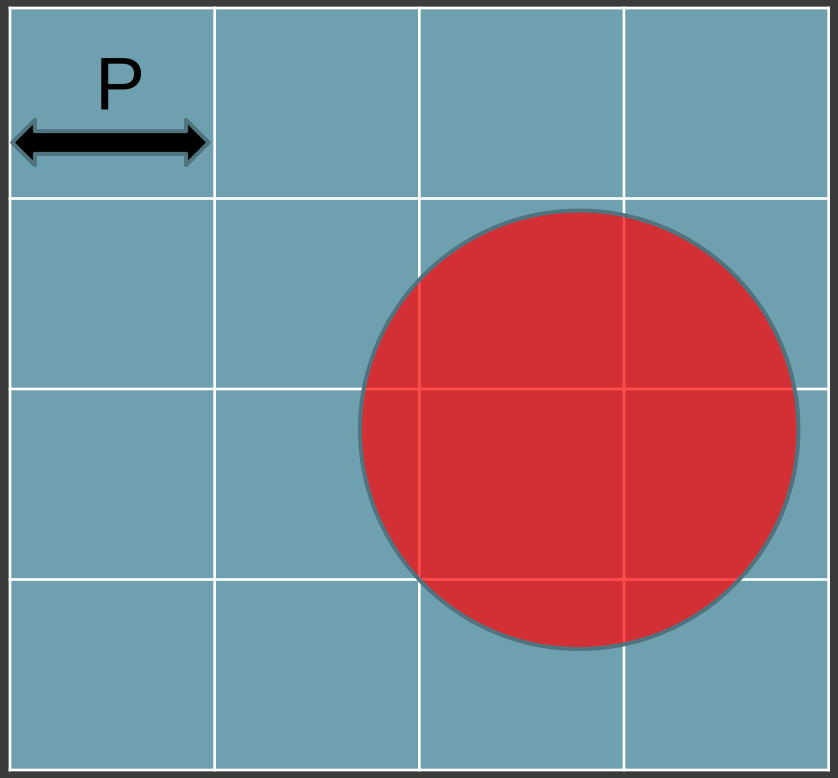
“Defocused” Stellar Images



$$\Delta_{x,y} = \frac{P}{SNR}$$

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.

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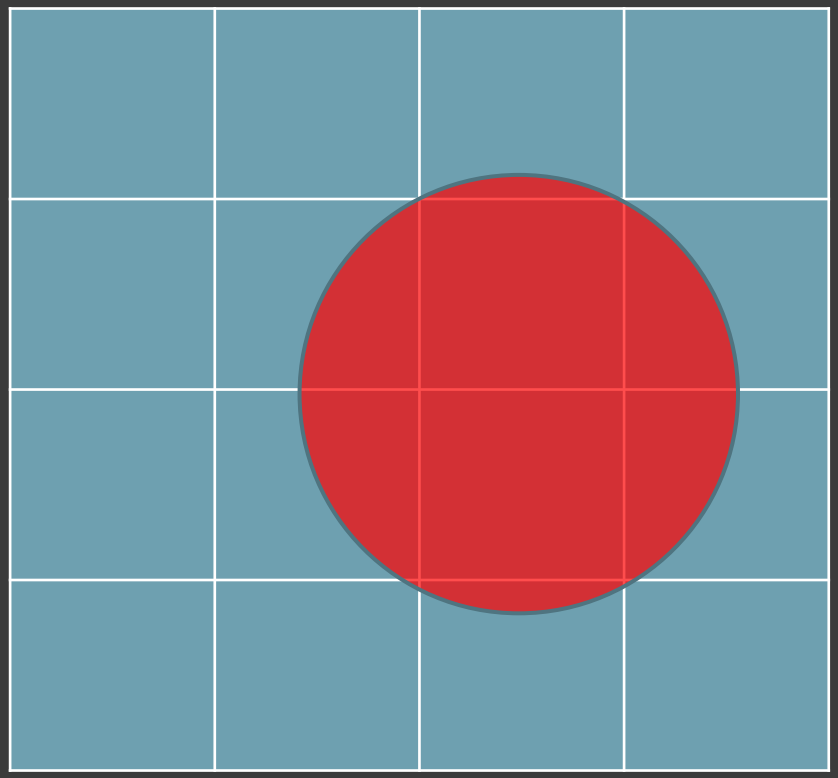
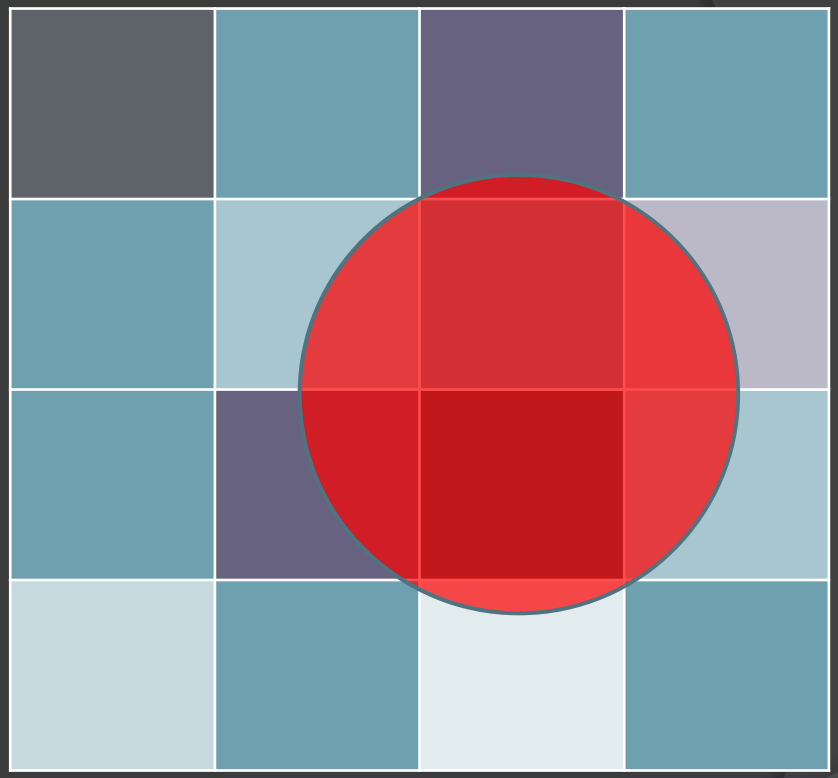
Individual Pixel Dark Currents



Ideal CMOS



Real CMOS

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

On-Orbit Calibration

Why is it necessary?

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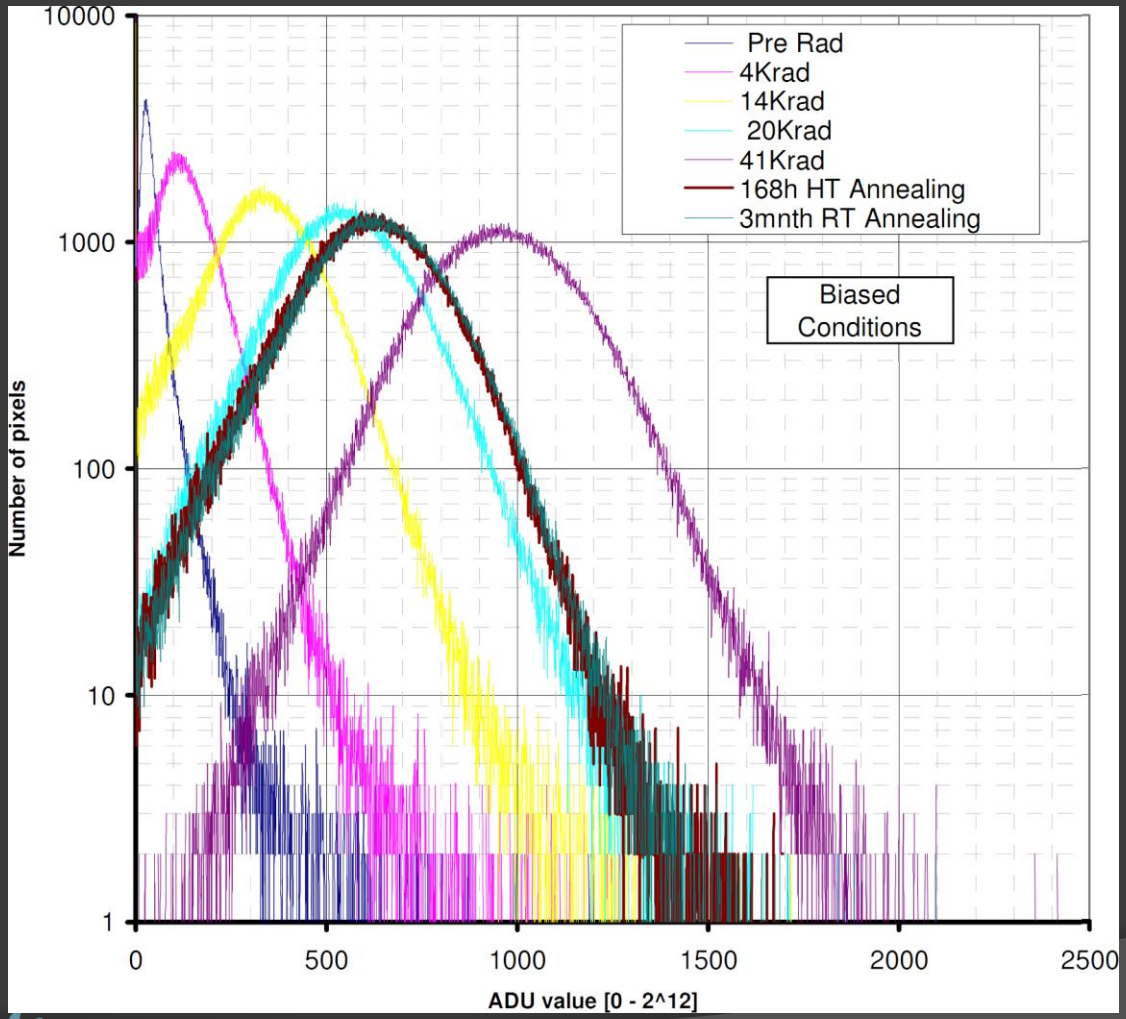
Dark Current Changes with Total Irradiation Dose



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

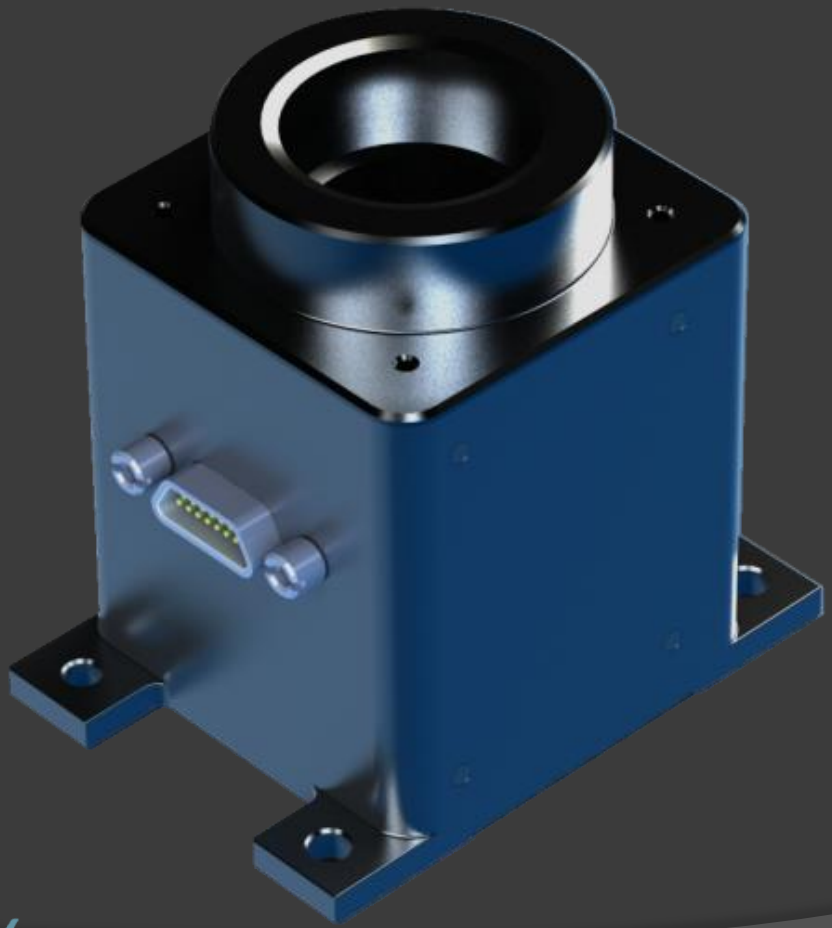
Source: HAS2 Detailed Specification - ICD

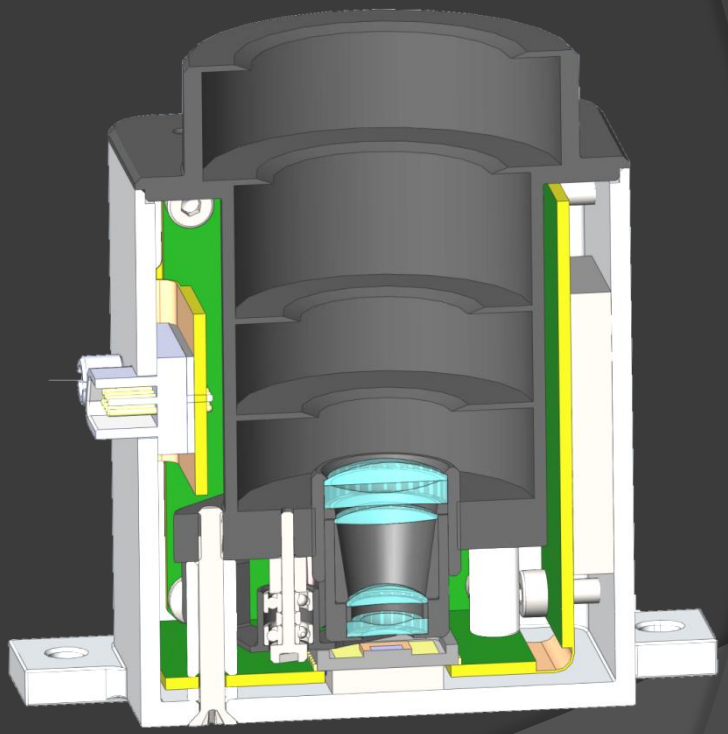
On-Orbit Calibration

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





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