institut für astrophysik
UNIVERSITÄTSSTERNWARTE WIEN

ARIEL: OPEN Conference 2020

The ARIEL Fine Guidance System (FGS), Photometer & NIRSpec

Mirosław Rataj, Piotr Wawer, Konrad Skup, Mateusz Sobiecki

Centrum Badań Kosmicznych PAN (CBK)

Mark Swain, Warren Holmes, Andre Wong

Jet Propulsion Laboratory, California Institute of Technology,

Roland Ottensamer, Franz Kerschbaum, Gerald Moesenlechner

Department of Astrophysics, University of Vienna

FGS objectives

1. Ensure the centering, focusing and guiding of the satellite

2. Provide high precision astrometry and photometry of the target for complementary science

To meet the goals for guiding and photometry, four spectral bands are defined:

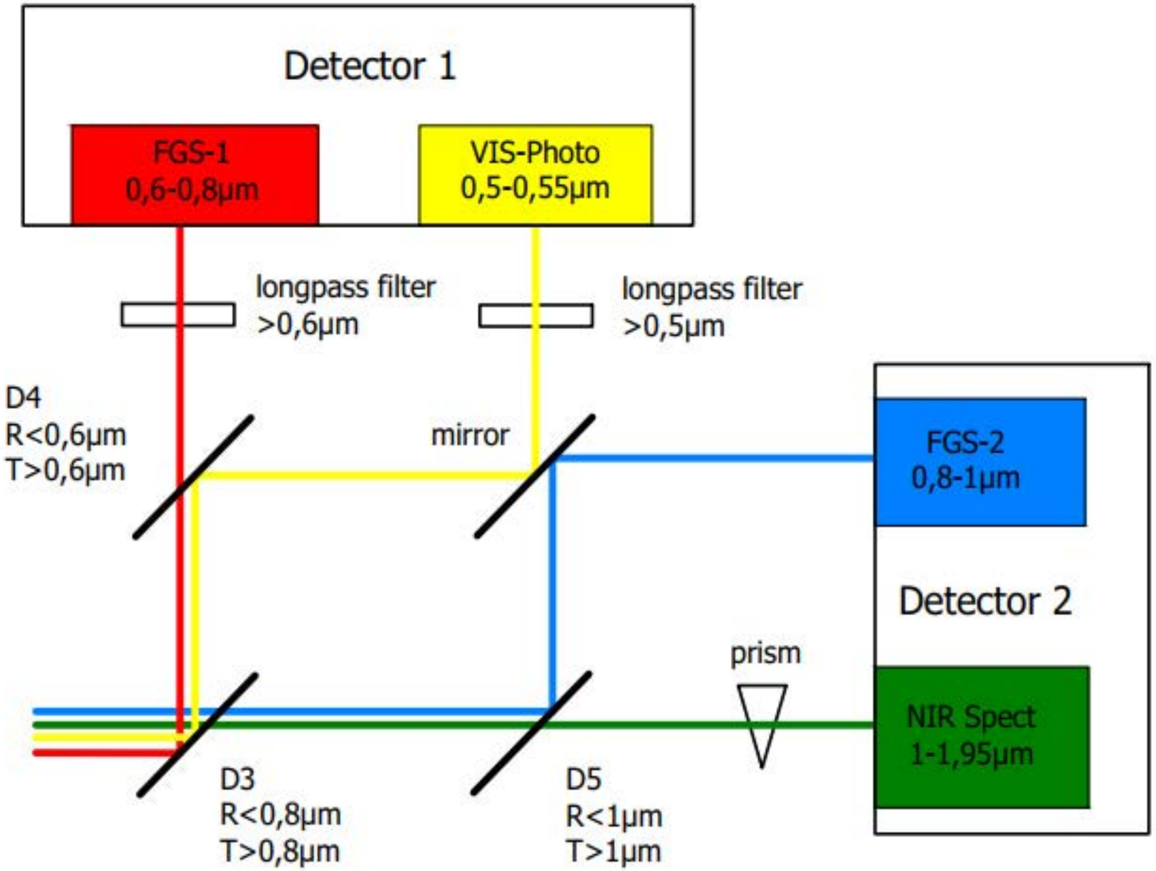
VIS-Phot: 0.50-0.6 µm

FGS 1 – 0.6-0.80 µm,

FGS 2 – 0.80-1.1 µm

NIR Spec: 1.1-1.95 (2.1) µm,

spectral resolving power R≥15



Functional and Performance Requirements

- The FGS shall start and stop the relative attitude measurement and the photometric measurement on command from S/C.
- For each measurement the FGS shall provide:
  - The position of measured star,
  - The time of validity for the attitude measurement ,
  - Data from spectral channels, integration time, window dimension
  - Status information on the operational mode, the sensor health and the attitude quality, H/K
- **The FGS shall deliver new measurements with 10 or 8 Hz update rate (AOCS),**
- It shall be possible to switch between FGS1 and FGS2 units and to work both channels on command for centroid calculation

PERFORMANCE

The FGS performance errors across LoS shall be better than:

- For bright targets:

- Measurement noise ≤ 20 mas at 10/8 Hz.

- For faint targets:

- Measurement noise ≤ 150 mas at 10/8 Hz.

Calibration Requirements – ARIEL MRD

R-PERF-230 Spectrometer relative photometric calibration
A relative photometric calibration accuracy of 5% shall be achieved for all targets within the brightest/faintest targets requirements, across the full waveband of ARIEL.

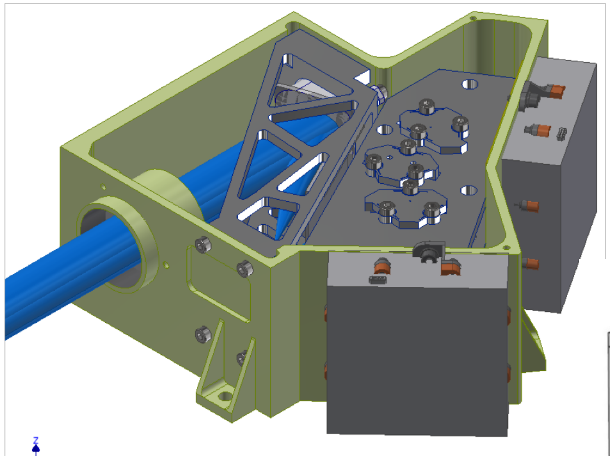
R-PERF-240 Spectrometer absolute wavelength calibration
An absolute wavelength calibration accuracy better than 1/3rd of the required spectral resolution shall be achieved for all targets across the full waveband of AIRS and NIRSpec.

R-PERF-260 VNIR absolute wavelength calibration
The absolute wavelength calibration for the 3 VNIR photometric channels cut-on/off shall be stable to within 10 nm(tbc).

R-PERF-090 Overlap
For adjacent spectral channels (between NIRSpec and AIRS, and within AIRS), a spectral overlap ≥1 spectral resolution element shall allow cross-calibration between channels.
Spectral range of NIR Spec enlarge up to 2.1 um

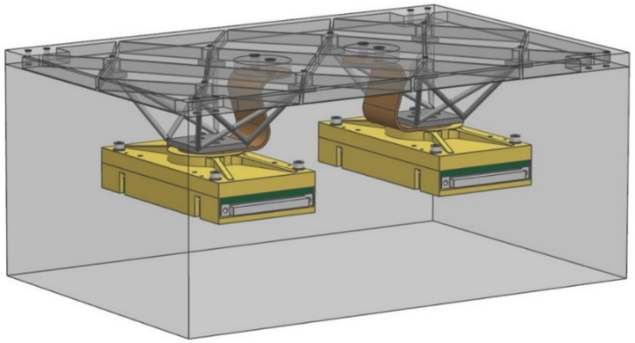
FGS top level architecture

TOB

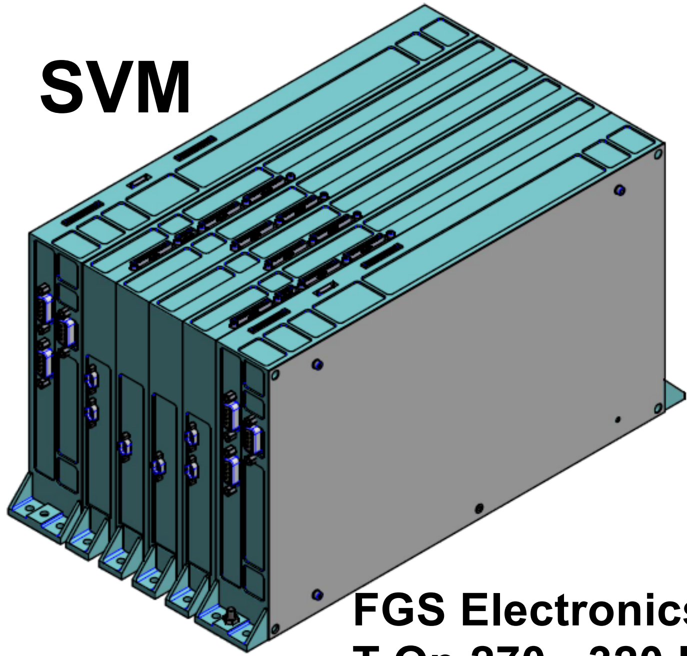


FGS Optics

FGS cFEE (Sidecar) Box
T Op 130-145K



SVM

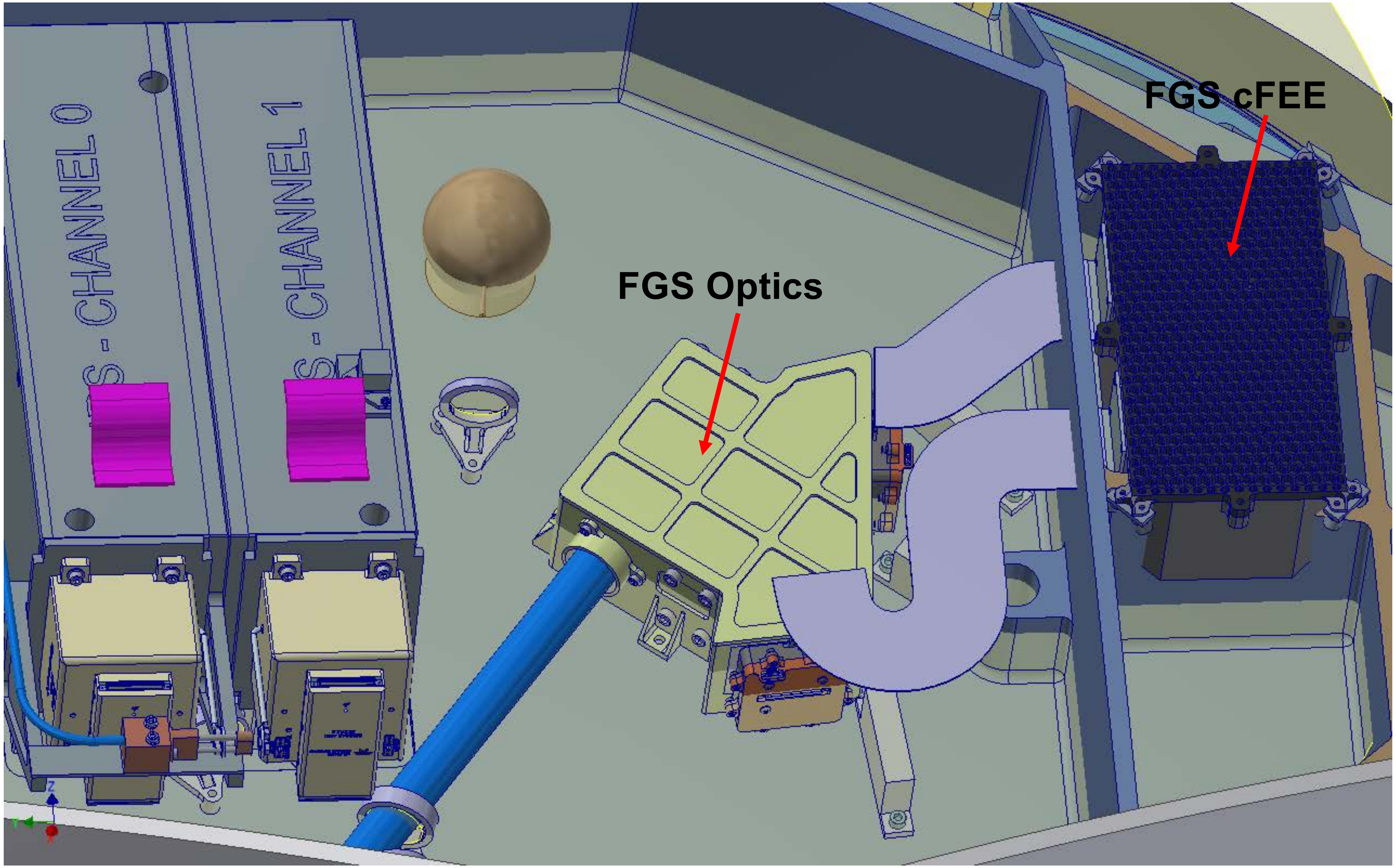


FGS Electronics
T Op 270 - 320 K

The system is composed of an optics box at the instrument optical bench containing cryogenic optics with two detector modules at 45-55K (op) and the box cold front-end electronics (CFEE - sidecar modules) operating in 130- 145 K.
Teledyne detector H2RG 2048x2048 pxs with SIDECAR.

In the service module the FGS Control Unit: WFEE (DCU), PSU and DPU are accommodated in temperature 270 K - 320 K to control and read the detectors, to carry out the data processing and communicate with S/C

FGS top level architecture

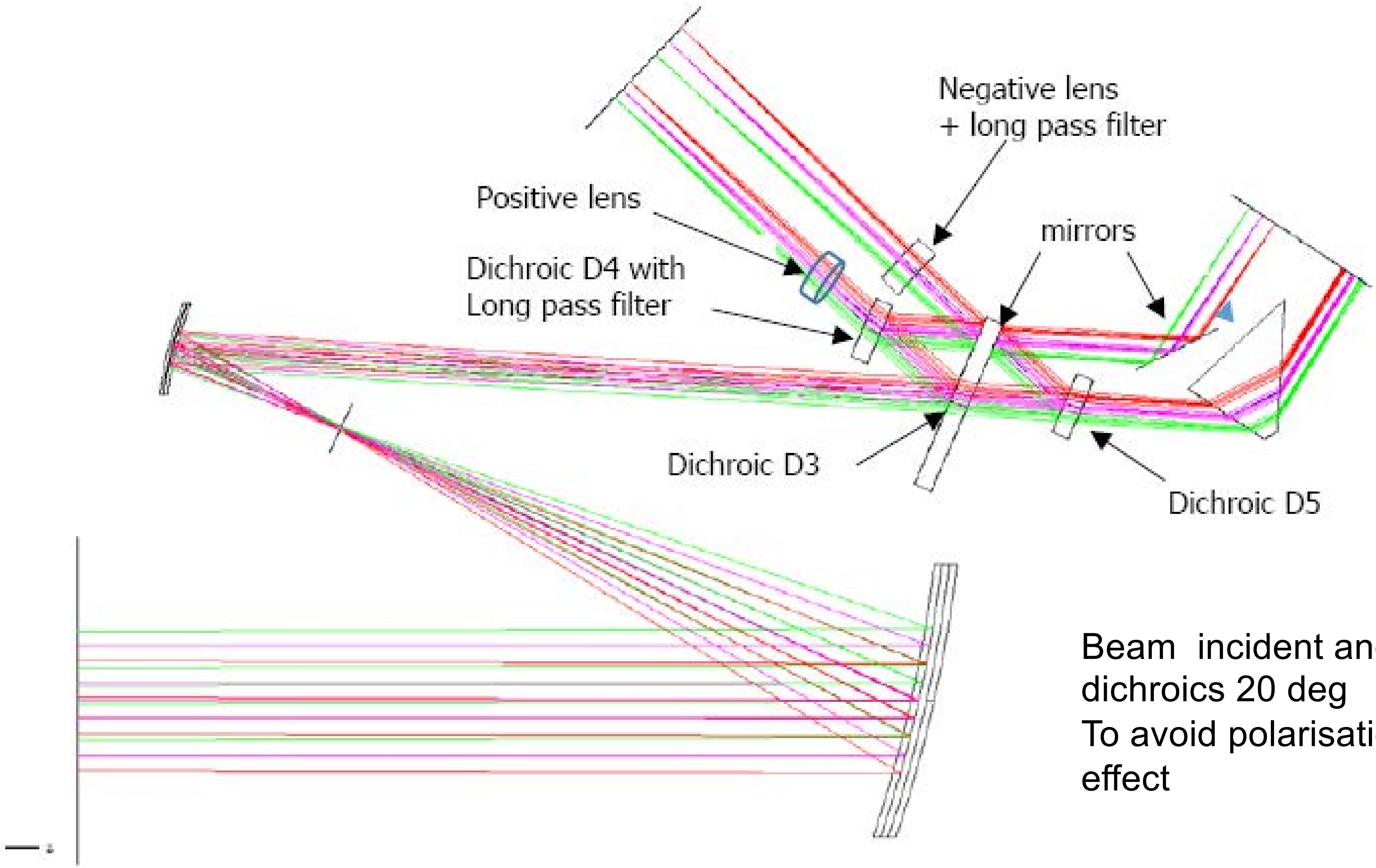


FGS Optical Module Design

The FGS optical module has been designed with the following basic assumptions:

- **FoV – max usable on sky FGS FoV is 25.2 arc sec, corresponds with ±0.19 deg (internal FGS's FoV)**
- Spectral bandwidth: 0.5-1.95 (2.1) μm is split into four bands
- Detector: MCT FPA ~2kx2k H2RG TELEDYNE with pixel size (18 μm) with SIDECAR
- Minimum bin/star image spread FWHM: 6x6 pixels
- Able to achieve centroiding to 1/10th of a pixel level
- Input WFE: 200 nm rms (= telescope diffraction limit @ 3 μm) + allocation for dichroics
- Low distortion (< 1% level over FoV)

FGS Optical Module Design



Beam incident angle on dichroics 20 deg
To avoid polarisation effect

FGS Optical Module Design Baseline

The off–axis Gregorian mirror telescope was designed for the FGS

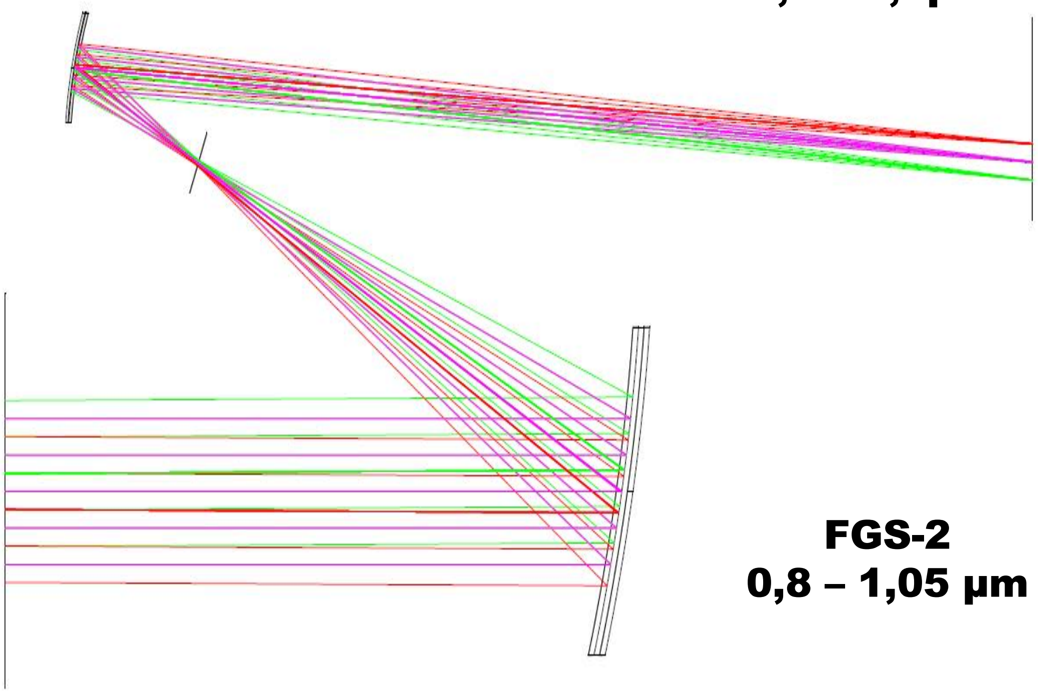
The main parameters of the telescope are:

focal length = 500 mm,

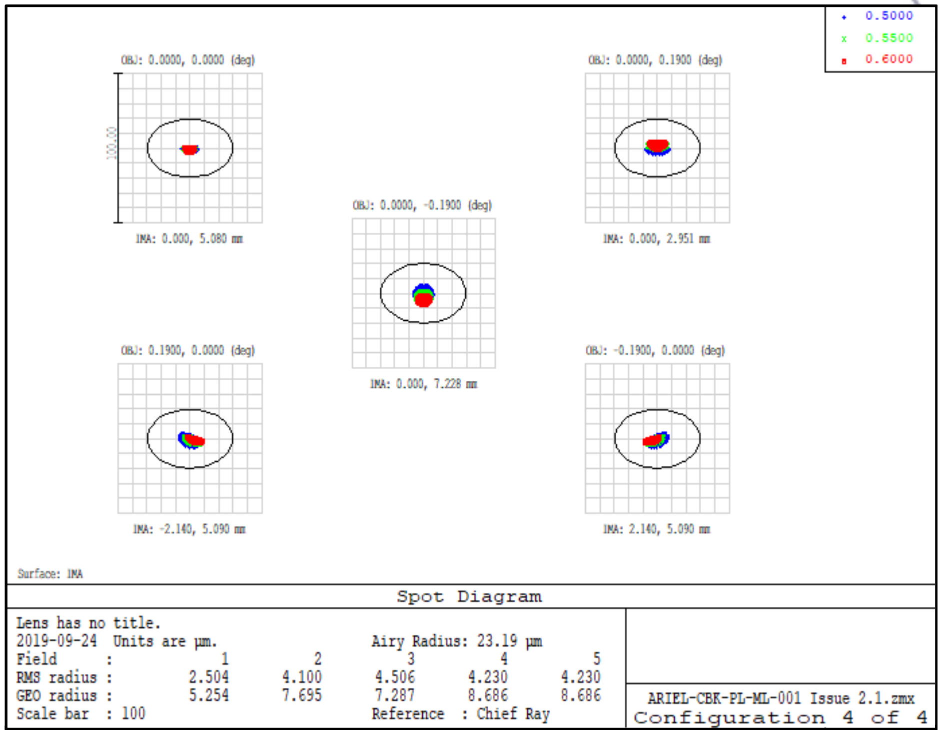
F-number = 25

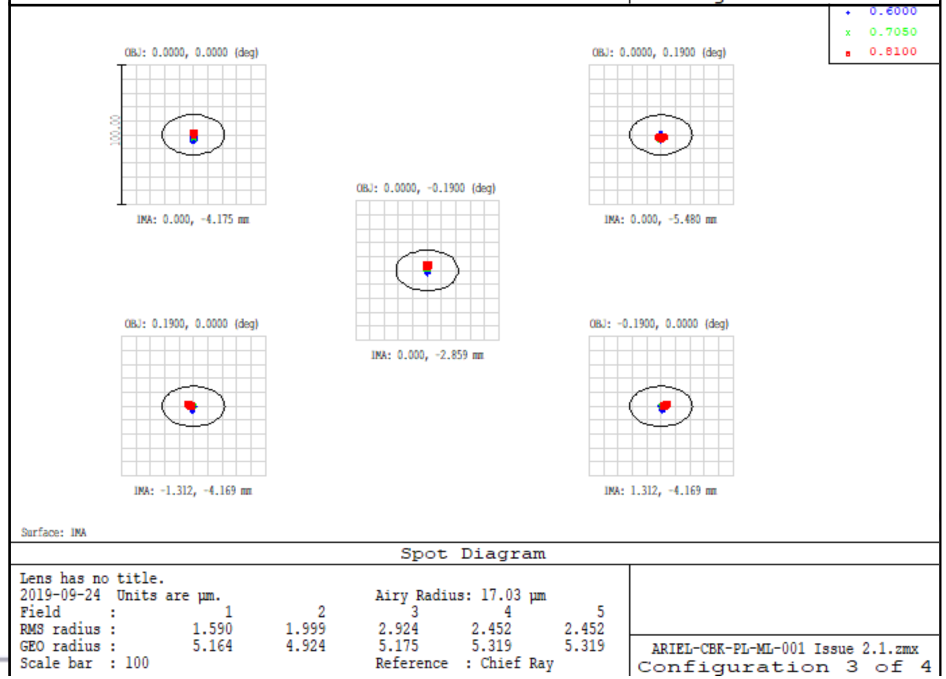
Diffraction limited

VISPhot
0,5 – 0,6µm



FGS-2
0,8 – 1,05 µm





FGS Optical Module Design

FGS – 1: 0,6-0,81 µm
VIS-Phot : 0,5 -0,6 µm

FoV of single px - 170mas

FGS – 2: 0,81 – 1.0 µm (main)
NIR Spec: 1.0 -1,95 µm

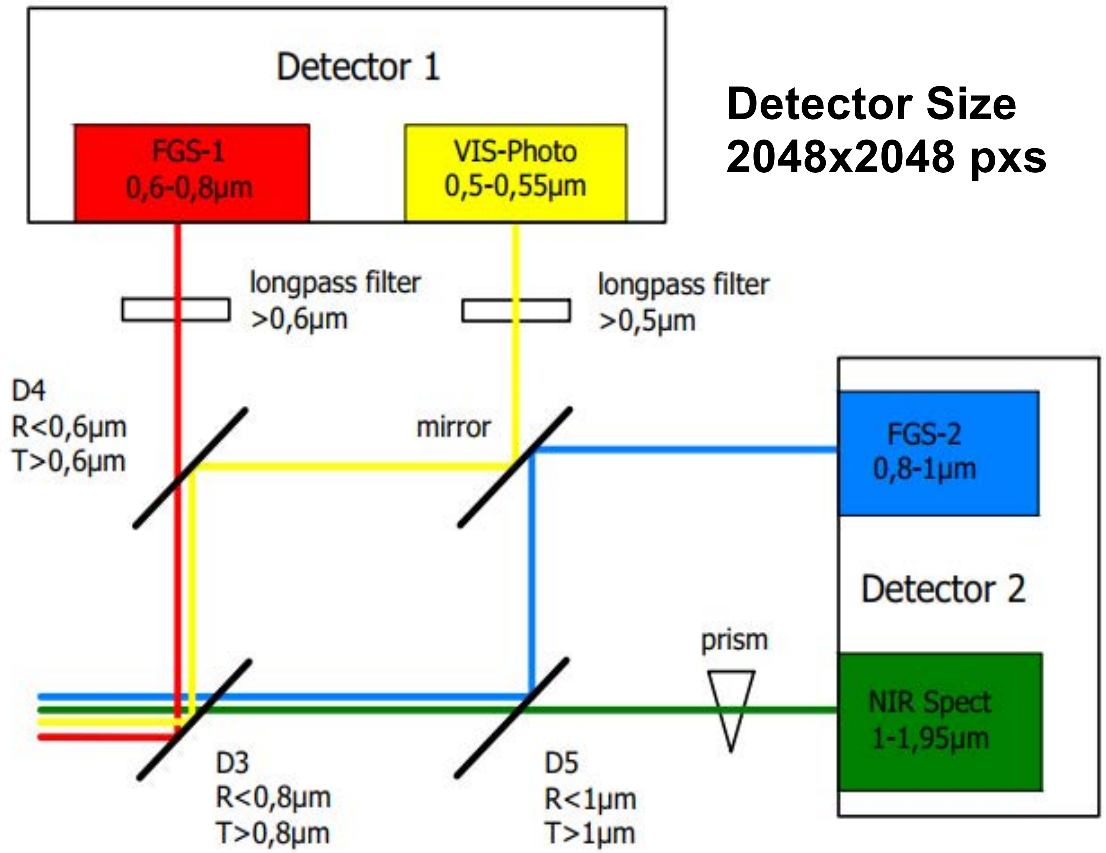
FoV of single px - 140 mas
LRS spectral resolving power R >15 (goal)

Size of FoV (windows)
in pixels

FGS – 1	148x148 pxs
VIS-Phot	240x240 pxs
FGS – 2	185x185 pxs
NIR Spec	212x135 pxs

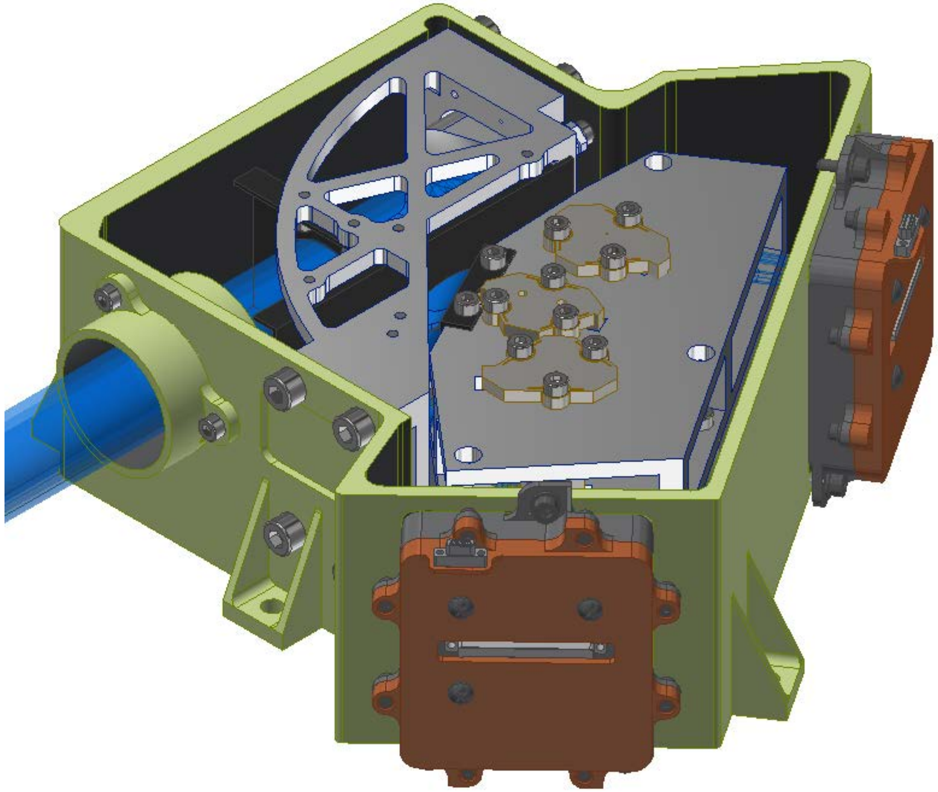
Size of windows for data collection

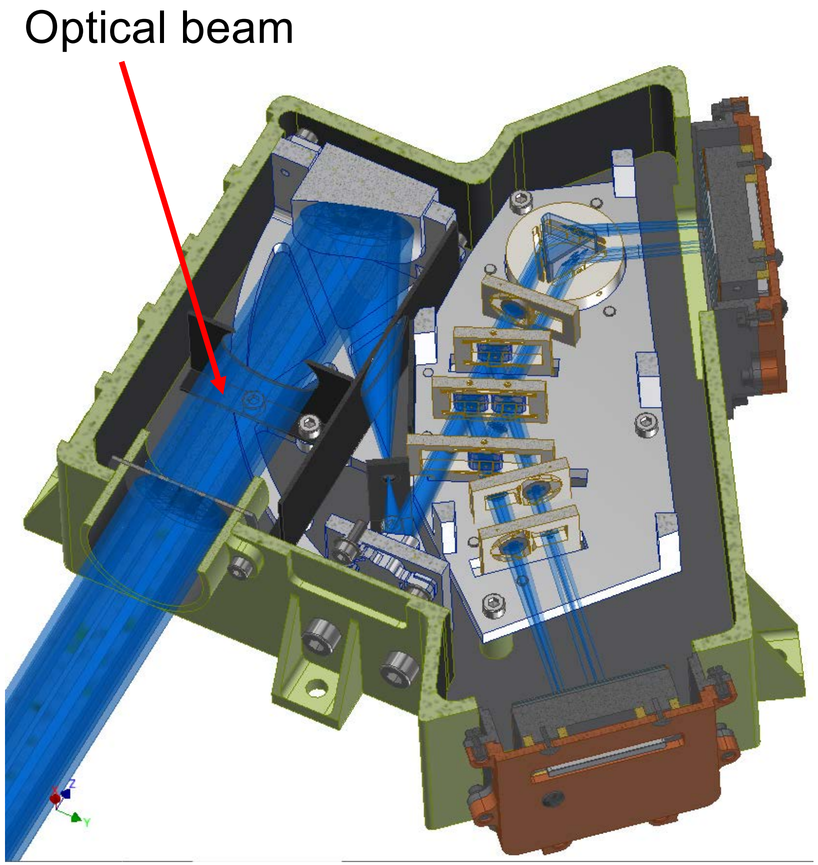
FGS-1, FGS-2, VIS - 30x30pxs
NIR Spec - 128x64pxs



Detector Size
2048x2048 pxs

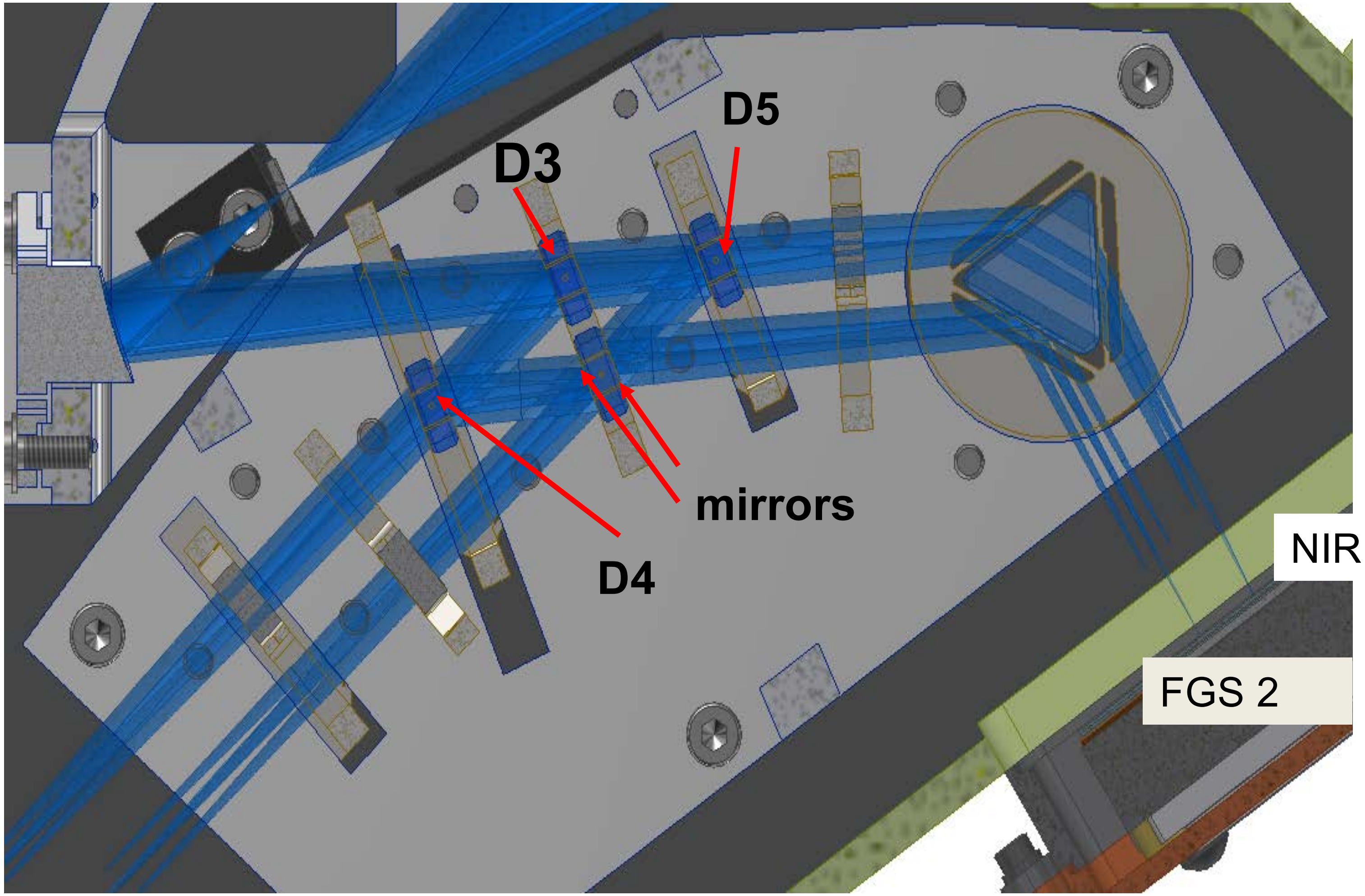
FGS Mechanical Design





Mass 2kg including
20% margin

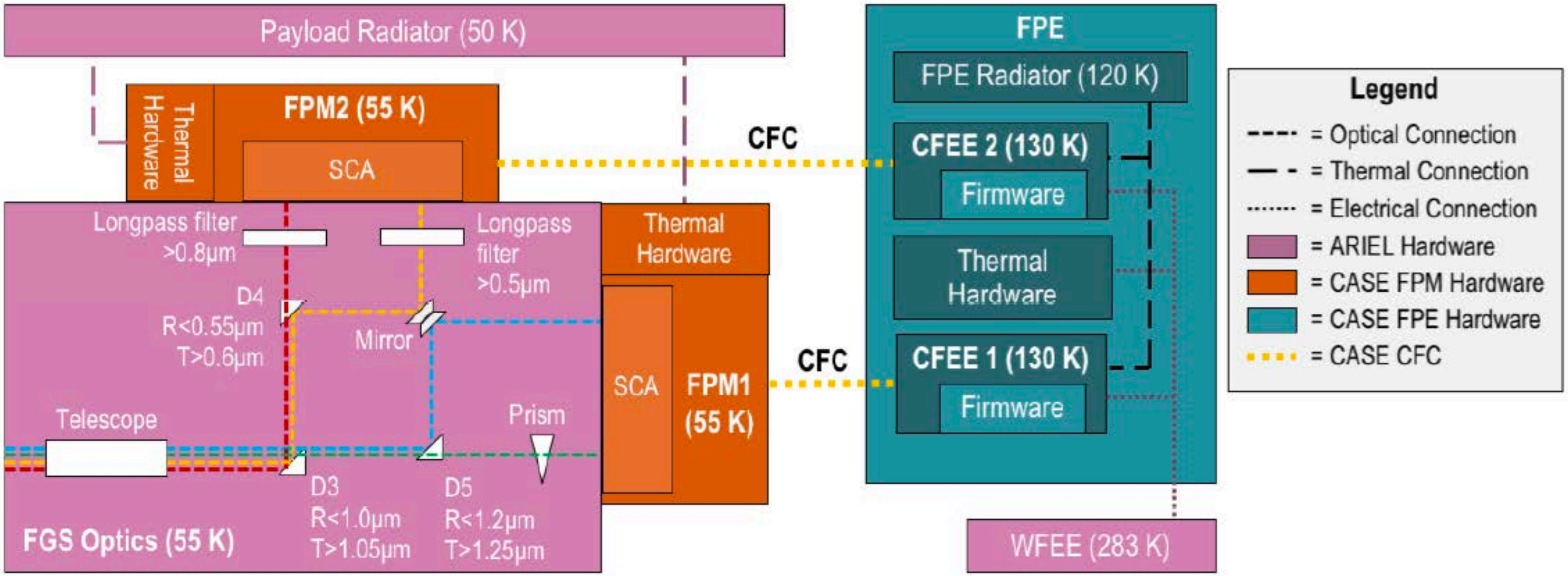
FGS Mechanical Design



VIS-Phot

FGS-1

CASE Block Diagram



FGS Module – Concept JPL

Heritage from EUCLIDE

3-point kinematic mount
w/ pinned interface
(primary interface with FGS)

H2RG 2.3um SCA
(image plane surface showing)

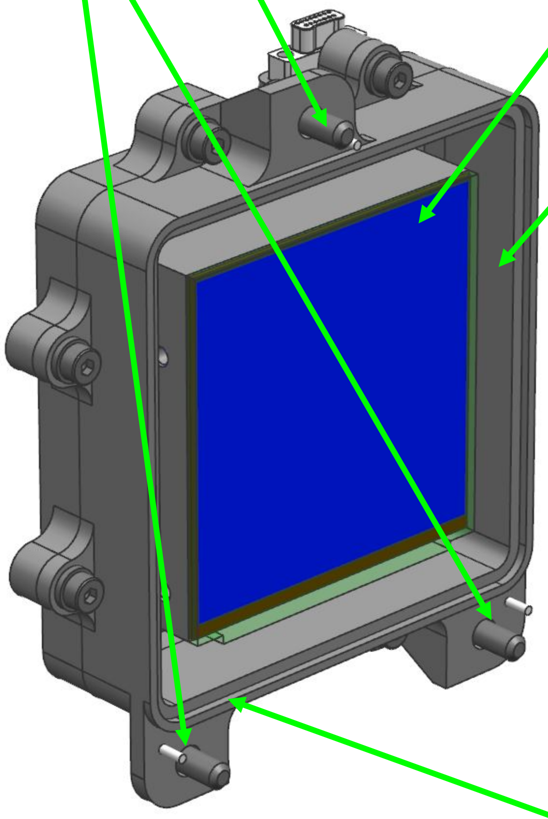
Enclosure (Molybdenum /aluminum)

Temperature Hardware Connector

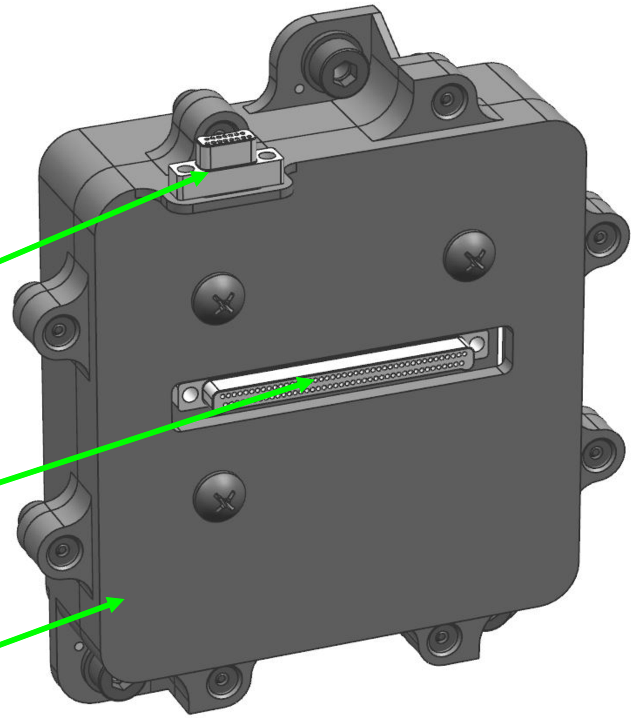
SCA I/O Connector

Rear Enclosure Panel (SCA mounting interface)

Front Enclosure Panel (FGS mouting interface)



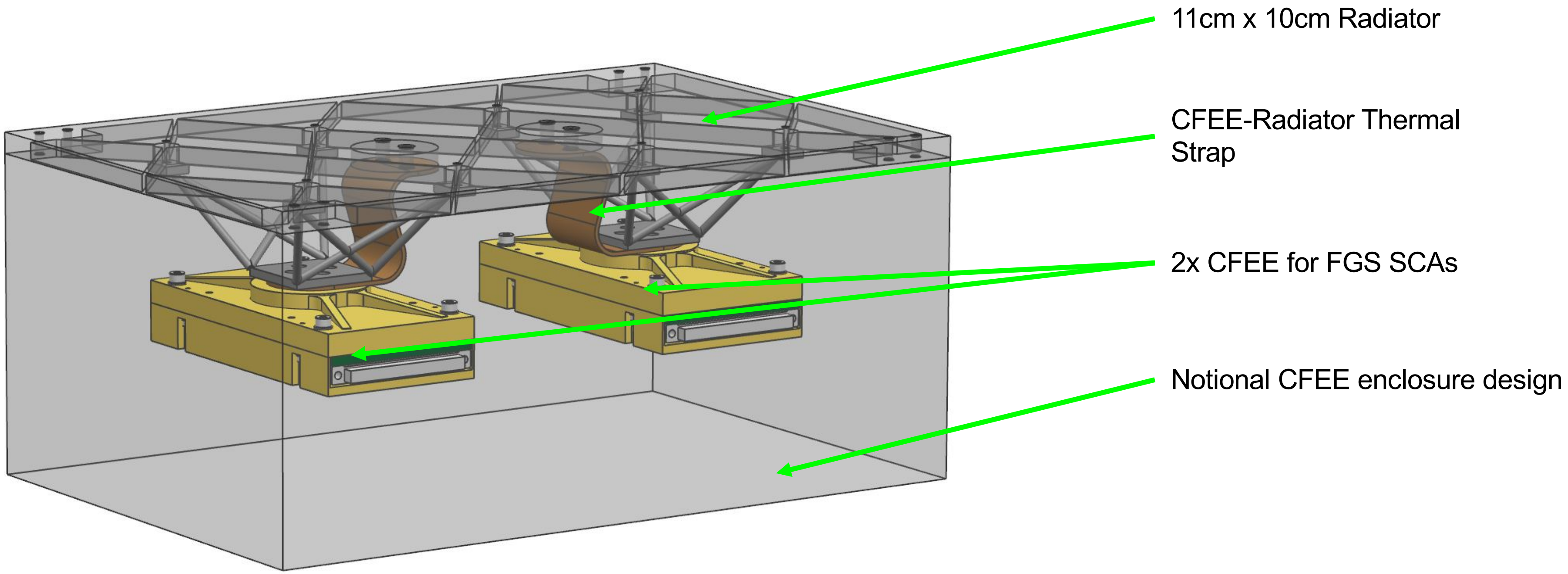
Front View (towards FGS)



Rear View (away from FGS)

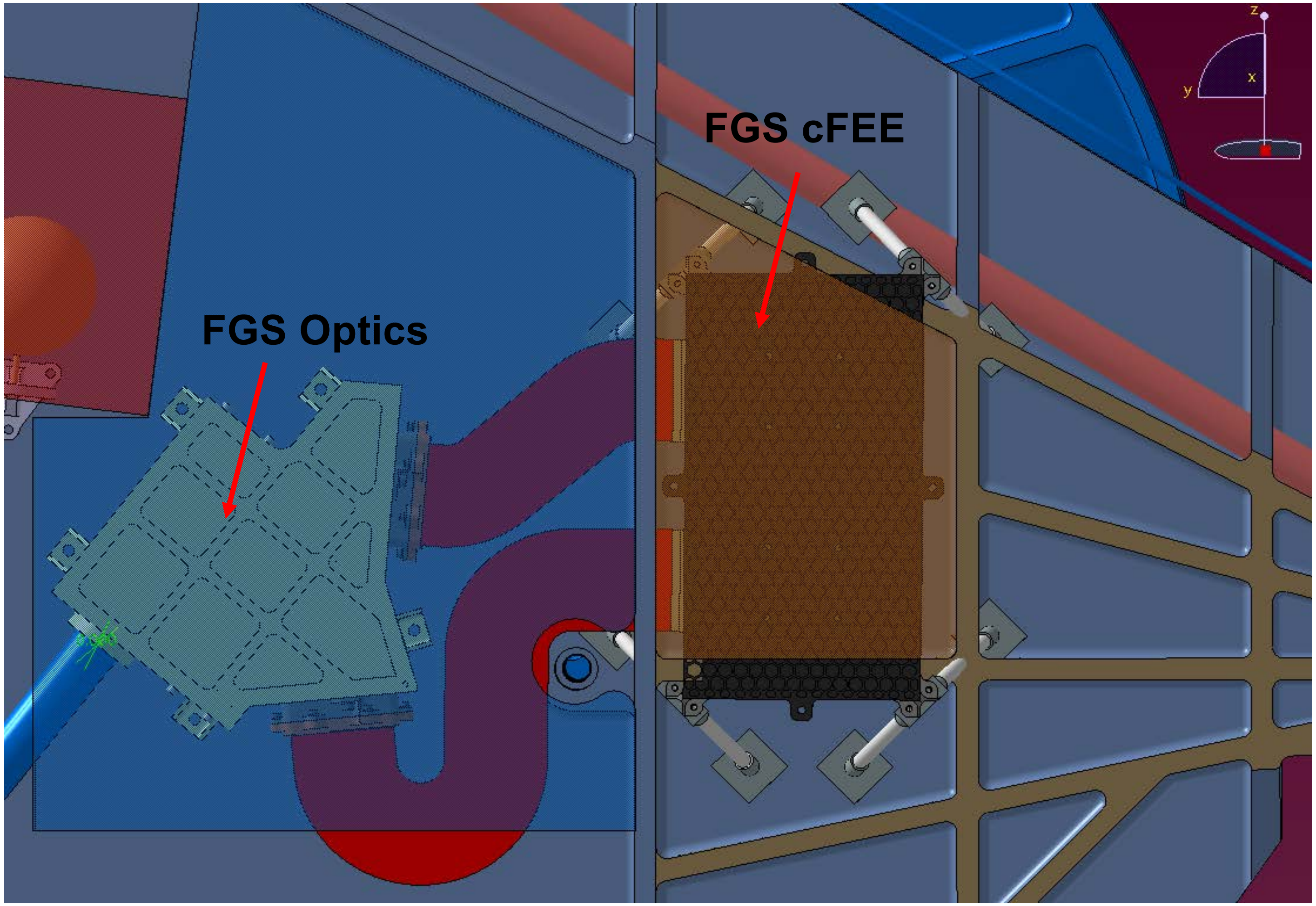
CFEE- Concept

Heritage from EUCLIDE



Mass: 3,6 kg + 20% margin

FGS top level architecture



FGS Control Unit (FCU) Hardware

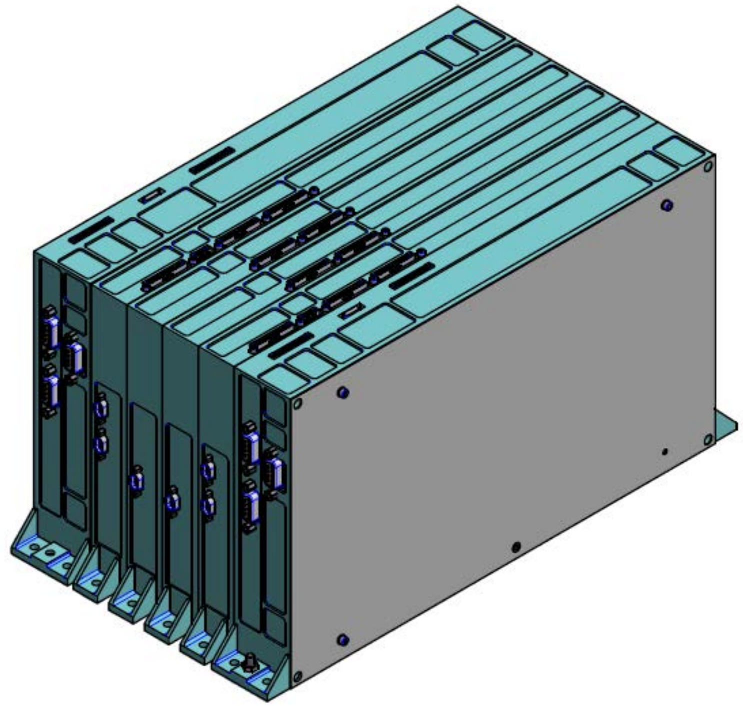
The FGS control electronics (FCU) in the service module consists of the following sub-units:

- **DCU – Detector Control Unit – is responsible for controlling Sidecars;**

- **DPU – Data Processing Unit – controls all subsystems in FGS, includes a processor on which the Flight Software is executed and SpW interface towards s/c;**

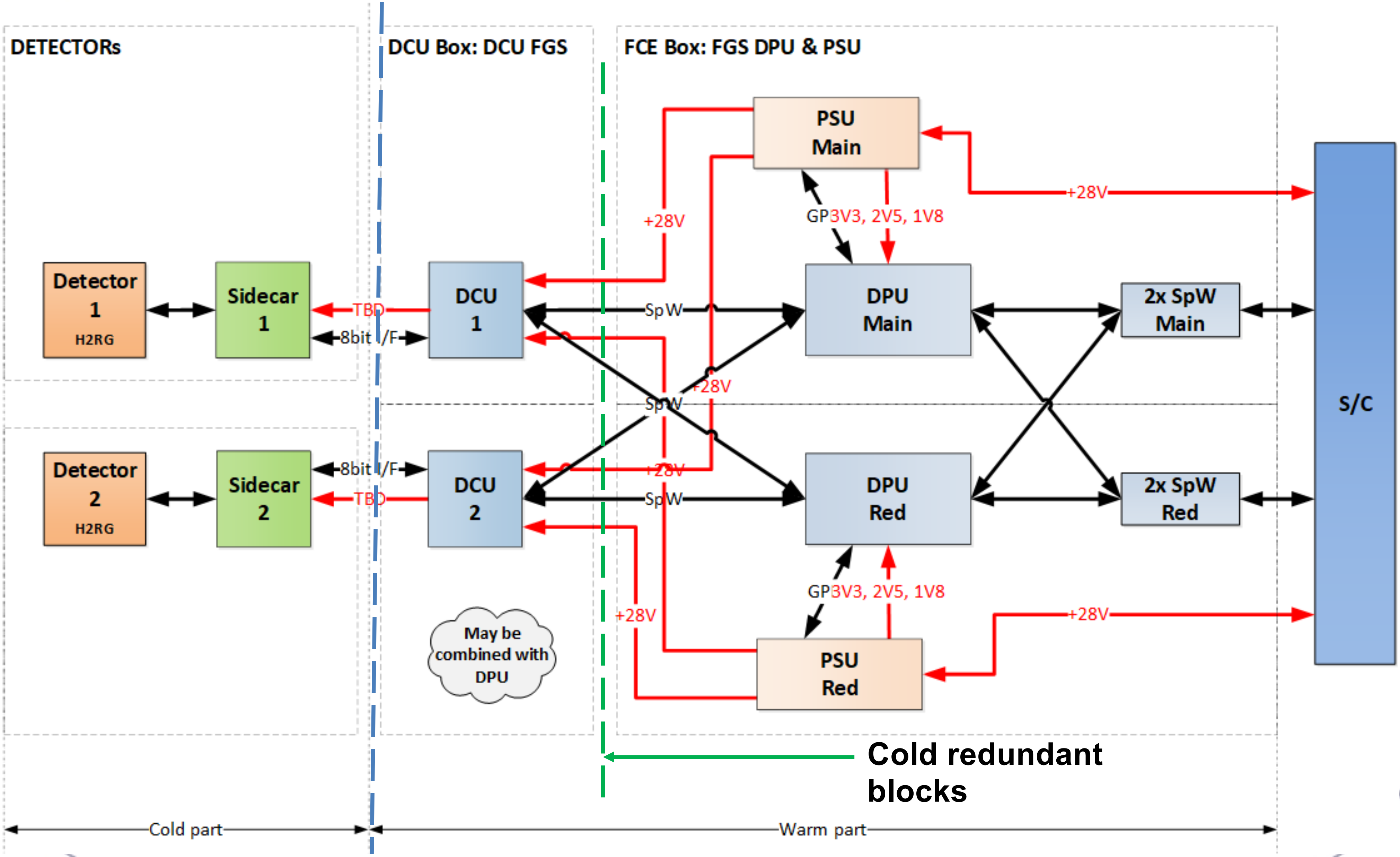
- **PSU - Power Supply Unit –provides secondary voltages to the FGS components.**

- **Mechanical chassis:**
typical warm electronics box,
with a total mass estimation of 8.5 kg ±20%

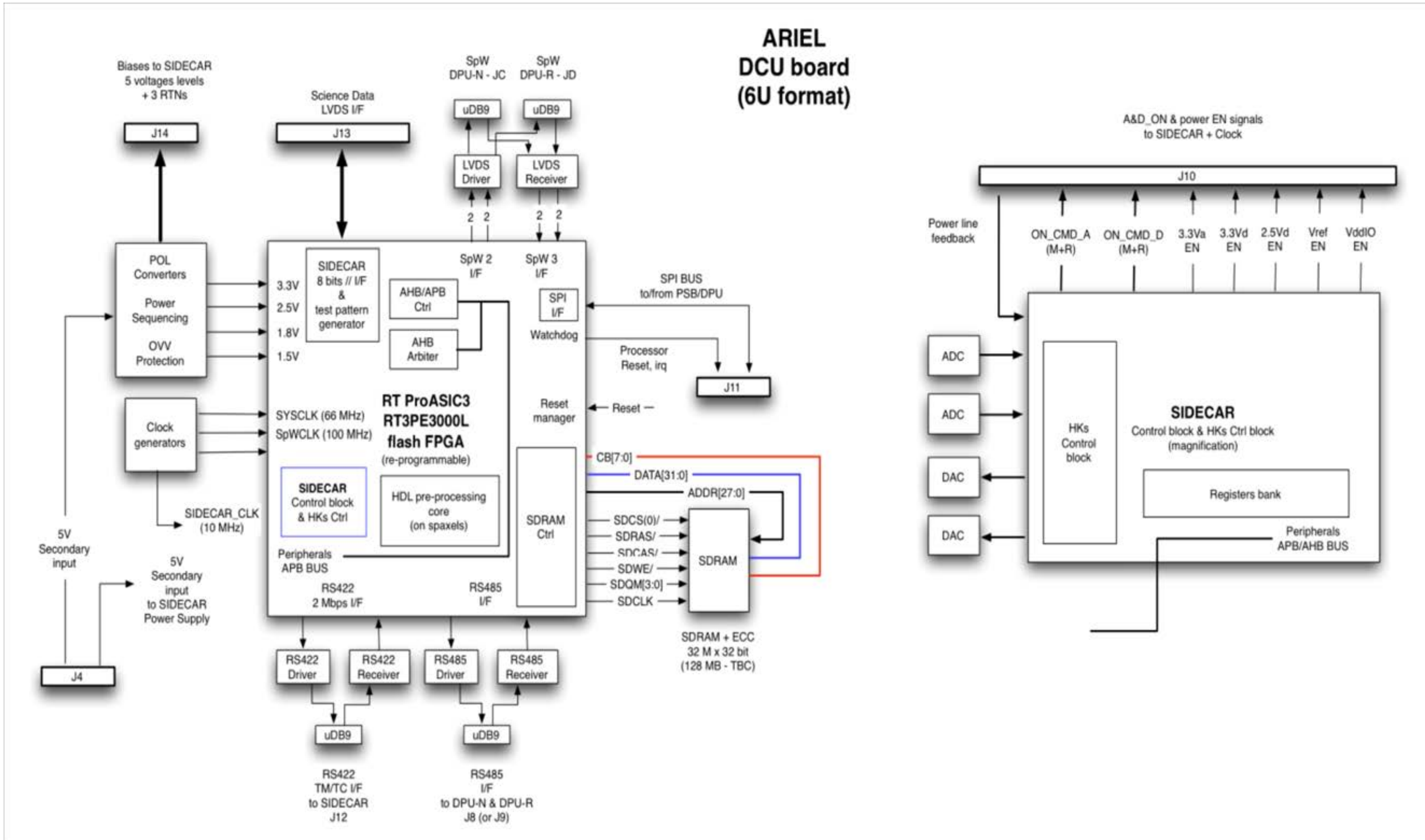


- **Power consumption: 26W with margin.**

FGS Control Unit (FCU) Hardware

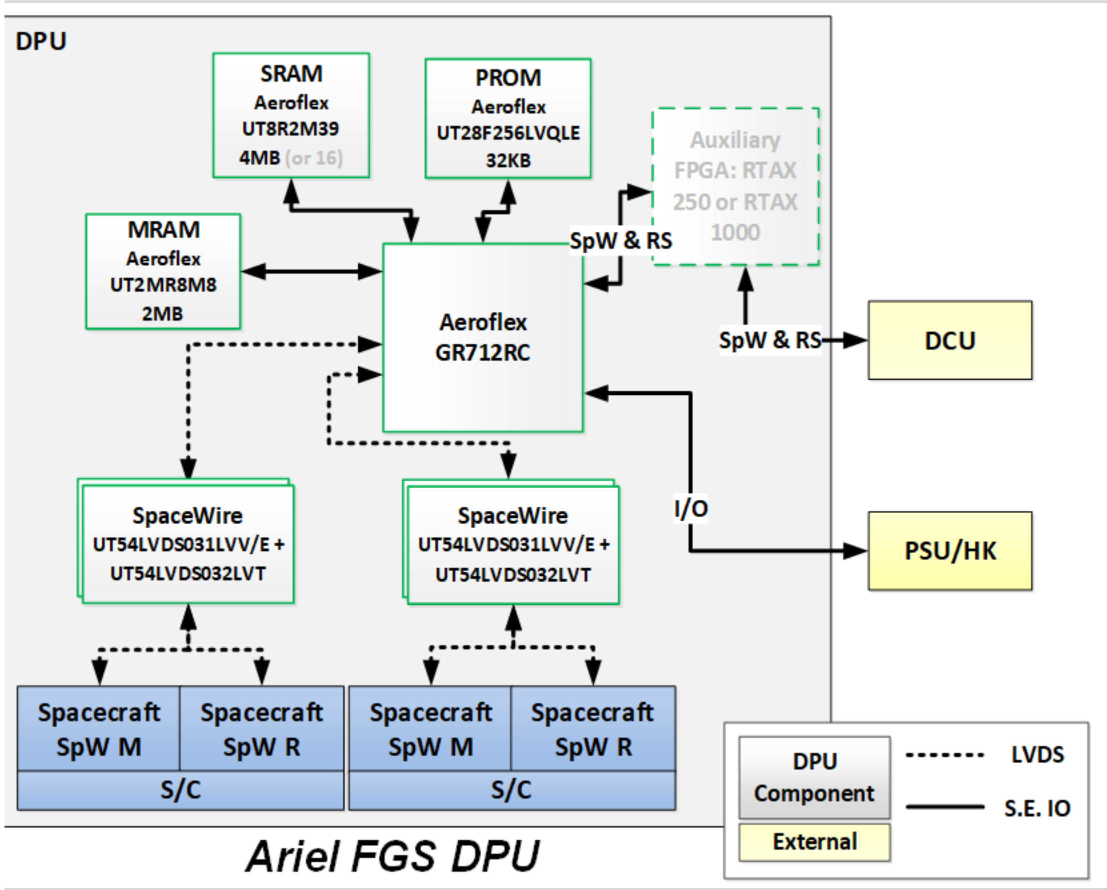


Detector Control Unit Design



The design of DCU for FGS is the same as proposed by ICU team EUCLID heritage. PCBs will be delivered by Italian team with small modification defined by CBK

FGS DPU Scheme



The central element of the DPU is Aeroflex GR712RC chip that implements Leon3FT processor.

The CPU will be clocked with 40MHz oscillator.

4MB SRAM memory from AEROFLEX
2MB MRAM memory from Aeroflex
PROM memory to store Start-up SW (Boot SW).

All memories will be protected by (39,7) BCH based EDAC provided by the fault tolerant memory controller (FTMCTRL) of GR712RC.

The design concept is similar to development made by CBK for SWI instrument for JUICE mission, where CBK is responsible for the DPU and PSU units. Similar architecture was also used by CBK in Proba3 project for Coronagraph Control Box.

FGS Software

SW provided by UVIE (AT)

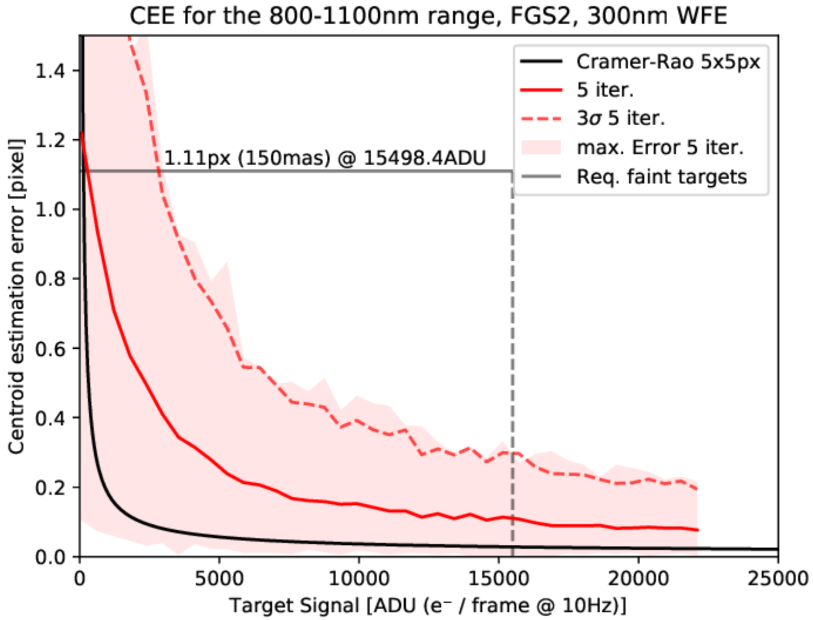
- ECSS SW based on CHEOPS (uses same HW)
- commanding and data processing tasks
  - FCU control, FDIR, time sync, heartbeat, heaters
  - finding, focussing, guiding the target
  - science procedures (NIR Spec, VIS Phot)
  - lossless compression of science data

The FGS shall permit in-orbit reprogramming of its software

The FGS shall download the complete detector images on command.

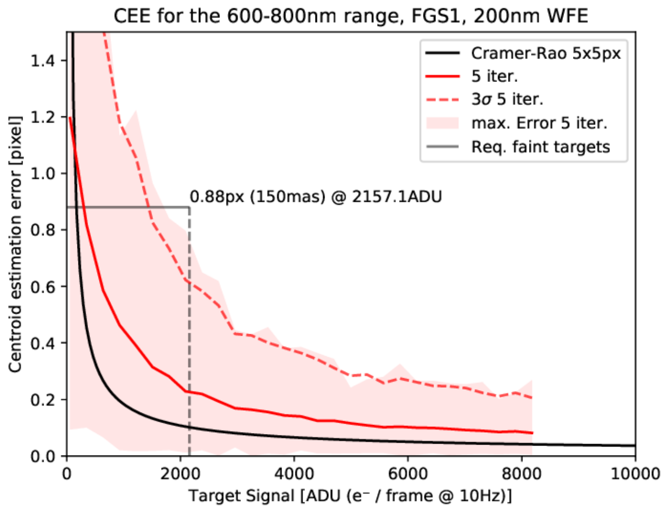
FGS Centroiding Performance

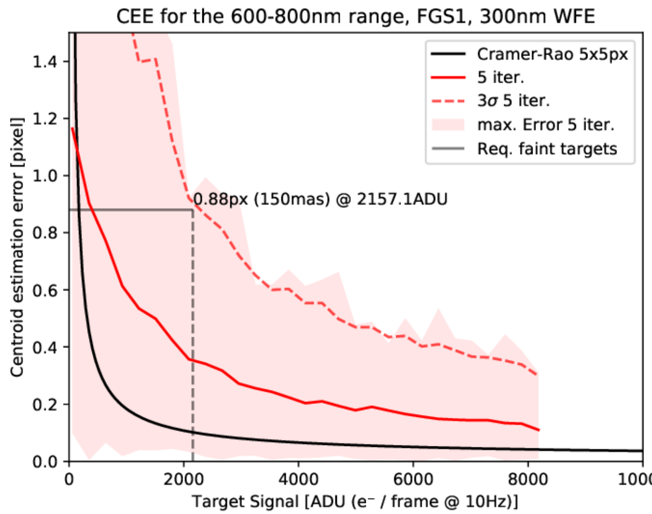
The performance of the algorithms is constantly assessed in Monte-Carlo simulations, making the consequences of requirements changes directly visible.



FGS 2 (main): required centroid measurement performance is easily met for all faint and bright targets, *even at 300 nm WFE.*

FGS 1: less signal → more challenging. *For 300 nm WFE we start struggling at the faint end.*





Thank you for attention