ARIEL Open Science Conference

ARIEL Payload Design Overview

Paul Eccleston

ARIEL Mission Consortium Manager

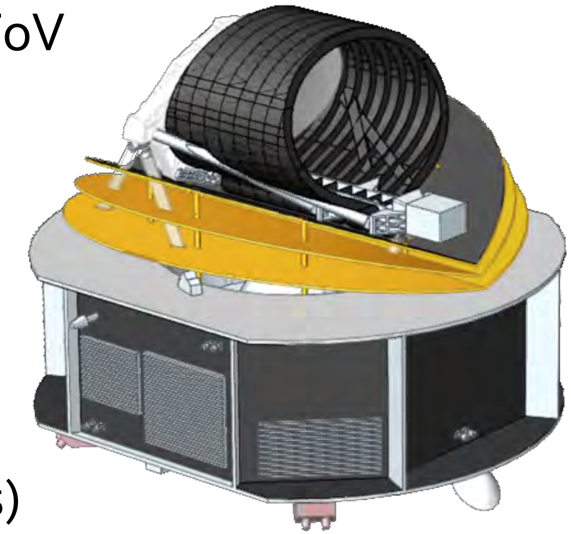
Chief Engineer – RAL Space – UKRI STFC

Introduction

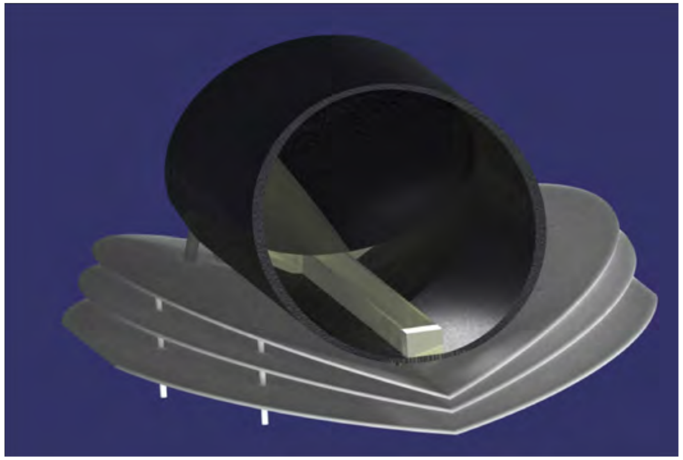
- Overview of current baseline design of payload:
  - System architecture
  - Telescope system
  - ARIEL InfraRed Spectrometer (AIRS)
  - FGS / NIRSpec
  - Thermal, Mechanical & Electronics overall concepts and performance
  - Ground Support equipment and calibration planning
- Management and Programmatic Considerations

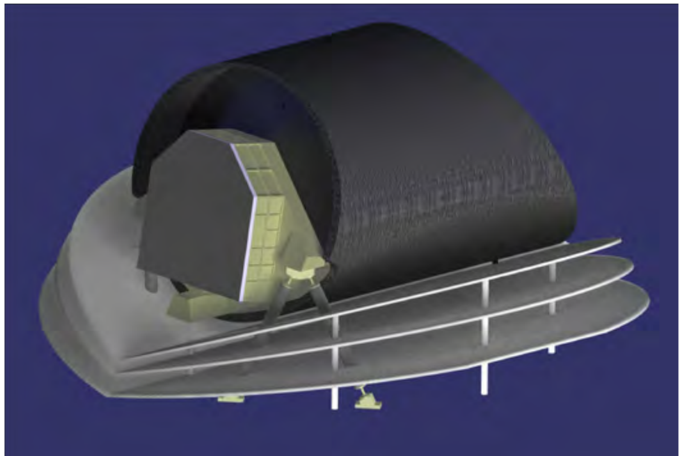
Key Payload Performance Requirements

- > 0.6m² collecting area telescope, high throughput
- Diffraction limited performance beyond 3 microns; minimal FoV required
- Observing efficiency of > 85%
- Brightest Target: Kmag = 3.25 (HD219134)
- Faintest target: Kmag = 8.8 (GJ1214)
- Photon noise dominated including jitter
- Temporal resolution of 90 seconds (goal 1s for phot. channels)
- Average observation time = 7.7 hours, separated by 70° on sky from next target
- Continuous spectral coverage between bands

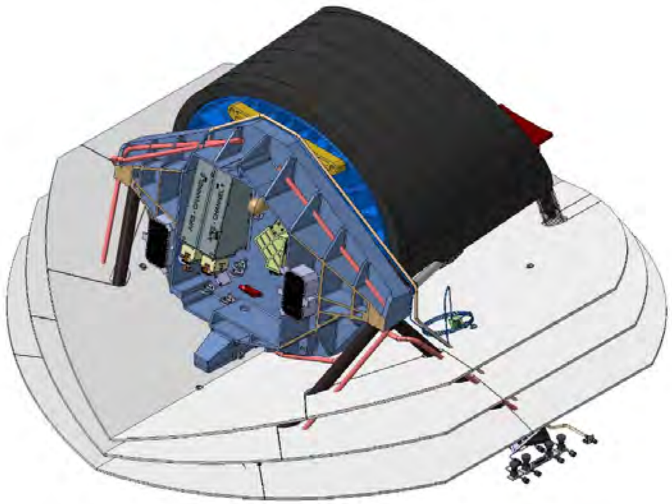


Evolution of Payload Design

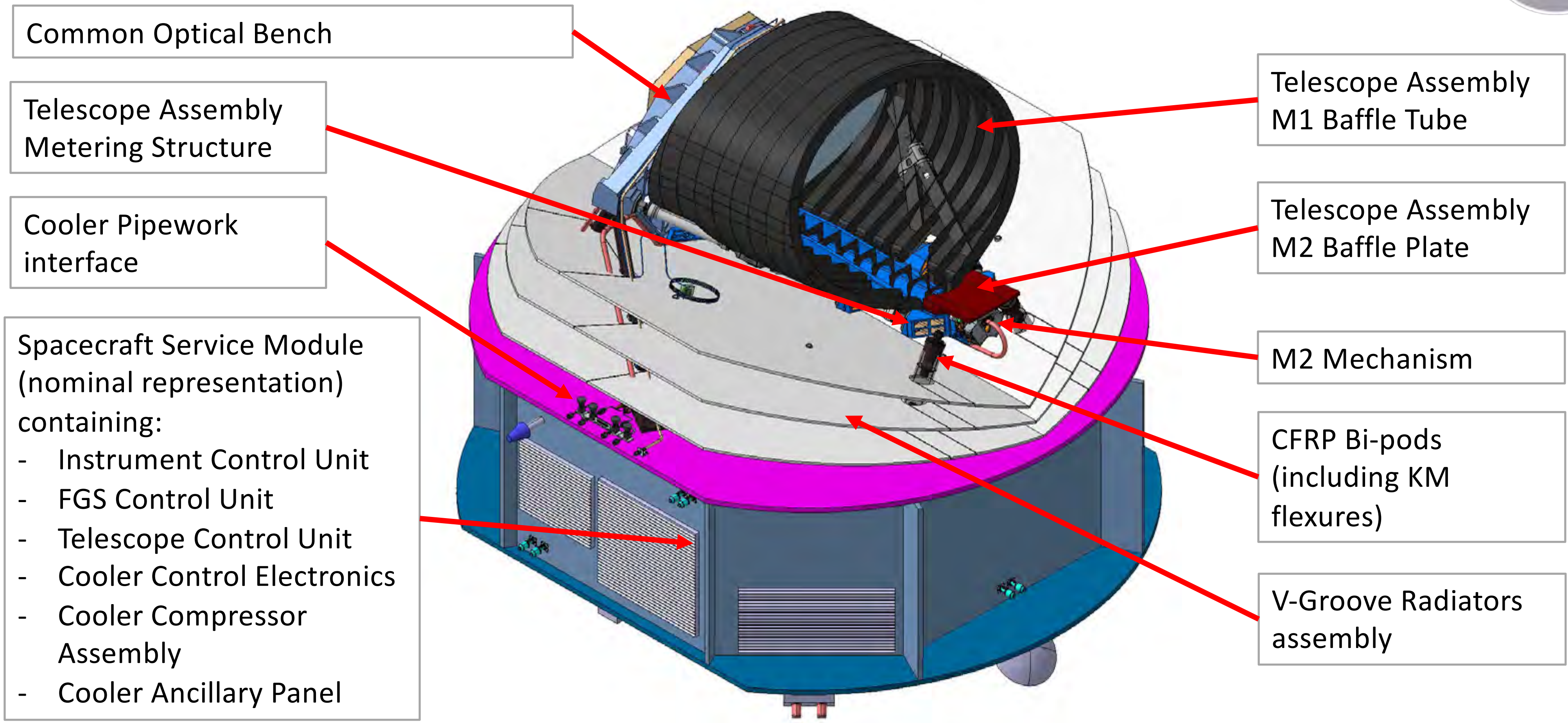




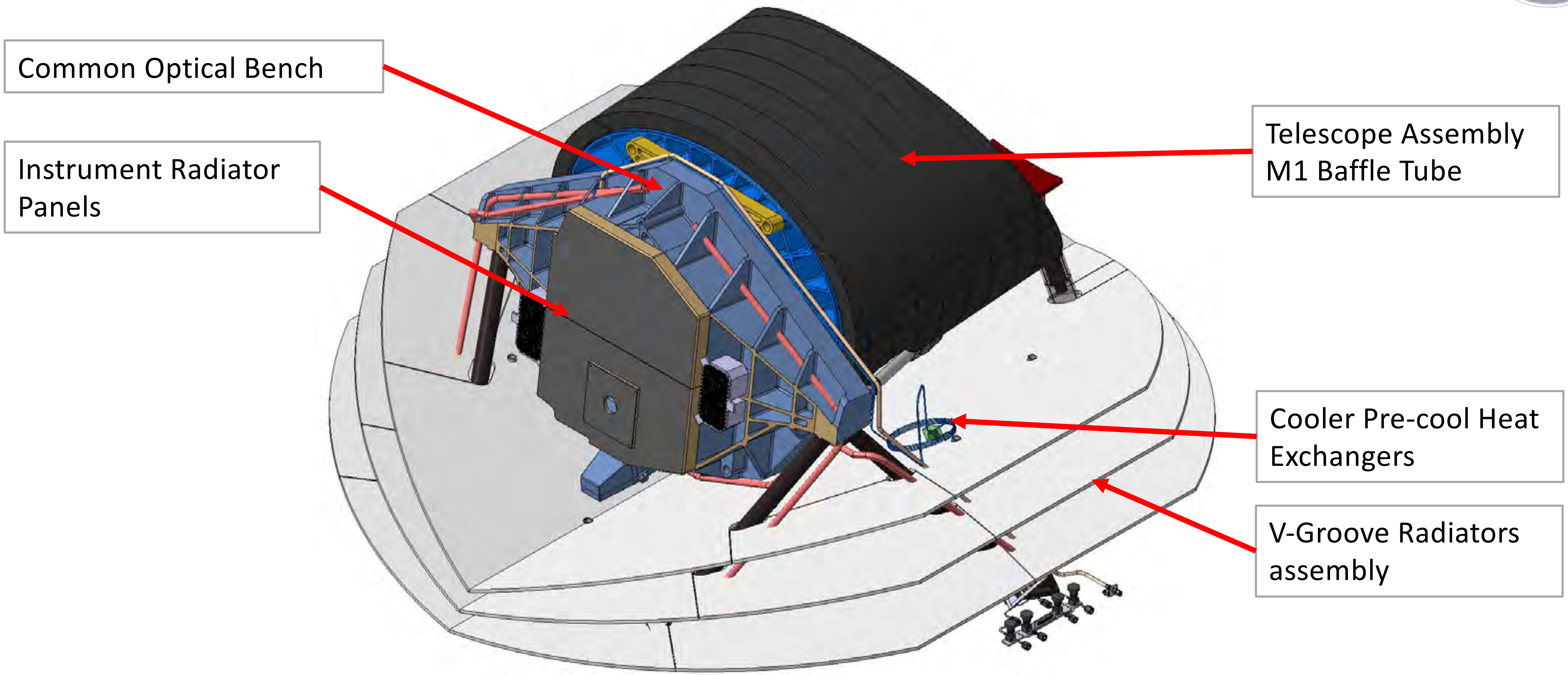
Phase A / B1
Design Work



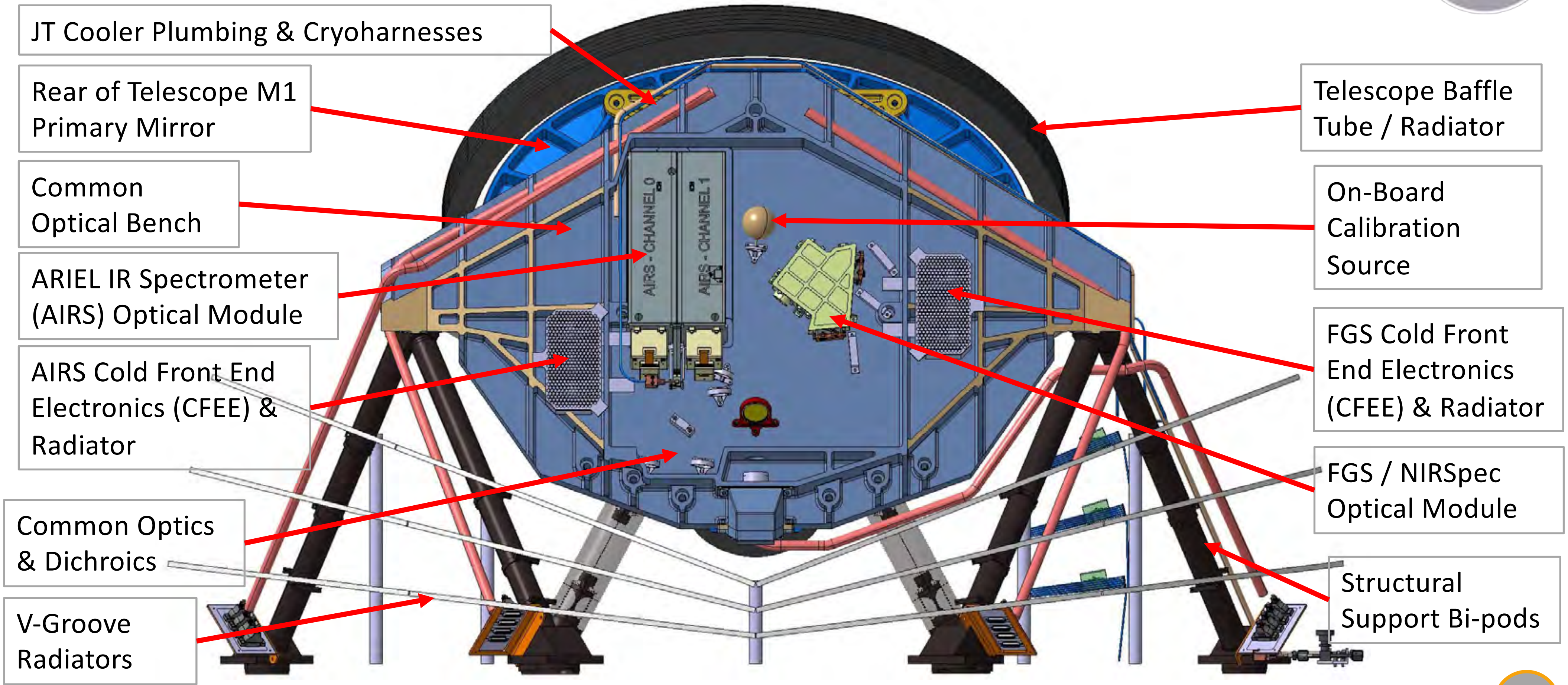
Overview of Payload Module - Front



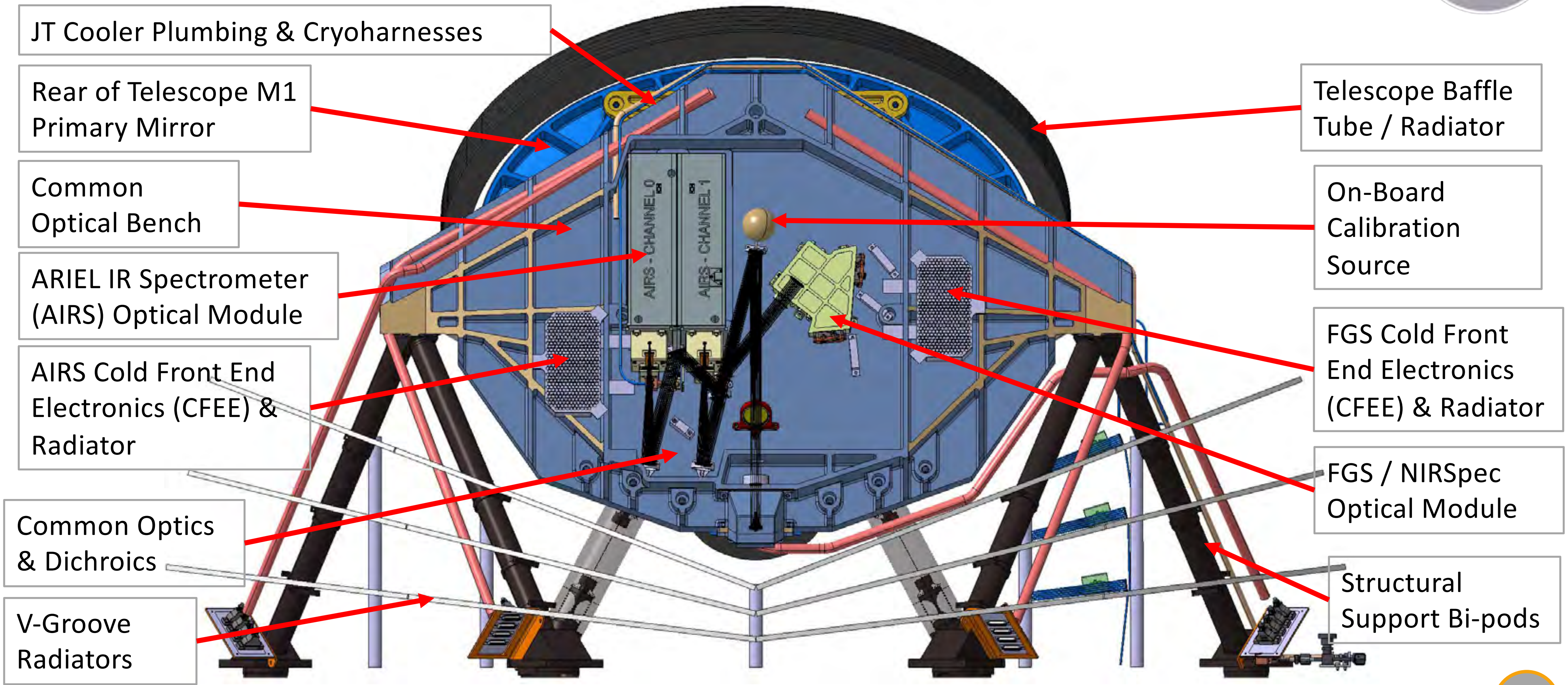
Overview of Payload Module - Rear



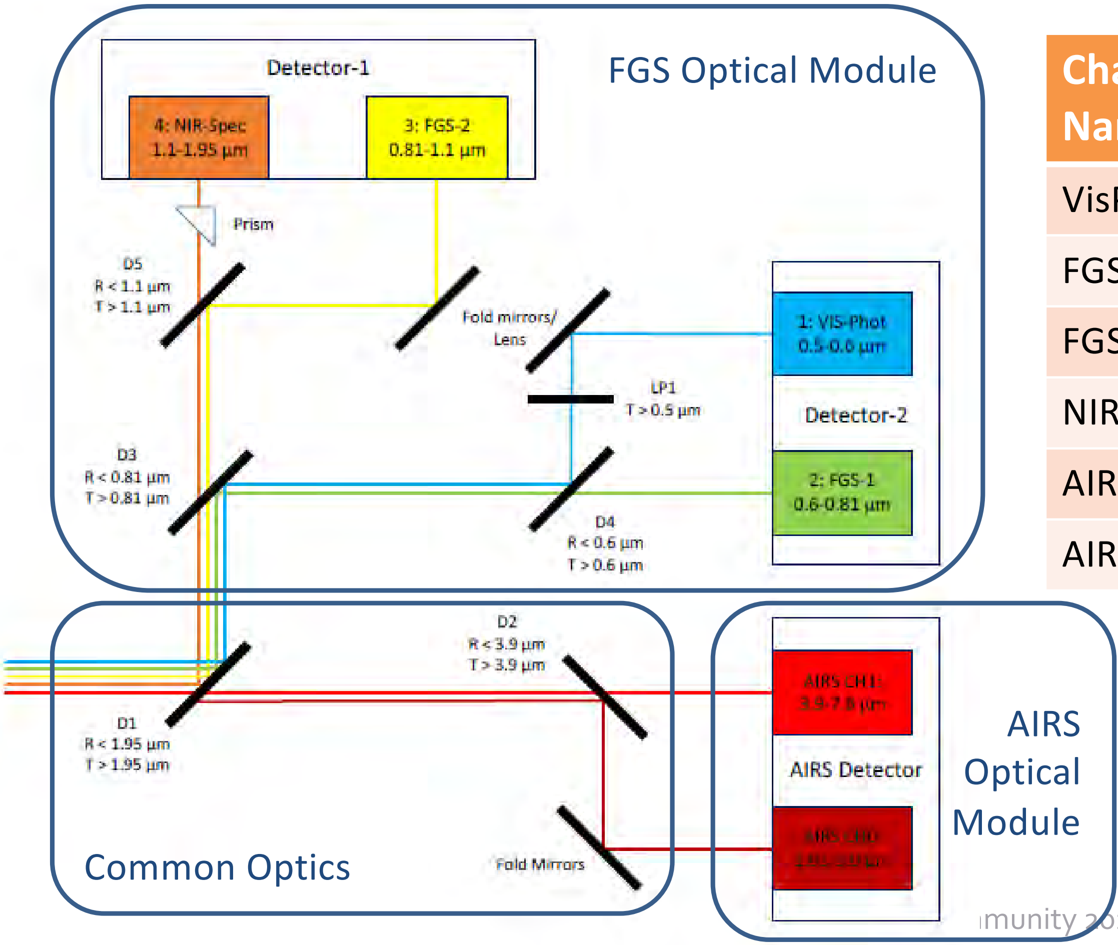
Overview of Payload Module - Rear



Overview of Payload Module - Rear

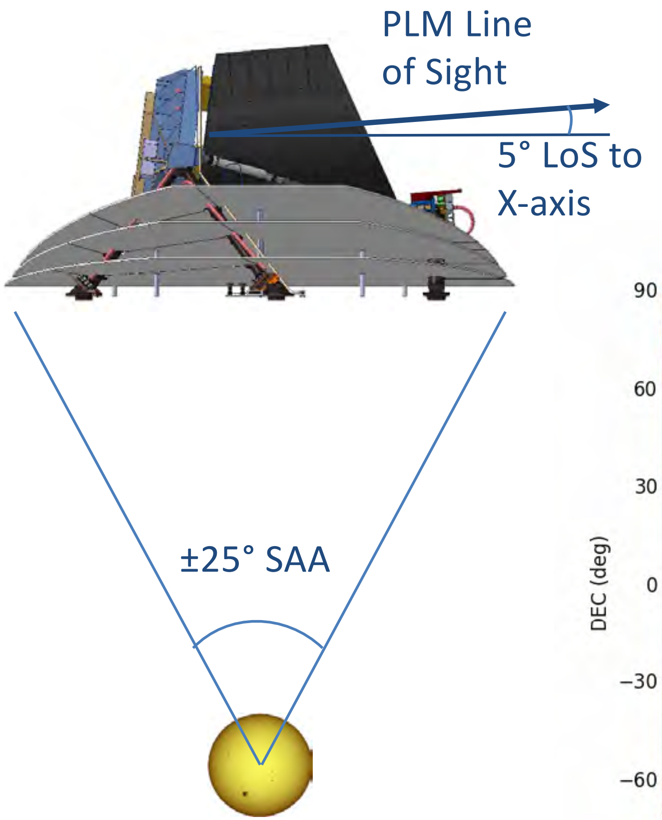


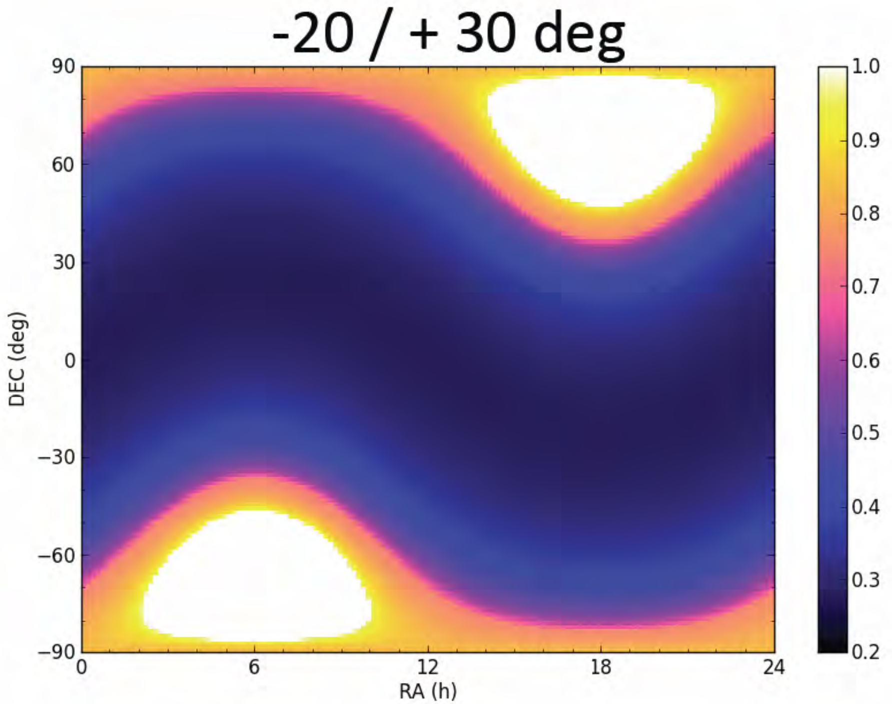
Optical Architecture – Channel Division and Definition

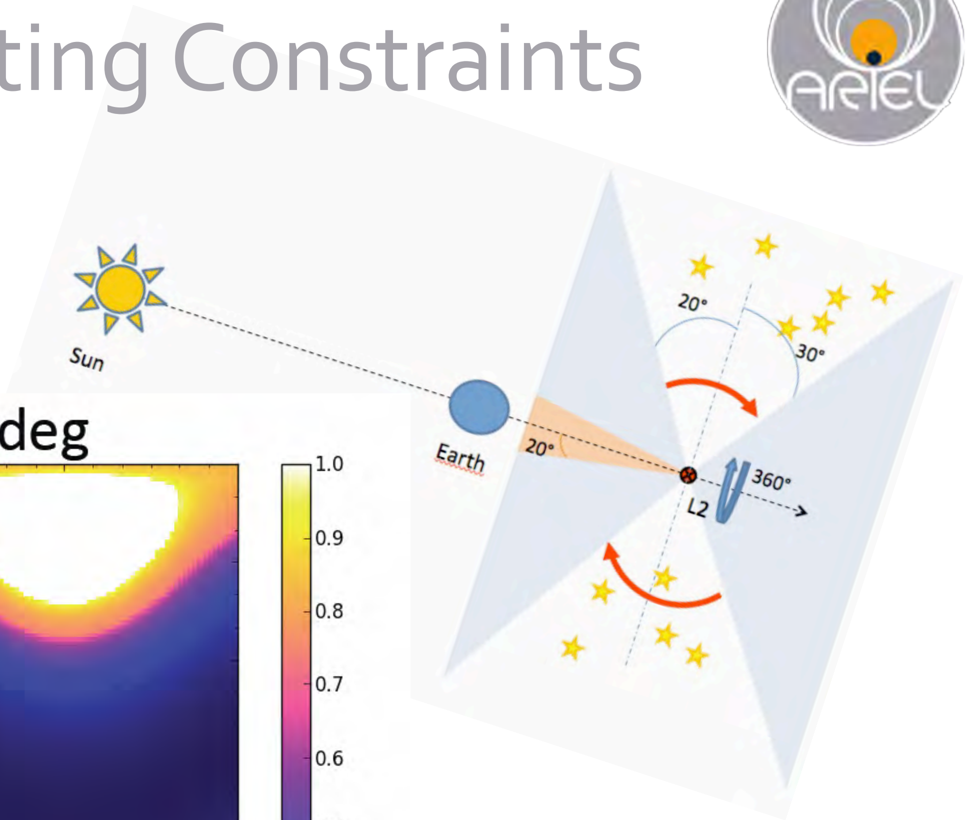


Channel Name	Wavelength (mm)	Spectral Resolution Reqt / Current Design
VisPhot	0.5 – 0.6	Photometer
FGS-1	0.6 – 0.8	Photometer
FGS-2	0.8 – 1.1	Photometer
NIRSpec	1.1 – 1.95	R≥15 / 15 - 20
AIRS-Ch0	1.95 – 3.9	R≥100 / 102 – 180
AIRS-Ch1	3.9 – 7.8	R≥30 / 30 – 64

Field of Regard and Pointing Constraints





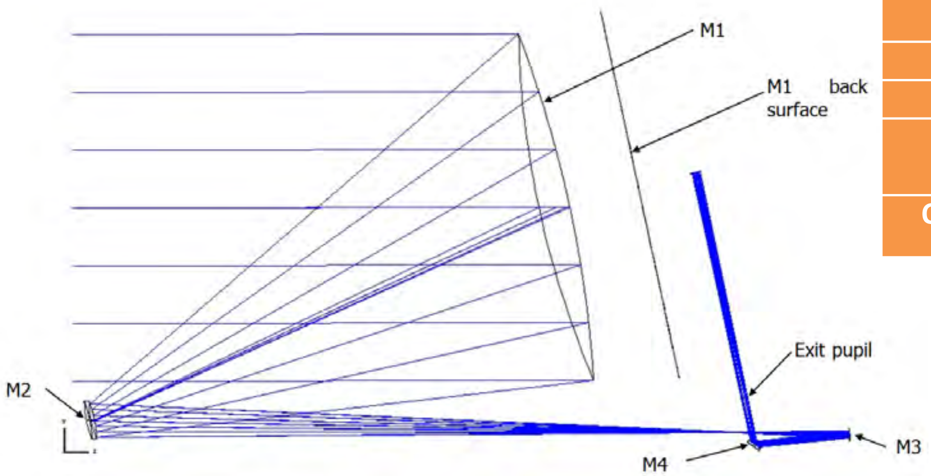


See details of impact in Scheduling talk – Weds @ 10:20

Telescope Assembly: Optical Design

- Off-axis Cassegrain telescope with recollimating tertiary mirror
- Redefinition and optimisation of phase A design is on-going – moving to free-form optics surface definitions
- All-aluminium design

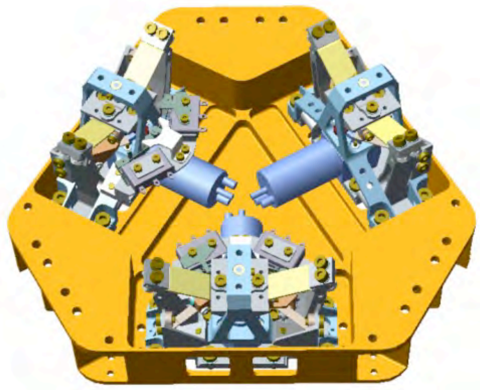
Parameter	Value
Collecting area	>0.6 m2; 1.1 x 0.7 m elliptical
FoV	30” with diffraction limited performance 41” with optical quality TBD allowing FGS centroiding 50” unvignetted
WFE	Diffraction limited @ ~3 µm; <200nm rms WFE
Wavelength range	0.50-8 µm
Throughput	Minimum >0.78 Average >0.82
Output beam dimension	20.0 x 13.3 mm elliptical

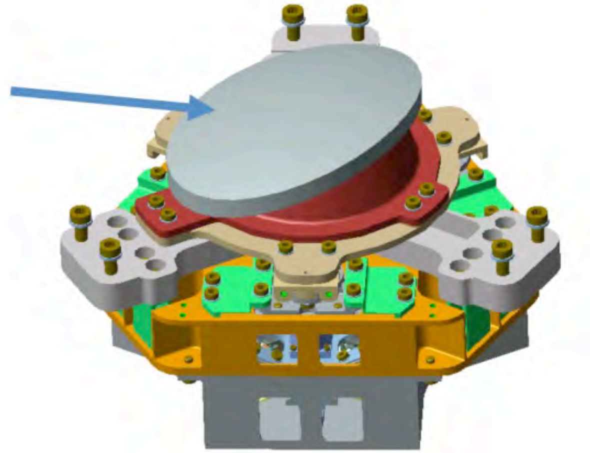


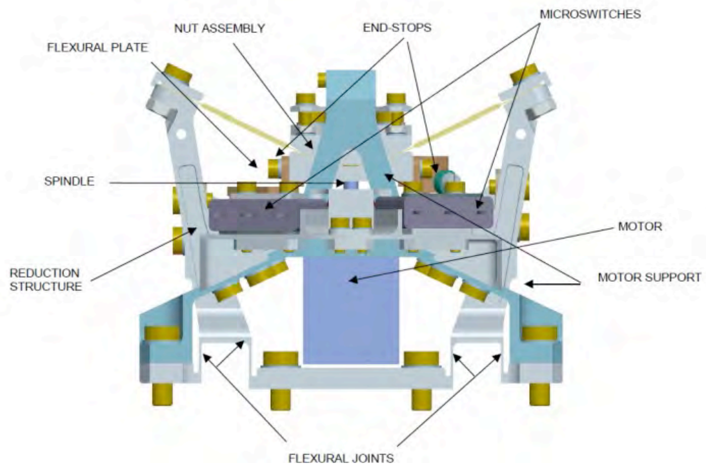
See details in Telescope Assy Talk – Weds @ 09:00

Telescope Assembly: M2M Mechanism

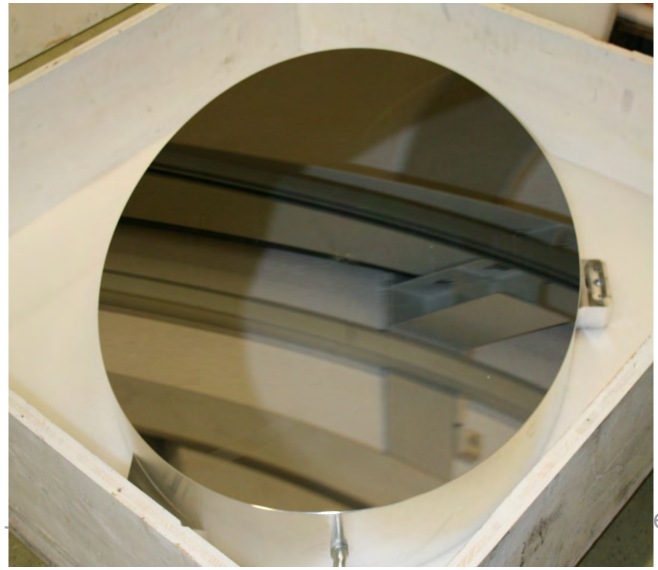
- Movement of M2 mirror along X axis: +/- 350 μm to accuracy of +/- 2 μm
- Rotation about Y & Z axes: +/- 412 arcsec to accuracy of +/- 8 arcsec
- Delta-qualification of actuator assembly (based on Euclid design) to 40K operational temp instead of 100K is on-going as part of ESA TDA
  - To complete in early 2020







Pathfinder Telescope Program



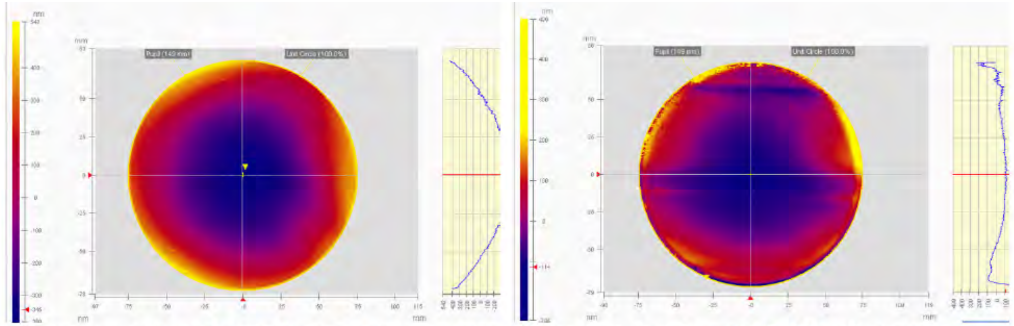


Figure 5-6. 150 mm disc LT1 at 220 nm RMS shape error after DT (left) and at 76 nm RMS shape error after two figuring runs (right).

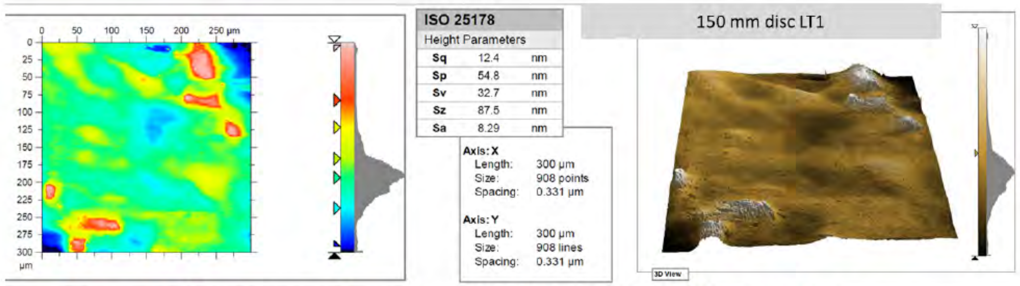


Figure 5-7. Roughness of the 150 mm disc LT1 after two Zeeko polishing runs.

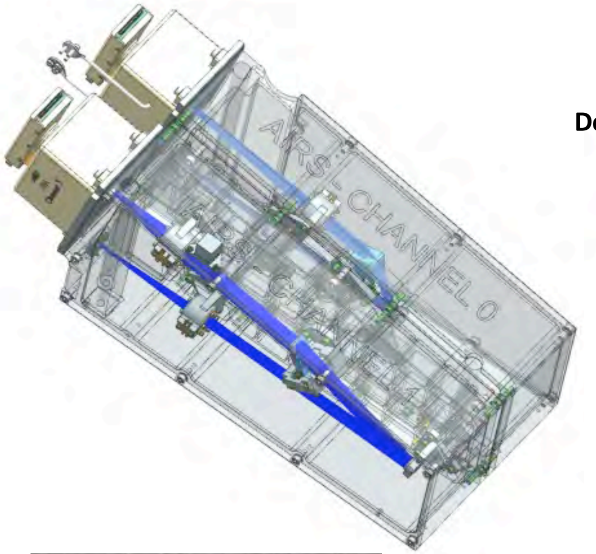
See details in Posters by Da Dappo et al & Pace et al

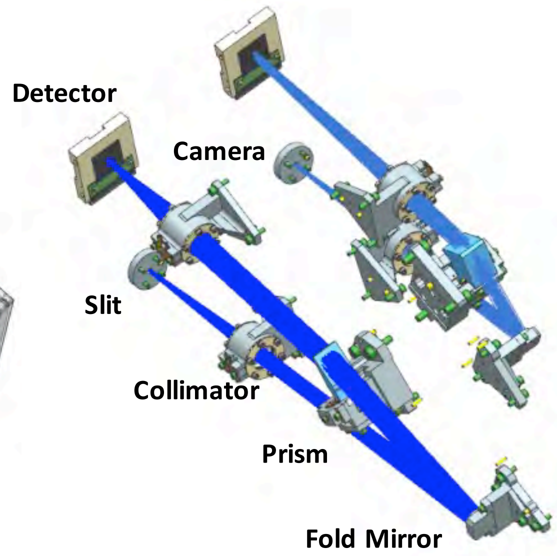
ARIEL InfraRed Spectrometer (AIRS) Architecture

- **Ariel Infra-Red Spectrometer (AIRS)** is the science instrument of the Ariel Payload providing Low Resolution Spectrum of the observed targets over broad IR wavebands covering the [1,95-7,8] μm range.

- AIRS Baseline Architecture is composed of four main architectural blocks:
  1. AIRS Optical Bench (**AIRS-OB**)
  2. AIRS Focal Plane Assemblies (**AIRS-FPA-x**)
  3. AIRS Cold Front End Electronics (**AIRS-CFEE-x**)
  4. AIRS Detector Control Unit (**AIRS-DCU**)

- Common optical bench for both AIRS Channels
- Independent mounting of all optical elements to bench – proto-type mounting in breadboarding



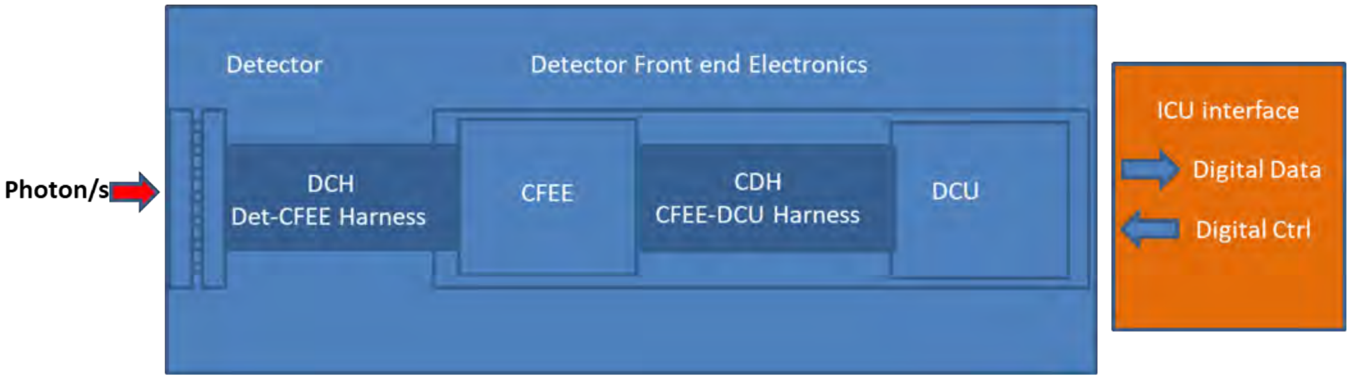


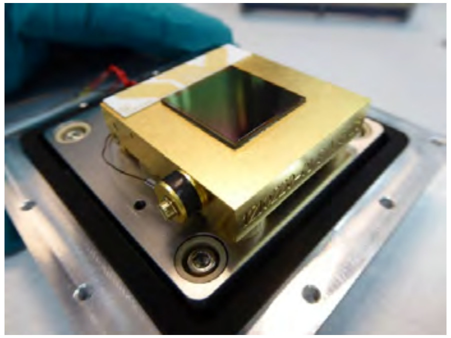
See details in AIRS Talk – Weds @ 09:20

AIRS Detector Chain

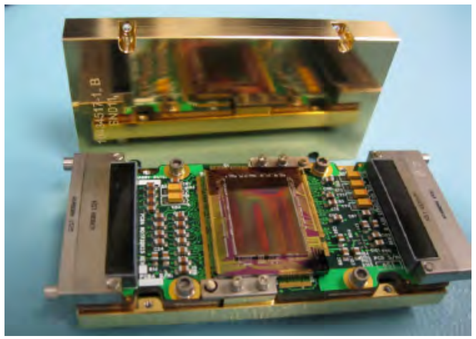
- Ch-1 detector breadboard procured by ESA in phase B1
  - 1 sample currently in test at ESA
  - Second sample going to test at CEA
- Trade-off in process on cold front end electronics
  - SIDECAR @ >130K vs bespoke discrete electronics solution (at AIRS OB temperature)

AIRS Acquisition Chain

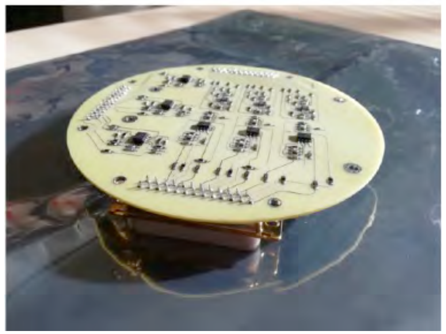




Credit: P-E Crouzet (ESA)

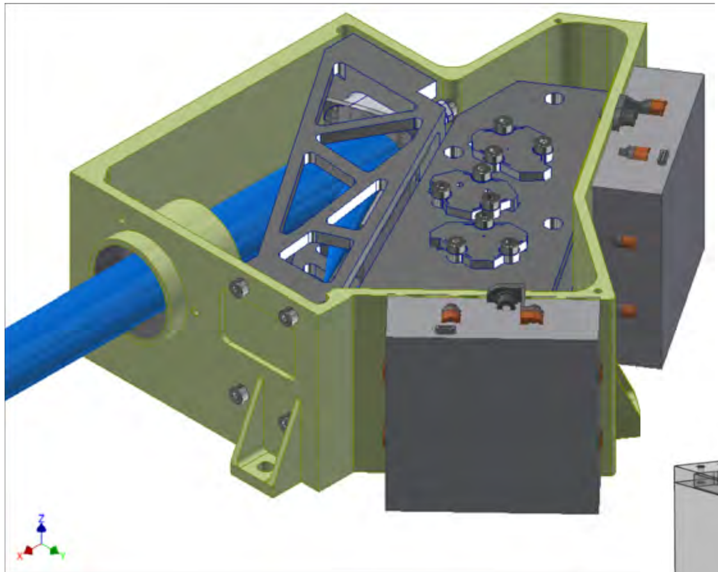


Credit: JPL / Euclid



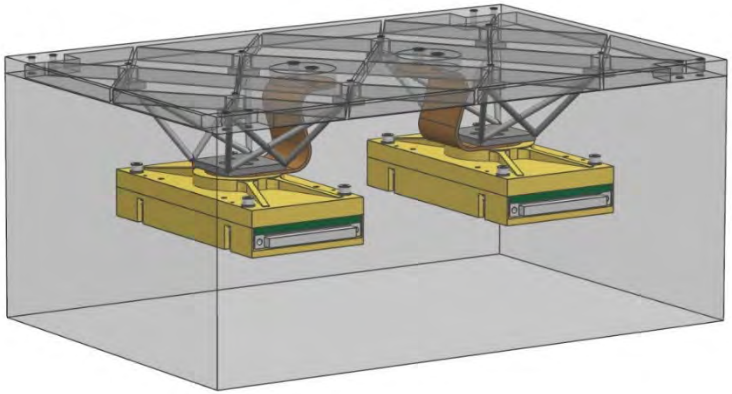
Credit: CEA

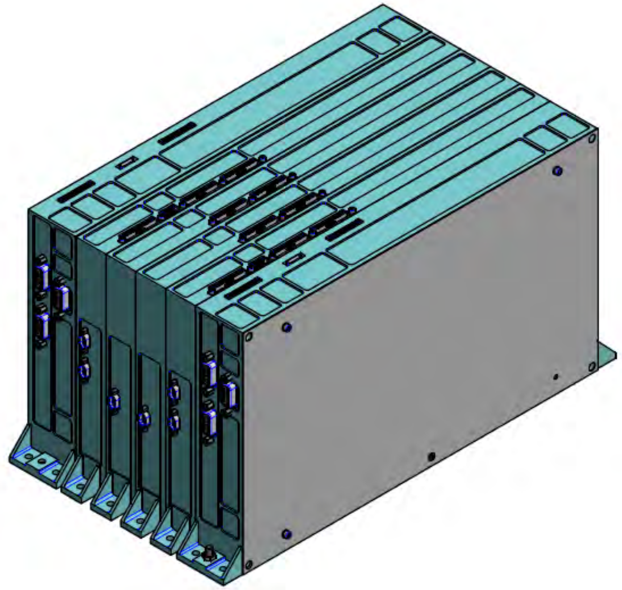
Fine Guidance System / Near-IR Spectrometer (FGS / NIRSpec) Instrument Architecture



FGS Optics Module
In PLM OB Instrument Cavity
T Op 40 – 80K

FGS cFEE (Sidecar) Box
Separately on PLM OB
T Op 130 – 145K



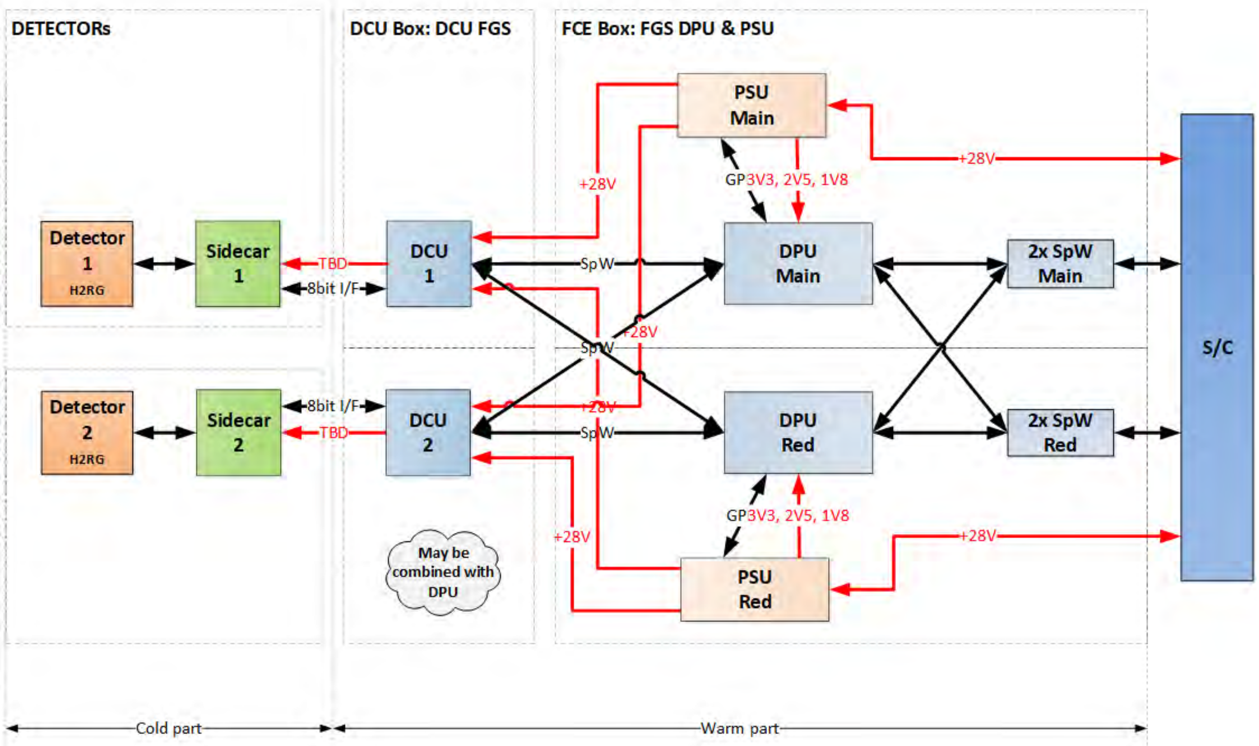


FGS Control Unit (FCU)
Mounted in SVM
T Op 253 - 323 K

See details in FGS talk – Weds @ 09:40

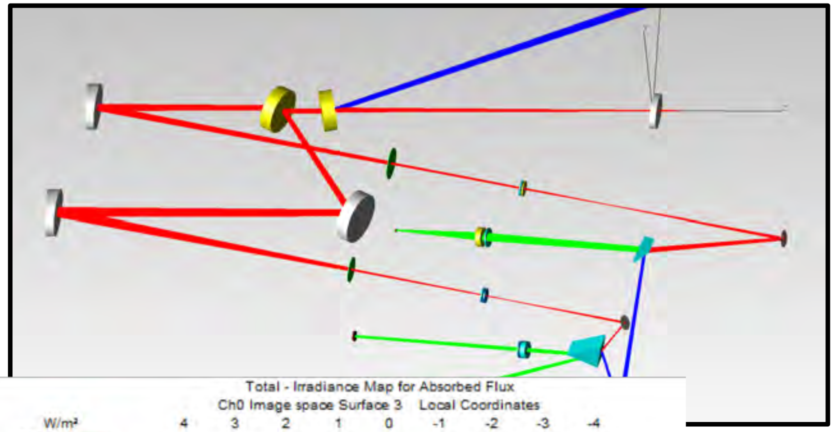
FGS Control Unit (FCU) Overview

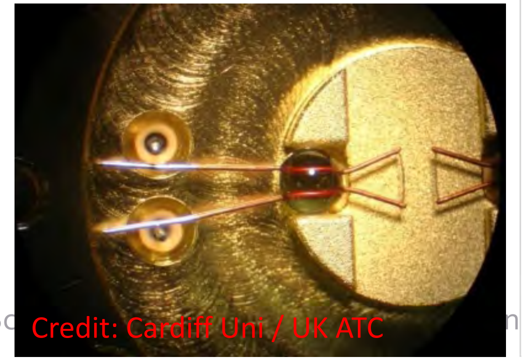
- FCU (located in SVM) is responsible for:
  - Control of CFEE and detector chains
  - Readout of images
  - Processing for centroiding of star as input to S/C AOCS
  - Interfaces to S/C OBC & AOCS
  - Control and monitoring of FGS OM and CFEE temperatures
- Mass estimate of 5.5 kg
- Power estimate of 22 W

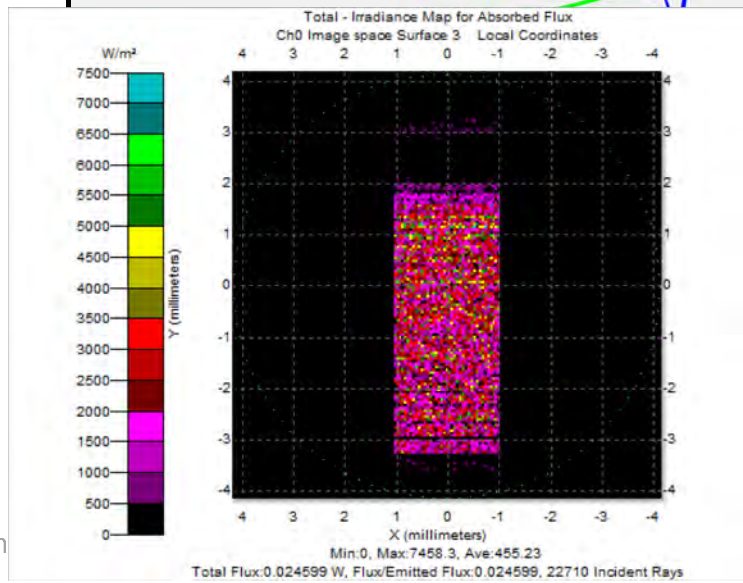


On-Board Calibration Source (OBCS)

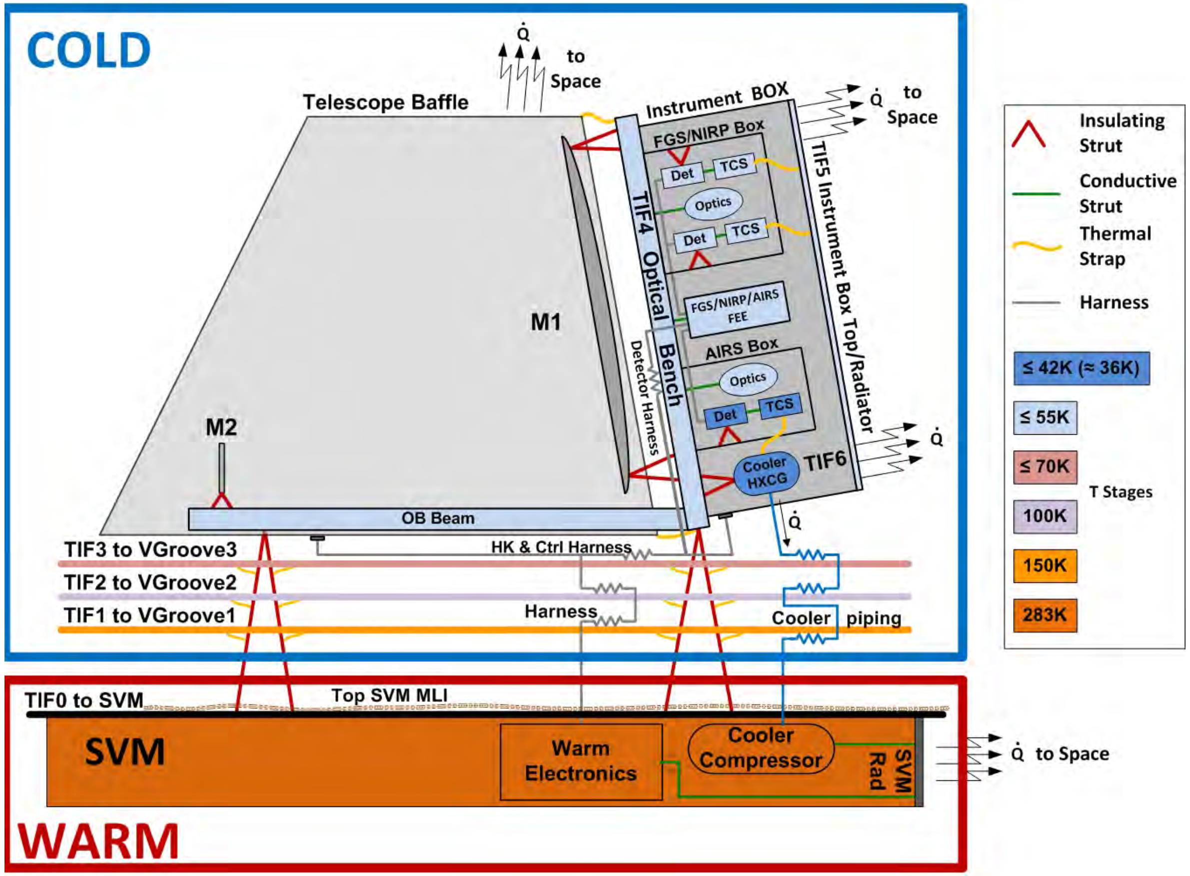
- OBCS baselined to provide flat field illumination of detectors for short & medium term monitoring of gain stability
  - Complementary to on-sky calibration against stable (point) sources
- Consists of integrating sphere (50mm with ≤1mm aperture baseline) with filament (for NIRSpec & AIRS) and LED (for photometer channels) inputs
- High stability drive from TCU to give stable output flux







Payload Module Thermal Architecture

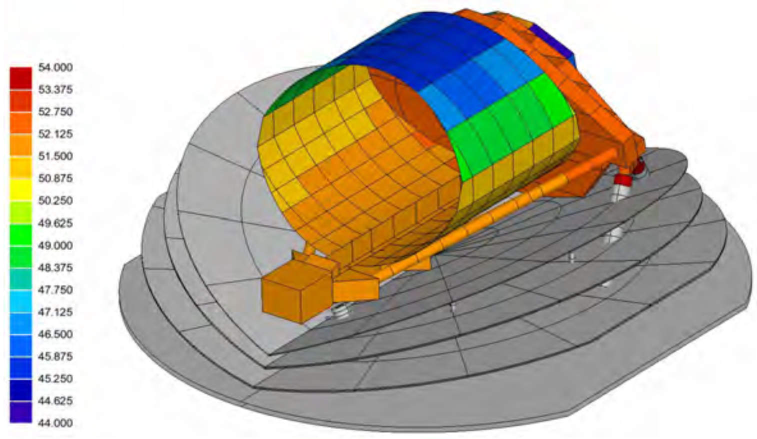


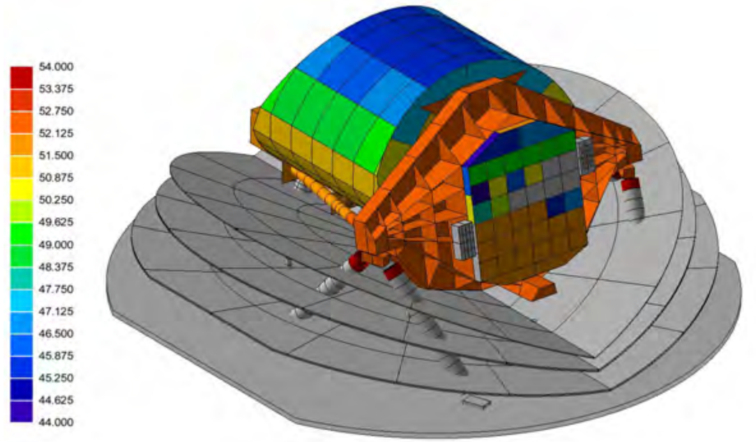
- Passive cooling design:
- PLM to SVM IF @ 270K - 290K
- V-Grooves based design (three stages): VG1 (180K) – VG2 (120K) – VG3 (70K)
- Radiators for instrument cooling:
- Instrument Box
- Telescope Baffle
- Orbit & attitude:
- L2 halo orbit, to exploit thermal environment
- Max SAA along two S/C axes:
  - $\pm 30^\circ$ (incl. $\pm 5^\circ$ contingency margin)
  - $\pm 6^\circ$ (incl. $\pm 5^\circ$ contingency margin)

See details on poster by Morgante et al

PLM Thermal Performance: Temperatures & Stabilities

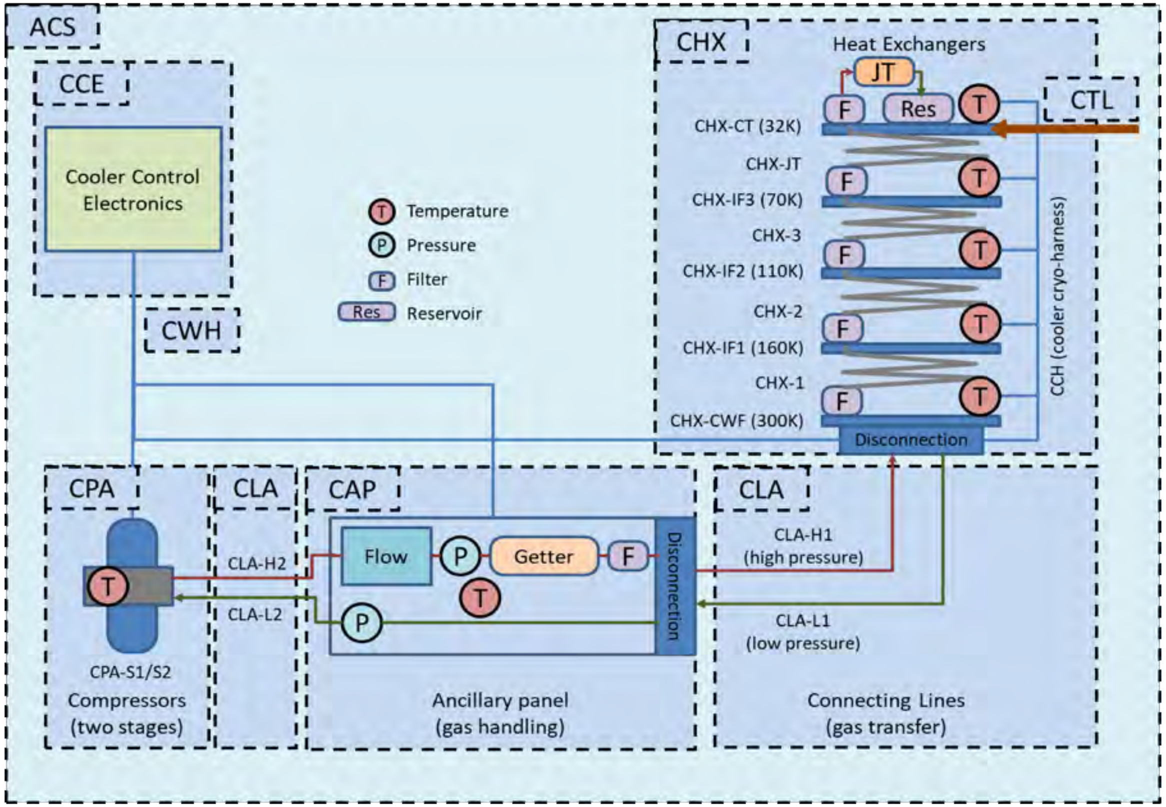
PLM Units	Predicted/Expected Limits (inc. Uncertainties)				
	T Functional [K]			T Non-Op [K]	
	TMin	TMax	ΔT [K]	TMin	TMax
AIRS Box	45	60	± 1	40	313[8]
AIRS FPAs	32	42	± 0.005	32	313
AIRS CFEE	130	145	± 0.050	130	313
FGS Box	45	60	± 1	40	313
FGS FPAs	70	90	± 0.010	40	313
FGS CFEE	130	145	± 1	130	313
Calibration Unit	45	60	± 1	40	313
TOB Optics	45	60	± 1	40	313
M2 Mechanism	45	60	± 1	40	313
Telescope Mirrors	45	60	± 1	40	313
Telescope Baffle	45	60	± 1	40	313
Radiator	45	60	± 1	40	313
VGroove 3	45	60	± 1	40	313
VGroove 2	75	100	± 2	70	313
VGroove 1	115	150	± 2	110	313





Active Cooler System (ACS) –Architecture

Required to provide 88mW heat lift at 32K

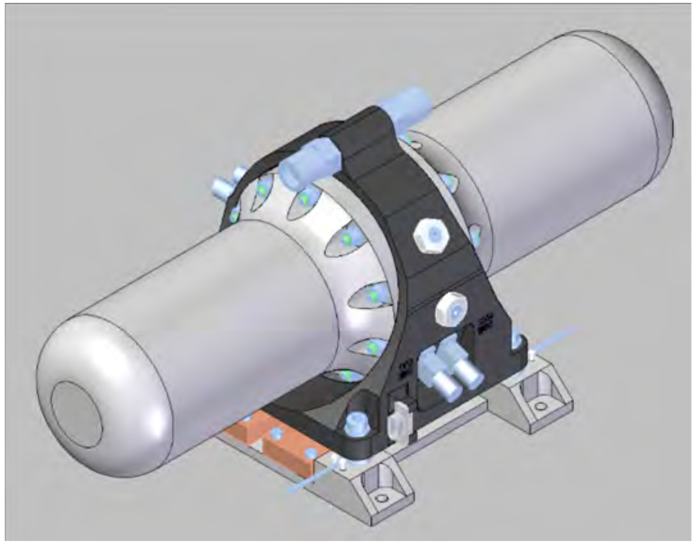


ACS – Active Cooler System
CCE – Cooler Control Electronics
CWH – Cooler Warm Harness
CPA – Compressor Assembly
CAP – Cooler Ancillary Panel
CLA – Connecting Line Assembly
CHX – Cooler Heat Exchanger Assembly
CCH – Cooler CryoHarness
CTL – Cold Tip Thermal Link

Two ESA Tech Development Activities in progress to demonstrate TRL6 for MAR

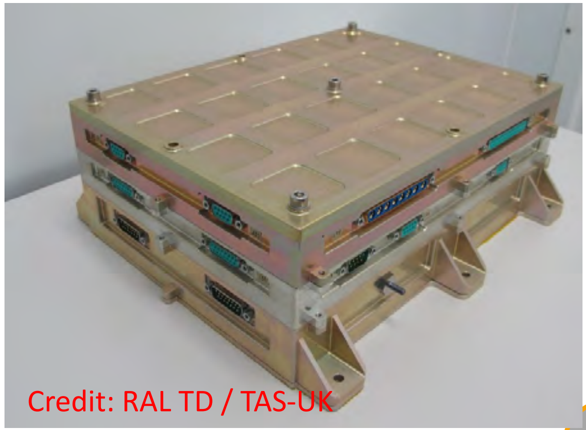
- Compressor and Ancillary Panel development
- Heat Exchanger development
- System demonstration and test
- CCE derived from existing Cryoblue Stirling Cooler drive electronics and supplied by TAS-UK

ACS – Compressors and Drive Electronics

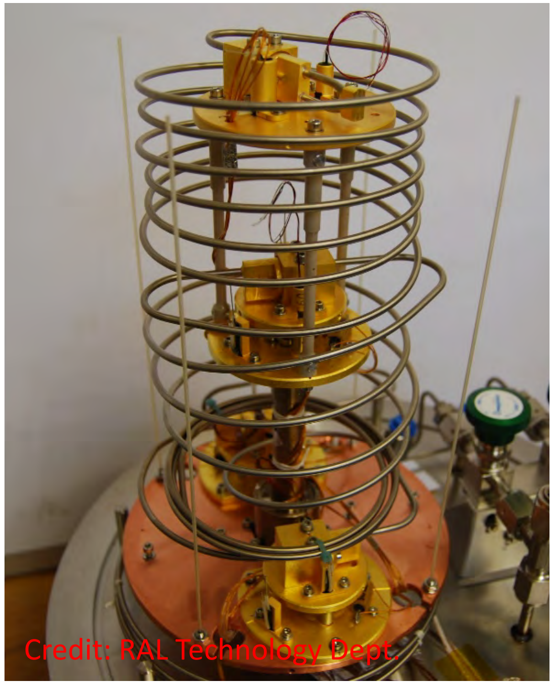


- Next Generation design derivative of the Planck 4K JT-cooler compressor and 2K JT-cooler compressor
- Reciprocating linear motor mechanism with flexure bearing suspension for non-contact of moving parts
- Position sensor for closed loop drive
- Force/Accelerometers for active vibration control
- Dimensions: 391 x 172 x 170 mm
- Total Mass: 7.7 kg (including thermal links and force transducers)

- Modular architecture; three modules with two backplane interconnects
- Compressor management and closed loop drive
- Micro-vibration reduction control loop
- Active line filter to absorb load variations on main power bus
- Dimensions: 295 x 256 x 107 mm
- Total mass: 5.7kg


Credit: RAL TD / TAS-UK

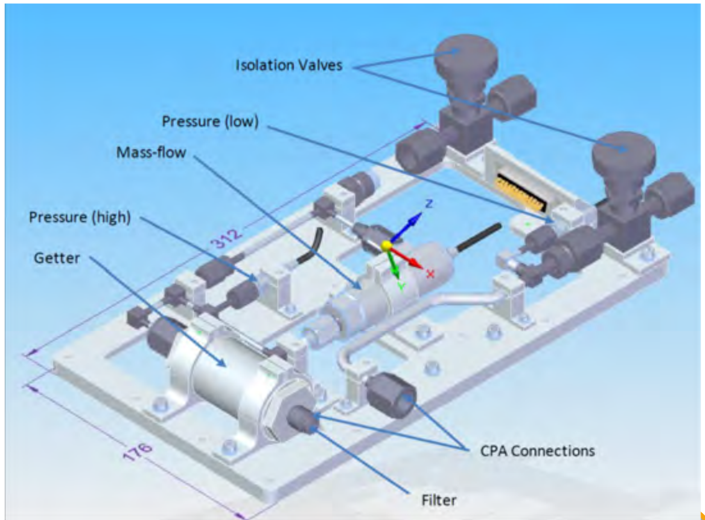
ACS – Heat Exchangers and Ancillary Panel



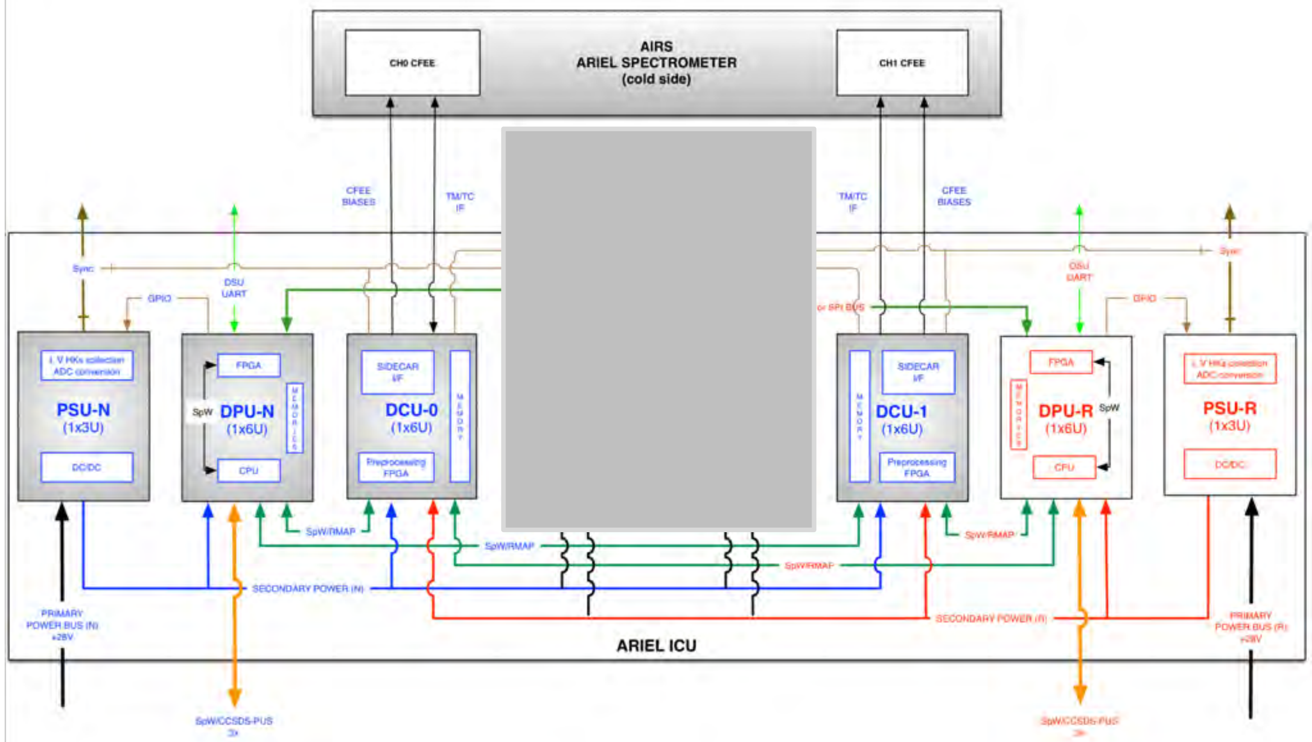
- Three pre-cooling interfaces, one at each V-groove
- Counter-flow heat exchangers between stages; to reduce heat rejected at pre-cooling interfaces
- Filters at each interface to improve thermal contact of gas to pre-cooler and to provide a contamination trap
- Orifice restriction for JT expansion and liquid reservoir
- Total Mass: 2.9 kg

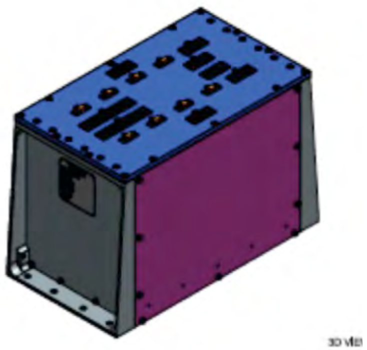
See details on poster by Crook et al

- CPA/CAP delivered as an integrated assembly; isolation valves allow independent integration
- Pressure sensors and mass flow sensors for cooler health monitoring
- Reactive getter to ensure gas cleanliness
- Particulate filters to protect compressors from possible particulate debris migration
- Dimensions: 312 x 176 x 78 mm
- Total Mass: 2.4 kg



Instrument Control Unit (ICU) Summary





Legenda:

- Nominal board
- Redundant board (cold redundancy)

- Very strong heritage & TRL
- Minimised P-M-V budgets
- Minimised complexity

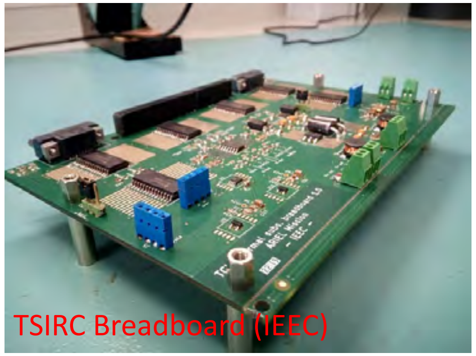
- Adoption of a single processor
- Only a high-level SW (ASW) running
- Simplified I/F to S/C (slave TCU)

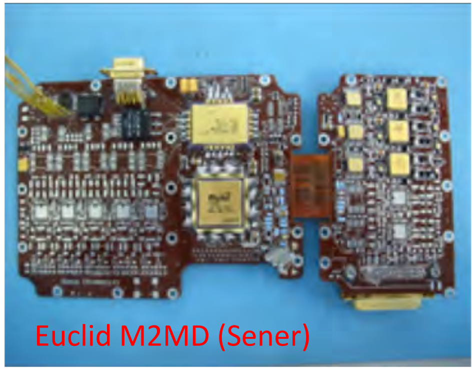
- Very high reliability
- Compact design and easy AIV/AIT
- Minimised on-board data processing

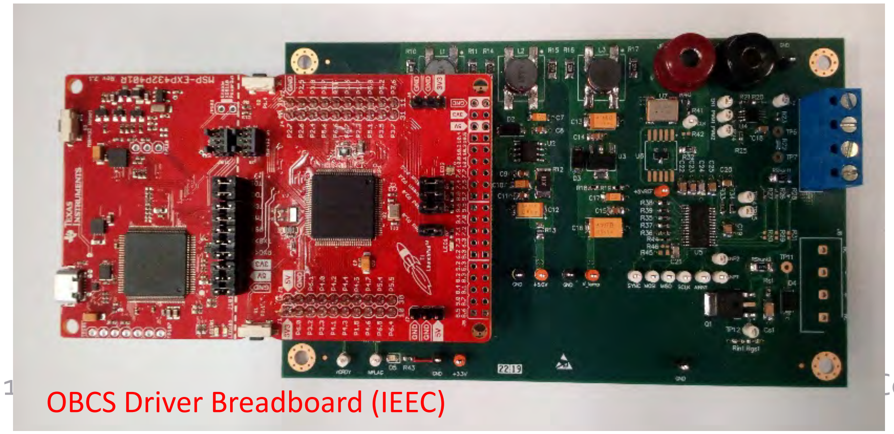
Telescope Control Unit (TCU) Summary

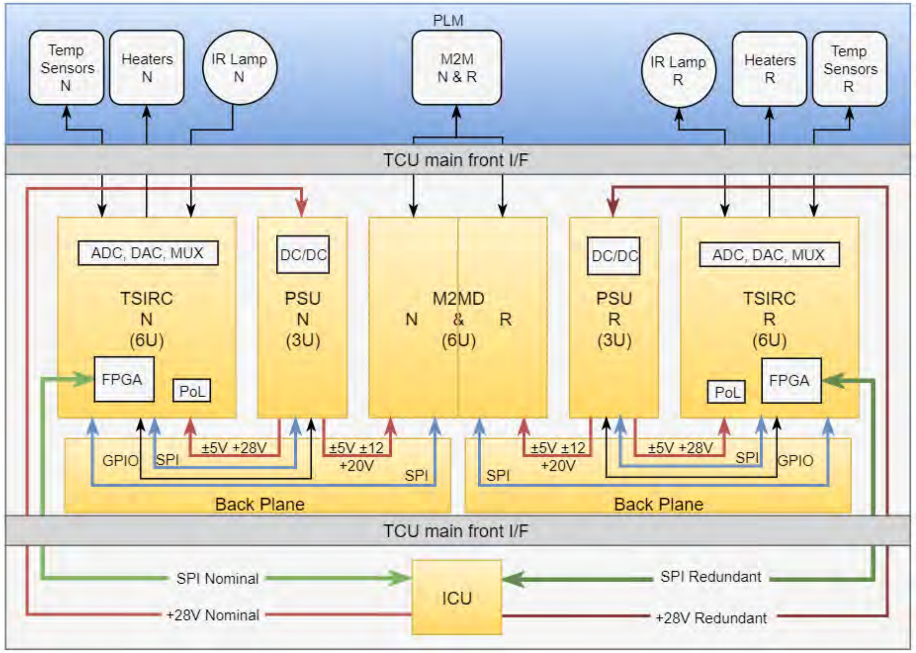
- Fully redundant philosophy, no cross-strapping.
- Power interface with S/C, commanded by ICU

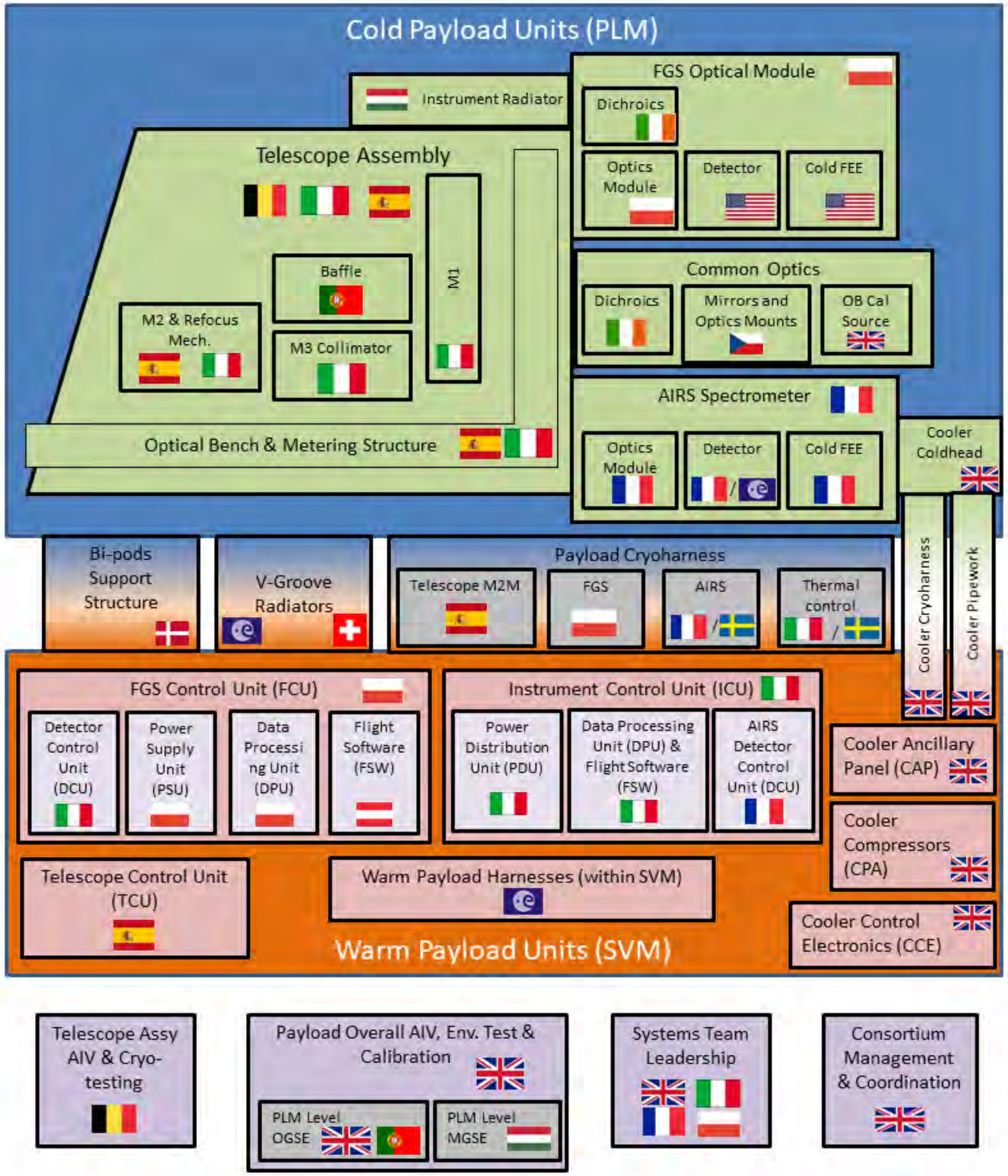
- First breadboards of Thermal and Calibration subsystems designed and manufactured.
- M2M Driver based on Euclid heritage


TSIRC Breadboard (IEEC)


Euclid M2MD (Sener)


OBCS Driver Breadboard (IEEC)

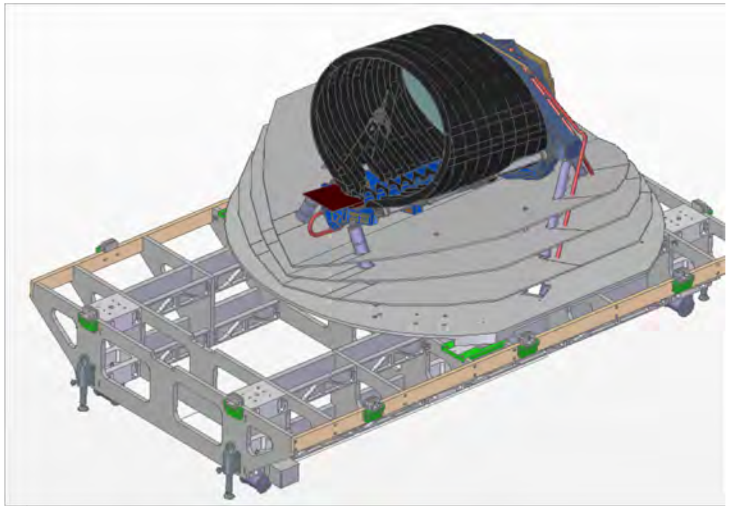




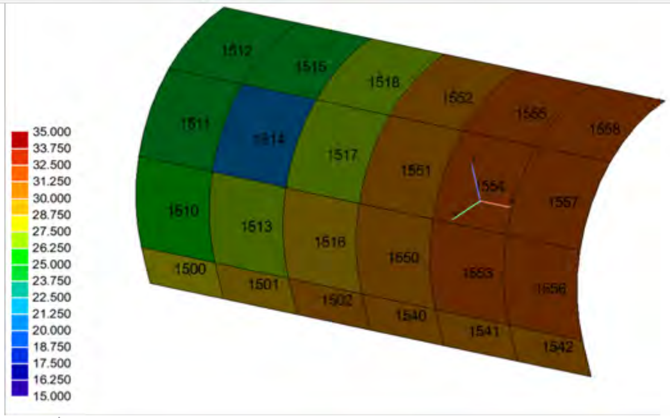
Payload Consortium Responsibilities

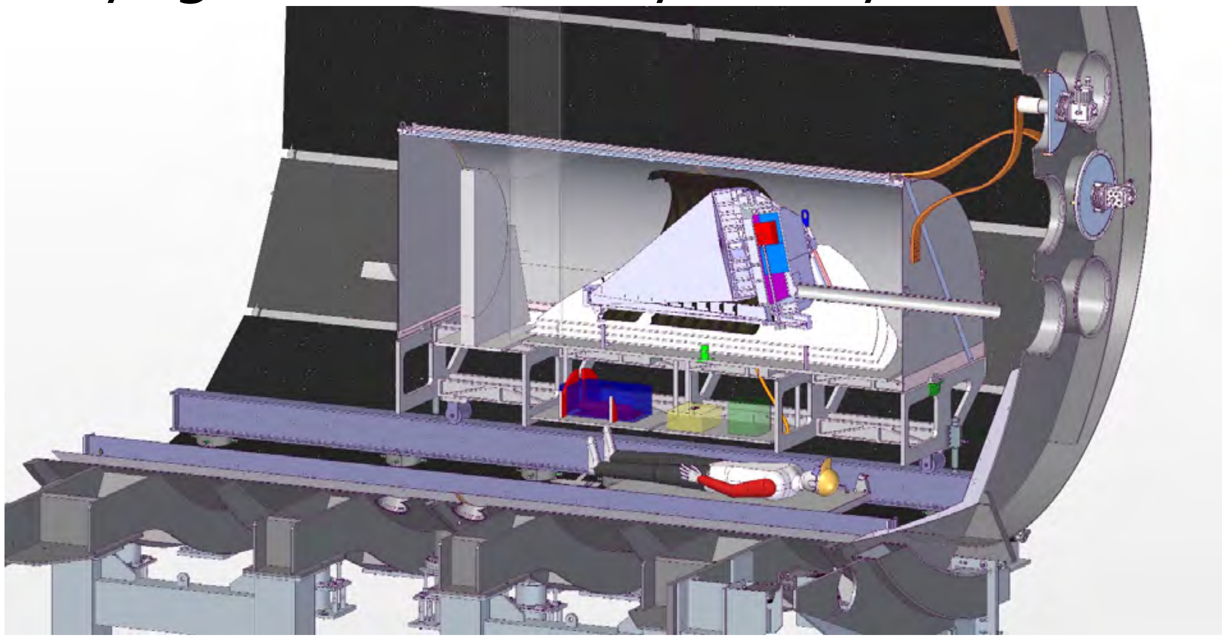
- Mission Consortium contributions to the payload are now confirmed and stable throughout the phase B1 ready for the adoption later this year.
- Team of 17 European countries and NASA contribution with heritage and experience in IR space instrumentation
- Major hardware roles concentrated in fewer key participants
- Central coordination of the payload design by distributed payload systems engineering team led by UK.

Payload Cryogenic Calibration Facility

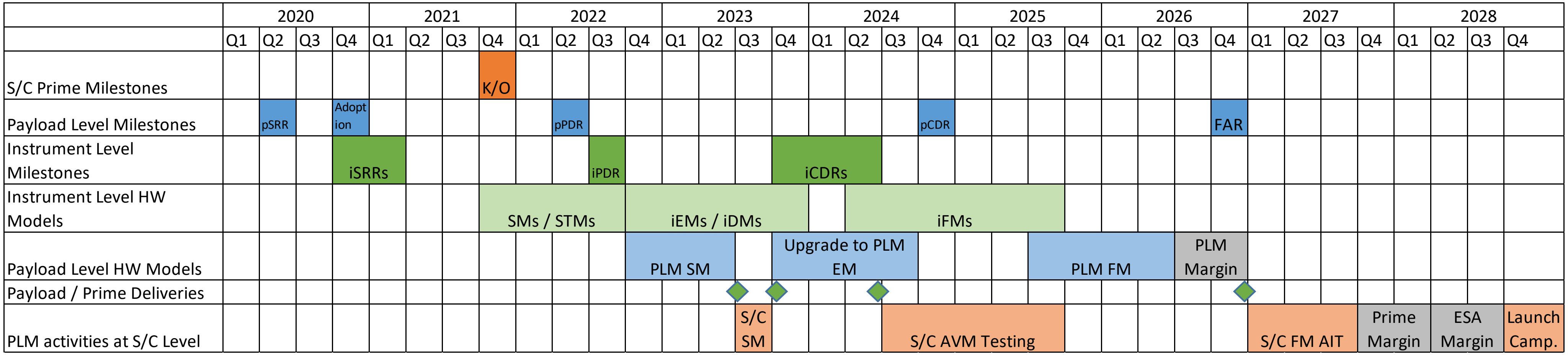


- Payload calibration within dedicated cryogenic test facility trolley.





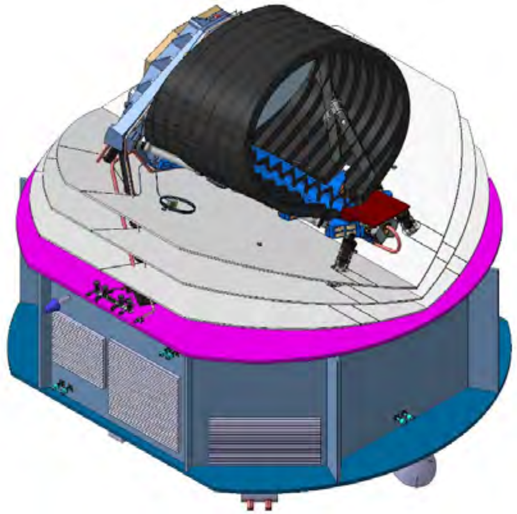
Payload Schedule Summary



- Development schedule and planning has evolved significantly during phase B1.
- Maintaining scheduled delivery dates to ESA / Prime consistent with launch in 2028, assumes successful adoption in Nov 2020.
- Closely coupled development schedule with Primes is requiring early interaction and freeze of mechanical interfaces in order to build and test SM (which becomes EM PLM & some FS hardware) early.

Conclusions & Questions

Credit: ARIEL Mission Consortium / CBK-PAS



Thanks to whole ARIEL Mission Consortium Team for input

Questions?