Euclid Cleanliness and Contamination Control and challenges due to ice contamination

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ESA ESTEC

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Outlines

First part

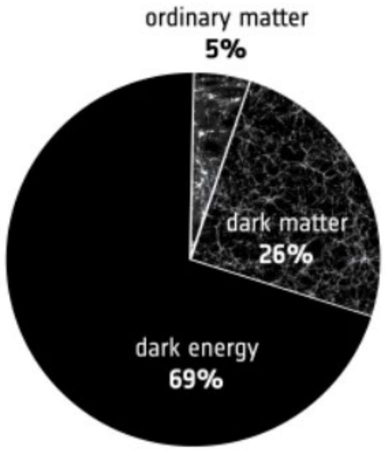
- Euclid satellite and mission
- Cleanliness and contamination control

Second part

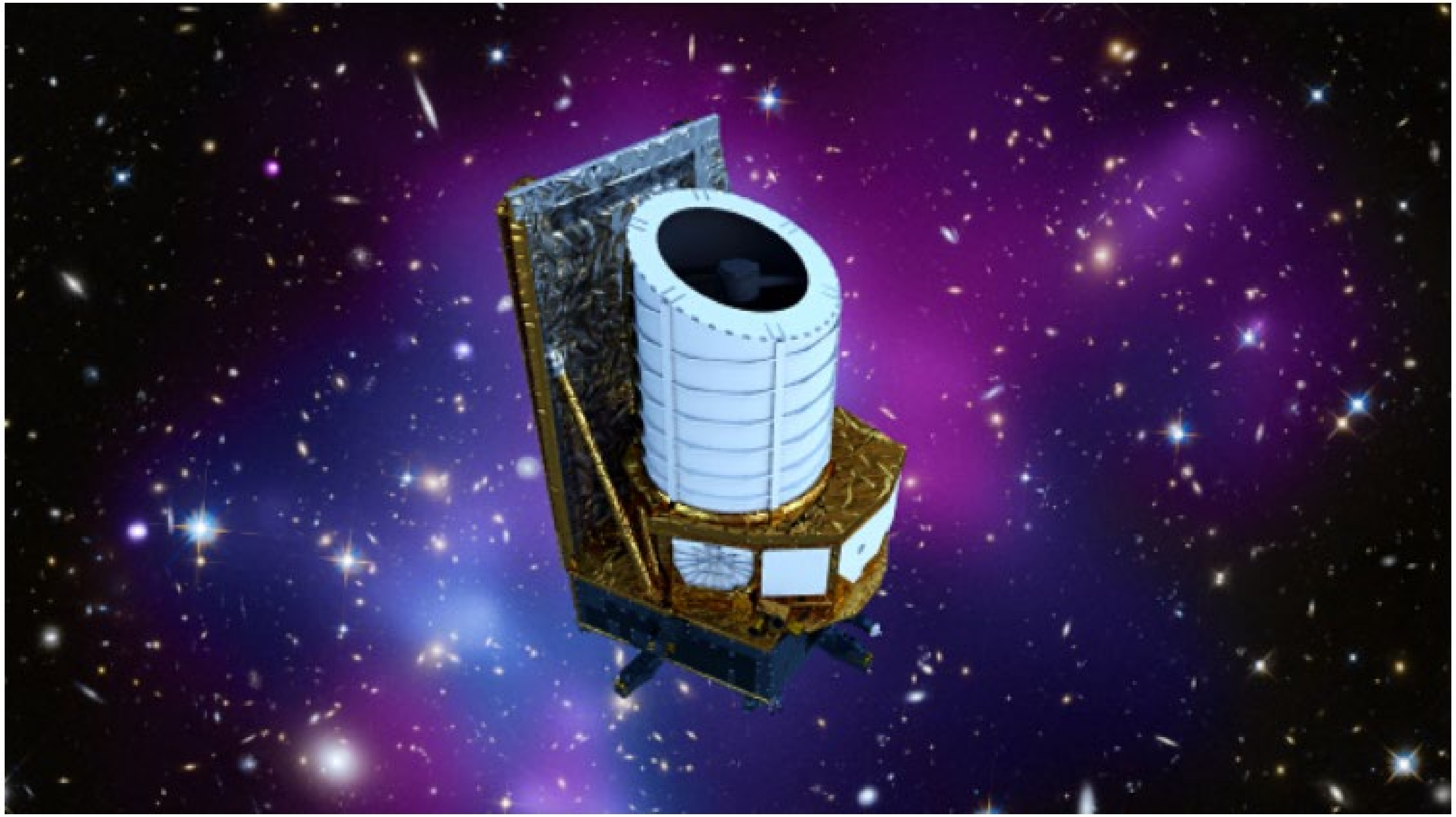
- External baffle ice contamination
- Ice contamination tests and results

Euclid mission[1]

Euclid is a space-based optical/near-infrared survey mission of the European Space Agency (ESA) to investigate the nature of dark energy, dark matter and gravity by observing the geometry of the Universe and on the formation of structures over cosmological timescales. I will operate at L2



Cosmic budget. *Credit: ESA*

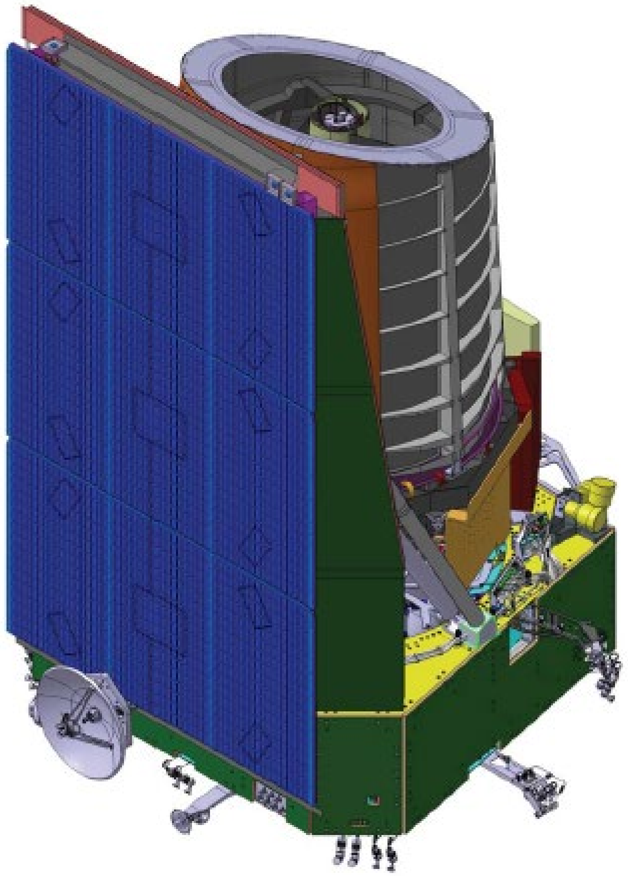


Artist's impression of Euclid. *Credit: ESA/ATG medialab (spacecraft); NASA, ESA, CXC, C. Ma, H. Ebeling and E. Barrett (University of Hawaii/IfA), et al. and STScI (background)*

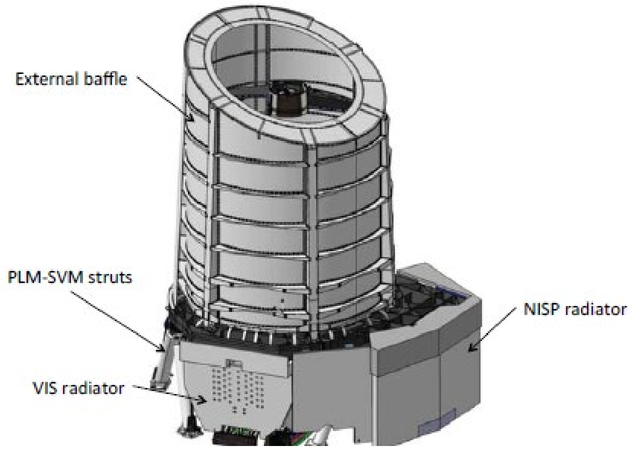
https://sci.esa.int/web/euclid

Euclid satellite[1]

The Euclid Spacecraft is composed of a Service Module (SVM) and a Payload Module (PLM). SVM

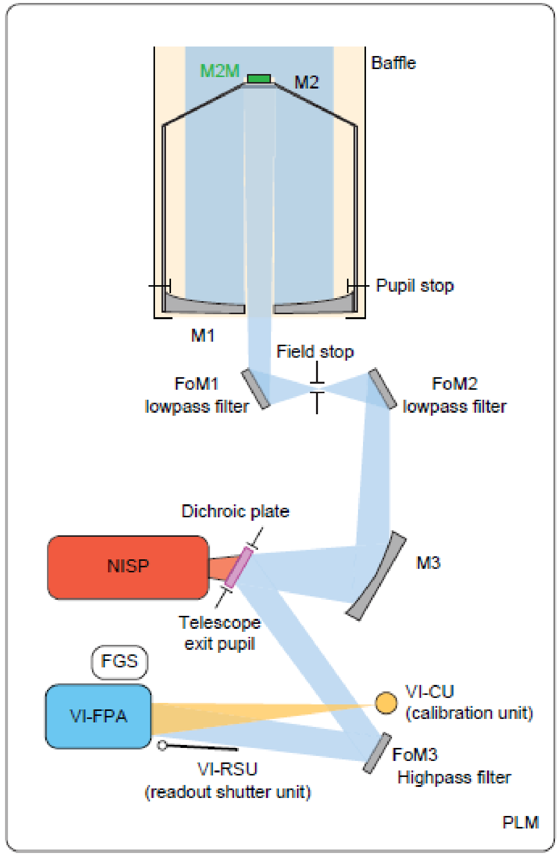


The Payload Module consists of a 1.2 m telescope and two instruments, the visible imager VIS and the near-infrared spectro-photometer NISP



- Excluding the photovoltaic assembly and sunshield, most sensitive surfaces are cryo/cold.
- Practically no view factor between PLM and SVM
- Short commissioning and with a beneficial thermal profile
- Baffle aperture facing up and with exposed optics

Euclid payload module - PLM



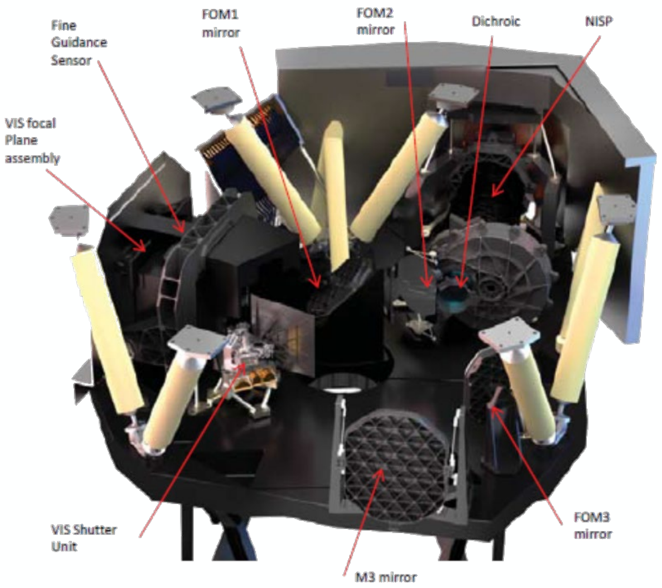
Left

The schematic functional view of Euclid PLM

Right

Rear cavity of the PLM:

- VIS Visible Imager (0.55-0.9μm)
- NISP Near Infrared Spectro-Photometer (0.9-2um)

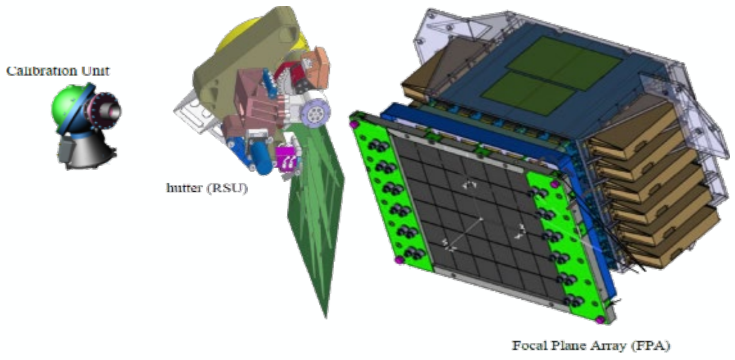


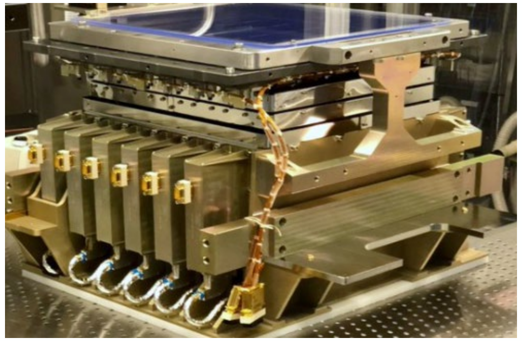
- PLM rear cavity is open -> cross contamination
- Purging not feasible to implement
- AIT operations allowed inspections and cleanings operations until MLI closure

Euclid instruments on PLM

VIS Euclid Visible Imager [2]

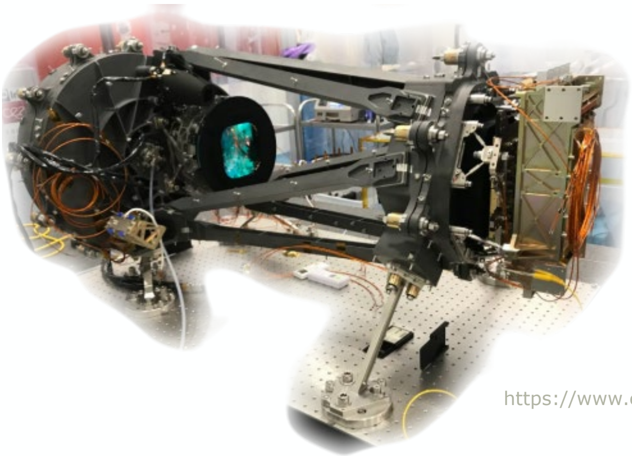
Large focal plane, enabling weak lensing measurements. It includes 36CCDs - 604Mpix-12μm pixel size, spectral band is 550-900nm.

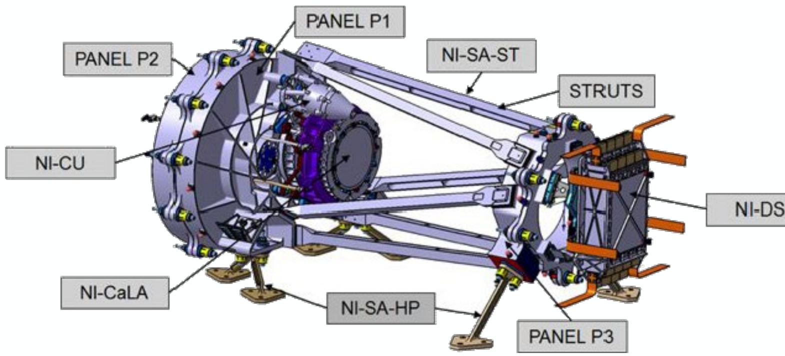




NISP Near Infrared Spectro-Photometer [3]

Operates in the 0.9-2.0 micron range at a temperature lower than 140K, and detectors ~95K. The photometric mode is for the acquisition of images with broad band filters, and the spectroscopic mode is for the acquisition of slitless dispersed images on the detectors.





https://www.esa.int/ESA_Multimedia/Images/2020/07/Euclid_s_NISP_instrument

Use of inert materials: SiC, light metals, MoS2, inorganic coatings

QCM monitored vacuum bake-outs

All AIT activities under ISO5 + covers + limiting time in horizontal.

PAC and MOC monitoring in close vicinity of the optics using PFO and MOC crystals (CaF2, ZnSe)

Instrument cryogenic temperatures act as MOC traps during testing and in-orbit phases

VIS non protected, fully exposed to the rear cavity

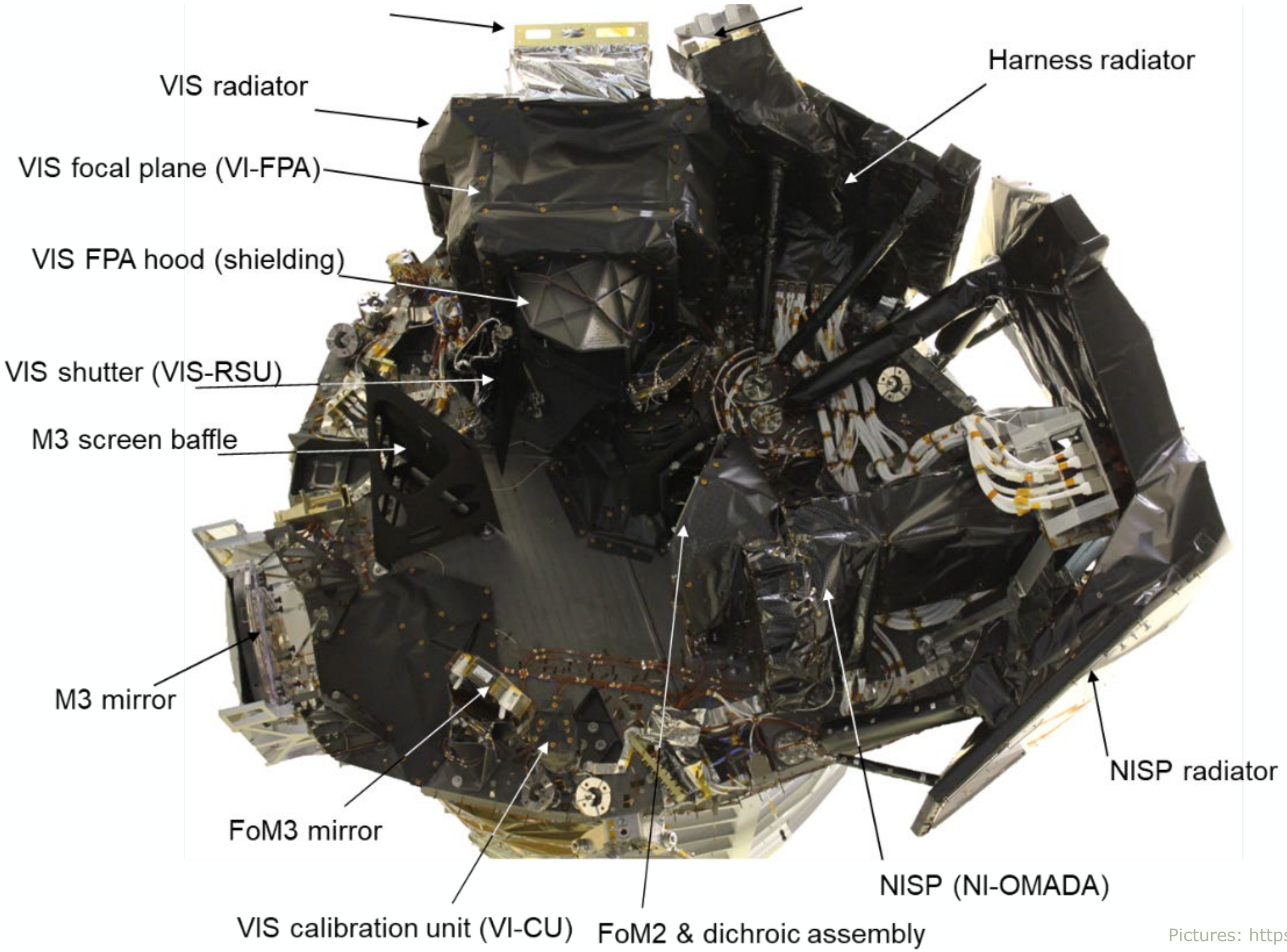
Cleanliness requirements

Instruments and example of optics contamination requirements. More details are annexed

	At delivery to PLM	At EOL
VIS Focal plane	260ppm - 0.5µg/cm2	1200ppm – 4.0µg/cm2
NISP ext.optics	700ppm - 1.0µg/cm2	1600ppm - 2.0µg/cm2
M3,FM2,FM3, Dichroic	150ppm - 0.05µg/cm2	1200ppm - 0.55µg/cm2

Payload module - CCC approach

Scientific contamination sensitive surfaces

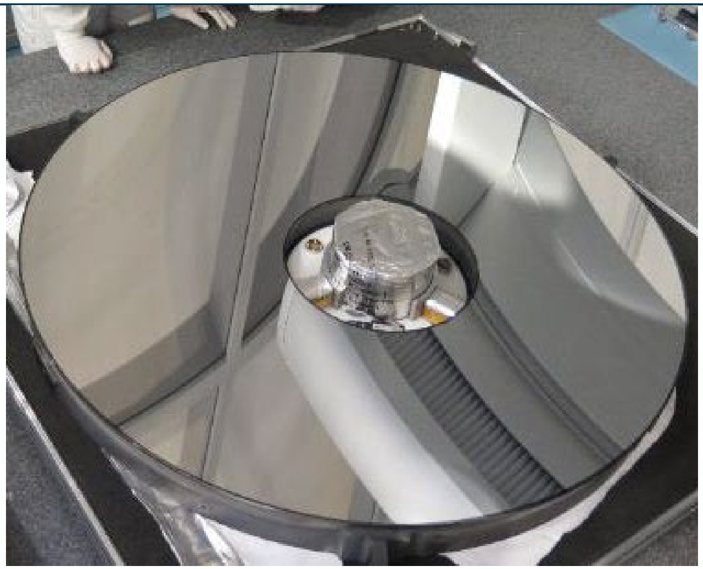


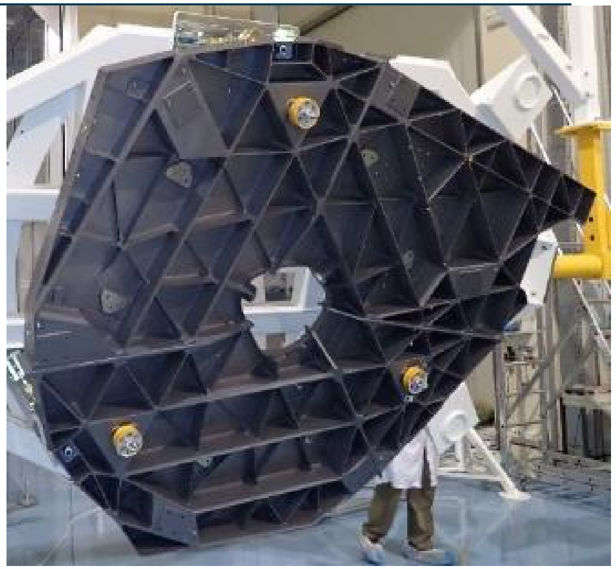
Pictures: https://sci.esa.int/web/euclid/-/euclid-s-optical-and-infrared-instruments-integrated-in-spacecraft

Payload module - CCC approach

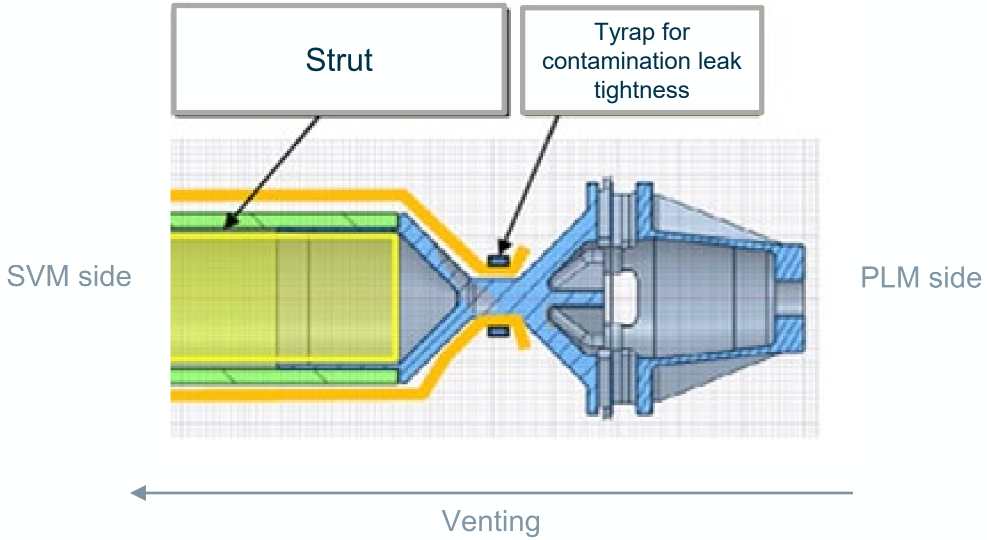
Materials

- ✓ Whole SiC PLM: primary structure (baseplate, secondary mirror support structure), mirrors, supports, NISP and VIS, with metallic parts (Invar, Titanium)
- ✓ Reduction of organic materials exposed to the internal cavity to minimum, warm electronic units outside
- ✓ Major contributors to in-orbit outgassing are MLIs, harnesses and black paints. All materials have been baked out with a TQCM monitoring





M1 Flight Model (left picture) and baseblate rear face (right)

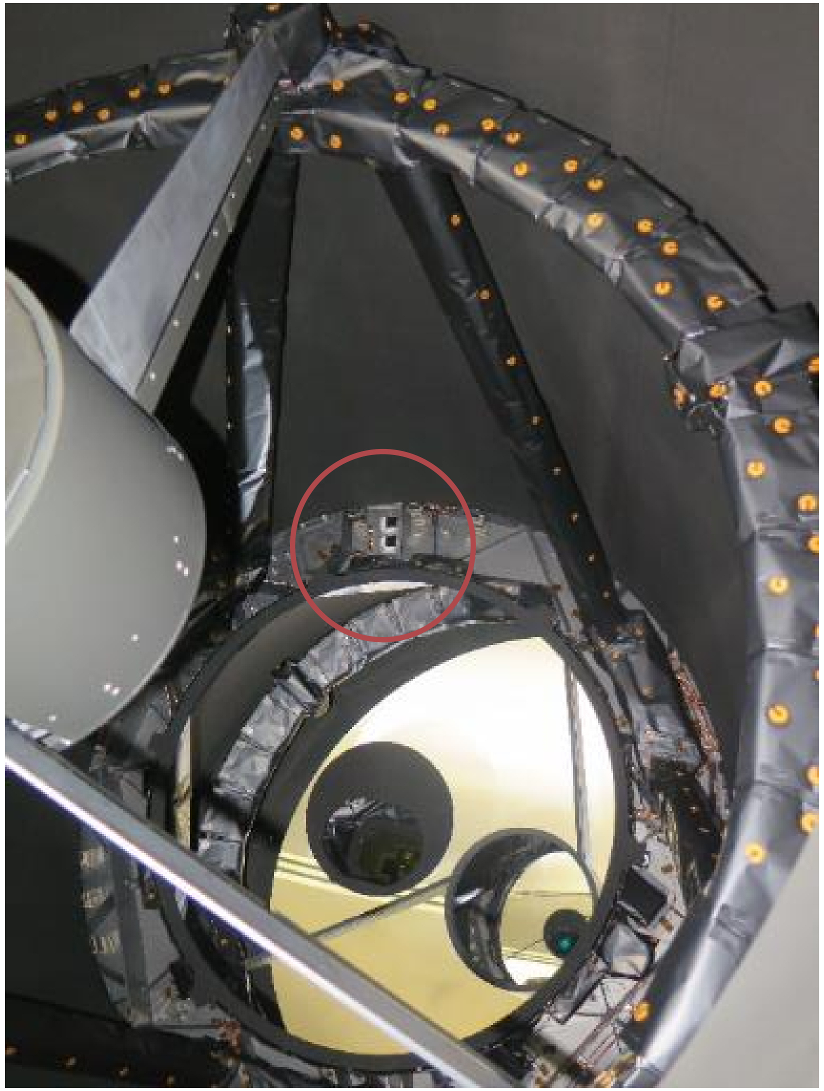


Design choices

- ✓ Use of decontamination heaters on all optics, externally directed MLI ventings, bipods hidden and SVM with no view factors to the rear cavity
- ✓ Design studied the in-orbit contamination impact with Systema Outgassing software

Systema

Payload module - CCC approach



Contamination witness samples in the front cavity

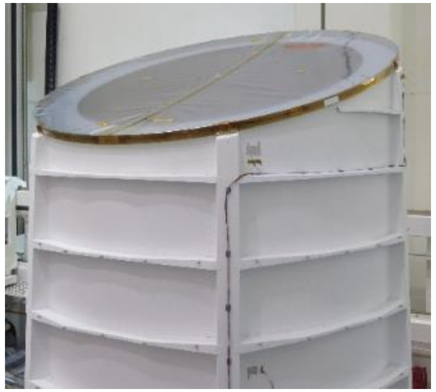
Cleanliness during AIT

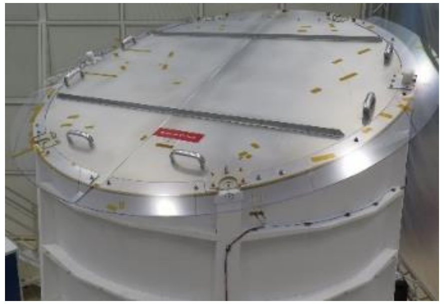
- ✓ The PLM AIT has been performed in ISO 5 environment (2 ppm/24h)
- ✓ In situ monitoring of particulate and molecular contamination has been implemented all along the integration and during the thermal vacuum test
- ✓ A cleaning of the mirrors has been performed by nitrogen blowing and with a single hair brush before the cavity closure in order to obtain the cleanest state possible

Covers

- ✓ A soft cover has been developed to protect the PLM during the mechanical tests at PLM and Spacecraft level
- ✓ A hard cover is used for the transport of the PLM

Both covers have a gap of less than 5 mm with the external baffle in order to guarantee a protection factor 95% against particulate contamination.

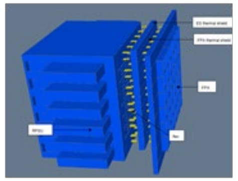




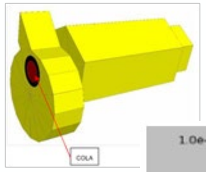
Euclid PLM with soft cover (upper) and hard cover (bottom)

Payload module - CCC approach

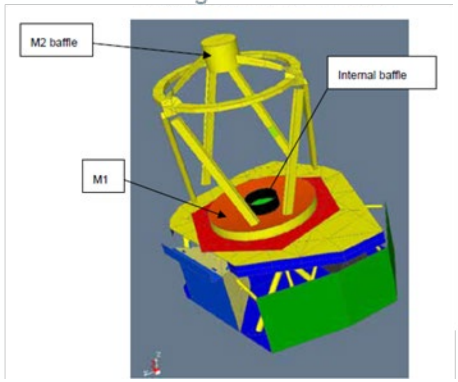
VIS geometrical model

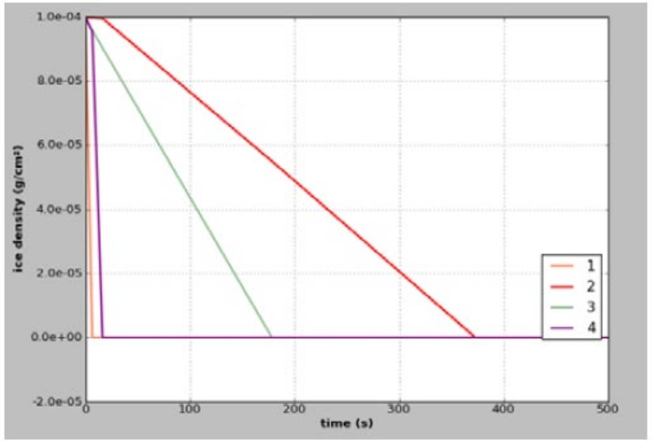


NISP geometrical model



PLM geometrical model

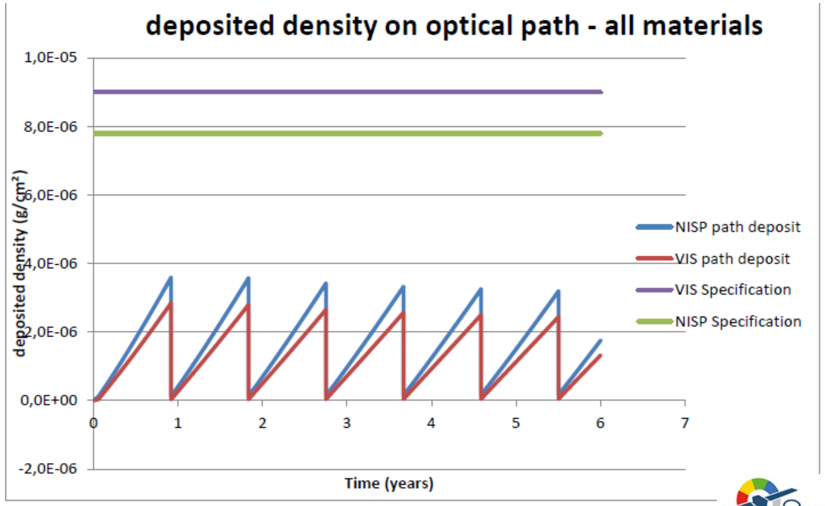




Deposited density of ice in the different cavities (1 to 4)

Venting analysis

- ✓ Validation of a 24h decontamination cycle at 220K
- ✓ Sublimation and venting of ice takes only few minutes to leave the telescope



Systema

In-orbit outgassing simulation

Materials dynamic outgassing test data sets based on ECSS-Q-TM-70-52

Lack of experimental data regarding outgassing of materials at cold / cryo temperatures

- ✓ Two cases have been considered:
  - ✓ Conservative approach by extrapolating room temperature data to cryo temperatures: 1 decontamination per year is needed
  - ✓ Best estimation considering sticking coefficient for temperatures lower than 135K: Only the 1st in flight decontamination is mandatory

Spacecraft - CCC approach

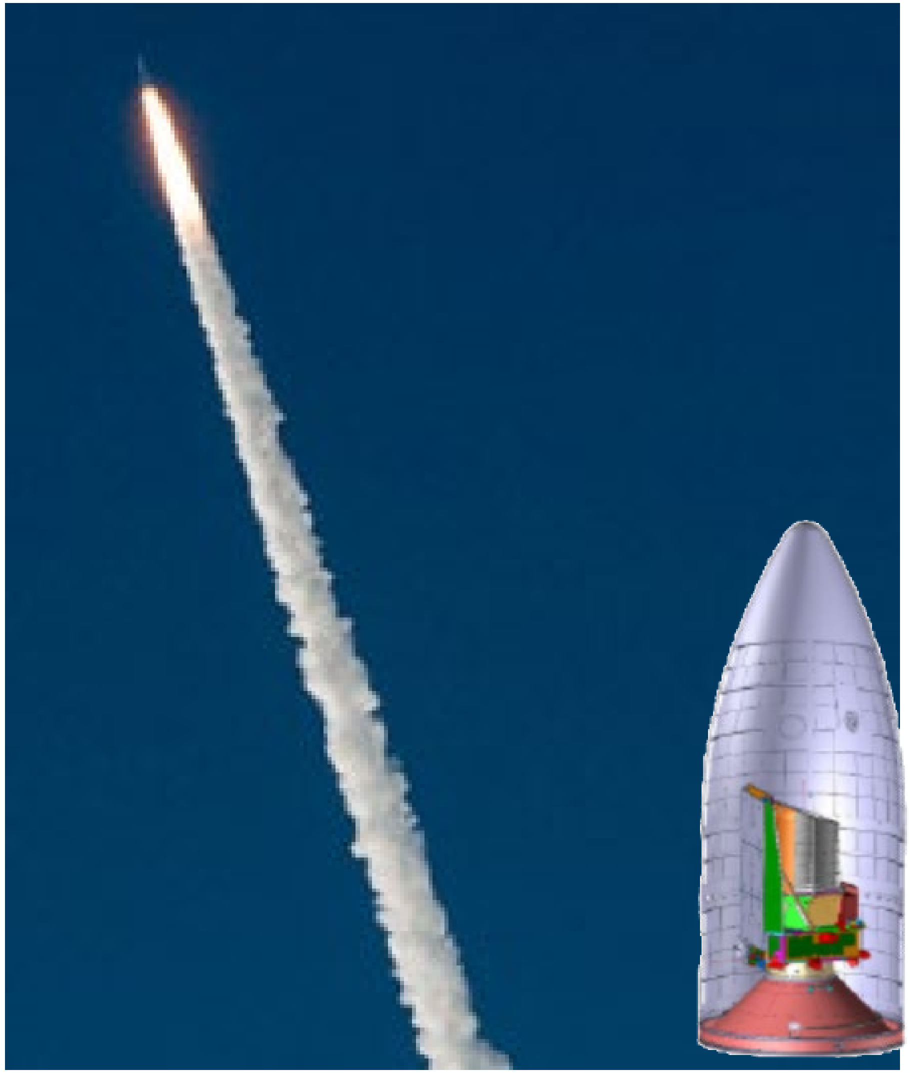
- ✓ PLM-SVM are decoupled thus avoiding cross contamination in orbit
- ✓ PLM-SVM are not necessarily independent during testing, requiring dedicated control of facilities such as blanks or dry runs
- ✓ The payload module remains fully protected with specific covers for each AIT phase until Launch
- ✓ Vacuum bake-out with QCM monitoring of structures, solar arrays, MLI and harness to reduce risks of cross contamination towards PLM during testing
- ✓ Tests at STM level have been used to study and improve the PFM CCC strategy

Euclid Structural Thermal model
https://twitter.com/Thales_Alenia_S/status/1174621128230391808?s=20

Spacecraft - CCC approach

Launch in vertical orientation, the launch phase receives special attention to avoid entrance of particulate through the open baffle.

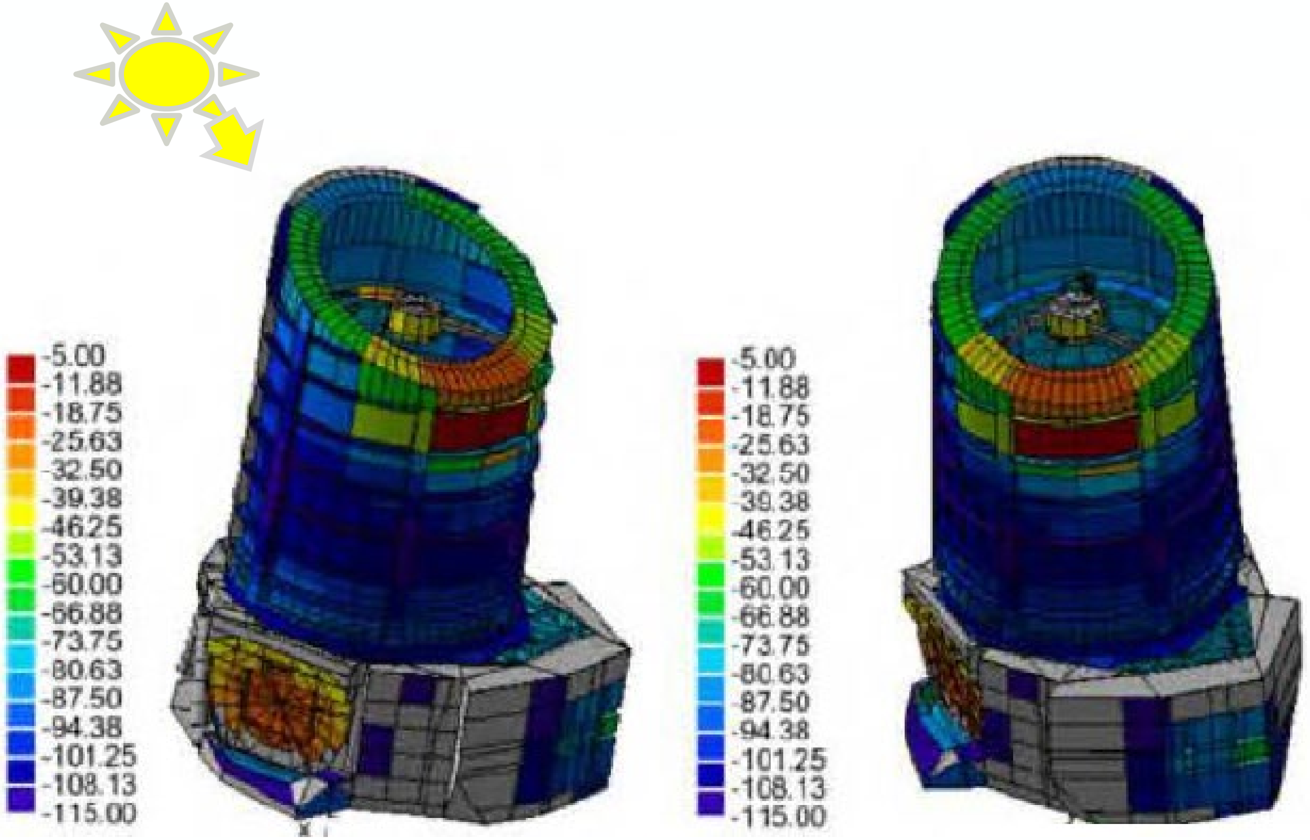
More details will be shared on ISMSE15- 2022.



Part 2 – Ice contamination challenges and tests

In orbit ice contamination of external baffle

To mitigate the risk of ice contamination, it is planned an external baffle ice decontamination phase utilising sun-illumination. The efficiency and potential ice effects have been studied resulting in positive feedback to the de-icing phase.

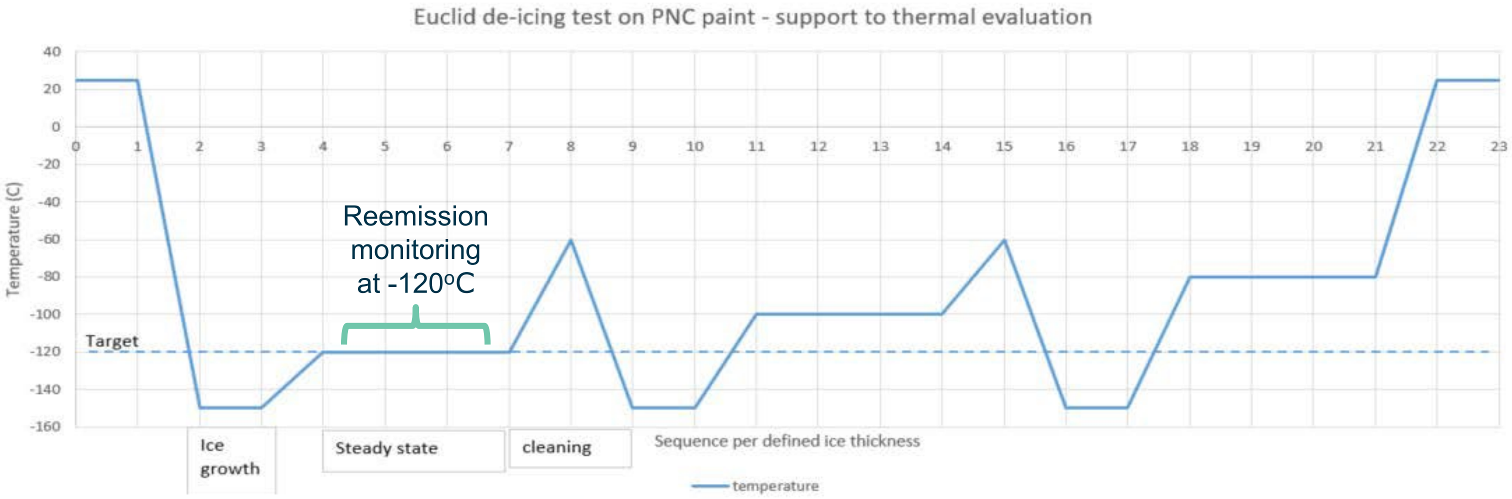


Time dependency ice testing

Re-emission of ice deposits at different temperatures

- Pressure **< 1E-7mbar**
- Temperature of deposit: **-150°C**
- Re-emission monitoring at **-130°C**, **-120°C**, and **-100°C**
- QCM → MAP PNC surface validation through optical measurements
- Ice morphology: not verified and controlled, however test conditions are deemed representative of the in-orbit case

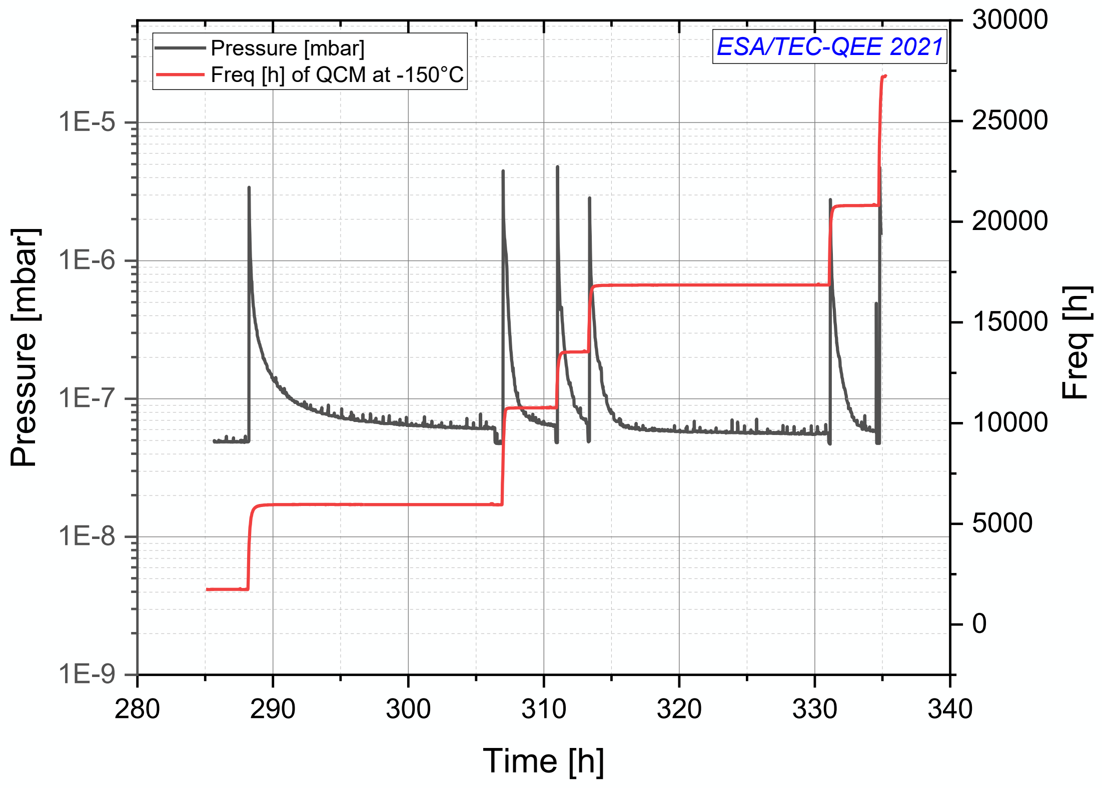
Example of Temperature profile:

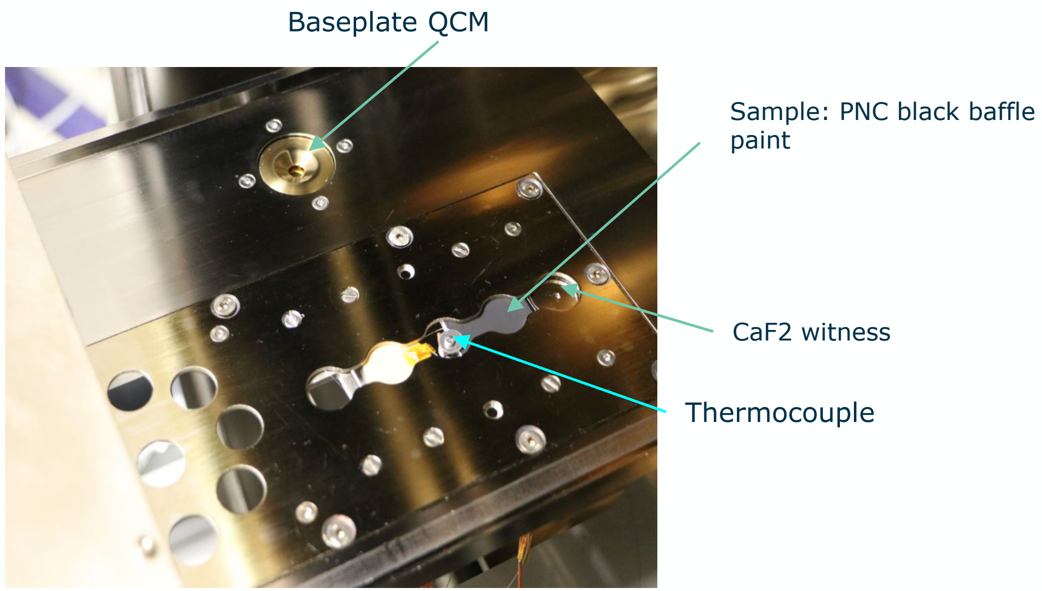


Legacy study
IN-SITU ICE FORMATION INVESTIGATION, B.Bras, P.Janik, R.Martins, R.Rampini
13th ISMSE, Pau, France, 22-26 June 2015.

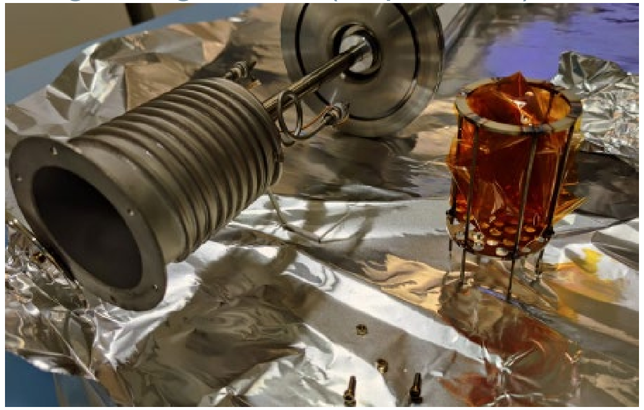
Time dependency ice testing

Example of ice deposit step (50µg/cm2):



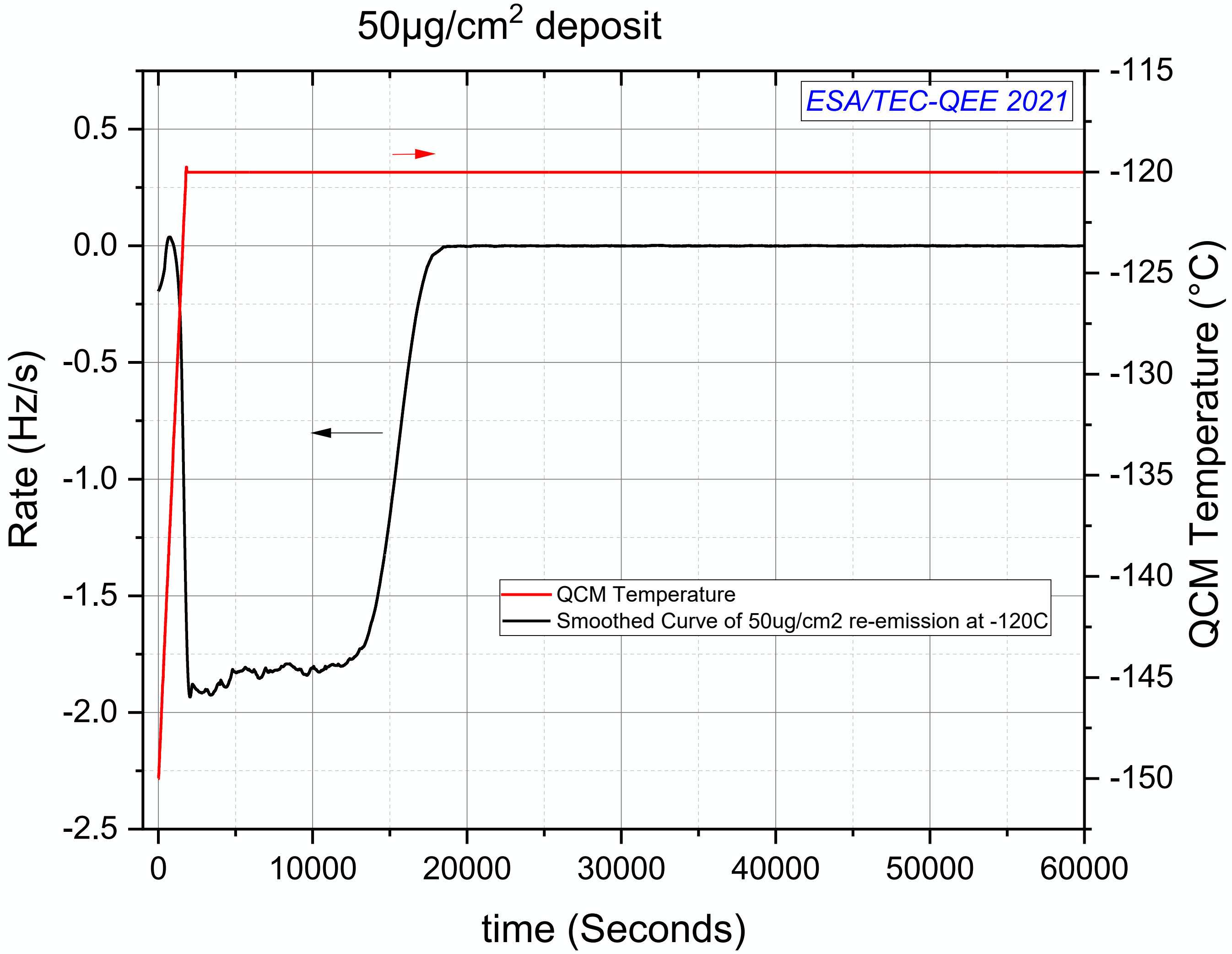


Outgassing source (Kapton HN):



Time dependency ice testing

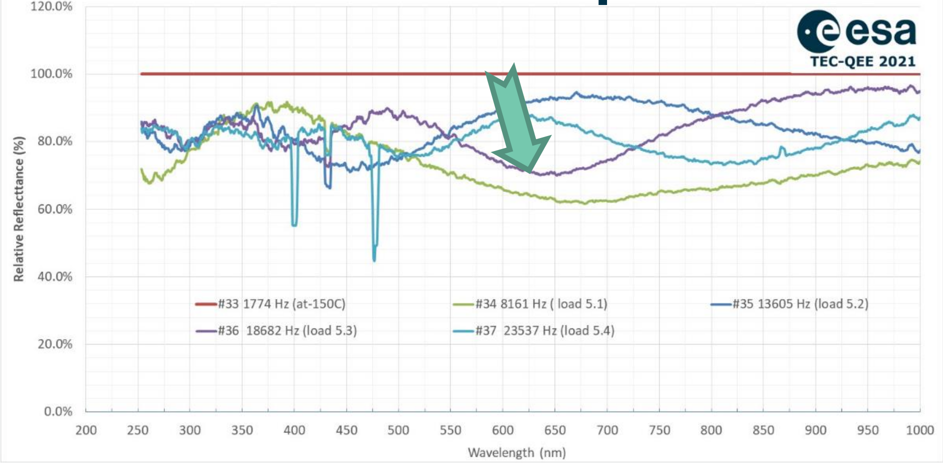
Example of re-emission at -120ºC



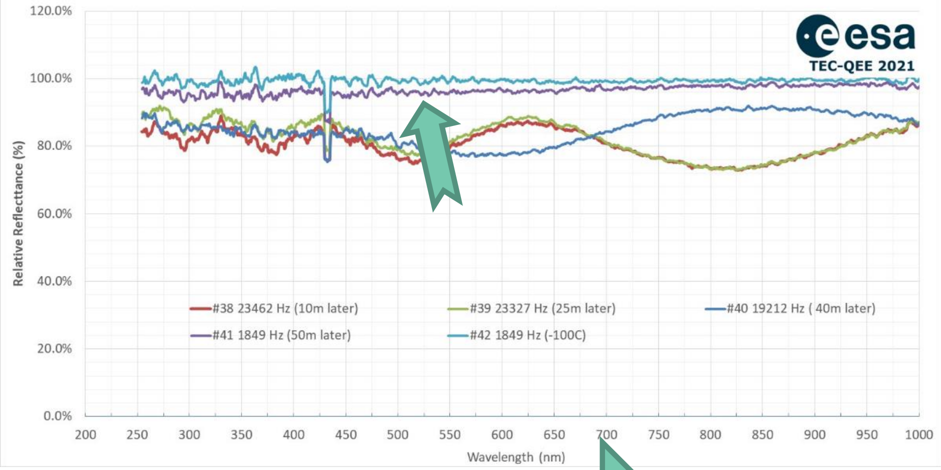
Peak stable rate: ~3.9e-9g/cm2/s

Optical response of MAP PNC (comparison to QCM)

Contamination phase



Re-emission phase



50µg/cm2 deposit at -150°C is depleted practically simultaneously on the MAP PNC and QCM:

- QCM decontaminated within ~55min.
- Optical response of PNC sample ~50min (at/slightly after spectrum #41)

Notes:
- Total reflectance measured in-situ throughout the test.
- Measurements are relative to clean conditions at -150°C

Re-emission results summary

Steady-state ice re-emission rate at **4E-8mbar**:

@ -130C **~ 3E-10 g/cm2/s** ,

@ -120C **~ 3E-9 to 4E-9 g/cm2/s**,

@ -100C **~ 1.5e-7g/cm2/s to ~ 2E-7g/cm2/s**

Note: This dynamic equilibrium is closely dependent to pressure conditions. At ~1E-5mbar, ice can condense at -100^{o}C !

Conclusion and forward work

✓ The Euclid CCC approach has been presented

✓ The ice formation risk has been explained with a focus on the external baffle. Positive feedback was provide to the Euclid on regards to the de-icing phase efficiency.

✓ At ESA ESTEC TECQEE, a facility to verify ice kinetics correlating with ice optical behaviour is available.

✓ **Forward work**

✓ Euclid PLM to SC integration phase and acceptance tests to be carried out followed by launch in 2022.

✓ Ice formation and effects study on specific critical areas - by mid 2022.

✓ More about Euclid CCC including launch details will be presented ISMSE15 - 2022 (Leiden - The Netherlands).

ISMSE 2022

International Symposium on Materials in a Space Environment ISMSE2022 (Leiden The Netherlands 15-20May 2022).

Everyone is welcomed!

References

[1] The Euclid Mission Design_ Racca et al_2016_Proc. of SPIE Vol. 9904 99040O-1_arXiv1610.05508

[2] Cropper, M. et al., “VIS: the visible imager for Euclid”, Proc. SPIE 9904-20 (2016)

[3] Maciaszek, T., et al., “Euclid Near Infrared Spectro Photometer instrument concept and first test results at the end of phase C”, Proc. SPIE 9904-22 (2016)

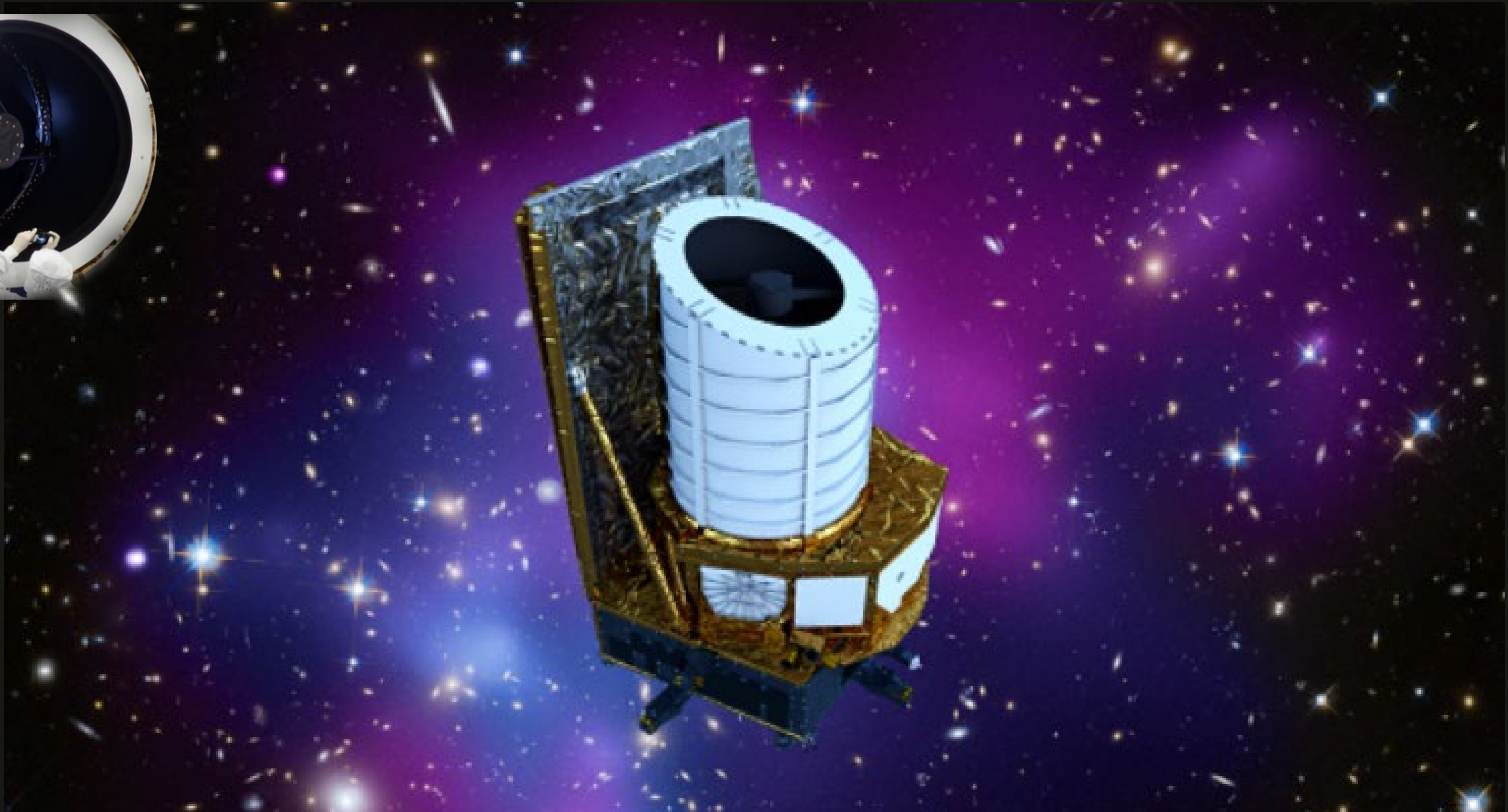
[4] The SiC Primary Mirror of the EUCLID Telescope, M.Bougoin et al, ICSO 2016 Proc. of SPIE Vol. 10562 105623Q-1

[5] B.Bras, et al., In-situ Ice formation investigation, 13th ISMSE, Pau, France, 22-26 June 2015.

Standards

- ECSS-Q-ST-70C Materials, mechanical parts and processes
- ECSS-Q-ST-70-01C Cleanliness and contamination control
- ECSS-Q-ST-70-02C Thermal vacuum outgassing test for the screening of space materials
- ECSS-Q-ST-70-05C Detection of organic contamination of surfaces by infrared spectroscopy
- ECSS-Q-ST-70-29C Determination of offgassing products from materials and assembled articles to be used in a manned space vehicle crew compartment
- ECSS-Q-ST-70-50C Particle contamination monitoring for spacecraft systems and cleanrooms
- ECSS-Q-TM-70-52A Kinetic outgassing of materials for space
- ECSS-E-ST-35-06C Cleanliness requirements for spacecraft propulsion hardware
- ISO 14644 Cleanrooms and associated controlled environments

Thanks for attention



Artist's impression of Euclid. *Credit: ESA/ATG medialab (spacecraft); NASA, ESA, CXC, C. Ma, H. Ebeling and E. Barrett (University of Hawaii/IfA), et al. and STScI (background)*

https://sci.esa.int/web/euclid/-/61010-artist-s-impression-of-euclid
#EuclidMission

Annex - more pictures


https://twitter.com/AirbusSpace/status/1313829646157348865?s=20

Annex - Cleanliness requirements

Payload module sensitive items

MOLECULAR CONTAMINATION ALLOCATION [μg/cm²]				
	At delivery to PLM	At delivery to S/C	At BOL	At EOL
VIS FPA optical surface	0.5	2.2	2.7	4.0
FGS	0.5	2.2	2.7	4.0
NISP external optical surfaces	1.0	1.6	1.7	2.0
M1, M2, FM1	0.05	0.5	0.85	1.0
M3, FM2, FM3, Dichroic	0.05	0.5	0.55	0.55

Table 1 - Scientific Sensitive Items MOC allowable levels

PARTICULATE CONTAMINATION ALLOCATION [ppm]				
	At delivery to PLM	At delivery to S/C	At BOL	At EOL
VIS FPA optical surface	260	600	1200	1200
FGS	200	500	1200	1200
NISP external optical surfaces	700	1200	1600	1600
M1, M2, FM1	150	1050	3000	3000
M3, FM2, FM3, Dichroic	150	1050	1200	1200

Table 2 - Scientific Sensitive Items MOC allowable levels

Service module sensitive items

MOLECULAR CONTAMINATION ALLOCATION [μg/cm²]			
	At delivery to S/C	At BOL	At EOL
Star tracker	1.0	2.5	4.0
Sun sensors	1.0	2.5	120.0
Solar arrays	HS-VC	2.0	4.0
Radiators	HS-VC	6.0	10.0
Thrusters' lines (internal) (1)	1.0	1.0	1.0

Table 3 - Non scientific sensitive items MOC allocation

PARTICULATE CONTAMINATION ALLOCATION [ppm]			
	At delivery to S/C	At BOL	At EOL
Star tracker	5000	10000	10000
Sun sensors	300	1000	10000
Solar arrays	300	5000	5000
Radiators	HS-VC	5000	5000
Thrusters' lines (internal)	See note (1)	See note (1)	See note (1)

Table 4 - Non scientific sensitive items PAC allocation

Ref: Euclid cleanliness requirements specification
Thales Alenia Space Italy