# Technology building blocks and ongoing activities for spectral sensing for relative navigation

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ESA ESTEC
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# Agenda

- Brief company intro
- Technology building blocks
  - Optics
  - Sensors and ROE
  - Backend electronics
  - Algorithms and processing software
- Ongoing activities
  - Spectral imager VNIR IOD
  - TIR channel breadboarding
  - Other spectral channels

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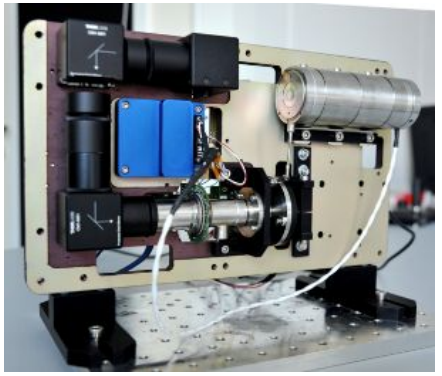
# Brief company intro

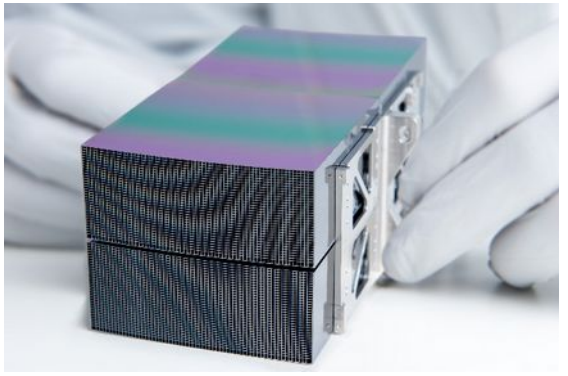
cosine

# develops and builds measurement systems


**Inspection systems**
for
Medical, Oil/Gas,
Food & Pharma



**Remote sensing systems**
Space and air-borne
spectral cameras
for
Agriculture, Environment
and Disaster Management



**High energy optics**
X-ray and gamma-
ray optics
for
Astronomy, Material
Analysis and Health

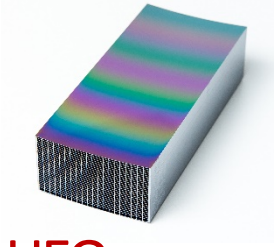
# Core business

- Develop new technology for & with strategic customers
  - Space and non-space customers, science, energy etc
  - ESA, NASA, Shell, Heerema, Nissin, …
  - Working with universities, institutes, high-tech SME, also in H2020, STW, etc
- Use the technology to build custom measurement systems
  - Spectroscopic imaging, IR to gamma-ray
  - Generic core, many applications
- Generate recurring business for a specific product-market combination through spin-offs
  - 3D-one BV for multi-camera spectral imaging hardware
  - condi food BV for inspection cameras for food quality and safety
  - cosine High Energy Optics BV for Silicon Pore Optics based products

a cosine company

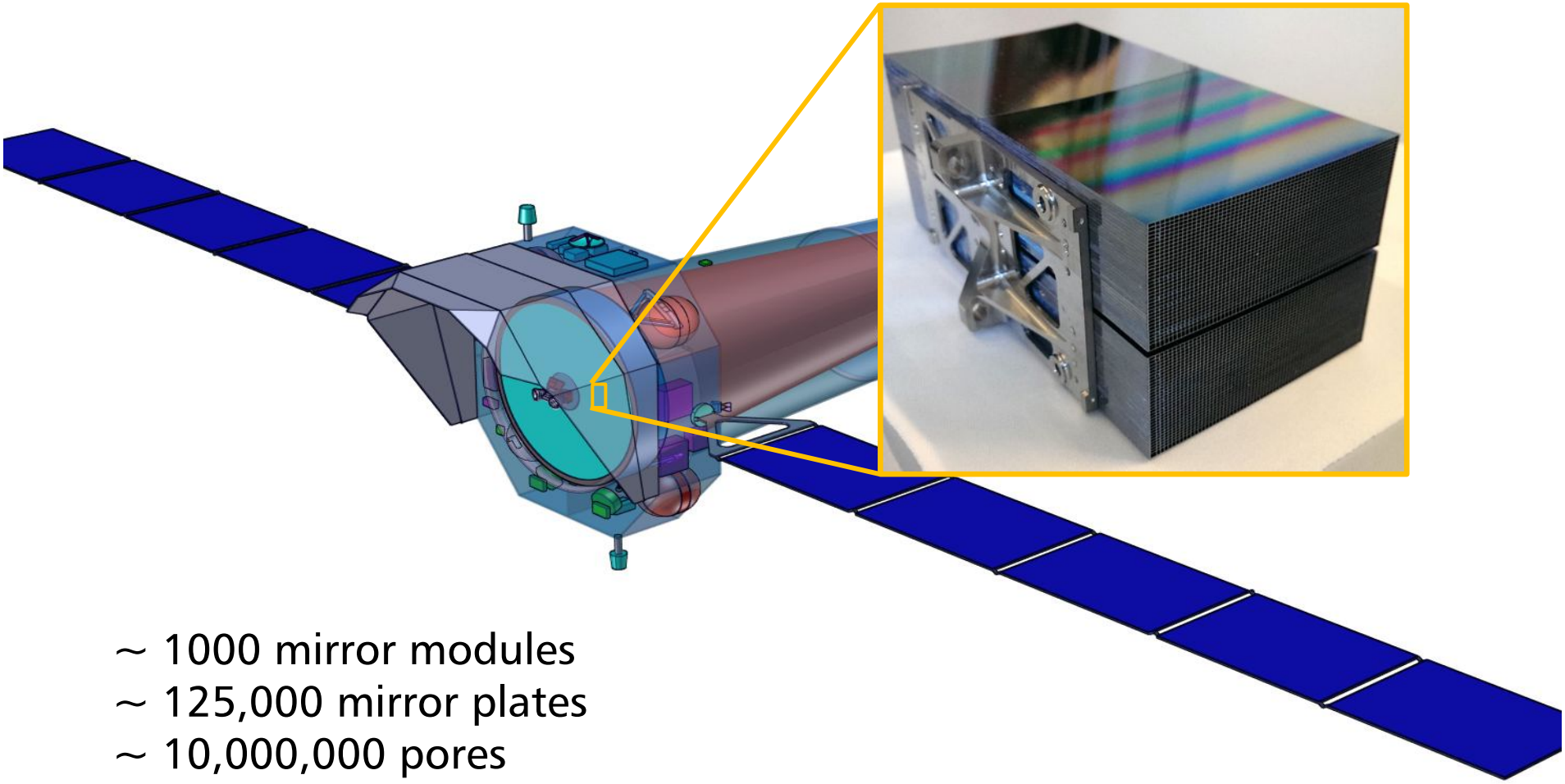
condi food

3D-ONE



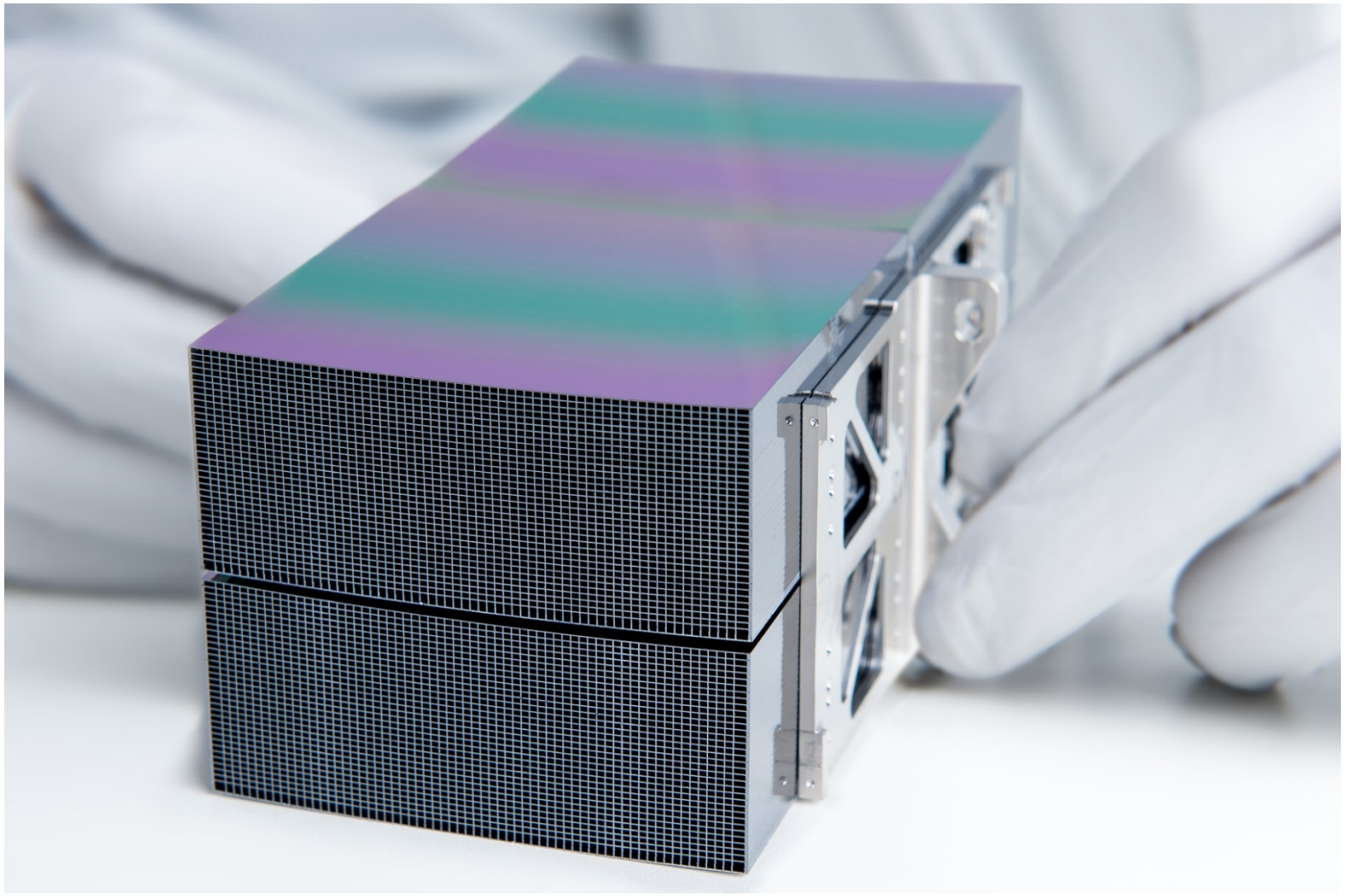
HEO

# Athena Silicon Pore Optics Mirror Modules



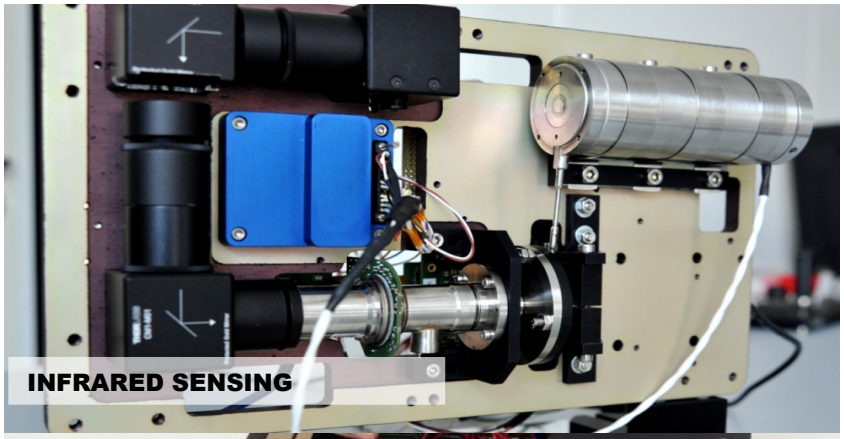
~ 1000 mirror modules
~ 125,000 mirror plates
~ 10,000,000 pores
~ 500 $m^2$ polished area

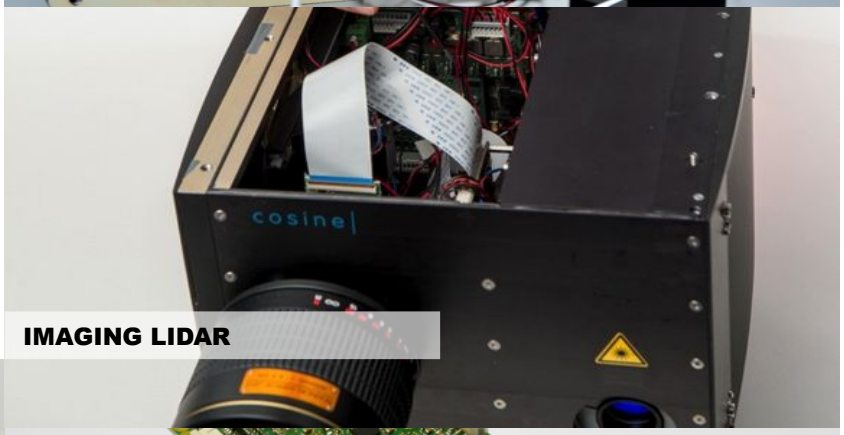
# Final Product – a Silicon Pore Optics Mirror module



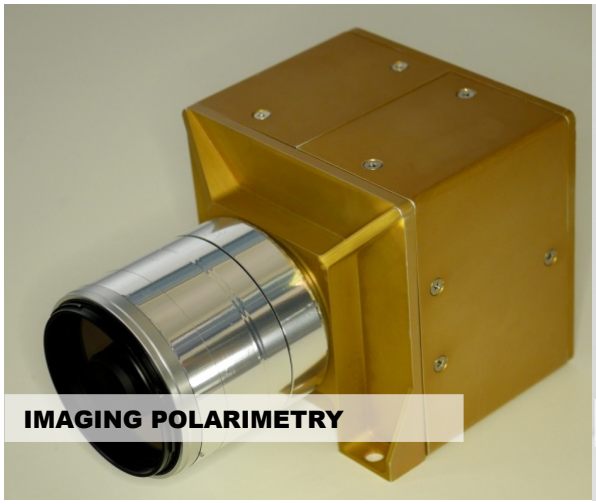
# Technology Lines for small instruments

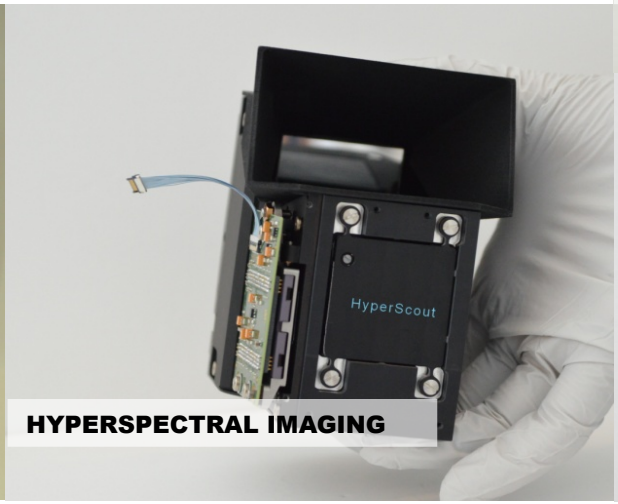
- Five technology lines are leading developments at cosine
  - Hyperspectral imaging
  - Infrared sensing
  - Imaging lidar
  - Imaging spectroscopy
  - Imaging polarimetry
- These technologies are exploited in commercial *products* and commercial *service* missions


INFRARED SENSING

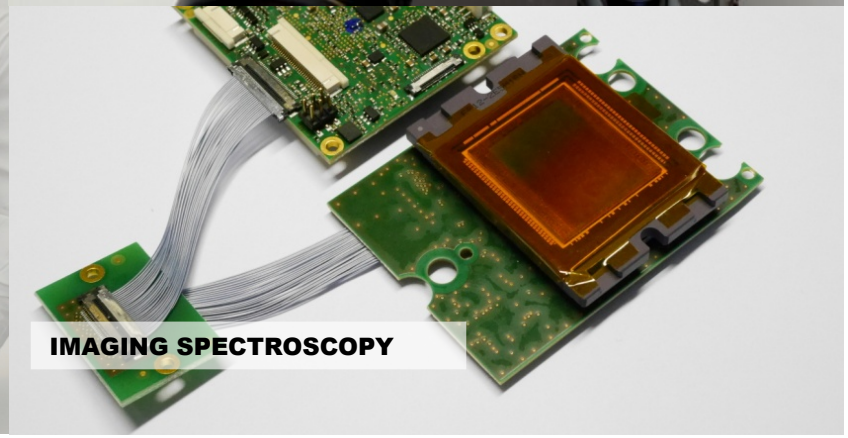


IMAGING LIDAR


IMAGING POLARIMETRY



HYPERSPECTRAL IMAGING


IMAGING SPECTROSCOPY

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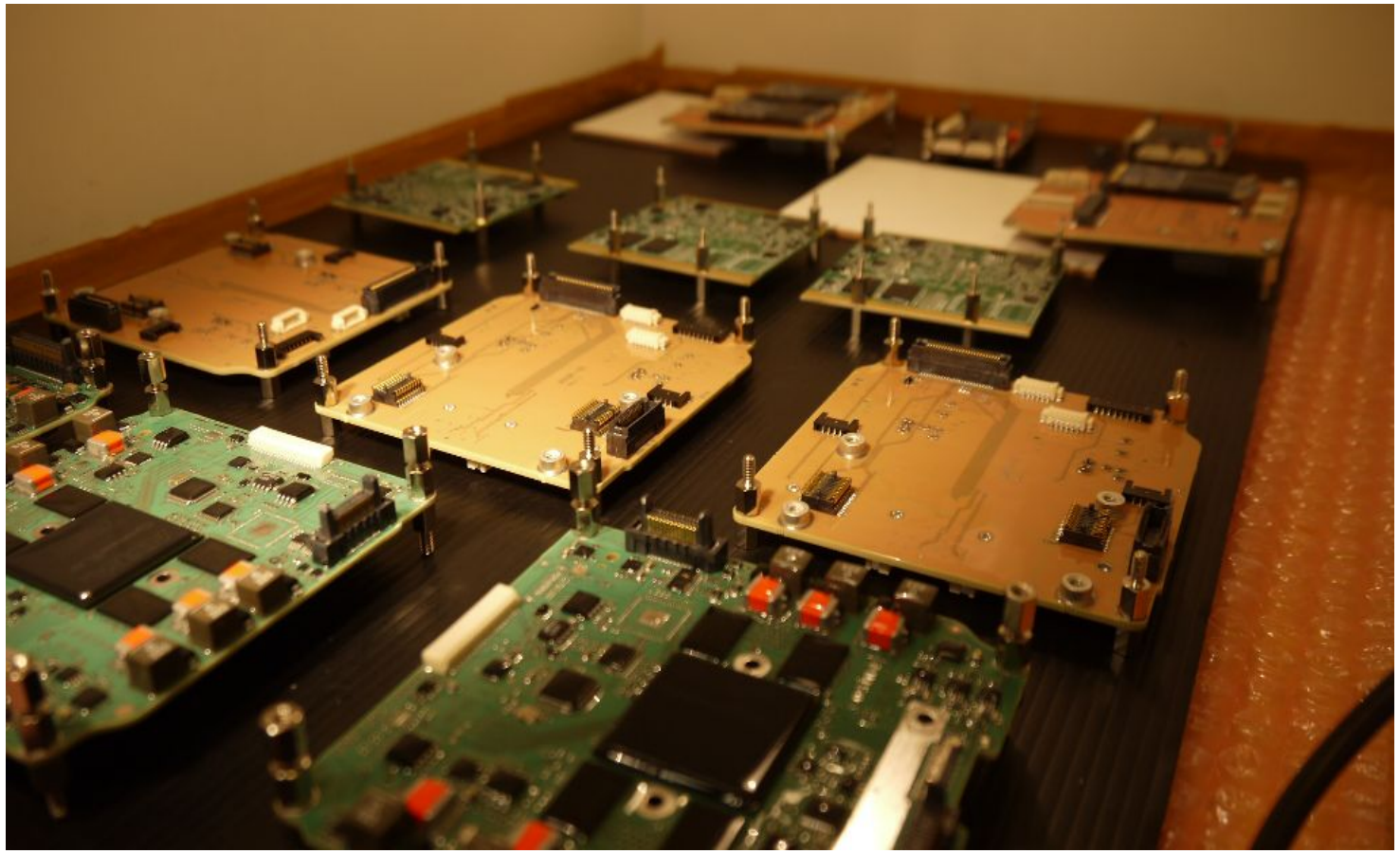
# Technology building blocks

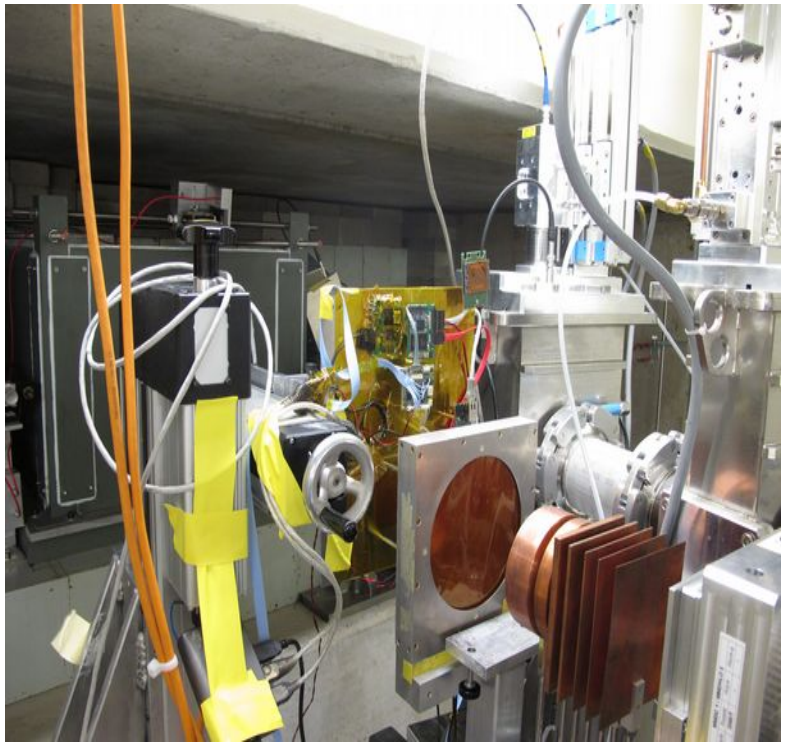
# Generalized electronics



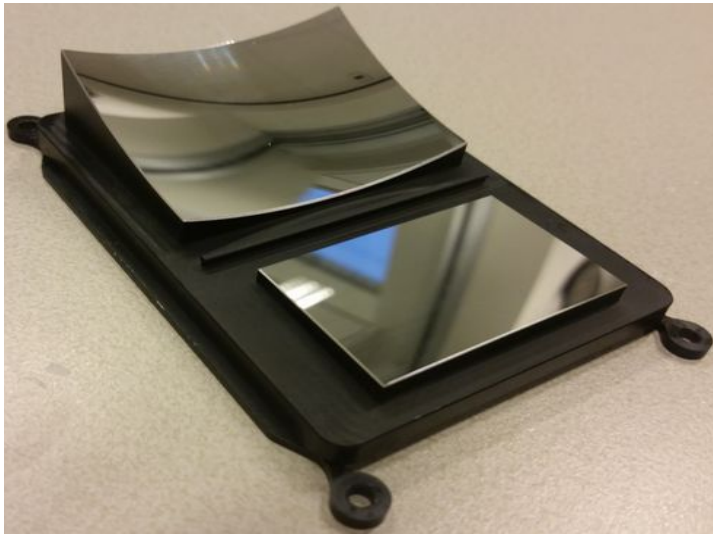
- Developed for handling multiple camera heads
  - Multiple spectral channels
- ECSS tailored for commercial EO applications
- Hibrid approach FPGA, CPU GPU for high processing power and reliable control
- Hot and cold swappable high capacity memories

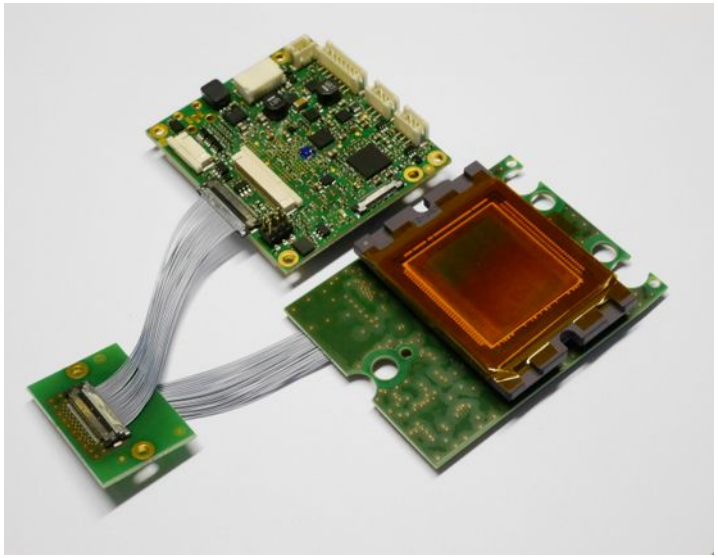
# Electronics testing

- Developed at cosine and withstand incremental design and production iterations
- 3 proton irriadiation testing campaigns performed at PSI with two design iterations
- Electronics has been separately shocked and vibrated at qualification levels



# Reflective telescopes, sensors and filtering

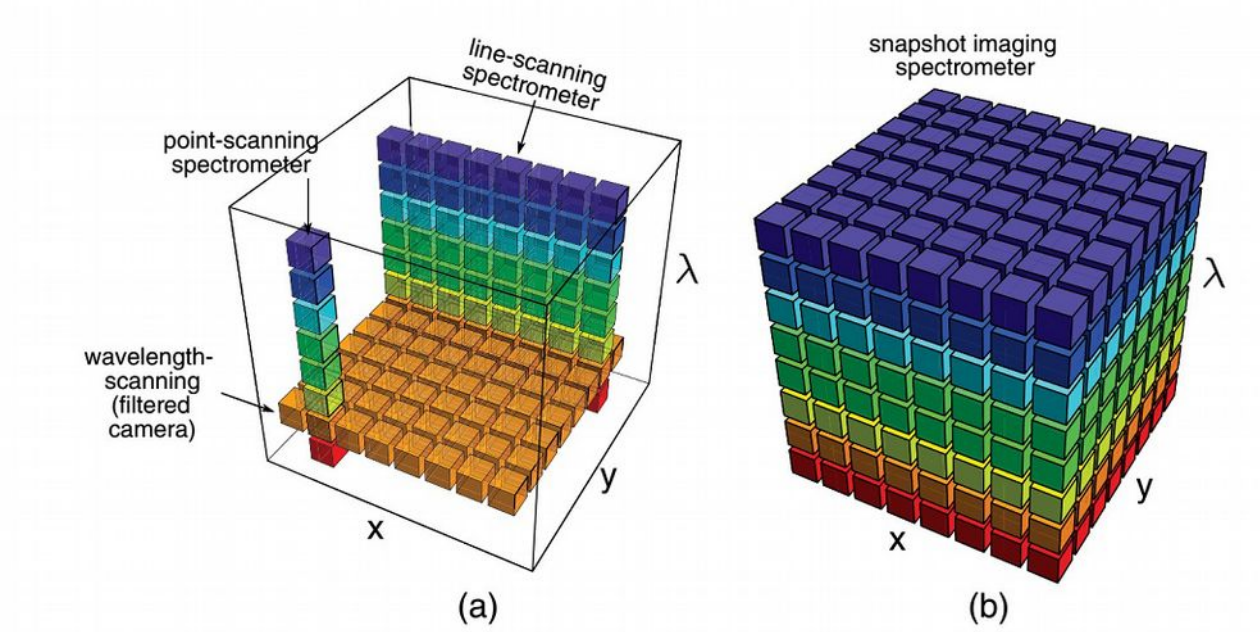




- Plug and play telescope
  - Enabling series production
- First off-axis 4 mirror system with very large field-of-view in both directions
- Rugged system
- Large 12MPx focal plane array
- Flexible front end for different spectral channels

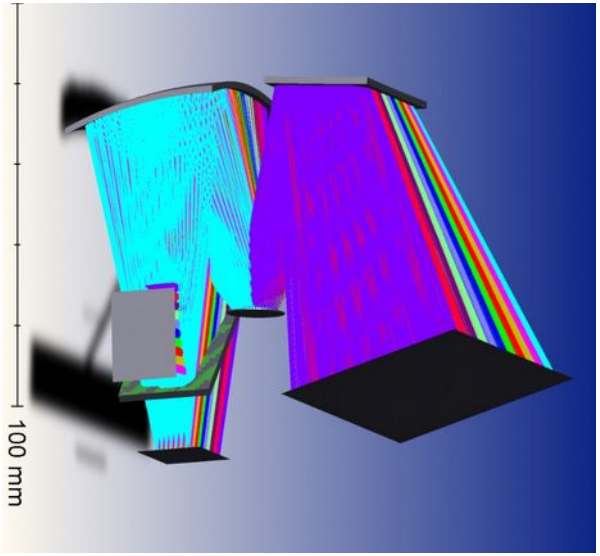
# Spectral Imaging methods

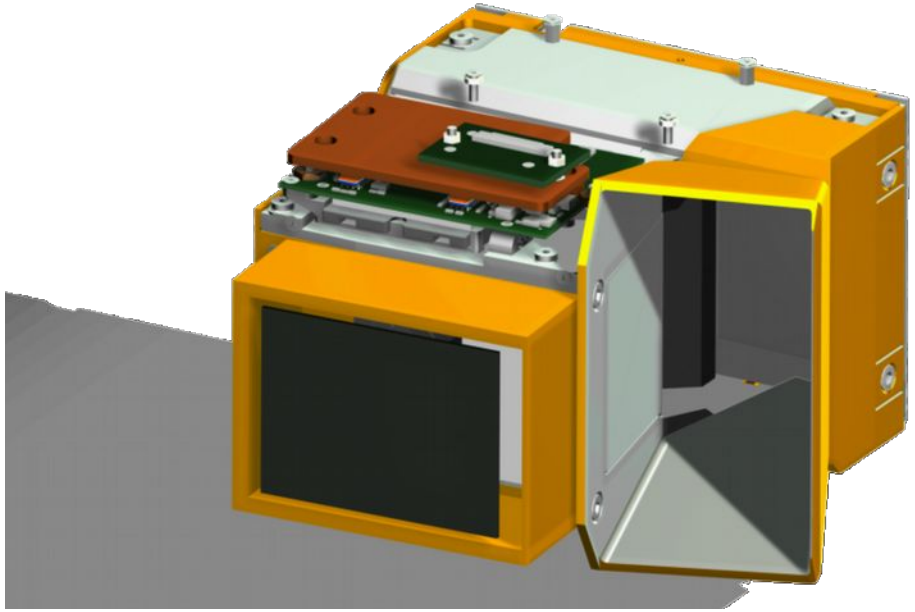
- Image two spatial and one spectral dimension with a 2D focal plane array
  - Point-scanning spectrometer (whiskbroom sensor)
  - Line-scanning spectrometer (pushbroom sensor)
  - Wavelength-scanning spectrometer (staring sensor)
  - Snapshot imaging spectrometer



# Multi spectral channels

- Baseline
  - 50 bands in the VNIR
- Additional bands under development
  - UV
  - SWIR
  - TIR

# Panorama – large fields and broad spectral range

- 4 spectral imagers with 2 channels each
- Total of 8 channels spanning from 250 nm to 14 um
- Minimum mass of 6 Kg

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# Ongoing activities: HyperScout IOD

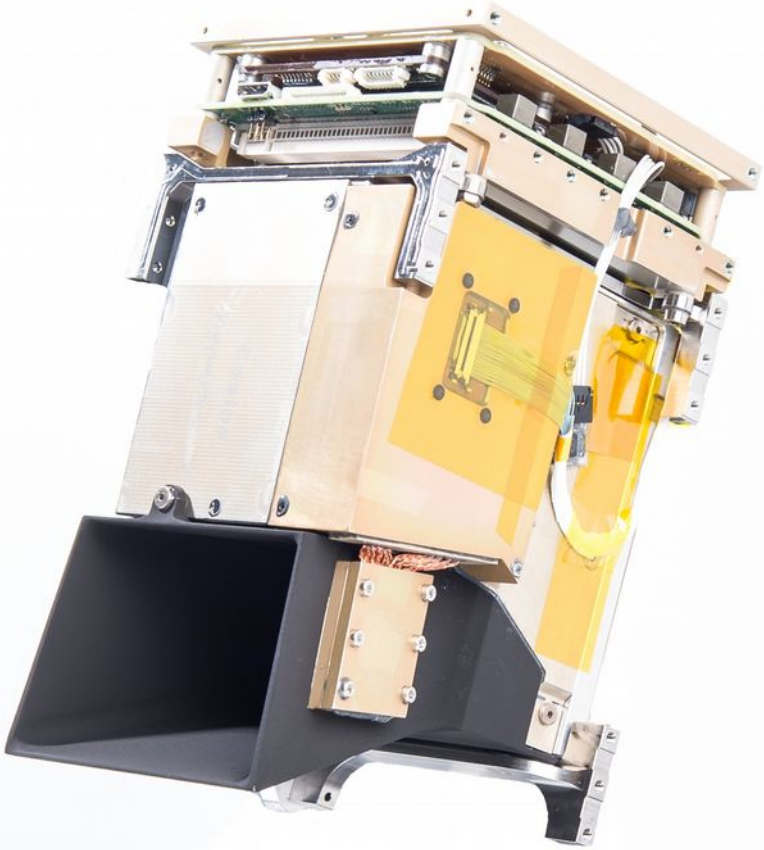
cosine | measurement systems

esa

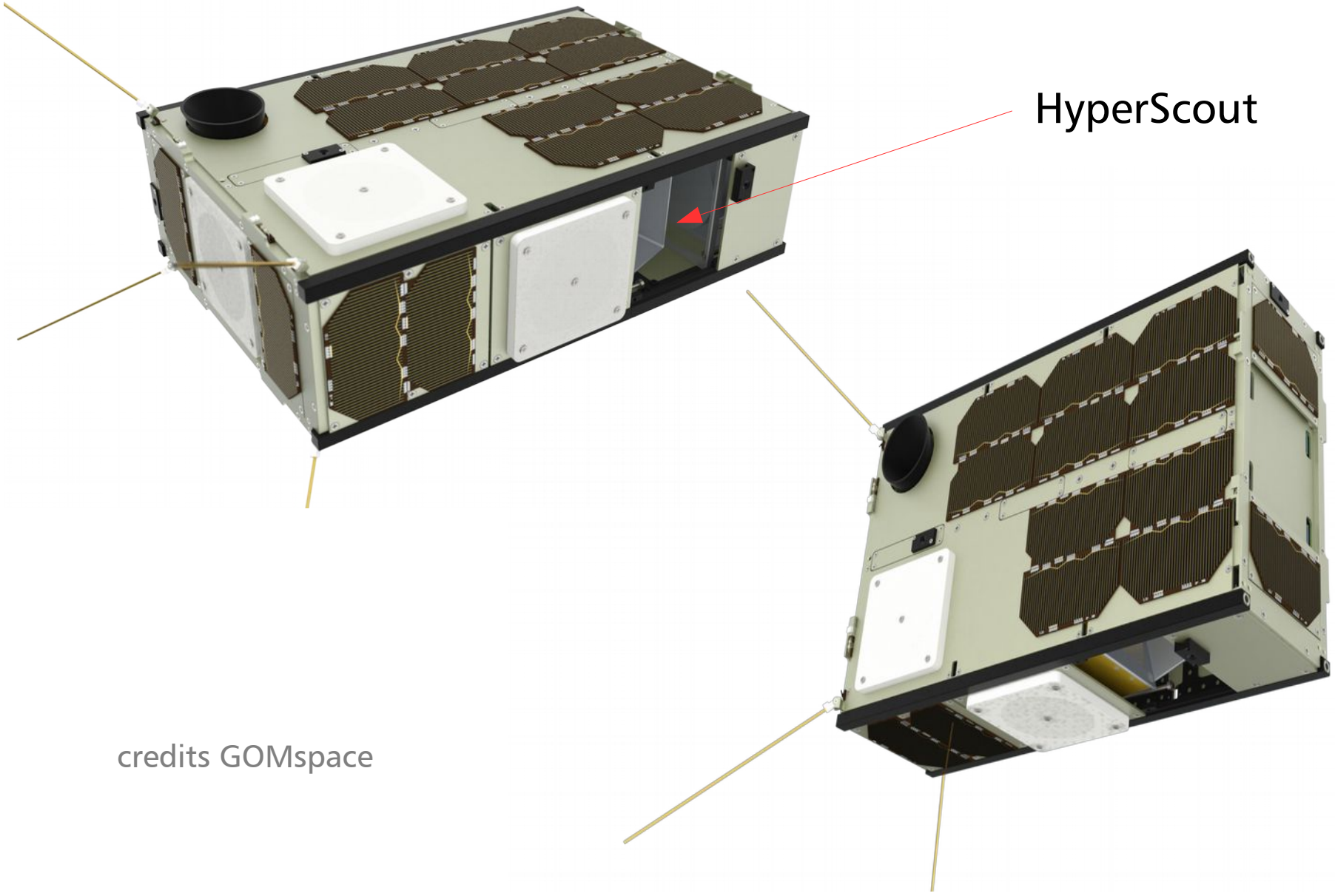
# HyperScout Flight Model delivered in March 2017

# HyperScout FM for GOMX-4B flight in February 2018

# HyperScout FM for GOMX-4B flight in February 2018

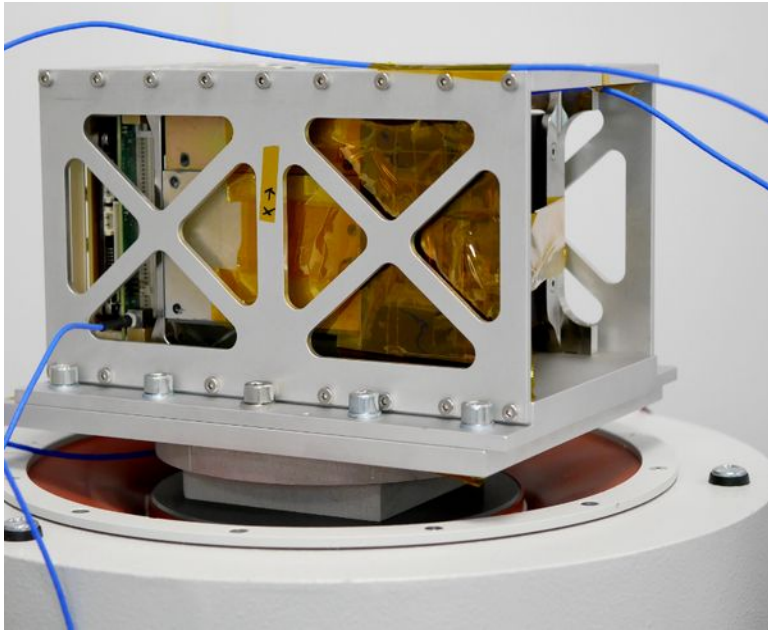


# HyperScout® maiden flight on GOMX-4B



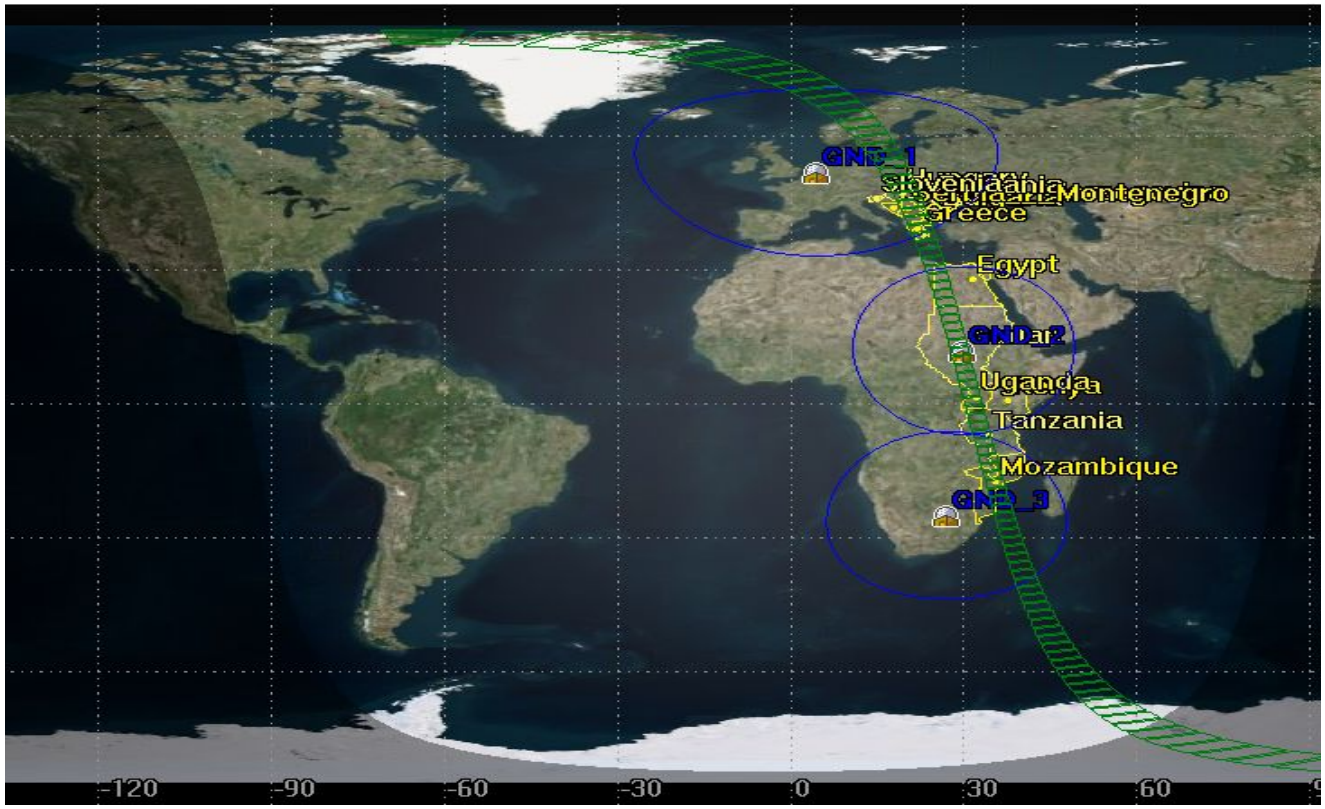

credits GOMspace

# HyperScout environmental campaign successfully passed



- Pre-delivery environmental campaign executed at cosine
- Vibration testing on three axes
- TVAC chamber
- Optical check at different temperatures
- Further testing has been performed as part of the GOMX-4B satellite campaign

# One Earth Revolution - Multiple Applications




- Multiple applications
  - Mozambique (fire hazard, floods)
  - Tanzania (fire hazard, floods)
  - Uganda – Kenya (fire hazard, change detection)
  - Sudan (droughts)
  - Egypt (floods, droughts, crops, change detection)
  - Greece (fire hazard, change detection)
  - Balkan regions (floods, crops)

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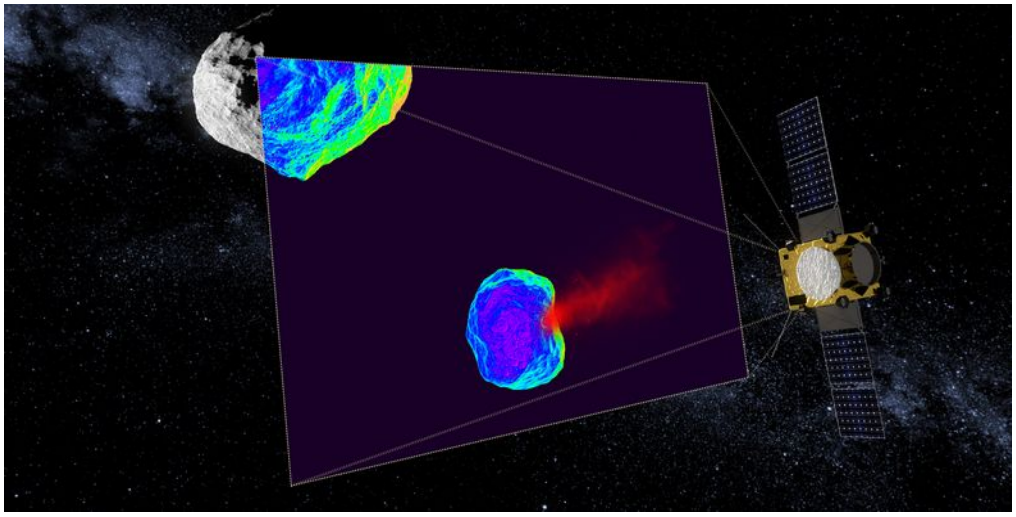
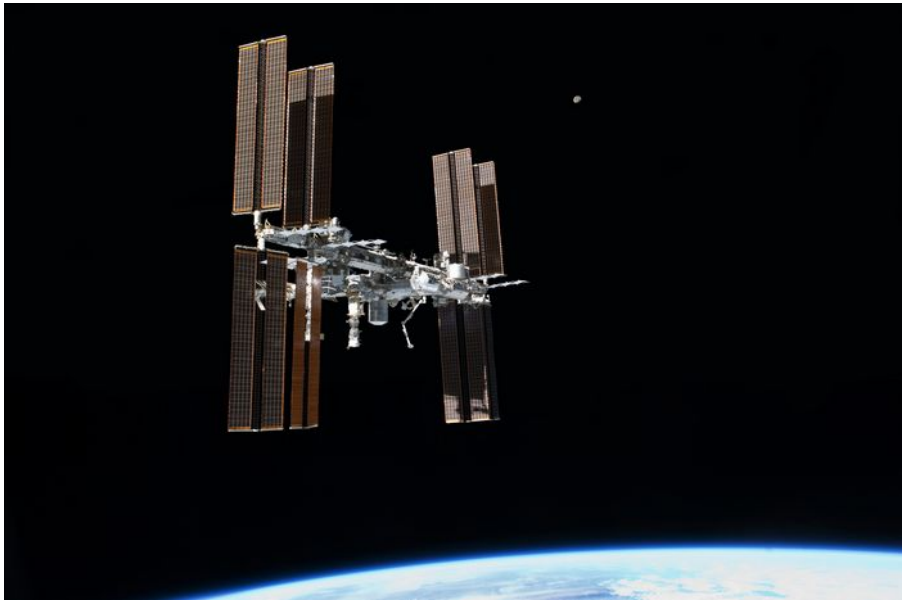
# Ongoing activities: Spetral imager IR channels BB

# Multispectral camera for multi-mission scenario

| Scenario | Test description |
|---|---|
| RDV Envisat | Different phases:<br>• From 900 m to 800 m<br>• From 500 m to 400 m<br>• From 300 m to 200 m<br>• From 100 m to 75 m<br>• Hold orbit at ~50 m<br>• Few meters from the target |
| RDV ISS | Hold point at ~280 m |
| D&L | From 2 Km to landing |





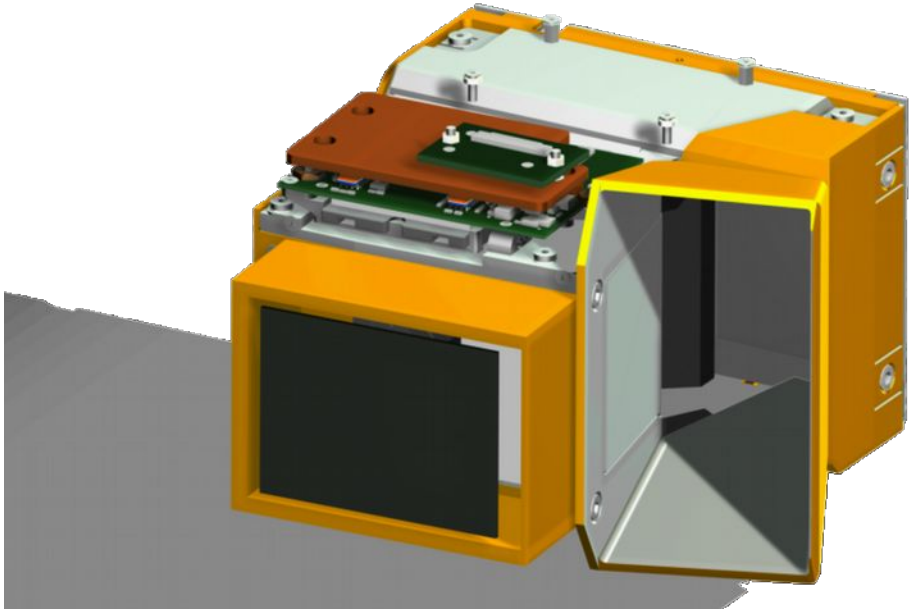
# Thermal Infrared Imager (TIRI) for AIM


- cosine developed the TIR imager (TIRI) for the AIM mission under ESA GSP project.
- TIRI is a dual purpose instrument:
  - Scientific instrument: characterization of the asteroid surface;
  - Navigation camera: aid to spacecraft navigation.
- Line spectrometer
  - 5 K temperature retrieval accuracy for LST higher than 100 K.
  - >5 spectral bands
- NavIR™: navigation camera
  - 2D field of view
  - foV comparable to the VIS camera

# NavIR™

## NavIR™

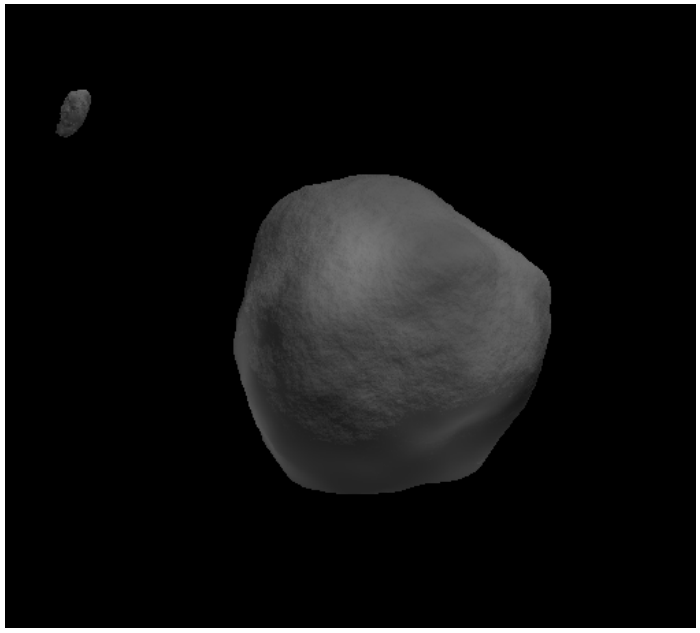
- HyperScout® tailored for navigation in the Thermal InfraRed;
- Developed under an ESA GSTP contract for VNIR operation;
- Fully reflective architecture.

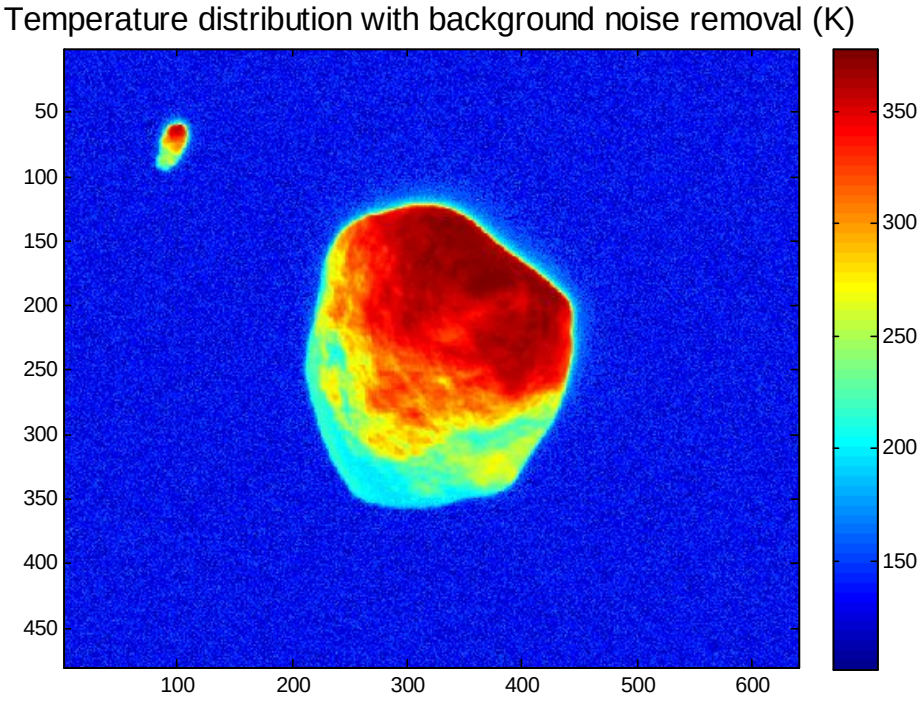


| Parameter | Value |
|---|---|
| Instantaneous field of view [mrad] | 0.41 |
| Field of view [deg] | 15 x 11.3 |
| Maximum radial field of view [deg] | 9.36 |
| Focal length [mm] | 41.25 mm |
| Aperture diameter [mm] | 10 mm |
| F-number | 4 |
| Hyperfocal length [m] | 5.45 at 8 µm<br>3.11 at 14 µm |
| Sensor size [px²] | 640 x 480 |
| Pixel size [µm²] | 17 x 17 |
| Ground Sampling Distance [m] | 16.4 at 40 km<br>4.1 at 10 km<br>0.82 at 2 km |
| Spectral range [µm] | 8 - 14 |
| Spectral resolution [µm] | 6 |

# NavIR™ imagery simulation

- Images of Didymos, as acquired by NavIR™, have been simulated.
  - Spatial variations of emissivity have been simulated.
  - Different surface thermal inertia levels have been simulated, accounting for different surface rocks configurations
  - Realistic surface temperature distributions have been obtained.
  - Synthetic images have been used as input for navigation simulations.





# NavIR™ navigation performance

- The S/C relative state with respect to the asteroid is determined using NavIR™ observations of the target body.

- Two image processing algorithms are used:
  - Centre of brightness detection (during approach and long distance observation)
  - Unknown landmark tracking (during detailed characterisation (~ 10 km distance) and asteroid descent.

- Performance are comparable with those of a VIS camera, irrespective of the surface thermodynamical properties (emissivity – thermal inertia)
  - In the table, performance figures for the landmark tracking algorithm, used during detailed characterisation phase.

| Thermal inertia level | Position error [m] | Position error st. dev [m] | Velocity error [cm/s] | Velocity error st. dev. [cm/s] |
|---|---|---|---|---|
| Zero | 32.1 | 31.9 | 1.4 | 2.2 |
| Low | 35.3 | 46.0 | 0.4 | 2.9 |
| High | 33.1 | 41.6 | 0.1 | 2.9 |

# Additional channels

- Project started to add TIR channel to the HyperScout telescope
- SWIR already tested in the lab, first picture of cosine parking lot below
- UV channel under development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