Spectral imagers for relative navigation, on-orbit servicing and debris removal

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Clean Space Industrial Days
ESA ESTEC
24 Oct 2018

Agenda

- Brief company intro
- Development activities
- Validation activities

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Brief company intro

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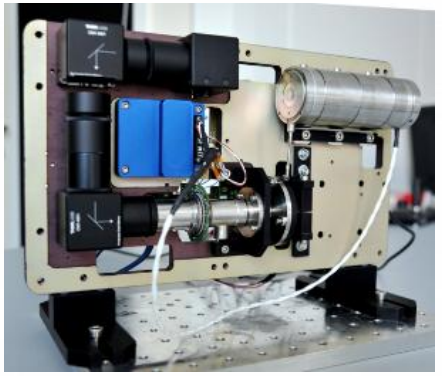
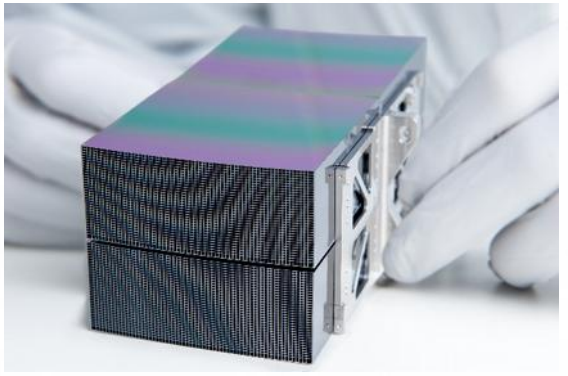
develops and builds measurement systems

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

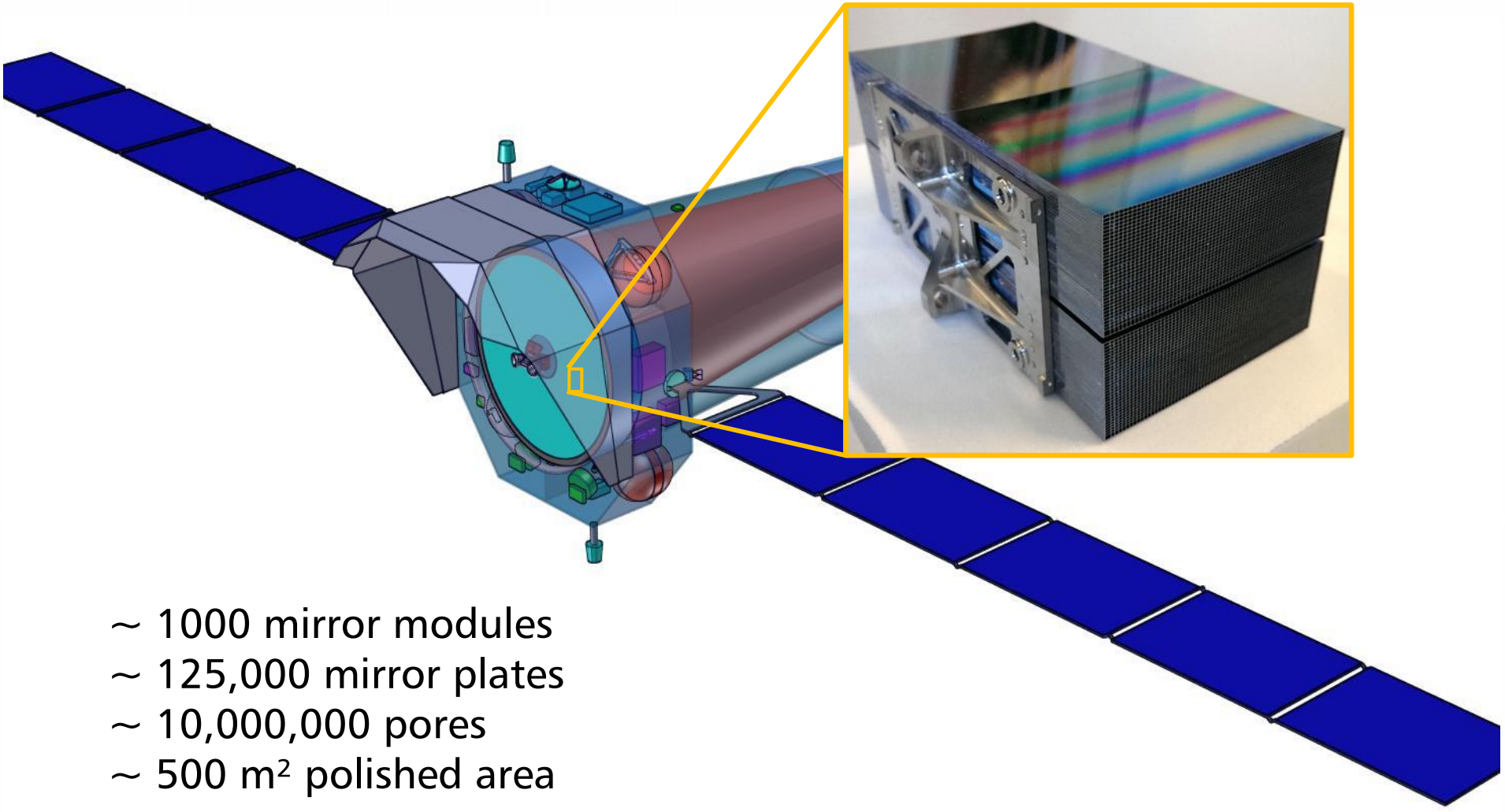


Remote sensing systems
Space and air-borne
spectral cameras
for
Agriculture, Environment
and Disaster Management



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

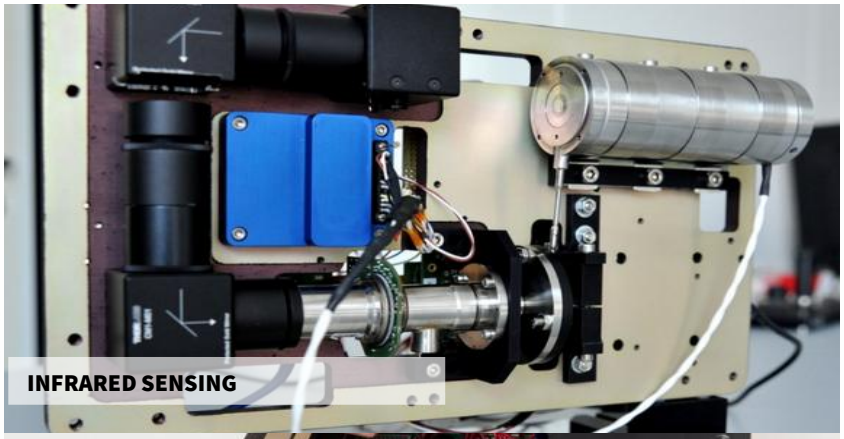
Athena Silicon Pore Optics Mirror Modules

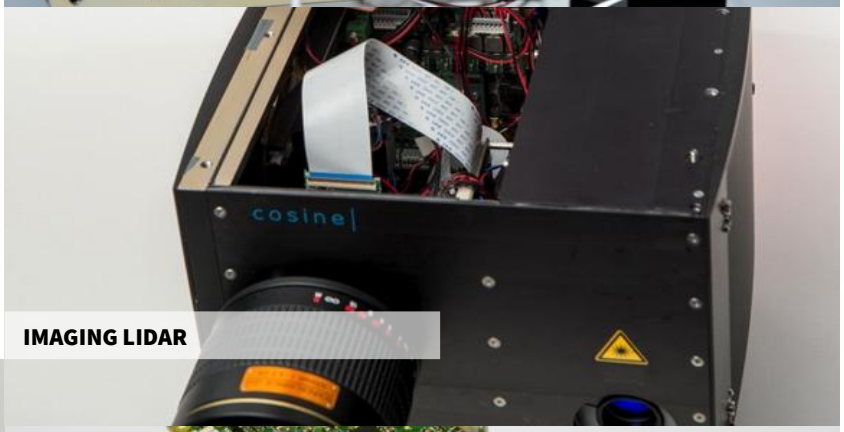


~ 1000 mirror modules
~ 125,000 mirror plates
~ 10,000,000 pores
~ 500 m^2 polished area

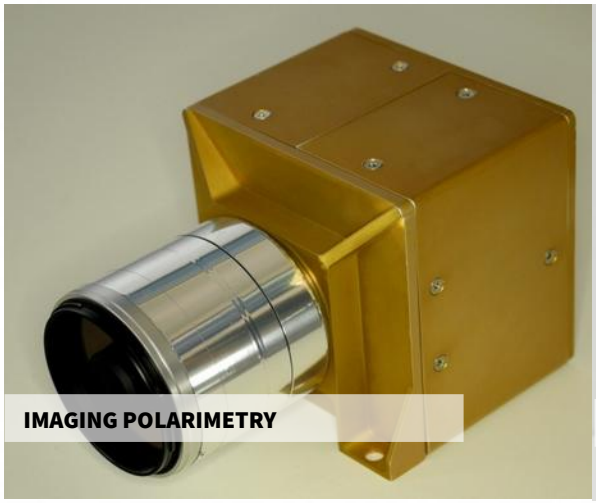
Technology Lines for small instruments

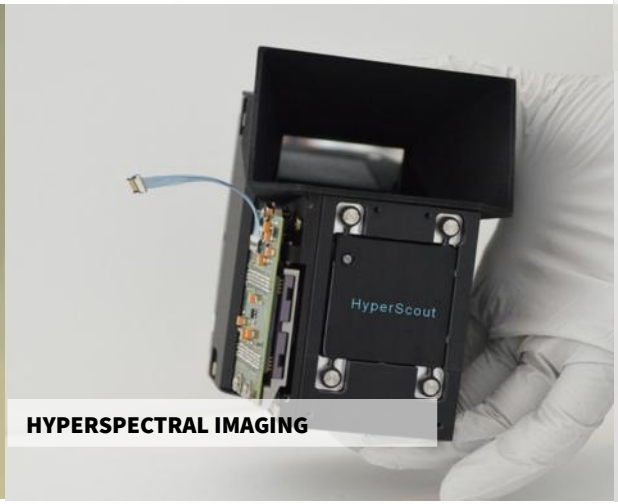
- Five technology lines are leading developments at cosine
  - Hyperspectral imaging
  - Infrared sensing
  - Imaging lidar
  - Imaging spectroscopy
  - Imaging polarimetry
- These technologies are exploited in commercial *products* and commercial *service* missions


INFRARED SENSING



IMAGING LIDAR


IMAGING POLARIMETRY



HYPERSPECTRAL IMAGING


IMAGING SPECTROSCOPY

Heritage – Asteroid landing

- Delivered the Optical Proximity Sensors (OPS) for the GNC system of MASCOT, one of the landers onboard the JAXA Hayabusa-2
  - Contracted by DLR
  - Launched in December 2014
  - Landed on Ryugu asteorid on the 3rd of Oct 2018
- Commercially available for servicing missions

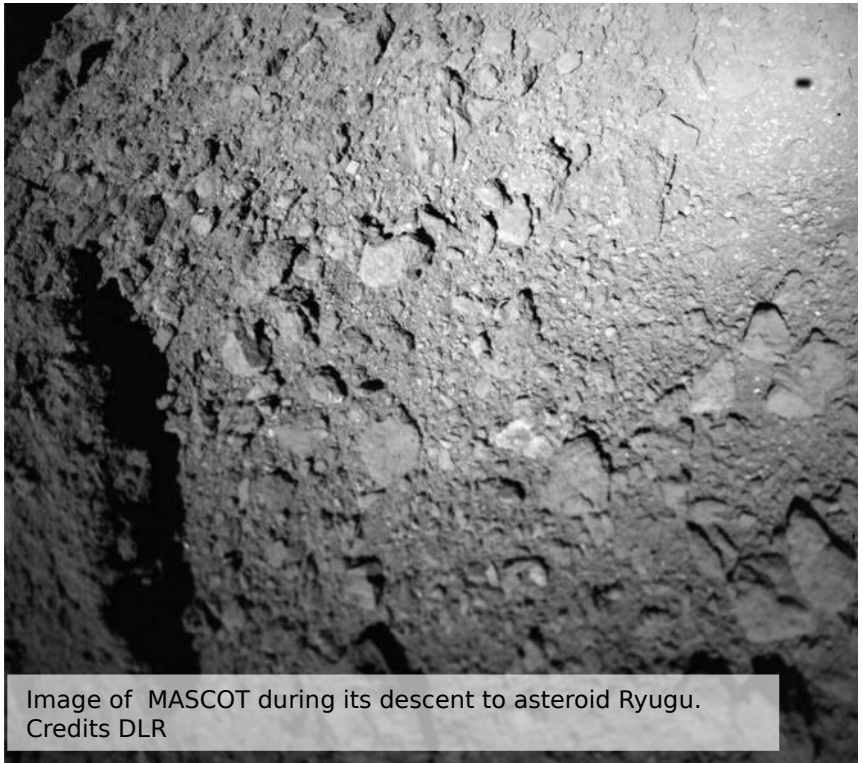
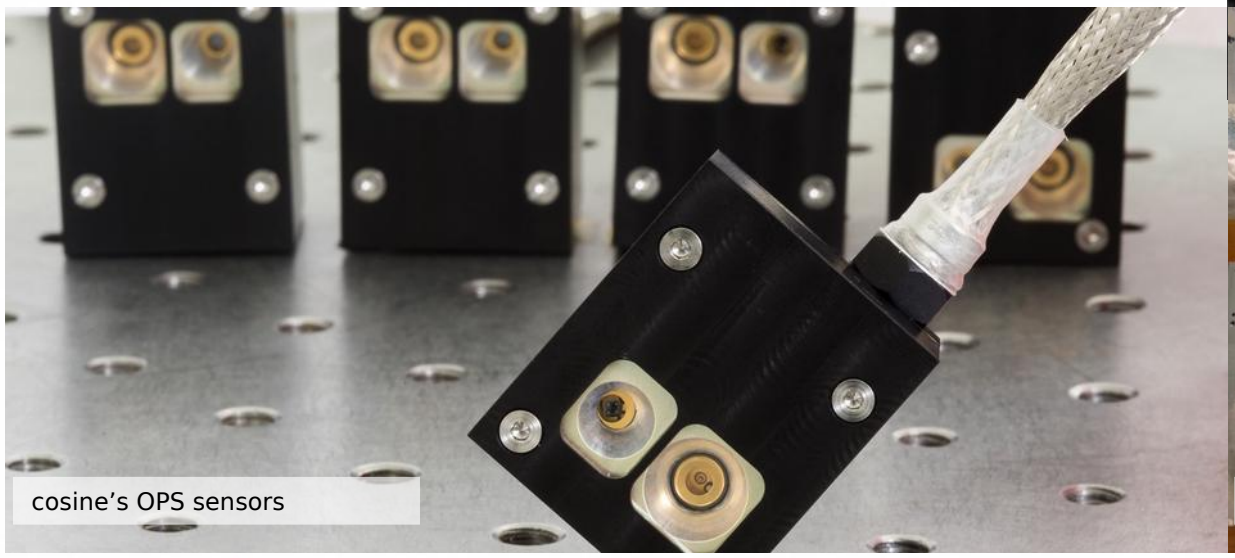
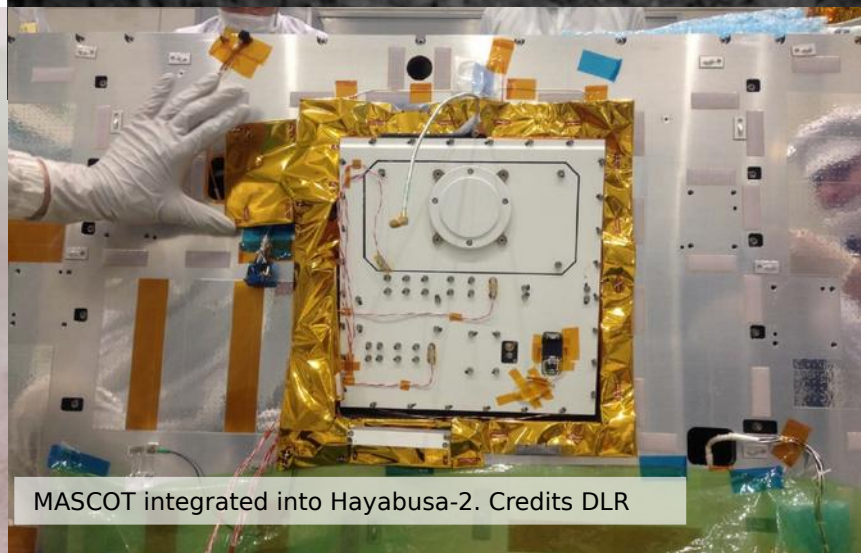


Image of MASCOT during its descent to asteroid Ryugu. Credits DLR



cosine's OPS sensors



MASCOT integrated into Hayabusa-2. Credits DLR

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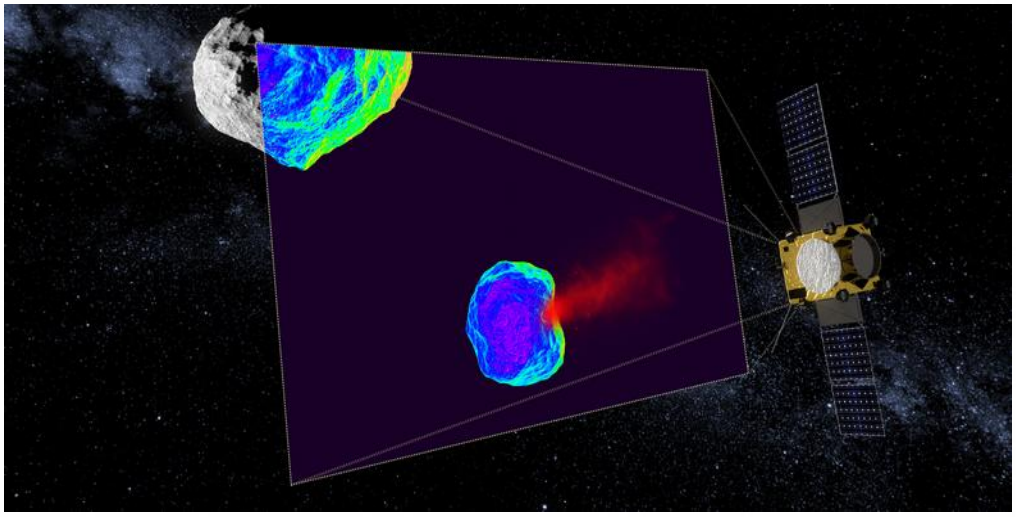
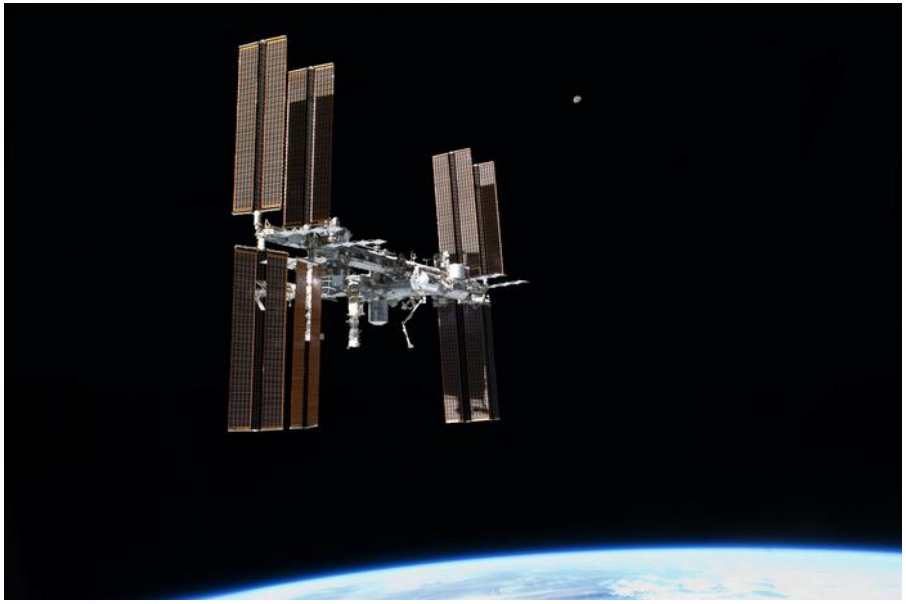
Design and developments for relative navigation

Multispectral camera for multi-mission scenario

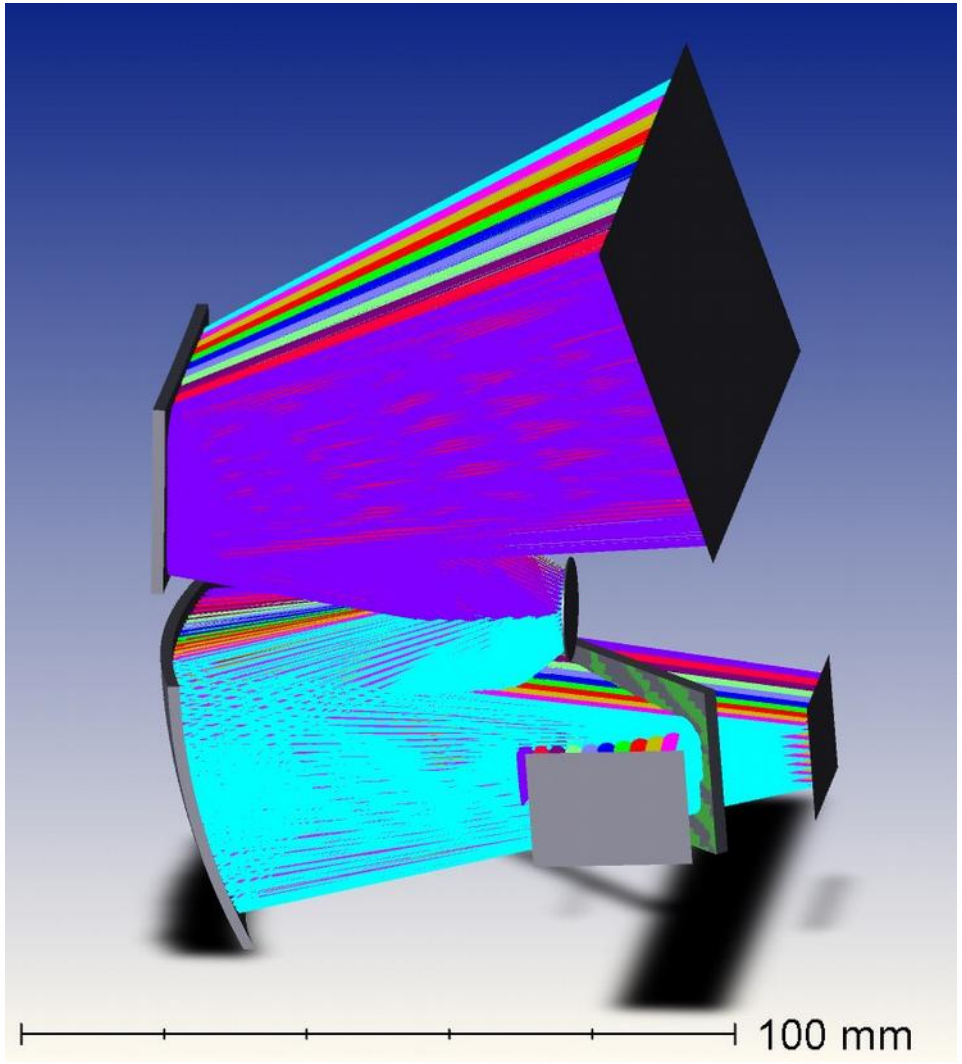
Scenario	Test description
RDV Envisat	Different phases: • From 900 m to 800 m • From 500 m to 400 m • From 300 m to 200 m • From 100 m to 75 m • Hold orbit at ~50 m • Few meters from the target
RDV ISS	Hold point at ~280 m
D&L	From 2 Km to landing





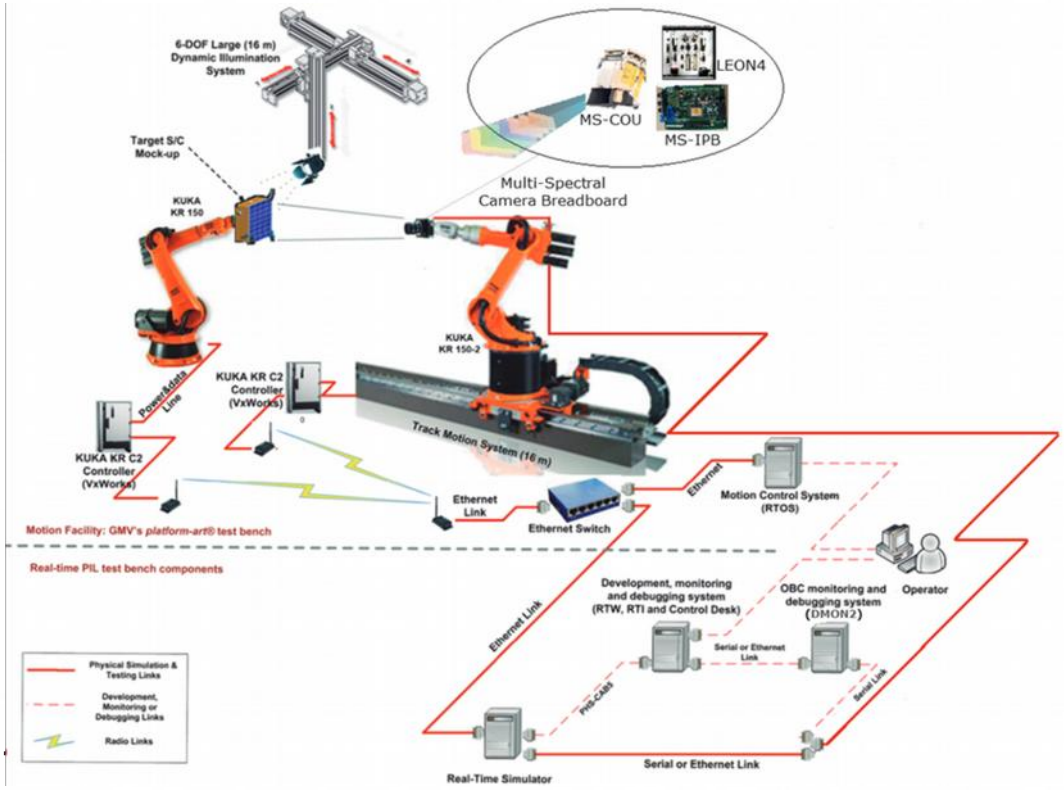
Dual channel HyperScout®

- A dual channel HyperScout® has been conceived
  - Large field of view, same for both channels
    - Hyperspectral in VNIR
    - Multispectral or panchromatic in TIR
  - Dichroic beam splitter separates short and long wavelengths
  - Relay elements for TIR
  - Temperature stabilized Infrared detection



Proposed follow-up activities

- Developing the breadboard of the multi-spectral camera to provide reliable images under any illumination and environmental conditions. Including the processing board.
- The camera specifications are derived from the design of a GNC for rendezvous and docking (RVD) in Near Rectilinear Orbits (NRO).
- Focusing on autonomous navigation systems for rendezvous missions in Lagrangian orbits of Earth-Moon system with special emphasis on NRO.



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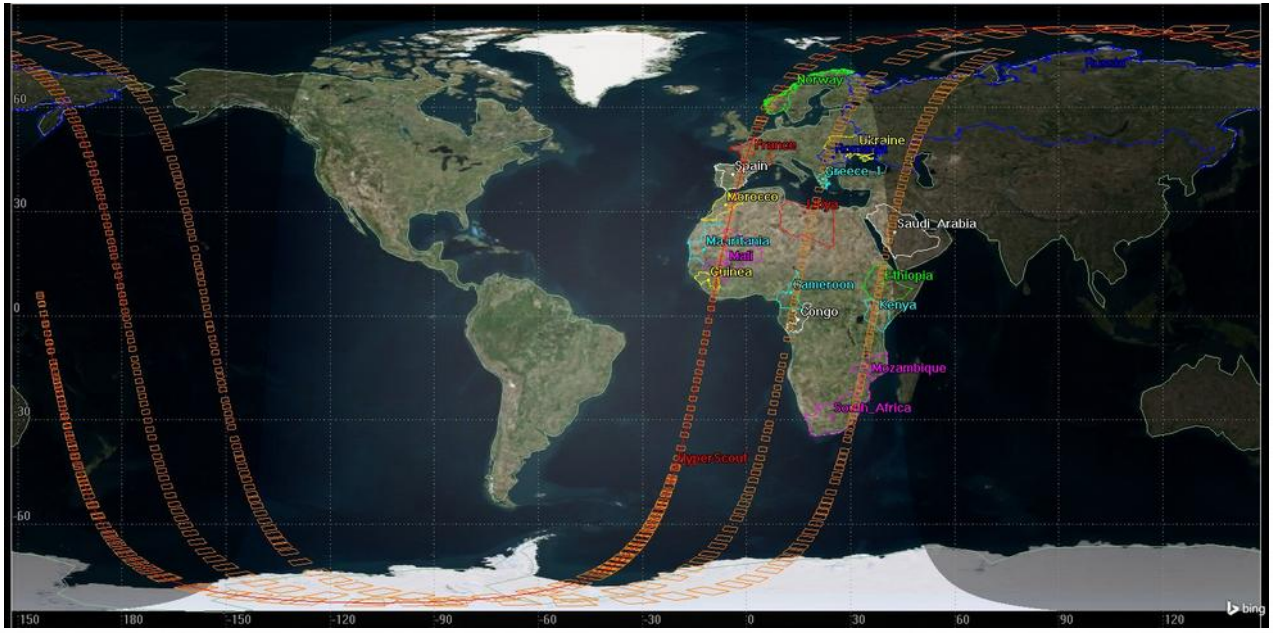
Validation activities: Hyperspectral VNIR in LEO

cosine | measurement systems

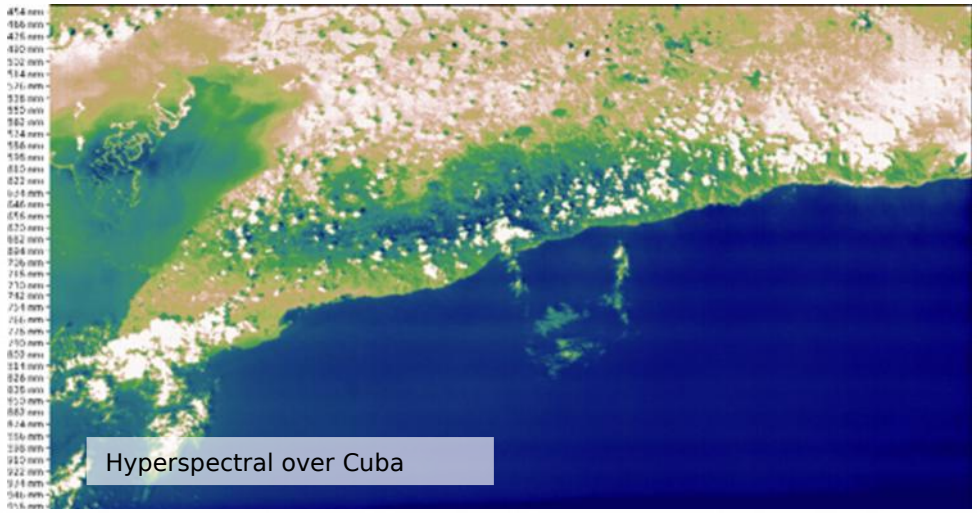
HyperScout-1 launched in Feb 2017

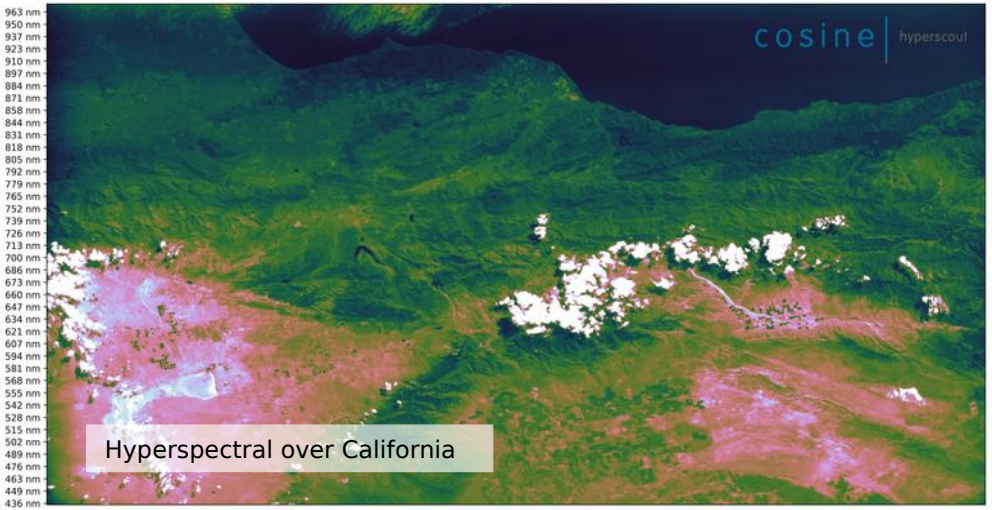
One Earth Revolution - Multiple Applications

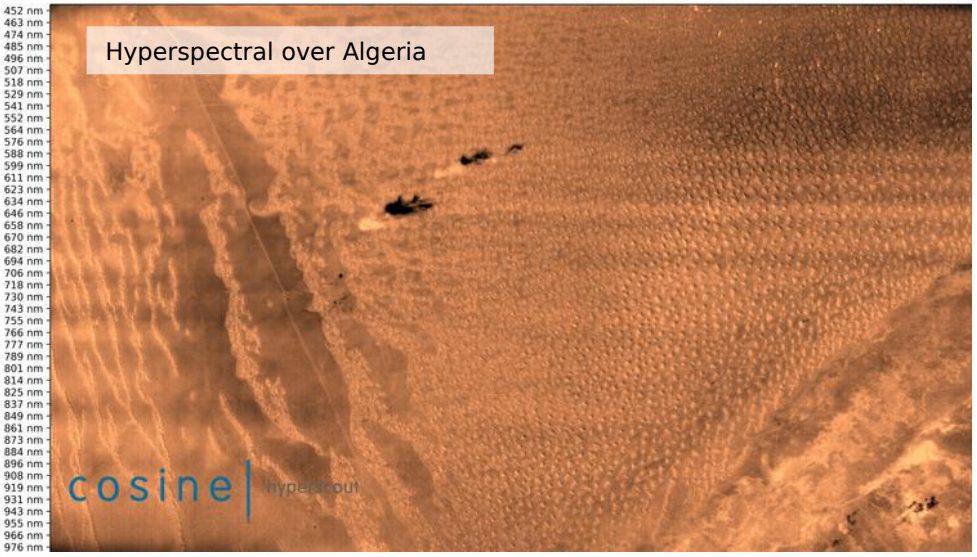
- Multiple applications
  - Mozambique (fire hazard, floods)
  - Tanzania (fire hazard, floods)
  - Uganda – Kenya (fire hazard, change detection)
  - Sudan (droughts)
  - Egypt (floods, droughts, crops, change detection)
  - Greece (fire hazard, change detection)
  - Balkan regions (floods, crops)

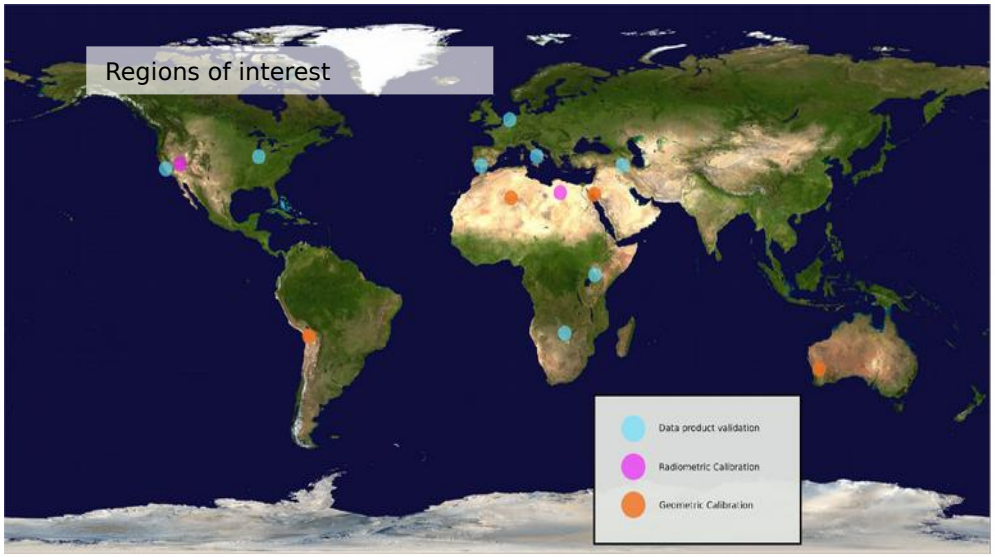


Hyperspectral over the globe









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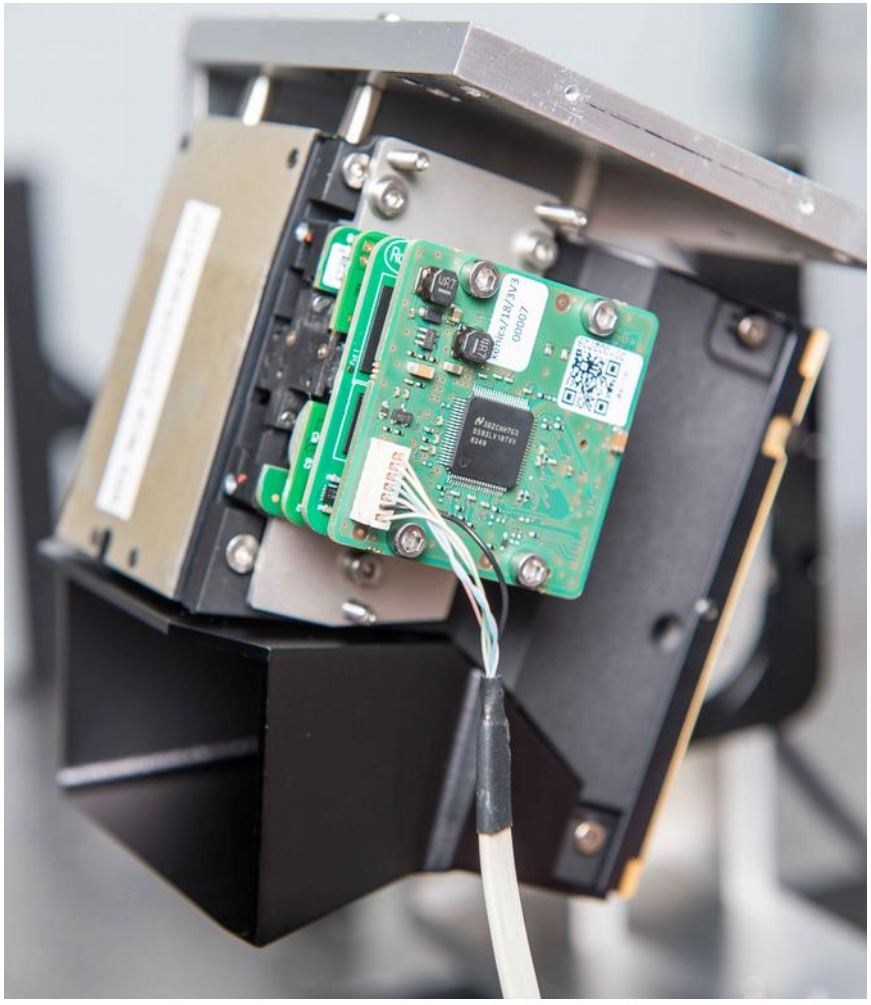
Validation activities: TIR in the lab

NavIR™: Thermal navigation camera to Didymos

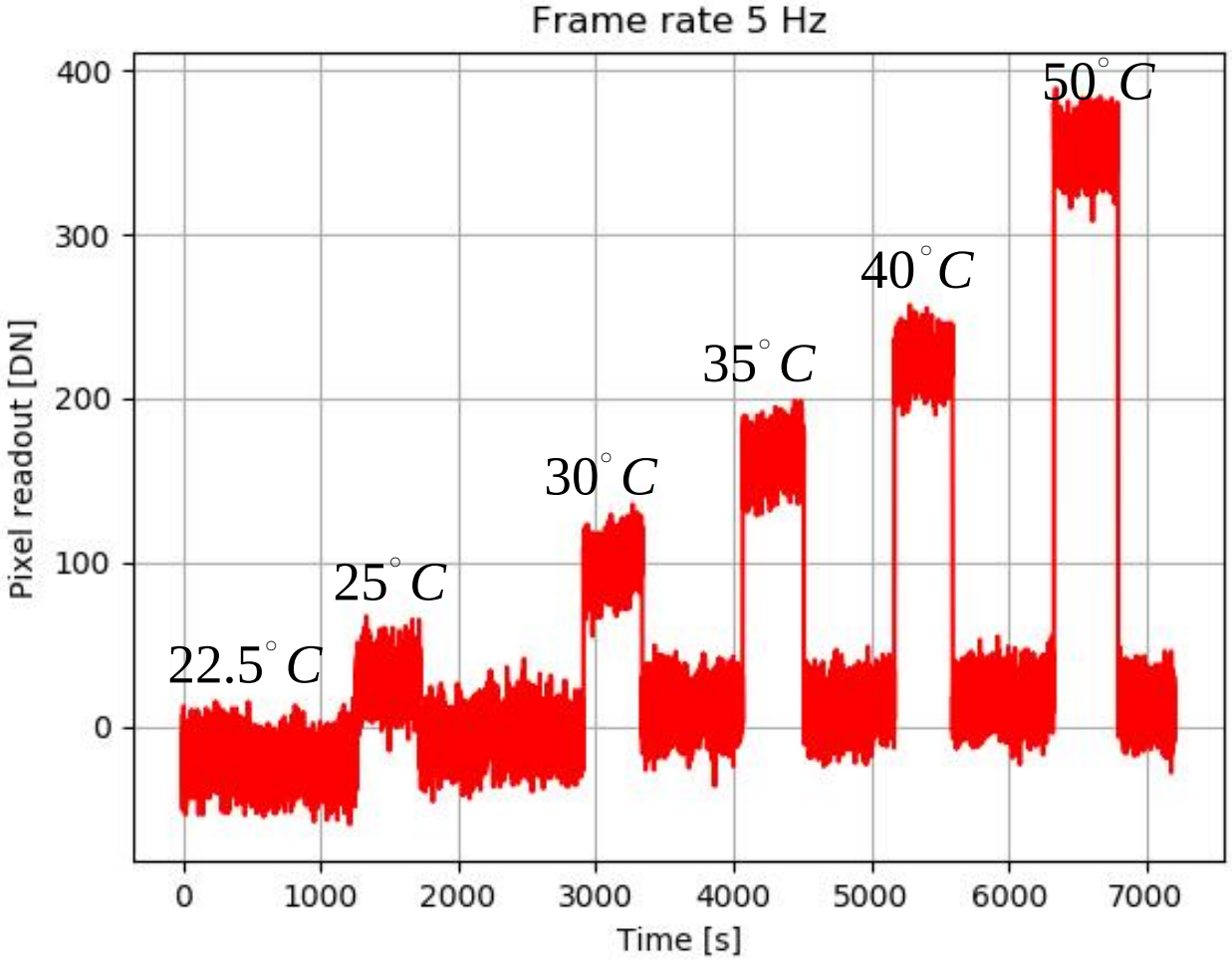
- NavIR™: TIRI thermal infrared navigation camera for navigation to Didymos
  - HyperScout® tailored for navigation in the Thermal InfraRed
  - Fully reflective architecture
  - Mass: ~1.1 kg
  - Volume: ~ 1.5 L

Parameter	Value
Field of view [deg]	15 x 11.3
Focal length [mm]	40
Aperture diameter [mm]	10
F-number	4
Sensor size [px^2]	640 x 480
Pixel size [μm]	17
Ground Sampling Distance [m]	16.4 at 40 km 4.1 at 10 km 0.82 at 2 km



NavIR™ instrument performance

- Diffraction limited optical performance
- Radiometric performance allowing TIR based navigation in deep space

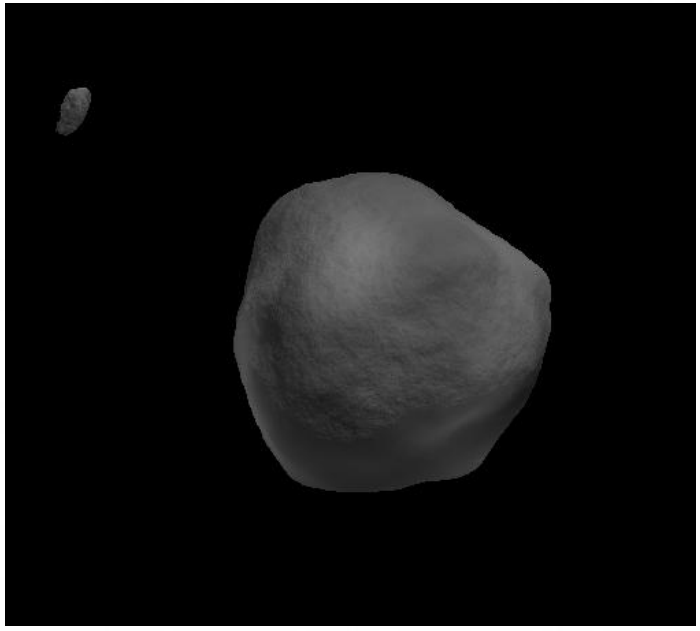


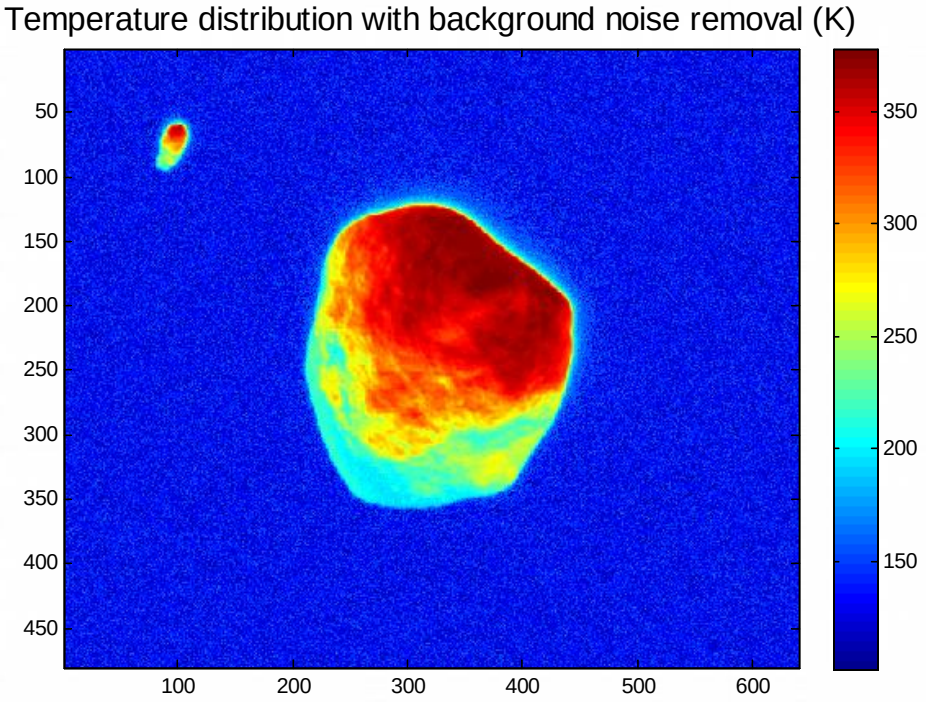
$$NETD = \frac{N_{rms}}{\frac{\Delta S}{\Delta T}}$$

- NETD ~1 K
  - Room temperature target
  - Room temperature instrument
- NETD ~9 K
  - Cryo-cooled target (150 K)
  - Room temperature instrument

NavIR™ as navigation camera

- 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.





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Validation activities: VNIR and TIR IOD in LEO

HyperScout-2: Dual Channel in-orbit in Q2/2019

- First ever **VNIR** hyperspectral and **TIR** multispectral in 1.5 liters
- Main application
  - High resolution soil moisture
- Flight in Q2/2019
- As part of the FSSCAT mission

	VNIR	TIR
Range [µm]	0.4 - 1	8.2 – 12.5
N of bands	45	4
FOV [deg]	31 x 16	31 x 16
GSD [m]	70	240
Pixels [-]	4096 x 2000	1024 x 768

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Validation activities: VNIR TIR and Stereo tested as part of I3DS

I3DS project

I3DS
INTEGRATED 3D SENSORS

- European Union Horizon 2020 funding

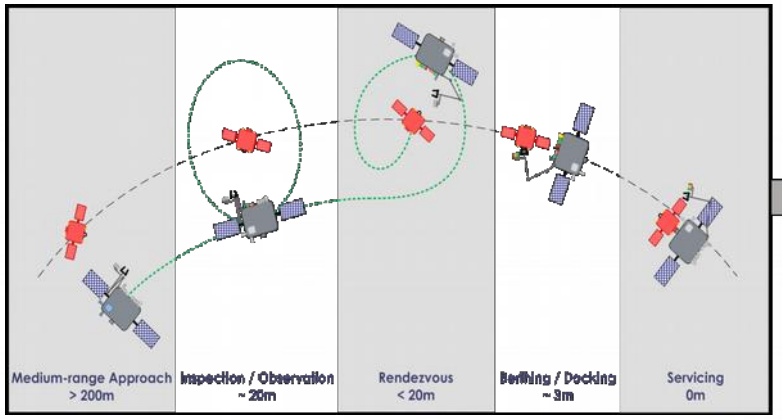
- Consortium members:

ThalesAlenia Space | cosine | SINTEF

Cranfield University | PIAP | HERTZ SYSTEMS | TERMA

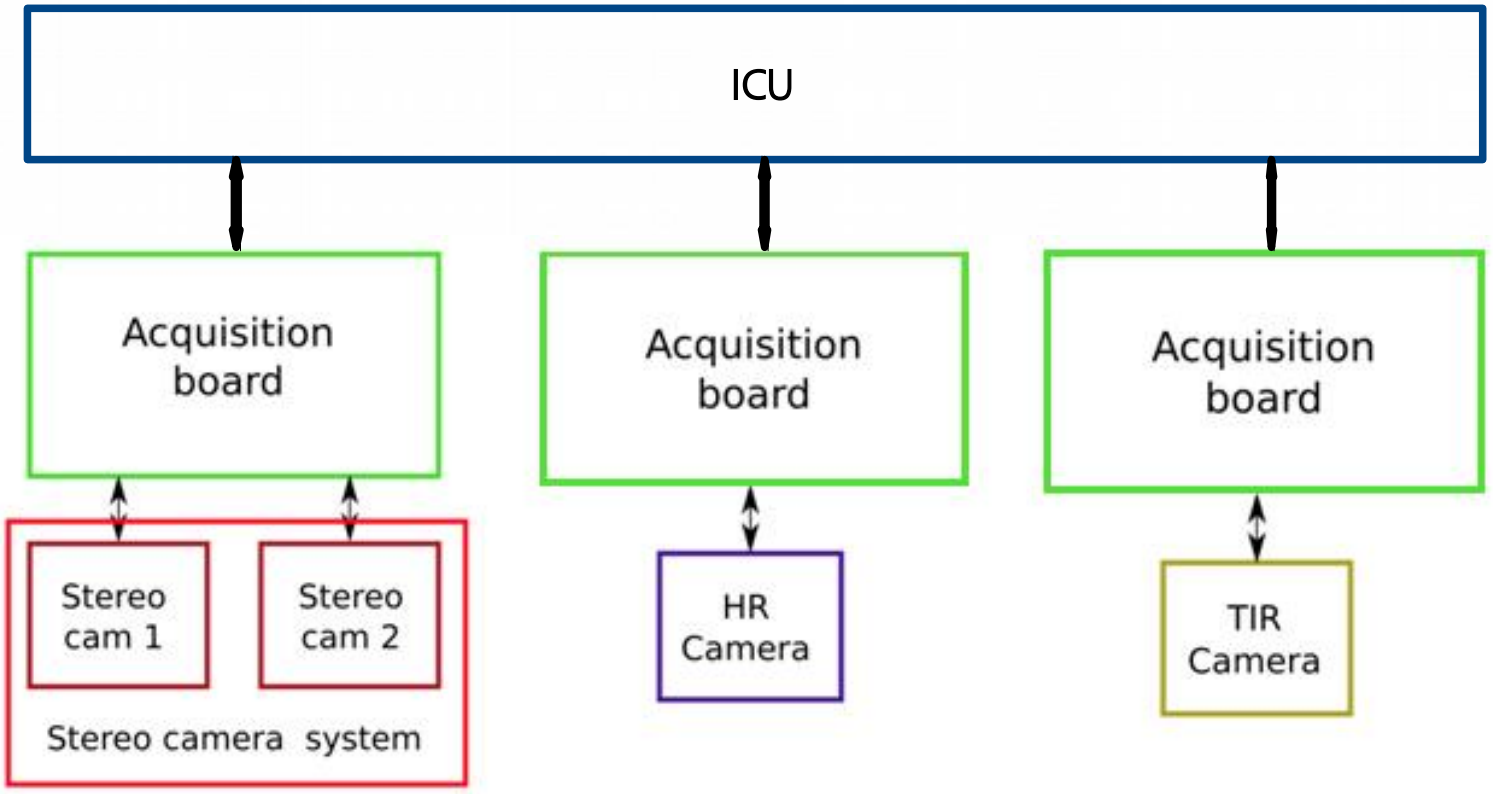
I3DS instrument and use cases

- Smart collection of building blocks that can be adapted as required by the application use case
- On-board processing to deliver a navigation solution from a fusion of multiple sensors
- Standardised interface to platform to shorten development time
- Baseline use cases:
  - Orbital rendezvous (cooperative and non-cooperative)
  - Planetary exploration on rover



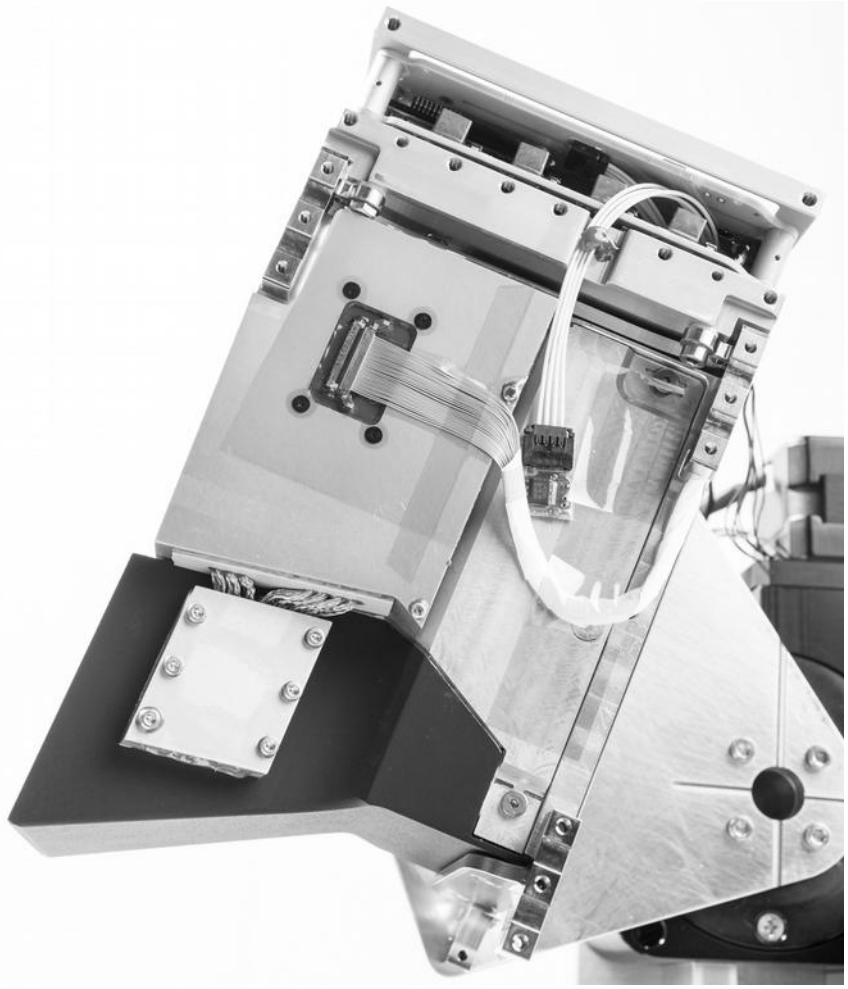
Payload architecture

- All payloads comminucate with ICU
  - Spacewire is baseline for full instrument, Ethernet used for current activity



Back-end electronics from HyperScout

- BEE EM from HyperScout
  - Modular design
  - FPGA based
  - CPU supported processing
  - Multiple interfaces
  - Route to space using HyperScout's EP-9S



www.hyperscout.nl

Camera system delivered for integration and testing

- High res camera
  - 21 mm fixed focus
  - 30 degree field of view
  - Pre-processing on ICU
    - Lens distortion
    - Vignetting
    - Histogram equalisation
  - Active illumination
    - Wide field illumination
    - Patterned projection
- Stereo camera
  - Same sensor as HR camera
  - ROI to reduce data volume
  - Adjustable intra-ocular distance and vergence
    - Baseline: 150 mm @ 2 m
  - Processing on ICU
    - Disparity map
    - Point cloud
- TIR camera
  - Uncooled microbolometer
  - 8 – 14 μm sensitivity
  - 640 x 480 px
  - 17 μm pitch
  - 75 mK NEDT

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