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Navigation on a Chip

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Navigation on a Chip: Project Status

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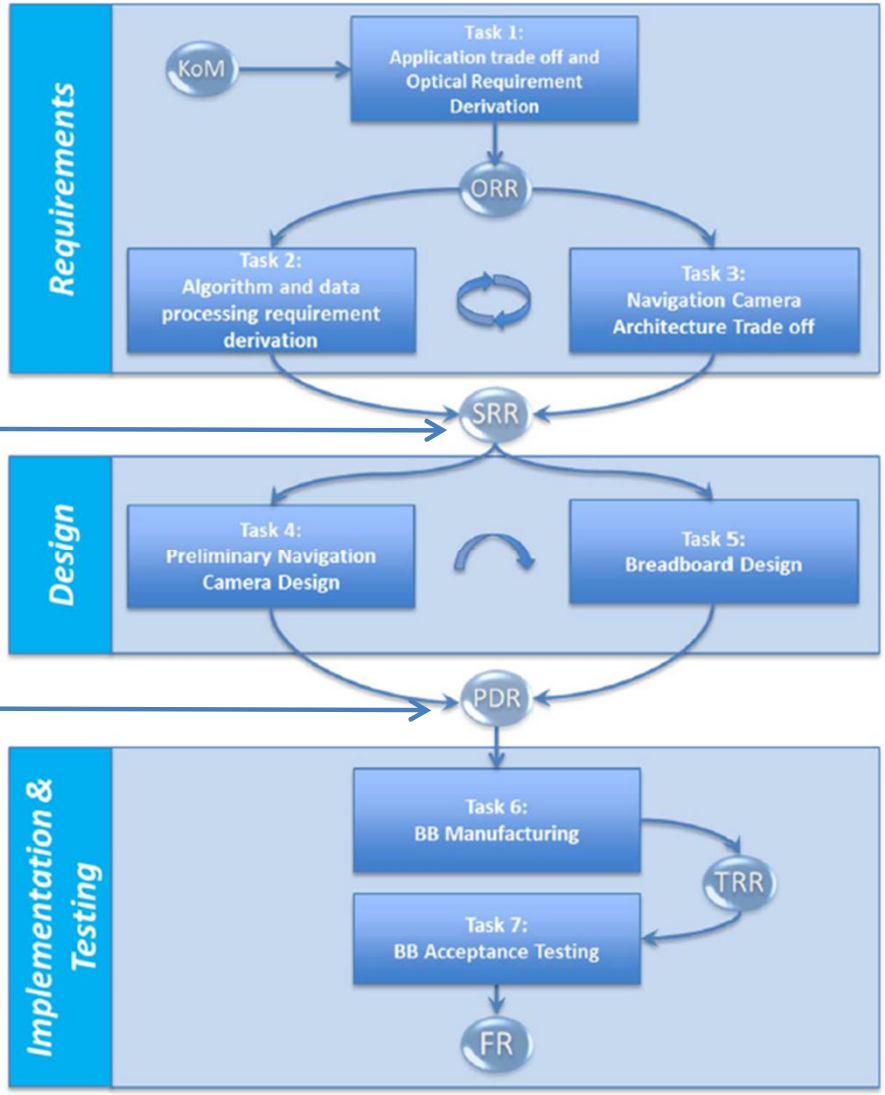
SRR closed on 4th October 2016

Key Point Meeting on 28th February 2017

PDR on 6th July 2017



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Mission Application Scenarios:

1. Small body navigation (Optics B with FoV 25°)
2. Decent & landing - low dynamics (Optics B with FoV 25°)
3. Planetary approach (Optics A with FoV 8°)

Navigation Camera System (NCS) configuration with

Separation of Optical Head (OH) and Electronics Box (E-Box)

OH consists of:

- Electronics Module with
  - HAS3 detector and proximity electronics, TEC optional
  - FPGA for detector control and data sequencing
  - Head power supply
  - SpW I/F to E-Box
  - mechanical I/F to the S/C
- Optics A or B, **alternatively** mounted to the OH Electronics Module
- Large Baffle A mounted to the S/C I/F, mechanically decoupled from Optics A or small Baffle B mounted directly to Optics B

E-Box contains:

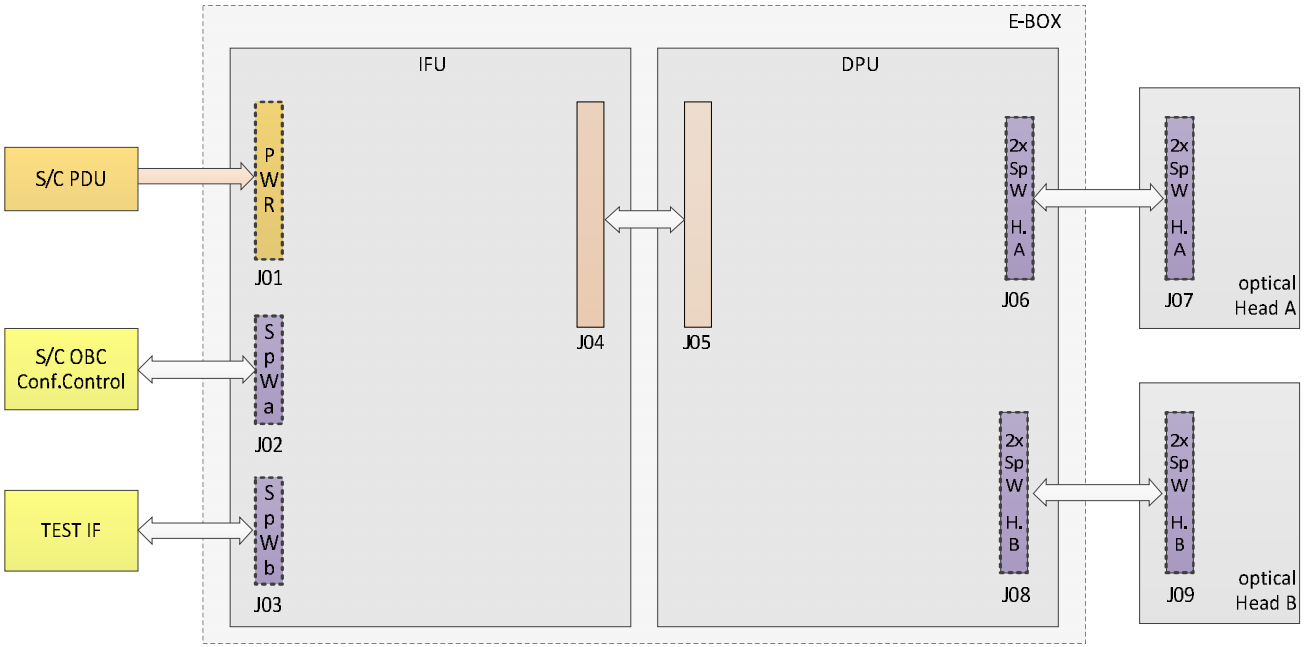
- Data Processing Unit (DPU) with
  - FPGA (RTG4/Virtex5) for H/W- and SW-based Image Processing
  - Memory (EEPROM, SDRAM and up to 3 SRAM-Banks)
  - SpW I/F to one OH or two OHs, alternatively.

- Interface Unit (IFU) with
  - Power supply and Power I/F to S/C
  - TC/TM SpW I/F to S/C and SpW Test I/F
  - TEC driver circuitry and FPGA reconfiguration circuitry as an option

- mechanical I/F to the S/C

NCS Configuration allows for:

- Baseline: One Optical Head per NCS which would be equipped on-ground with an appropriate optic (A or B) depending on the particular mission.
- Option: Two Optical Heads per NCS equipped with optics A and B respectively, as a potential option in case of need to switch camera FOV at one point of the approach, e.g. between mid-range and close-range.
- Depending on mission needs, the image processing content/complexity could be configured on-ground within DPU or re-configured in-flight via reconfiguration controller located on IFU as an potential option.



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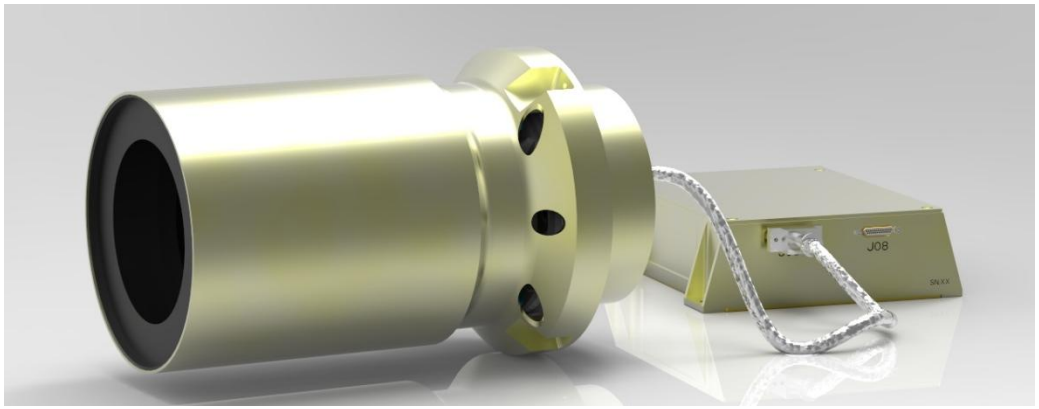
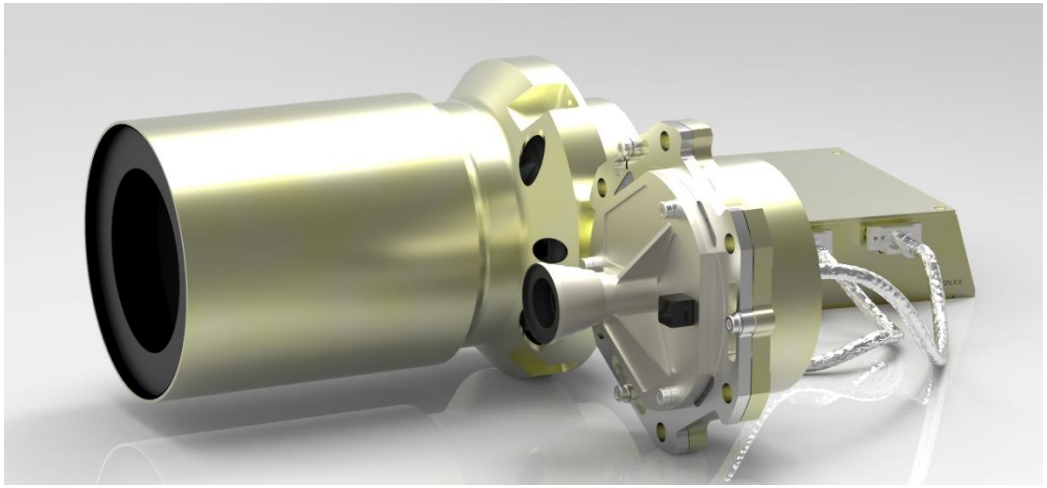
NCS Baseline Design with one OH (A OR B) and E-Box:



NCS Optional Design with two OHs (A AND B) and E-Box:



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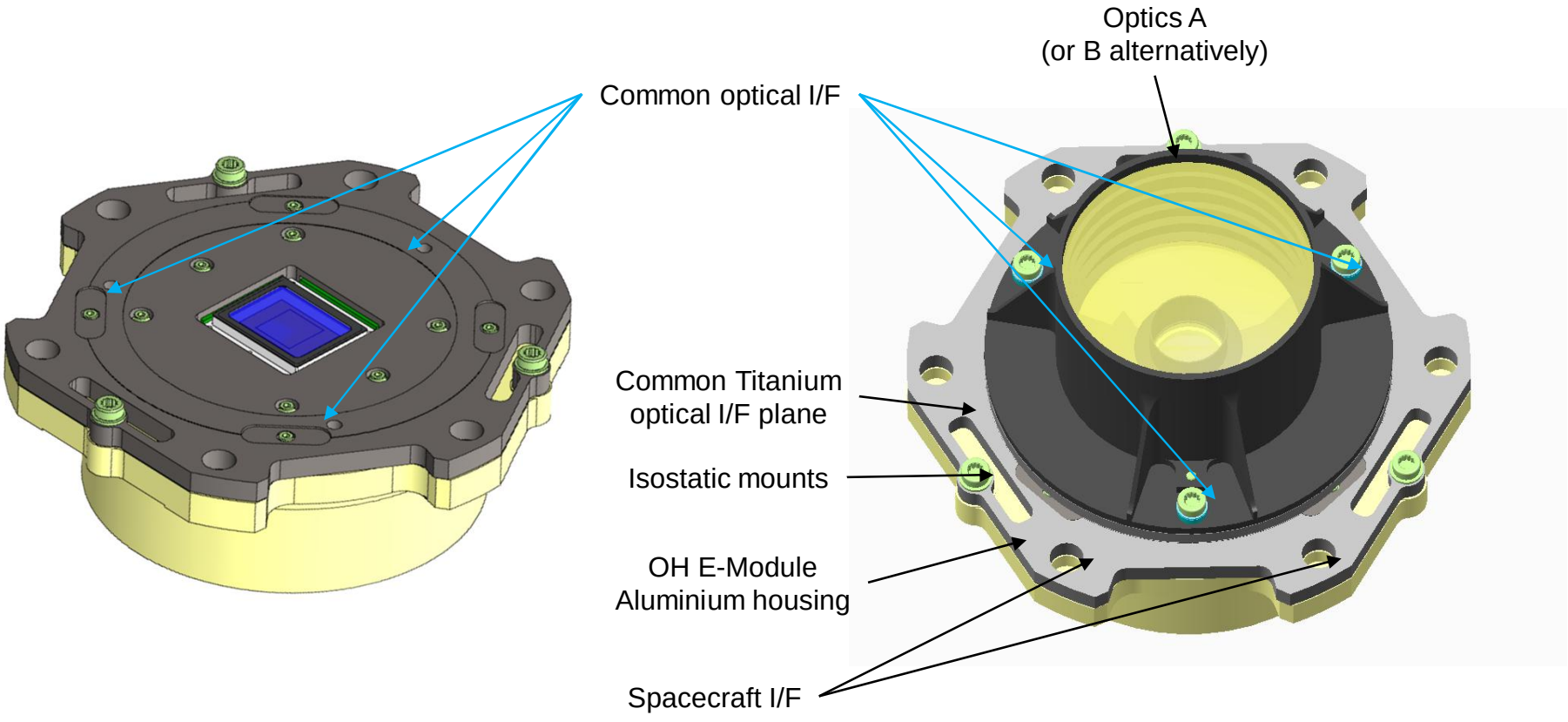
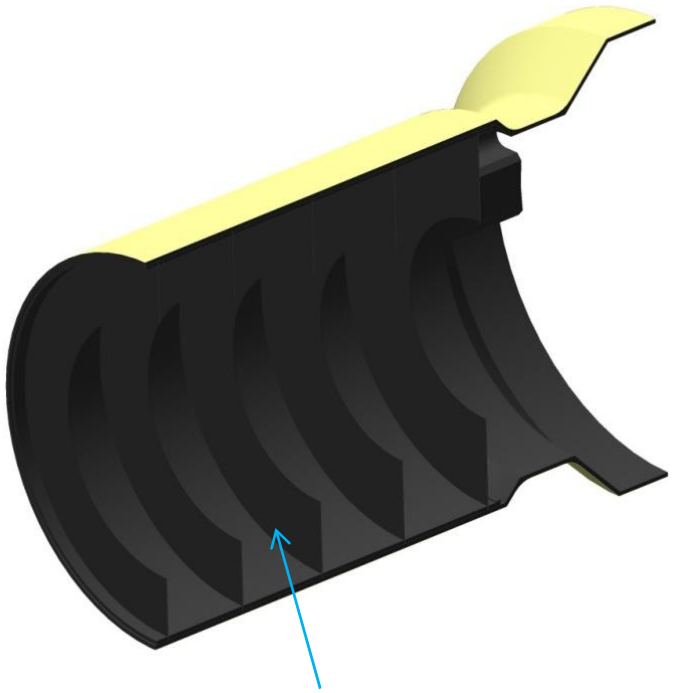
Optics requirements for identified optics solutions (ORR Status)

	unit	Optics A	Optics B
Applications	Small body navigation		x (10 km ... 1500 km)
	Planetary Approach	x (15 km ... 10^7 km)	
	D&L (low)		x (15 m ... 30 km)
target types	stars	yes	yes
	target	point-like → extended	point-like → covers full FOV
FOV	deg	8	25
Detector		HAS 3 (1280x1280 pixels, 11 µm pixel pitch)	
Aperture (re-fined)	mm	70	vario: 3 – 10
focal length	mm	100.7	31.8
Dynamic range		down to 1 m (see according applications) focus relaxation for very close range: TBD	
Focus		defocus (80% of energy in 3x3 pixel)	slight defocus (70-80% of energy in central pixel)
Vignetting		TBD	<10%
Distortion		not critical (80% of the power radial symmetric)	
Temperature range		operation: (-30 ...+50)°C cold start: -35°C hot start: +45°C	

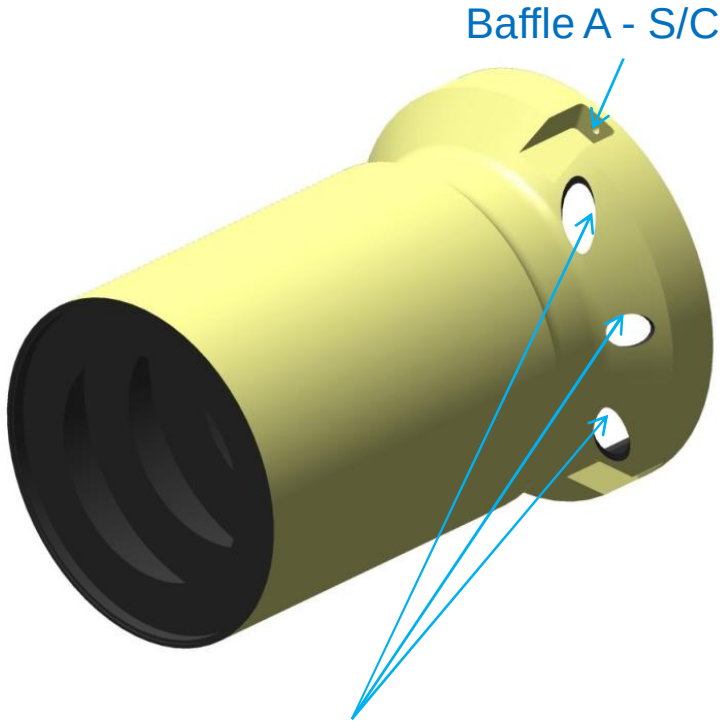
Optical Head (OH) Electronics Module with common I/F to both optics configurations, Optics A and B



Baffle A Sectional and outer view



5 Vanes



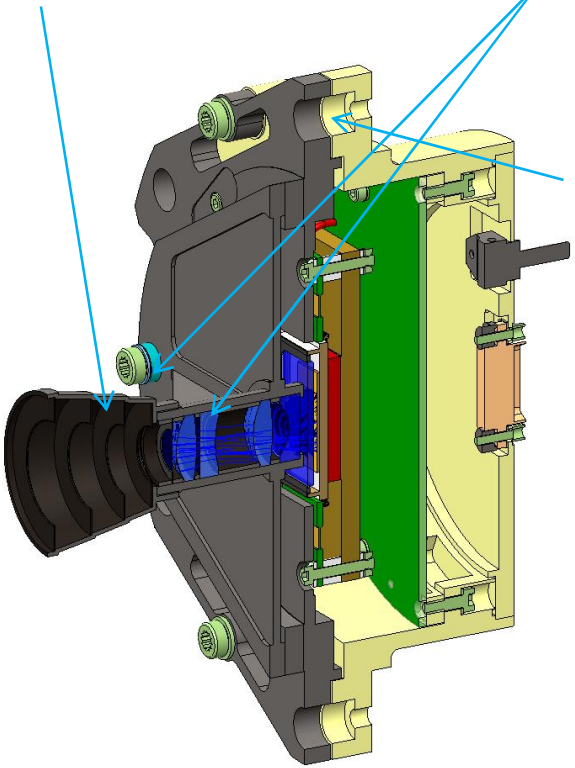
Baffle A Cut-outs for alignment cube access

Baffle made of Aluminium and black coated.
Knifes of vanes will be made of stainless steel.

OH B Sectional and outer view

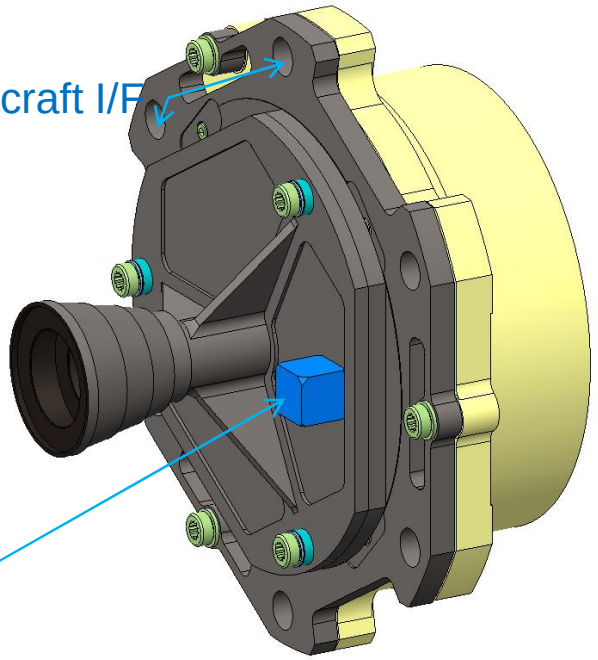
Baffle B assembled to Optics B

Optics B with adjustment ring and with OH E-Module I/F



OH E-Module – Spacecraft I/F

Alignment Cube



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System Electronics Design – Summary

Configuration	single or dual optical head, on-ground (optional inflight) reconfiguration
Components	E-Box: (Digital Processing Unit, Interface Unit) and up to two Optical Heads
Connectivity	6 SpaceWire Ports (192-200MBit)
Memory	independent configuration-, boot- and up to 4 independent memory banks (SDRAM/SRAM) for image processing
Image Processing	fast hardware-based image processing pipeline-matrix combined with complex software-based algorithms performed on LEON3 softprocessor within one FPGA (Microsemi RTG4 or Xilinx Virtex5)
Power Supply	23V / 28V / 32V
Envelope E-Box (approx.)	180mm x 165mm x 55mm (TBC)
Envelope Head (approx.)	75mm (length) x 170mm (diameter), excl. optics, excl. baffle (TBC)
Detector type	OnSemi HAS3; 4/3“; 11µm x 11µm pixel size
Detector Key Parameter	1280 x 1280 pixel; 12Bit; 18.75MBit image size, 10fps

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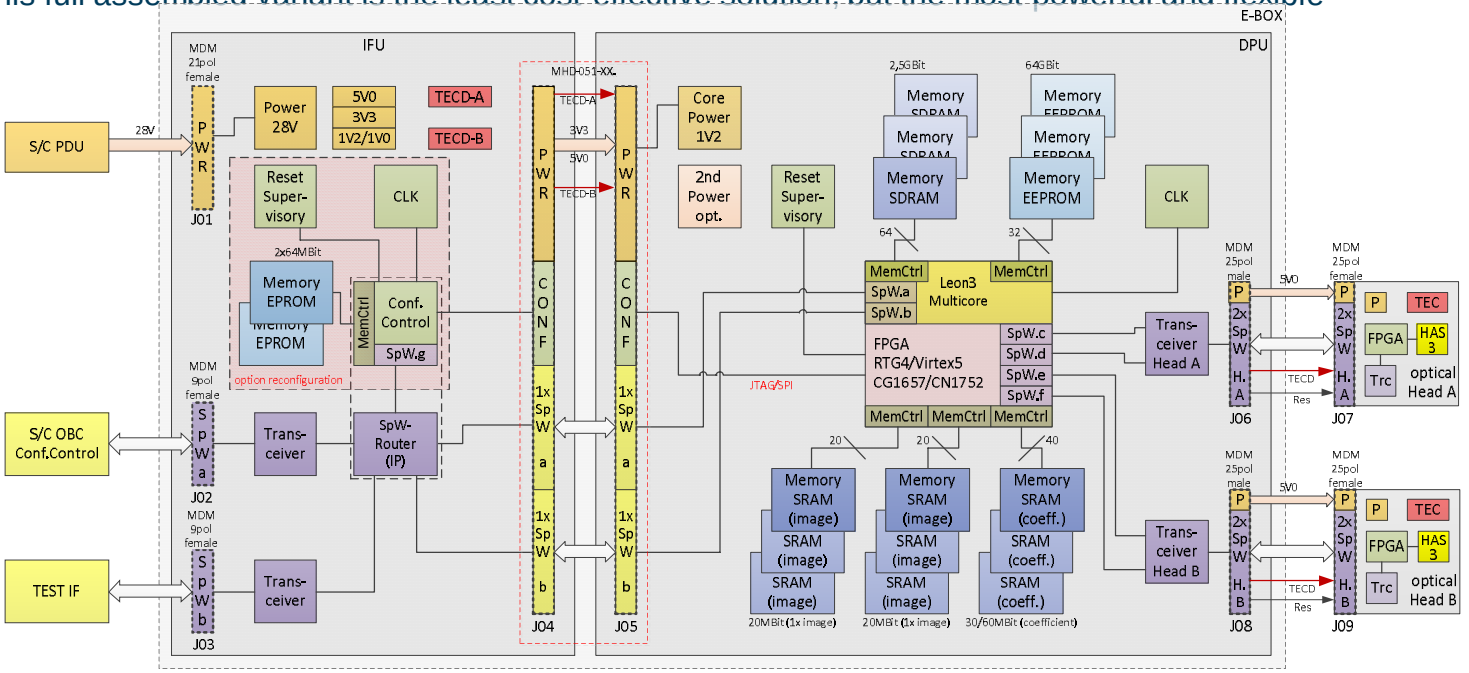
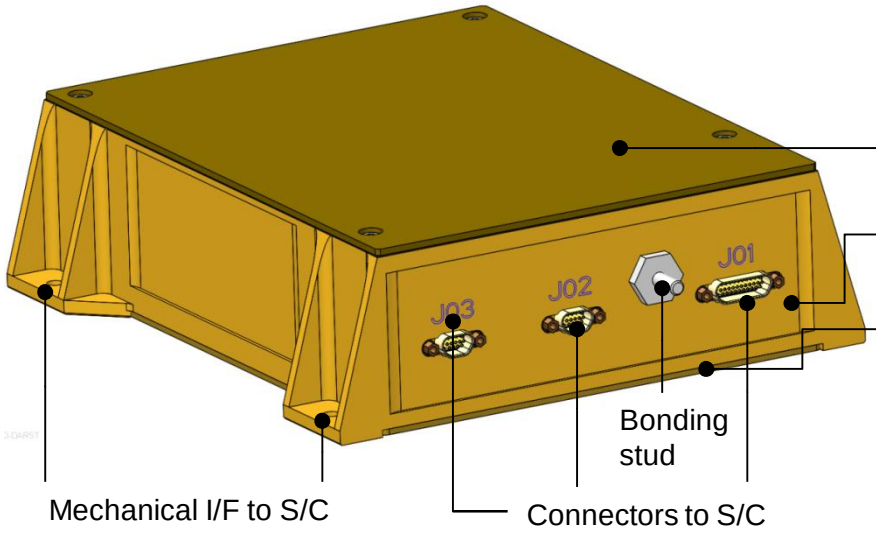
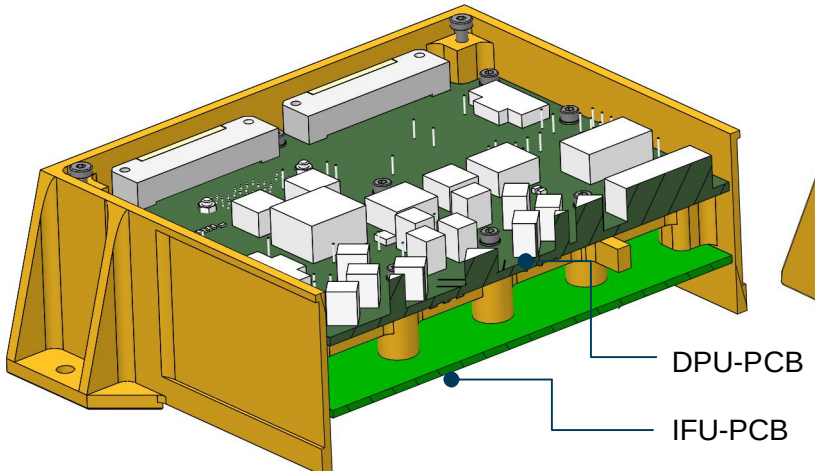
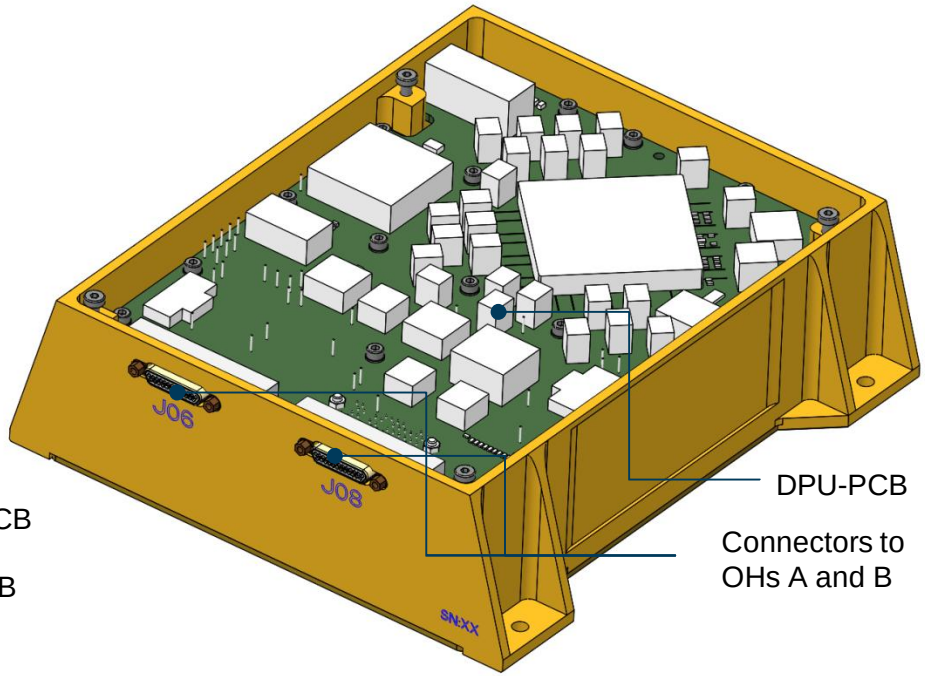
System Variant C: baseline + 2nd optical head + inflight reconfiguration

- two optical heads can be connected at the same time, one of them is operational
- Xilinx Virtex5 as an option, if fast or partial in-flight-reconfiguration is desired
- full featured HW image processing capabilities using two additional image buffers
- on ground and inflight reconfiguration (no partial reconfiguration possible on RTG4)
- GR712RC (TBC) based reconfiguration controller circuitry on IFU contains configuration memory EEPROM containing multiple (TBD) bit streams for full or partial reconfiguration
- partially reconfigured regions can be switched while LEON3 is permanently operational
- configuration memory scrubbing can optionally be carried out by reconfiguration controller on IFU in case a Xilinx SRAM-based Virtex5-FPGA is assembled
- highest power consumption compared to all other system variants presented before
- this full assembled variant is the least cost-effective solution, but the most powerful and flexible




J01
J02
J03
Top cover
Module frame
Bottom cover
Bonding stud
Mechanical I/F to S/C
Connectors to S/C


DPU-PCB
IFU-PCB


J06
J08
SN:XX
DPU-PCB
Connectors to OHs A and B

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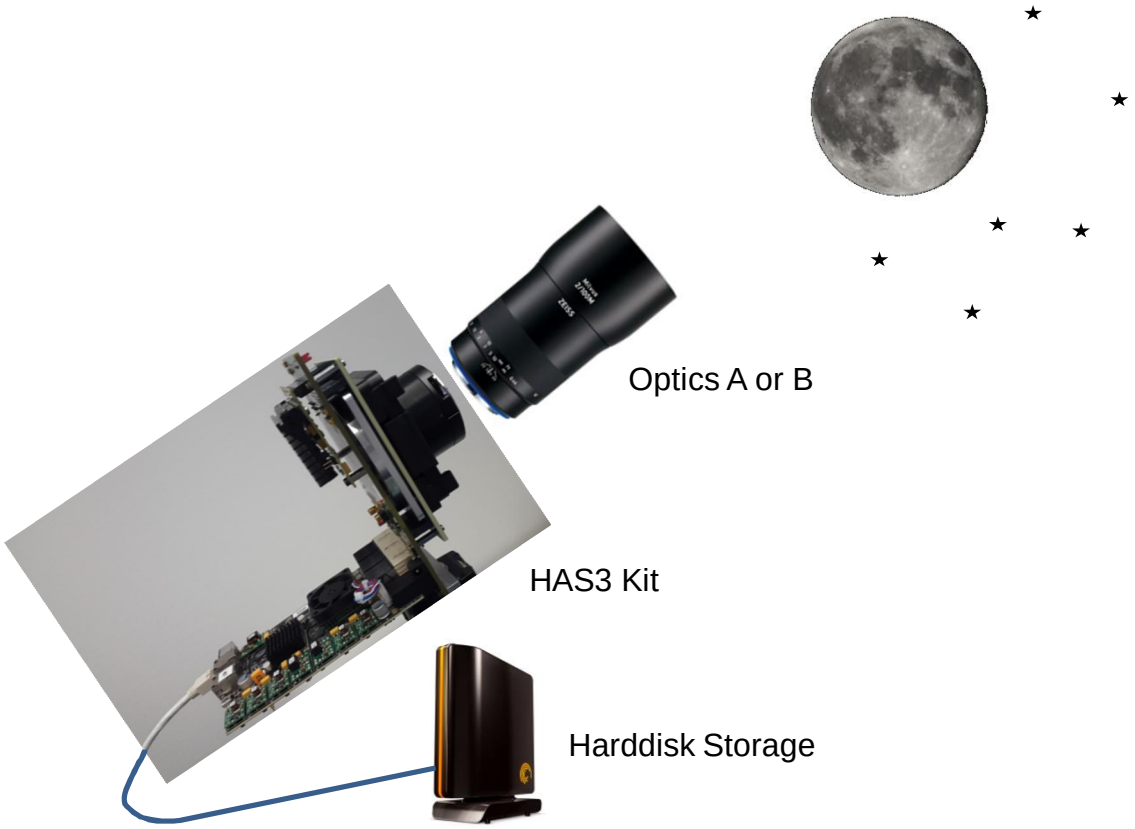
Algorithms identification for selected scenarios

- 9 key algorithms will be implemented
- every mission scenario needs a different set of key algorithms

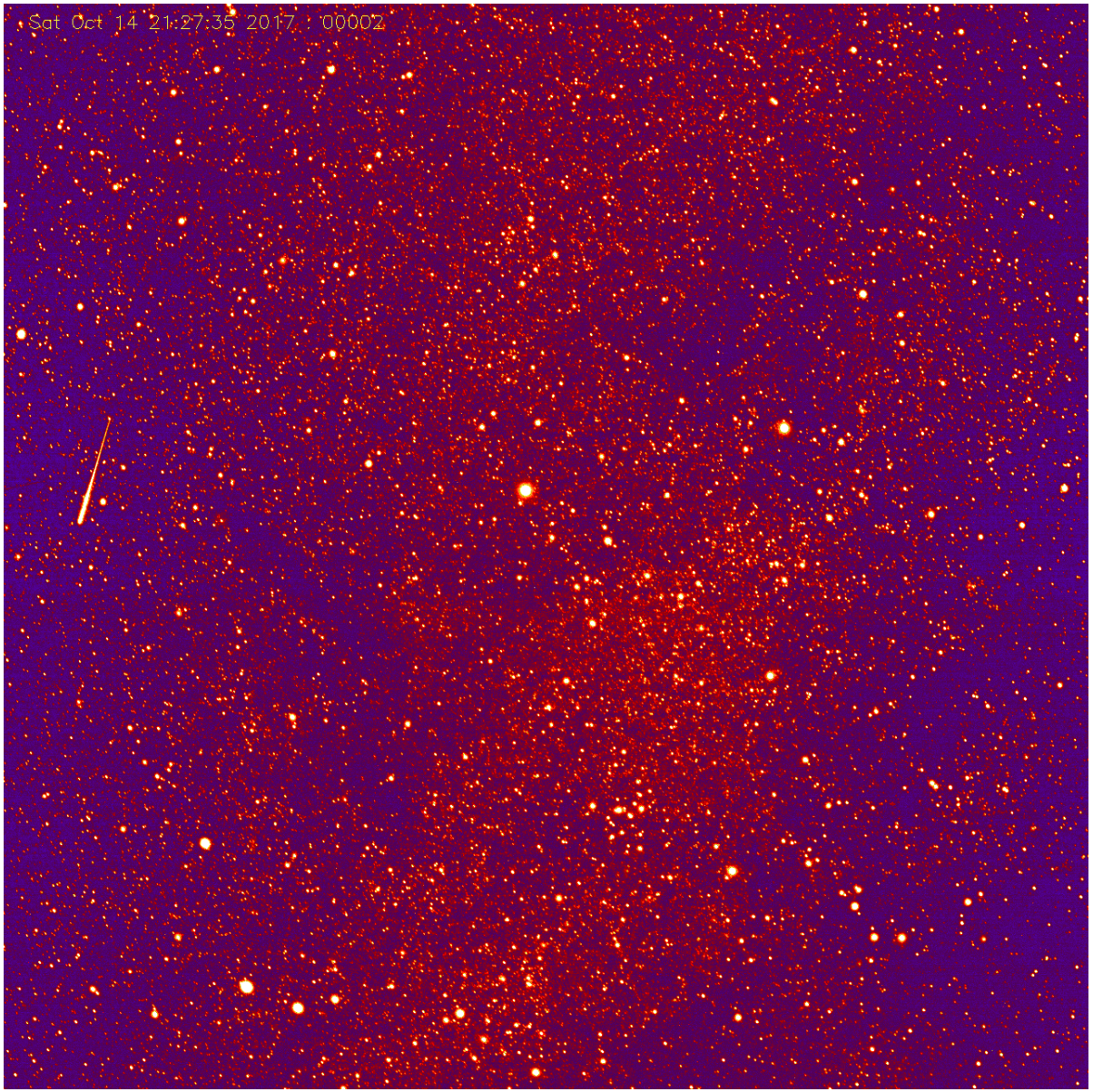
Algorithms / Mission Scenario	Unresolved Object Centroiding	Resolved Object Centroiding	Centre of Brightness	Limb/ Terminator Extraction	Landmark Detection	Landmark Recognition	Feature Tracking	Template Matching	Hazard Mapping
Small Body Navigation	X	X	X	X	-	-	-	X	-
Planetary Approach	X	X	X	X	-	-	-	X	-
Descent + Landing	-	-	-	-	X	X	X	-	X

First Night Sky Tests



NCS BB is electro-optical fully representative regarding the HAS3 CMOS detector chip and the main parameters of the optics to realize the targeted field of view and aperture.

Night sky experiment to determine the limiting magnitude using faint stars to benchmark the detection capability for any other point-like objects such as planets, asteroids, comets, etc. in far distance or a sample return container.



First Light on HAS3

October 14, 2017

Exposure time:
5sec

Star Pattern:
Swan with home galaxy background

Objects:
>10mag

Left:
Iridium Flare

Conclusion:

- System Trade Offs have been finished with a 2-head navigation camera system of a small and a wide field optical head.
- 3 Mission scenarios have been selected for verification.
- Key Software algorithm have been identified.
- First Light on HAS3 has been successfully performed begin of October 2017 using the HAS3 breadboard electronics with both representative optics for the small and medium field optical head.
- Night sky test will be completed next with the Moon in the FoV depending on weather conditions. Here the HAS3 dynamic range will be checked especially for the very short exposure times of a few micro-seconds.