Multispectral Sensing for Relative Navigation

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e.Deorbit session
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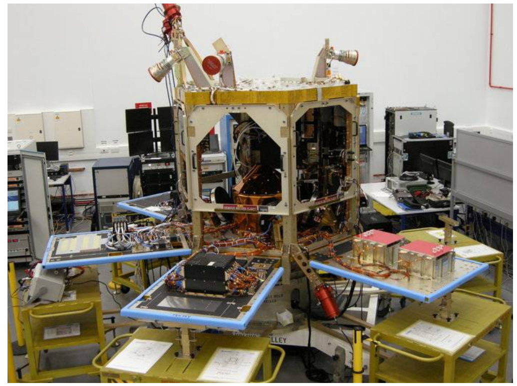
outline

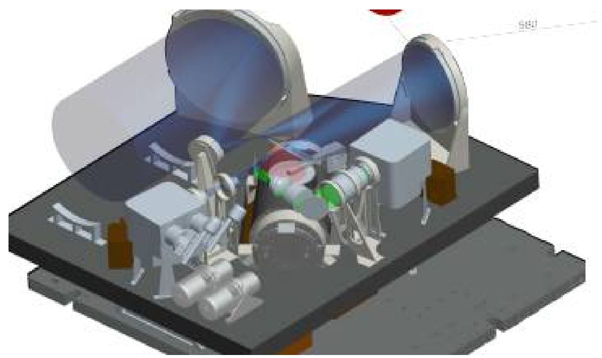
- Company introduction
- Multispectral Sensing for Relative Navigation project
  - Current status
- Conclusions

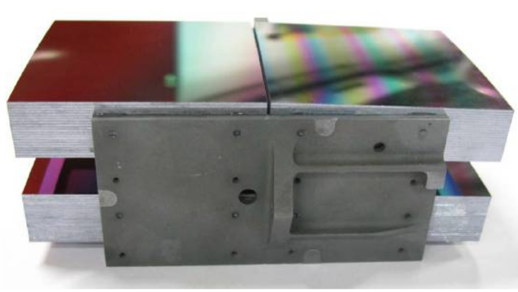
cosine measurement systems

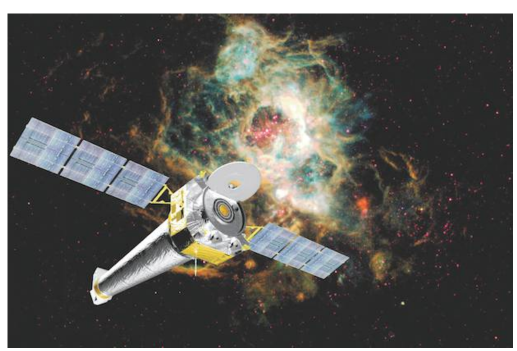
- Measurement systems
  - Remote sensing techniques
  - Space, aerospace, field and factory
  - Spectral imaging
  - White light, laser or environmental light
  - Multi-camera
  - Thermal infrared to gamma rays
- Applications
  - Astronomy, Earth observation
  - Airborne remote sensing
  - Agriculture, food & feed
  - Safety, security, surveillance, forensic
  - Oil, gas & energy
  - Machine vision
- Core team of 30 physicists and engineers
  - Analysis, lab study, design, procurement
  - Assembly, integration, verification, qualification
  - Calibration, data processing s/w
- Based in Leiden, The Netherlands
  - Italian subsidiary
- Development and test facilities
  - clean room, laser, radiation and electronics laboratories
  - calibration and thermal vac testing
  - extensive collaborations with external facilities
- Cluster of high-tech partners and suppliers
  - Institutes and universities
  - Small and large companies
  - Around the world
- Management
  - Prof. Dr Marco Beijersbergen
  - Dipl.-Ing. Max Collon

Contribution to Large satellite missions







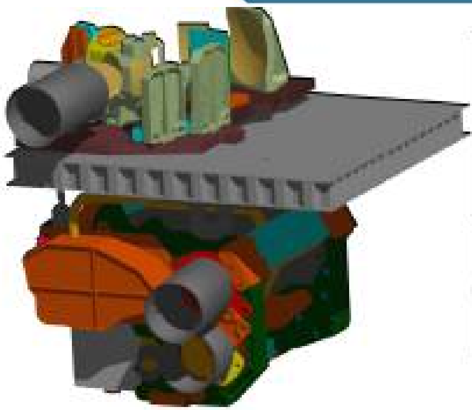


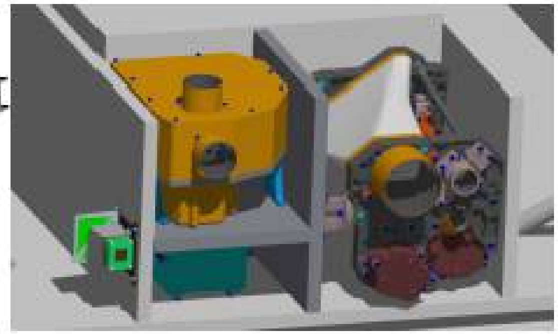
- XMM newton - computer models, level 0-1b processor
- TROPOMI - Requirement definition, Performance analysis. Level 0-1B processor, stray-light analysis.
- SPEX spectropolarimeter for EO - mission simulation, performance analysis, optical design, calibration
- Technology development for future lidar missions
- High-res Thermal Infrared for next generation EO missions.
- Athena - Silicon Pore Optics technology development

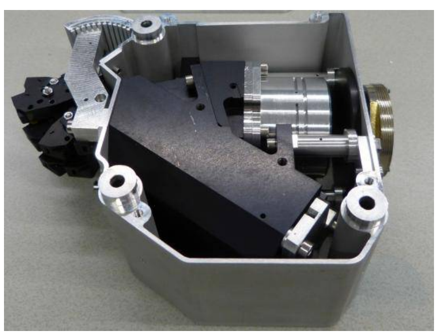
International Space Station payloads

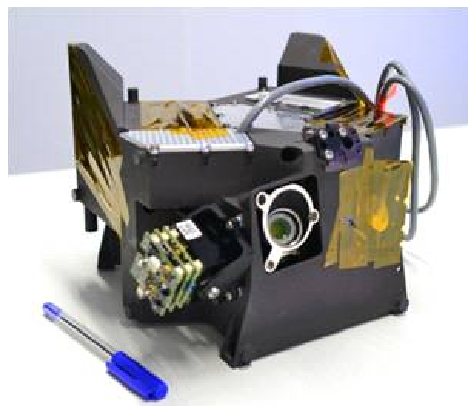
- ERB1: Stereoscopic camera launched on the ISS in July 2006.
- ERB2: Full HD stereoscopic camera launched on the ISS on the 3rd of February 2010.
- ERB2 User Home Base: Commanding, ERB-2 live 3D streaming from the ISS to ESTEC.
- NightPod: Nodding mechanism for nocturnal imaging of Earth from the ISS. Launched on the 21st of December 2011.

Interplanetary exploration designs and missions



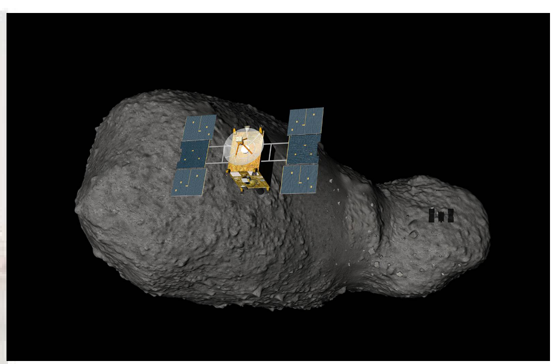


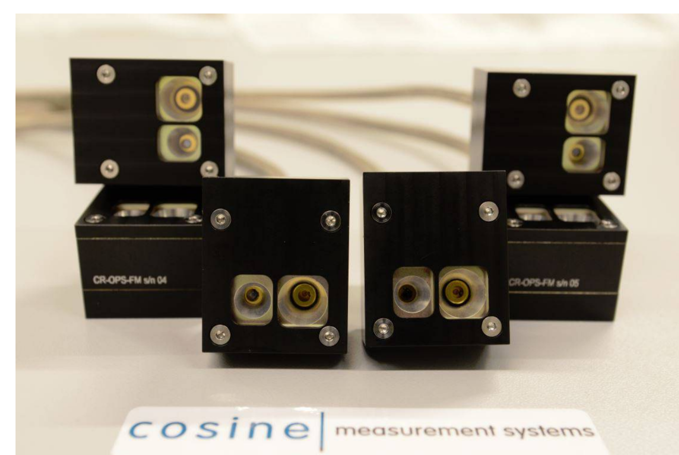




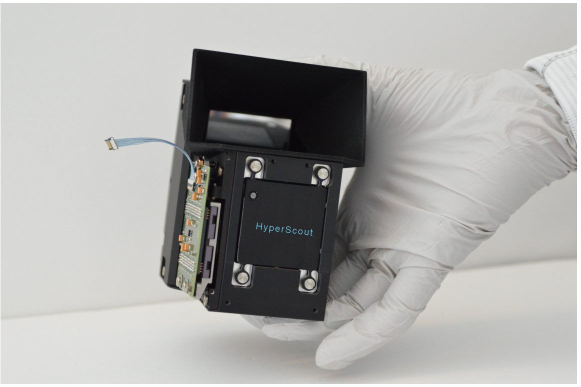
- Mercury and Jupiter suites (ESA Reference mission studies)
- SINPLEX compact multipurpose GNC system for planetary landing
- SPEX spectropolarimeter for space exploration
- Optical-GNC system for the MASCOT lander onboard the JAXA Hayabusa-2 (FM under production)

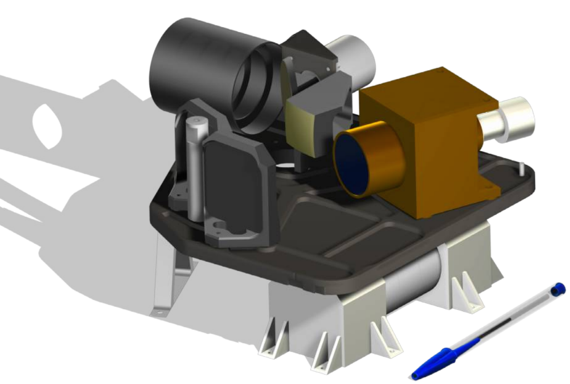
MASCOT STM-1, image copyright DLR





Smart Payloads for Multiscale Earth Inspection





- We are developing miniaturized remote sensing suites of commercial instruments for Earth inspection:
  - Frequent, medium resolution, global data from a fleet of microsats and nanosats
  - Complemented with on-demand high-resolution local data from UAVs
  - Complemented with on-demand local data from on-vehicle systems
  - Based on a common remote sensing technology
- Based on 5 technology lines
  - Hyperspectral, IR sensing, single photon lidars, polarimetry, spectroscopy
- Flight hardware for maiden space flight to be delivered Q4/2016

Introduction Multispectral for relative navigation

- Multi-spectral imaging can lead to significant improvements of space navigation systems.
  - ESA TRP project ongoing for the assessment in a bottom-up approach of the potential use of the combination of visible and infrared wavelengths for navigation.
  - Final goal is to provide an architecture and a preliminary design of a Multispectral Sensing Device (MSD).
- A more robust system can be obtained combining a VNIR spectral channel to a TIR spectral channel.
  - Navigation can be performed also if the Sun is in eclipse by detecting the thermal radiation.
  - Specific wavelengths dependent features can be identified by a finer sampling of the VNIR spectrum.
- Possible applications are:
  - Relative navigation between two cooperating space vehicles (Rendezvous)
  - Non-cooperative rendezvous (debris detection and removal)
  - Descent and landing on an asteroid

Project Consortium

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- Prime contractor
  - Multispectral Sensing Device (MSD) hardware design and modeling

gmv INNOVATING SOLUTIONS

- Subcontractor
  - Data generation, fusion, processing, navigation filters and MIL simulations.

Study logic

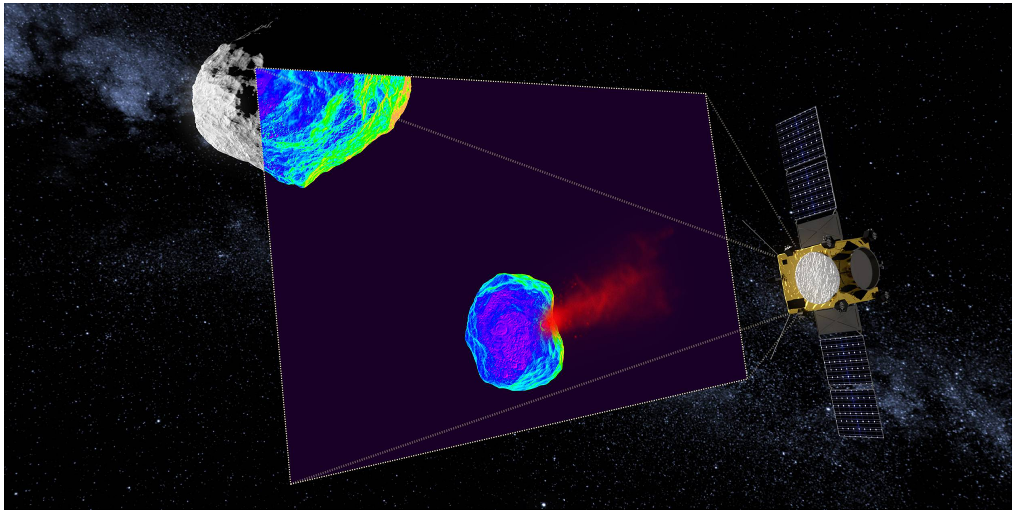

KO
Mission scenario review
SR
Technology and architectural review
AR
Test data generation
Simulation environment
Generate technical requirements
RR
MSD design and modeling
MIL simulation
Results analysis and preliminary budgets
DTR
Roadmap
AR and FP

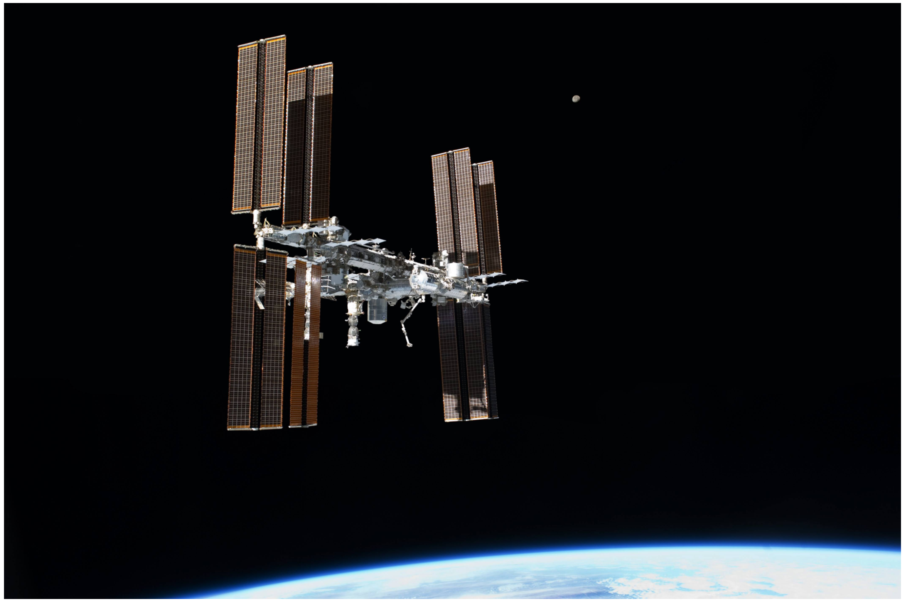
Algorithms subsystems and test environment

- Data fusion
  - At image level
  - At navigation level
- Different image fusion methods
- Navigation filter

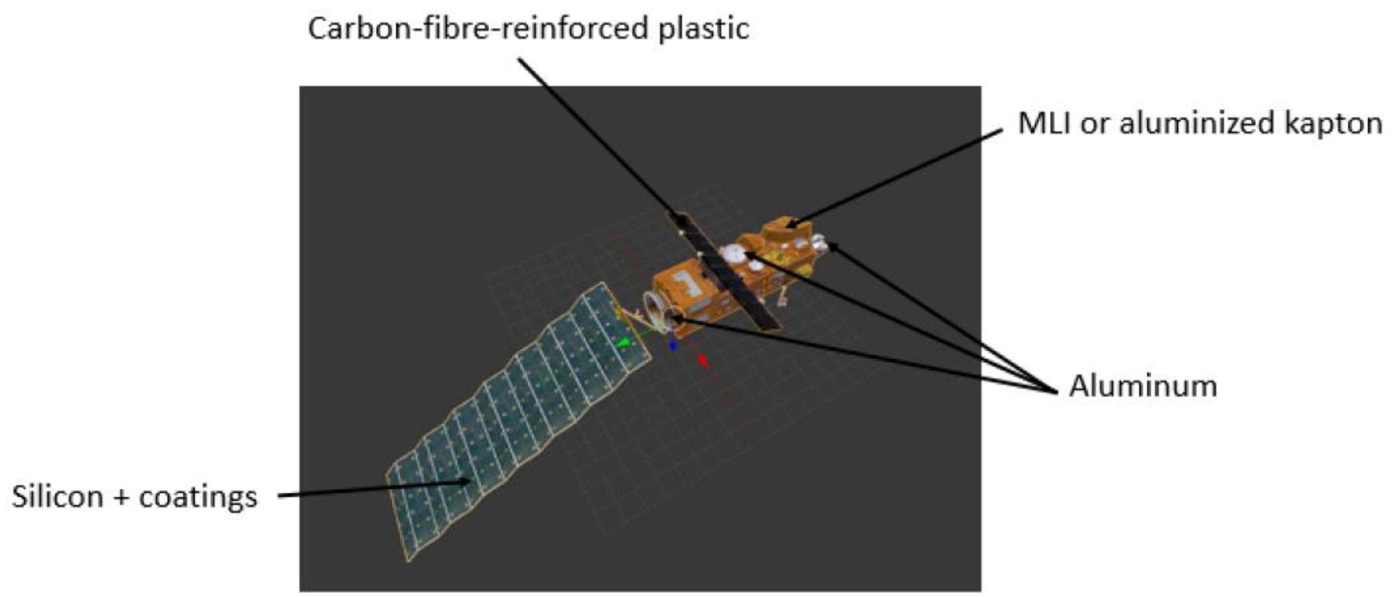
Mission scenario

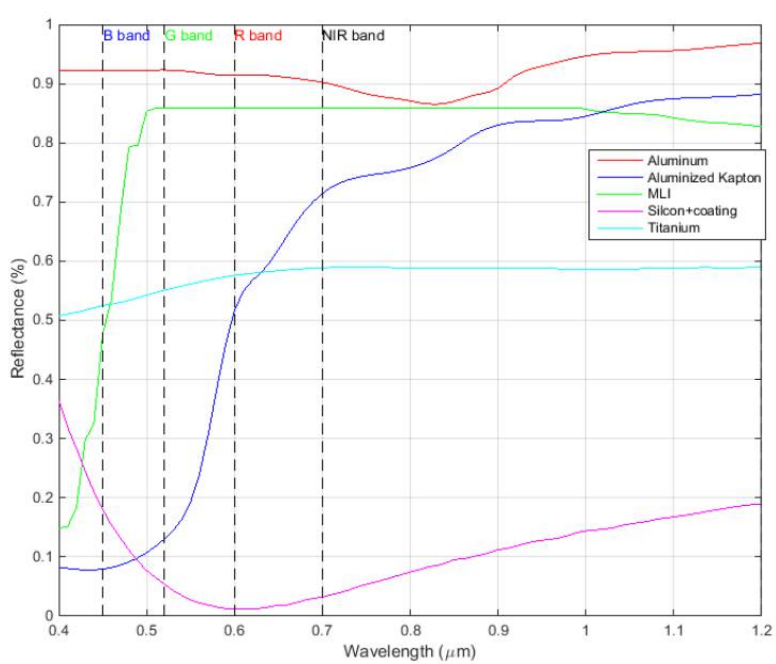
Scenario	Test description
RDV Envisat	Different phases: • From 900 m to 800 m • From 500 m to 400 m • From 300 m to 200 m • From 100 m to 75 m • Hold orbit at ~50 m • Few meters from the target
RDV ISS	Hold point at ~280 m
D&L	From 2 Km to landing





Spectral bands





- Simplified material model of the target
- Materials present different spectral features

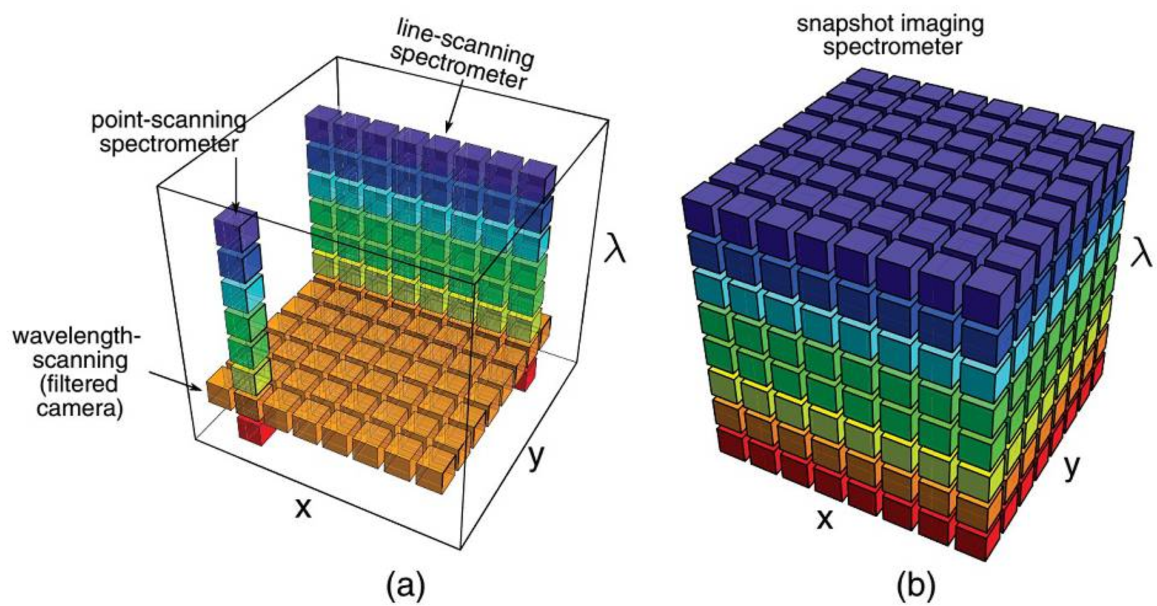
Considered bands and Instrument requirements

- Several band options considered for the VNIR channel:
  - Single VNIR band: 0.4 - 1 μm
  - VIS + NIR bands: 0.4 – 0.7 μm + 0.7 – 1.0 μm
  - 2 VIS + NIR bands: 0.4 – 0.5 μm + 0.5 – 0.6 μm + 0.6 – 1.0 μm
- For the Thermal InfraRed channel
  - Single TIR band: 8 - 14 μm
- The rendezvous scenario has been considered to derive the requirements for the conceptual design.

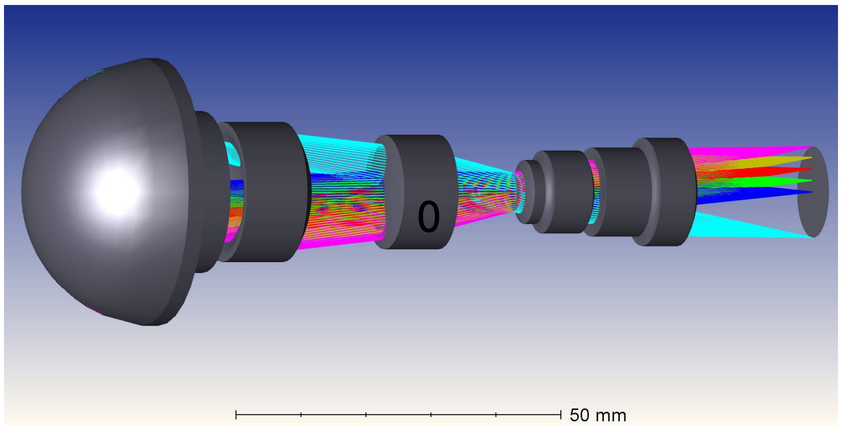
Parameter	VNIR	TIR
iFoV [mrad]	0.7	1
FoV [deg]	40	30
SNR	>4	>4

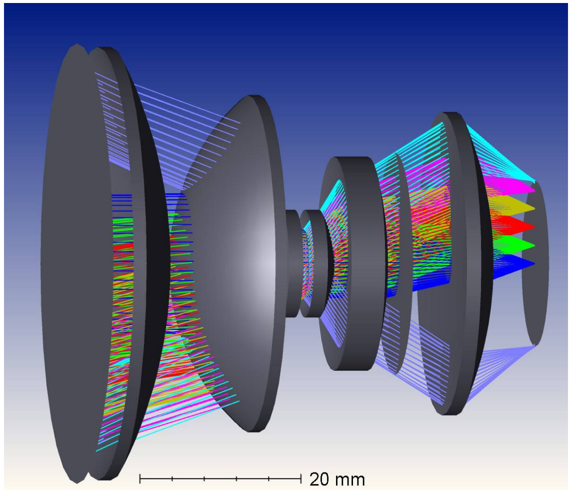
Spectral Imaging methods

- 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



Telescope concept: fully refractive





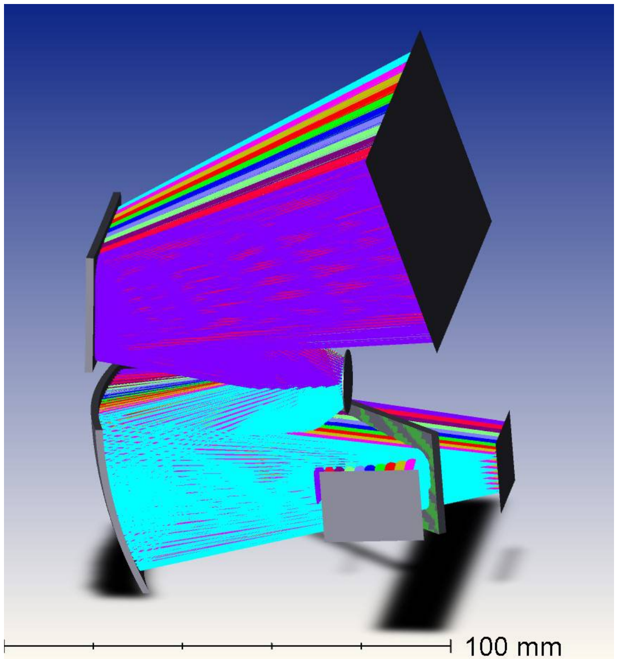
Visible Near InfraRed channel

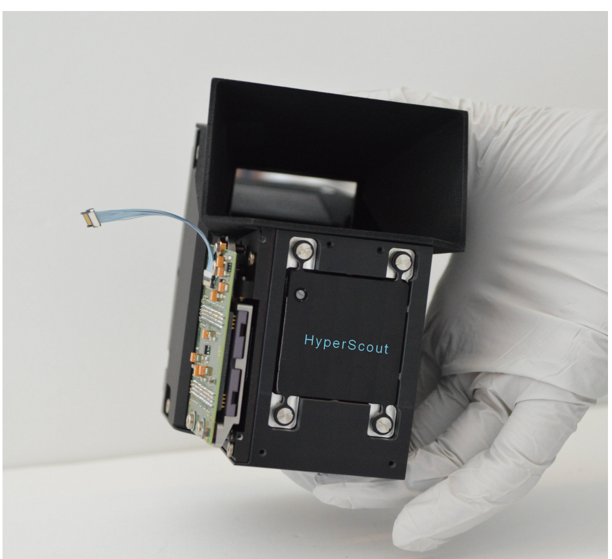
- 0.4-1 μm spectral range
- F/# = 5
- f=15 mm
- 2048 x 2048 pixel CMOS array
- 40° x 40° field of view
- Image space telecentricity
- Volume 20x20x130 mm^3

Thermal InfraRed channel

- 8-14 mm spectral range
- F/# = 1.5
- f=25 mm
- 1024 x 768 pixel
- 40° x 30° field of view
- Volume 50x50x60 mm3

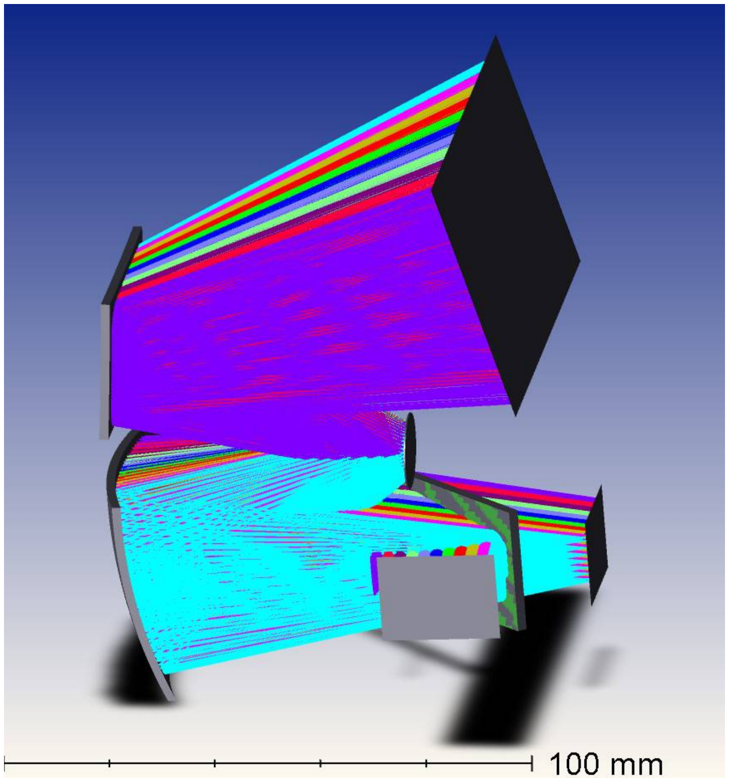
Telescope concept: fully reflective

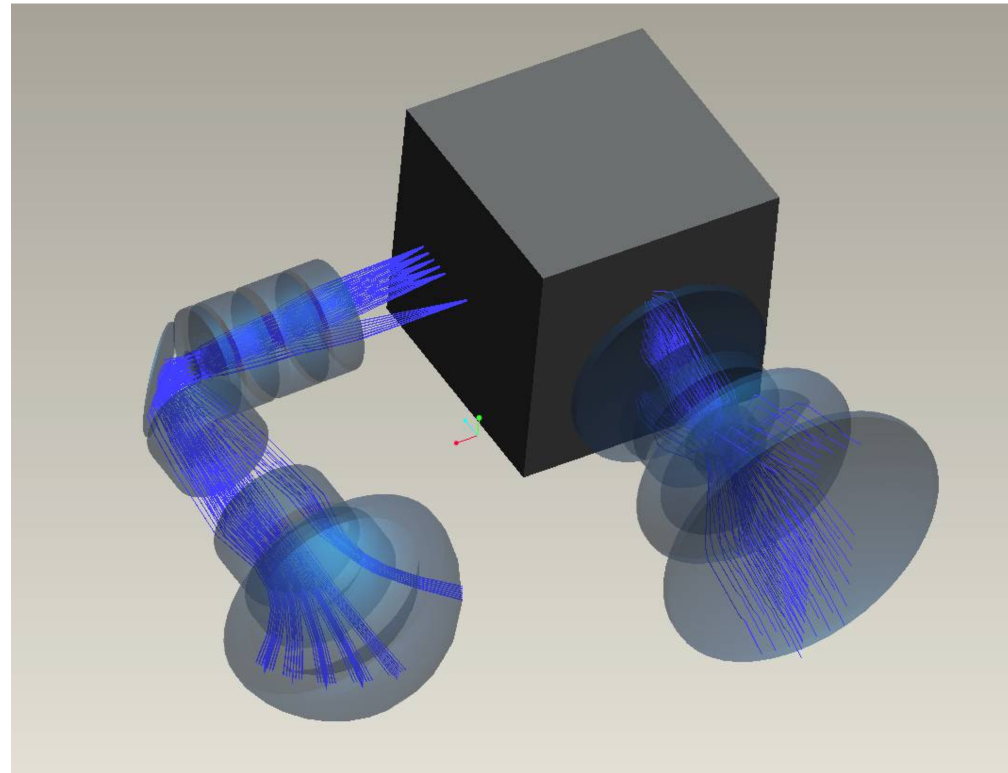




- Modified reflective telescope from existing nanosat based hardware for Earth Observation
  - 0.4 - 1 μm and 8-14 μm spectral ranges
  - F/# = 4
  - 4096 x 2000 pixels (VNIR)
  - 1024 x 768 pixels (TIR)
  - 30.5° x 16° field of view (VNIR)
  - 23.8° x 16° **field of view (TIR)**
  - Volume ~ 1 dm^3 (1U)

Summary configurations

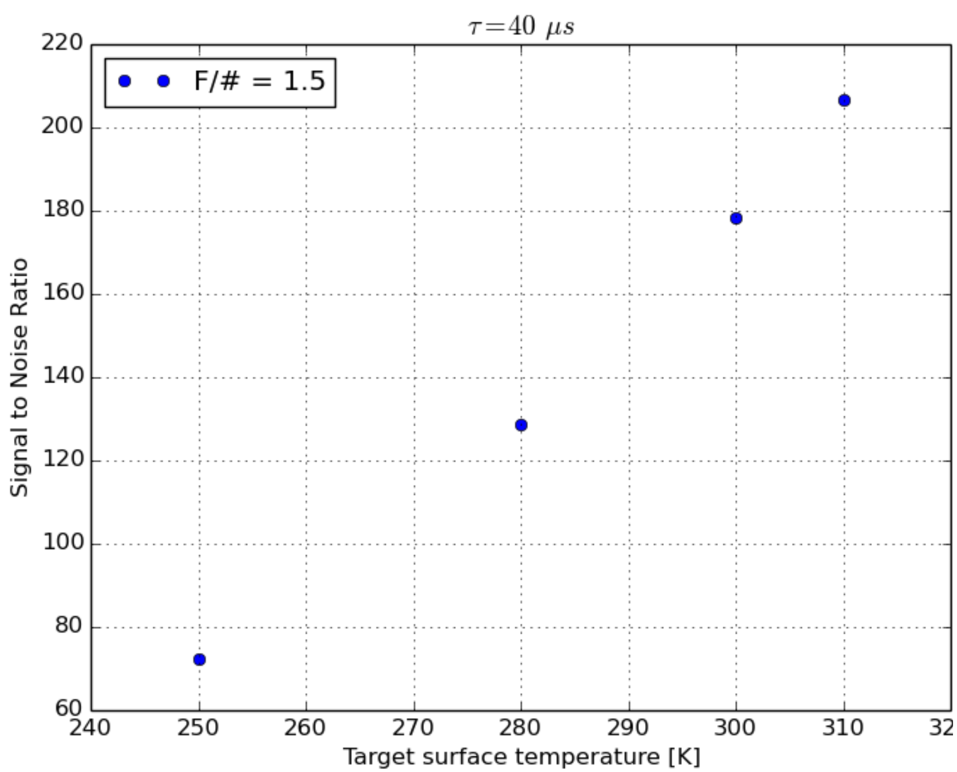


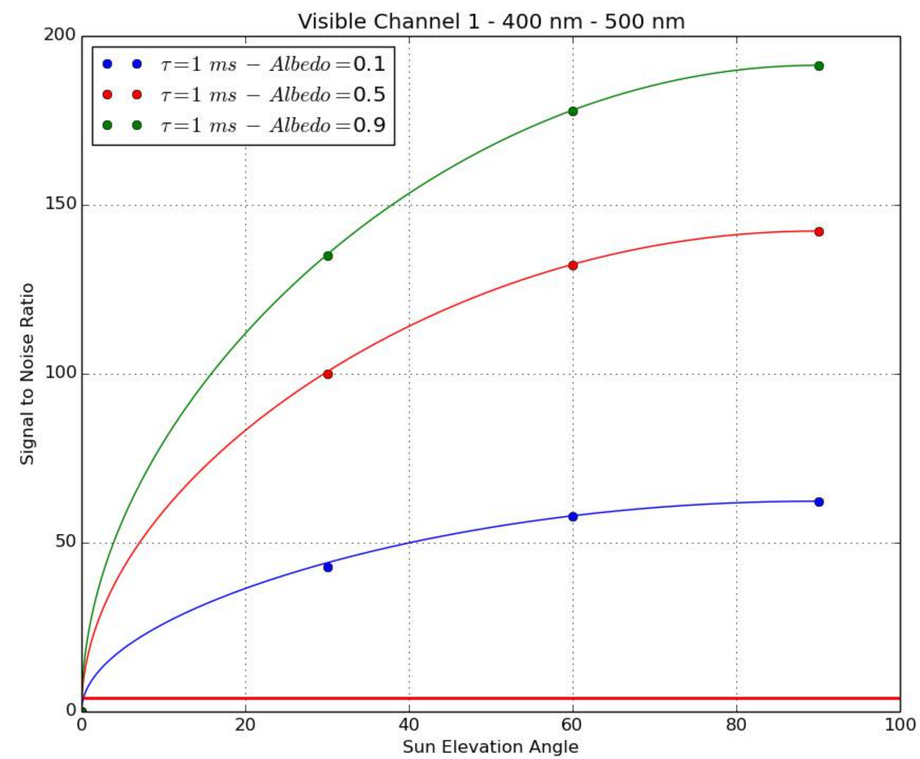


- Optical train is shared by the two spectral channels
  - Perfect coregistration
  - Very compact instrument
  - Good radiometric performance in both channels
  - Non optimized resolution for the TIR channel

- Dedicated lens system for each of the two spectral channels
  - Optimized resolution and radiometric response for each channel
  - Poorer coregistration
  - Larger volume occupation

Preliminary radiometric performance





Conclusions

- Project running and expected to finish end of summer 2016
- Mission scenario, data generation, requirements, simulation environment have been set
  - Rendezvous driving the requirements
- MSD possible architecture identified, preliminary design and MIL simulation ongoing in an iterative way

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measurement systems

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Technical requirements

Table 1: Requested bands

Band	Acro-nym	Range (approx.)	Comments
Near ultra-violet	NUV	300÷380 nm	Assumed to be either - Sun light reflected by the target surface - Light emitted by a cooperating target
Visible light	VIS	380÷750 nm	
Near infra-red	NIR	0.75÷1.4 μm	
Thermal infrared	TIR	8÷15 μm	Assimilated to long wave infrared (LWIR) band

Table 2: Requested missions and phases

Mission	Phase	Comments
Rendezvous with cooperating target in LEO	- Rendezvous with and capture by the ISS	The ISS cooperates with - inter-satellite communications (knowledge of target orbit and attitude) - target pattern (LEDs) for RV sensor
Rendezvous with cooperating target in Earth-Moon L2	- Rendezvous with a station at Earth-Moon L2	- Similar to the RV with ISS
Rendezvous with non-cooperating target	- Chaser rendezvous with a large debris - Forced translation of the chaser - Debris capture by the chaser	ADR mission for removal of a large debris The target rotational state may include nutation or tumbling
Descent and landing on an asteroid	- Far station keeping 35 km apart - Descent to low altitude - Delivery of science payload MASCOT - Ascent to safe distance	Within the AIM mission to binary asteroid 65803 Didymos
Navigation for planetary flyby	- Jupiter orbit insertion (JOI) - Swing by Galilean satellites	Optical navigation within the JUICE mission
NOTE: For this study purpose: rendezvous phases start once the multispectral sensor has acquired the target; target acquisition is considered		

Existing integrated cosine's suites of instruments

- Heritage from cosine's suites
  - Broadband infrared suite
  - Stereo imaging and hyperspectral (SILAT)
  - HyperScout – hyperspectral with onboard analytics

- Sensor types
  - NUV/VIS: CCD, CMOS
  - NIR/SWIR: InGaAs, MCT
  - TIR: MCT, microbolometers

- Cooling
  - Passive
  - Active