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Euclid cleanliness and contamination control

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Abstract. 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 the formation of structures over cosmological timescales. It will operate at L2 and it will survey about 36% of the sky on a 6 year mission, all with high image quality and stability. To allow such scientific achievements, an integrated cleanliness and contamination control (CCC) have been put in place covering all phases of Euclid development until end of operations. This document describes the design challenges, the engineering and AIT solutions used to control and to monitor the entire mission life time contamination from organic and particulate sources as well as the in-orbit water ice contamination.

1. Euclid spacecraft description

Euclid has the scope to study the dark energy and dark matter of the universe, by using galaxy clustering and weak lensing over a vast portion of the sky for 6 years. The satellite will orbit at L2 Sun-Earth Lagrange point. The spacecraft is designed in three main sections, the instruments, the Payload module (PLM) and the Service Module (SVM). The PLM contains the scientific elements of the mission, the telescope, optical cavity and the two instruments, near infrared spectro-photometer NISP and visible imager VIS. Science objectives, mission and Euclid spacecraft have been described by Racca et al[1].

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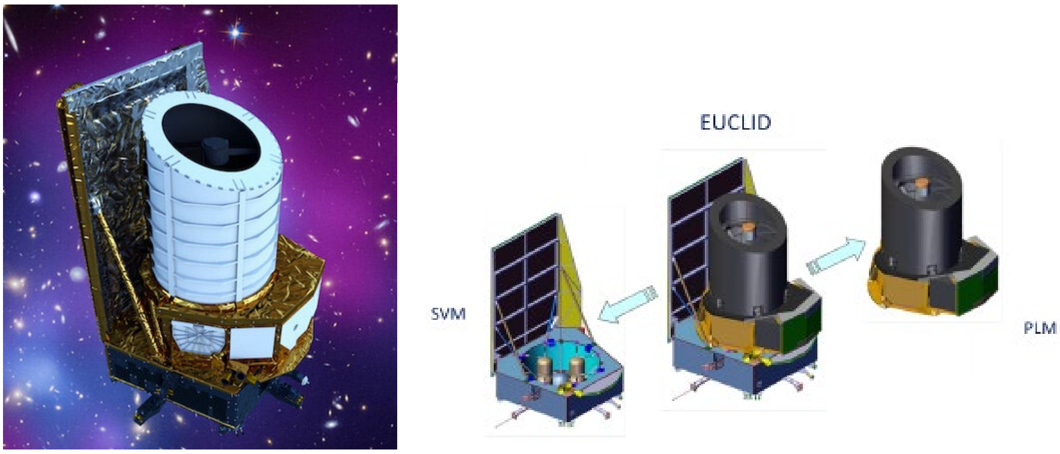


Figure 1. Left: Euclid artistic view (ATG medialab); right: Euclid is composed of a Service Module (SVM) and a Payload module (PLM).

1.1. Payload module
The Payload module contains the scientific core elements of the mission. It is composed of two cavities: the front cavity in which resides a telescope with M1 and M2 mirrors and the instrument cavity with VIS, NISP and FGS. A common SiC baseplate supports mechanically the PLM front and rear cavities and the interfaces with the SVM. The PLM schematic as well as a sketch of the instrument cavity and the front cavity can be seen on Figure 2. All contamination sensitive items can be clearly identified on these pictures. Instruments are described in a dedicated section.

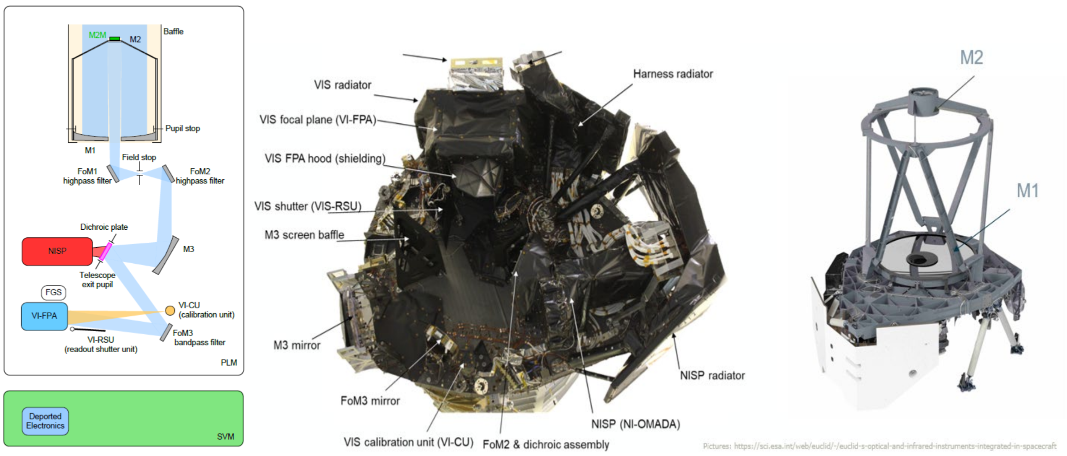


Figure 2. Left: PLM optical schematic; center: PLM rear cavity showing instruments and optics integrated and; right: PLM front cavity highlighting M1 and M2, baffle and MLIs removed.

1.2. Service Module
The SVM is mainly composed by two large sub-assemblies: the platform and the sunshield. The platform is an irregular hexagonal-base prism built around a central cone hosting the propellant tanks, providing the mechanical interfaces with the PLM and the launcher. The platform lateral panels accommodate all subsystems equipment, grouped by function, all radiators and insulators for the internal equipment thermal control and host the scientific instruments warm electronics, which functionally belong to the

PLM. The sunshield, is a wide structure protecting the PLM telescope and instruments from solar radiation and hosting the Photovoltaic Assembly.

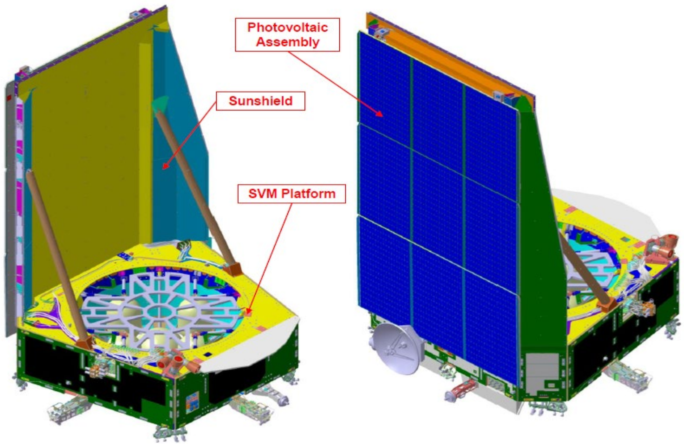


Figure 3. Service Module (SVM)

1.3. Scientific Instruments

Euclid carries two instruments, a Visible imager VIS and near infrared spectro-photometer NISP. Regarding VIS characteristics, VIS has a large focal plane, enabling weak lensing measurements. It consists of 36 CCDs, 604Mpix, pixel size 12μm - 0.1arsec pixel sampling size, spectral band 550-900nm over a field view 0.5deg^2 and survey area 15000deg^2 [2]. VIS units are sparse on the instrument cavity volume thus from a cleanliness perspective they share the PLM volume and cleanliness constraints.

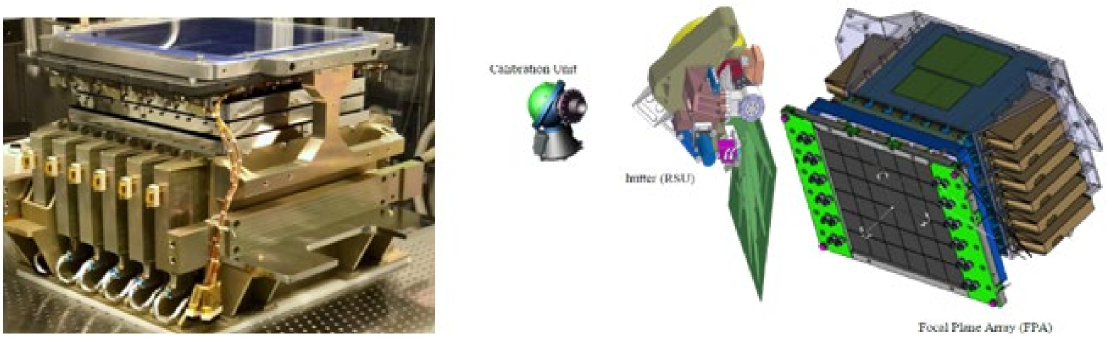


Figure 4. Left: VIS focal plane and; right: VIS units calibration unit, shutter and focal plane array

The NISP instrument operates in the 0.9-2.0μm range at a temperature lower than 140K, and the detectors at ~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 [3].

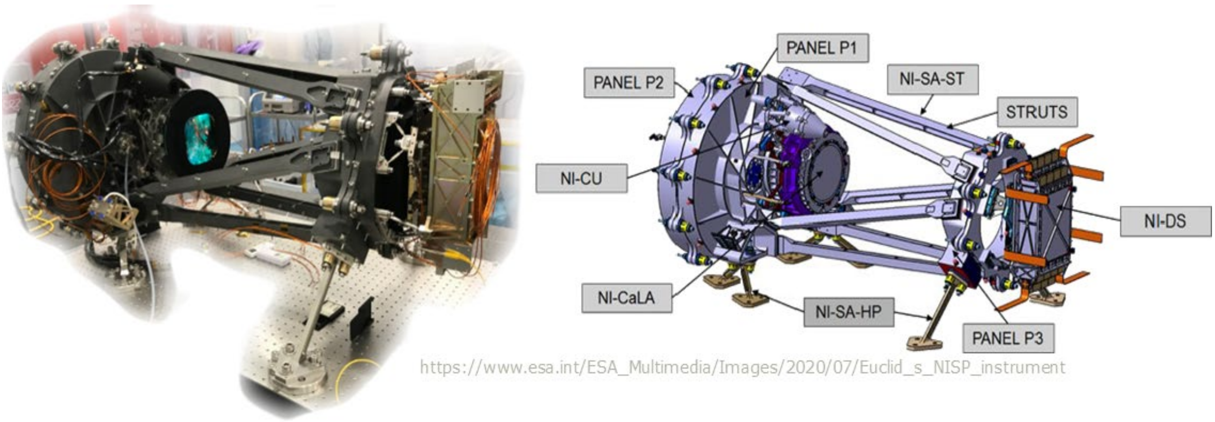


Figure 5. Left: NISP picture during integration, and right: NISP as designed with units described.

2. Euclid cleanliness and contamination control

2.1. Cleanliness requirements

From a contamination point of view, the most sensitive parts of the S/C are clearly those related to the scientific investigations and measurements, thus all items composing the optical chain (mirrors and dichroic) and the VIS, FGS and NISP detectors. Fully based on performances calculations, the maximum allowable PAC and MOC levels were split on the major mission phases: at delivery to PLM integration, at the end of PLM AIT, thus at delivery to the Spacecraft, at Beginning of Life and finally at End of Life. PAC is here most related to straylight issues, while MOC to signal intensity reductions.

Table 1. Euclid contamination specification of sensitive items on the optical path

	At delivery to PLM	At delivery to SC	At BOL	At EOL
VIS Focal plane	260ppm - 0.5µg/cm2	600ppm – 2.2µg/cm2	1200ppm – 2.7µg/cm2	1200ppm – 4.0µg/cm2
NISP ext.optics	700ppm - 1.0µg/cm2	1200ppm – 1.6µg/cm2	1600ppm – 1.7µg/cm2	1600ppm - 2.0µg/cm2
FGS	200ppm – 0.5µg/cm2	500ppm - 2.2µg/cm2	1200ppm – 2.7µg/cm2	1200-ppm - 4.0µg/cm2
M3,FM2,FM3, Dichroic	150ppm - 0.05µg/cm2	1050ppm – 0.5µg/cm2	1200ppm – 0.55µg/cm2	1200ppm - 0.55µg/cm2
M1,M2,FM1	150ppm – 0.05µg/cm2	1050ppm – 0.5µg/cm2	3000ppm – 0.85µg/cm2	3000ppm - 1.0µg/cm2

2.2. Contamination design approach

Being a big telescope with a wide aperture on the top, the Euclid S/C, and in particular the PLM, presents a design intrinsically prone to contamination. In fact the PLM internal side is organised in many cavities, the baffle front cavity, the optical instruments cavity and the NISP cavity it is evident how they represent enclosures where outgassed molecules during flight can more easily stick on colder surfaces rather than find the way to escape towards space through the baffle. Furthermore, working at cryogenic temperatures, ice formation represents one of the most critical design aspects and drivers.

In addition, considering the PLM external configuration, it is easy to understand how particulate contamination can enter the front cavity from its large aperture during on-ground phases, if not properly protected or where protecting it is not an option, like for instance during the PLM thermal vacuum test, during optical testing or verification needed both at PLM and at S/C level or during the S/C launch phase, from encapsulation to separation. Aside these considerations, because of its peculiar design from the moment of PLM integration and all subsequent phases, no cleaning is possible as well as direct monitoring of what happens inside.

For these reasons, an intense iterative process focused at matching all design needs with the many contamination control constraints took place early on the project, which has been refined continuously until the critical design review and beyond, progressively following all the manufacturing and assembly phase implementation. At this stage the design and the cleanliness provisions have been defined. In this view, contamination engineers role was of primary importance in all design aspects, other than in realizing how to implement it in a way to maintain cleanliness levels within the limits required, both on-ground and in-orbit.

Figure 6. End of PLM AIT. Picture from https://twitter.com/ESA_Euclid

As usual within missions with high sensitivity to contamination, the cleanliness process has been initialised identifying the technical performance losses associated to accumulation of contamination on scientific and non-scientific equipment. Starting from this crucial set of requirements, an end of life budget has been split throughout the main mission phases and budgets for ground and in-orbit contamination have been predicted. Ground contamination predictions tools have been used to determine how to meet each phase specification, by calculating how particulate and molecular contamination deposition rates on each surfaces and locations on each step of the AIT.

Based on first results, contamination engineers started iteratively refining all design aspects and on-ground activities possibly constrained by contamination risks, progressively optimizing a contamination control baseline, fully harmonizing needs and efforts to be exploited at all levels, being instruments, PLM, SVM or integrated S/C. All identified boundary conditions have been taken into account, which main are: cleanroom classes, geometries, time of exposure, use of mitigations, specific protections, stringent materials selection, bake-out plans, exploiting to the maximum extent all previous and relevant experiences. This process has been tuned until sufficient margin was identified for each project phase.
In this frame, as said common to applications highly sensitive to contamination, the big challenge for the Euclid project was represented by its complicated design and by the strong interconnections of the three main S/C branches, the Instruments Set, the PLM and the System Level. This implied an harmonized and shared work of the entire team of contamination engineers of the three different parties, collaborating to build and achieve the most contamination control design driven as possible. Whenever not meeting the specifications, the Euclid team has increased the facilities cleanliness classes, created one portable ISO 5 Euclid dedicated cleanroom, designed and implemented barriers and customized protections or directly changed physical/material design finding acceptable levels for the ground phases.

For the cruise and operational phases, contamination modelling analysis of outgassing and thruster plume have been carried-out to evaluate effects from self (PLM-instruments) and cross contamination (SVM-PLM), bringing to the establishment of a common full scale bake-out plan, requiring that all materials of the PLM, of the instruments, and of the majority of the SVM were submitted to TQCM monitored bake-outs. In this view, a common and agreed bake-out protocol has been developed by the whole contamination engineering integrated team, to optimize objectives and effort.

A sketch of the overall strategy is shown in the following Figure 7. Each choice in terms of design have been validated until EOL by modelling or by using ground prediction tools, once feasible dedicated contamination control would be implemented and receive a feedback loop about their technical feasibility or trigger a new change to compensate for lack of margins.

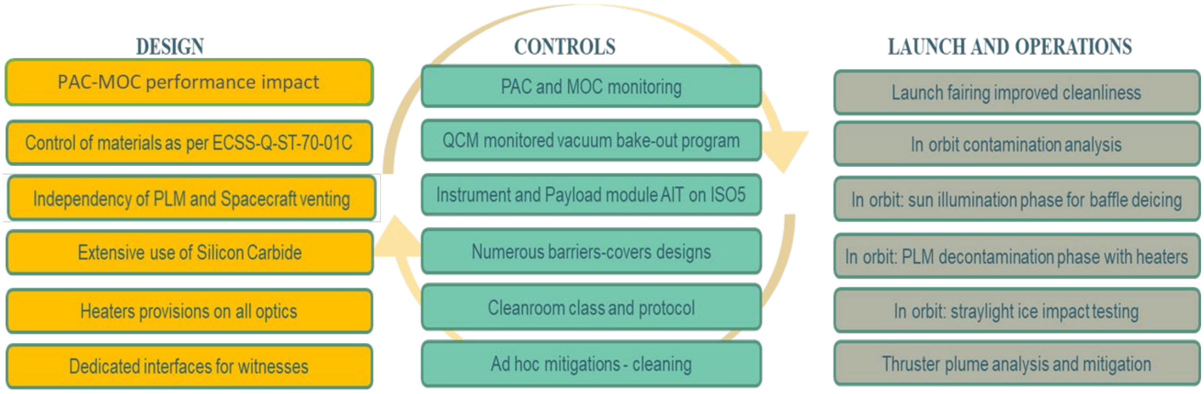


Figure 7. Contamination control implementation flow

Worth highlighting the differences between PLM and SVM. The PLM is designed to work as an independent contamination “system” than the spacecraft itself during operations, limiting connections. This separation allowed to broadly implement two different schemes of contamination control, one more stringent at PLM level where all instruments and PLM AIT required extensive use of ISO 5 facilities and another at SVM level which has been developed and integrated on ISO8. Once PLM and SVM have been mated, a mixed approach was necessary, implementing a more stringent control when the optics are exposed to cleanrooms or in vacuum to reduce the cross contamination during thermal vacuum tests.

In-orbit, the PLM cleanliness control is managed separately without any impact from outgassing or venting from SVM, in practice simplifying the outgassing and decontamination management in-orbit. Ground vacuum tests however need to have a mixed approach where cross contamination is considered, not only from SVM to PLM but also from the facility towards Euclid. Spacecraft contamination control is explained on a specific section.

2.3. Payload module contamination challenges and strategy

The main PLM challenges related to contamination control are connected to the high sensitivities of mirrors and scientific instrument detectors, to be preserved both during on-ground activities and during mission, in the frame of a wide open volume design, critically to be protected.

The PLM contamination control strategy has been based initially on control of materials selection process based on low outgassing properties assisted by an extensive bake-out campaign. Materials selected are highly inorganic, Silicon Carbide (SiC) has been used on a number of structural and optical elements, such as the M1 and the baseplate (Figure 8). All the PLM parts containing non-metallic materials were submitted to a TQCM monitored bake-out, implementing a common and agreed Euclid bake-out protocol and procedure, summarised as 72 hours of minimal duration, pressure lower than 1E-5 mbar, and stoppage criteria deviation from linearity of outgassing rate less than 1%. The success of the bake-out has been each time followed and agreed by the entire project contamination engineering teams. It is important to note that all bake-outs had a very advantageous temperature (between 333K and 353K) versus the operational temperature (between 125K and 150K), aspect found on cryogenic missions that comes handy to support cleanliness engineering.

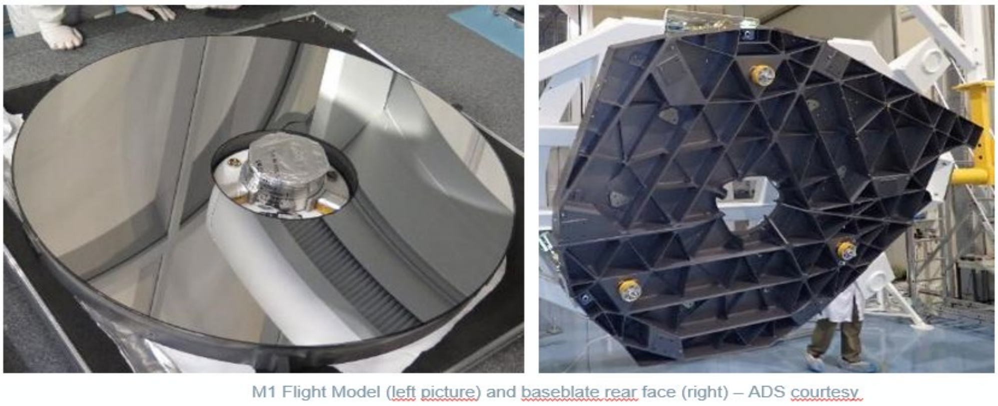


Figure 8. Depicted the M1 flight model (left) and the tilted baseplate (right), two of many parts in silicon carbide

The entire design of the PLM and of its interfaces with the SVM has been studied in such a way to completely segregate the two modules with the aim to avoid any contamination impact of the SVM towards the PLM. In fact, when mated, no part of the PLM internal volume is in direct communication with the SVM. In this view and with this objective, a specific design has been implemented on the main PLM struts in order to orient the outgassing coming from the glass fibre composite away from the PLM optical cavity.

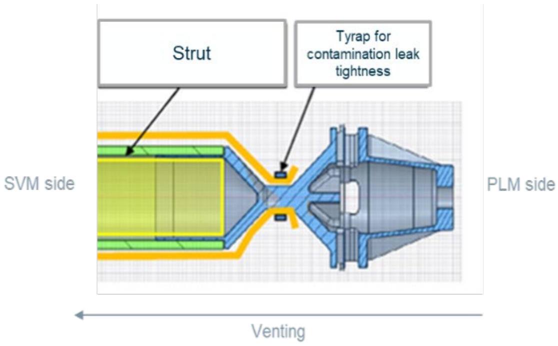


Figure 9. PLM-SVM struts showing a dedicated venting designed for Euclid

Finally, to further preserve the PLM from possible contamination coming from the external environment, all its external envelope is completely closed, so that the only aperture is represented by the baffle opening, protected on ground by suitable covers.

The PLM AIT has been performed in ISO 5 environment. In situ monitoring of particulate and molecular contamination has been implemented all along the integration and during the thermal vacuum test. The Figure 10 (red circle) highlights the presence of the witness samples representative of the front cavity exposed during the integration phases and during the thermal vacuum test thanks to the implementation of a dedicated bracket compatible with molecular contamination witness samples and cryogenic particulate witness plates. The same approach has been used for the instrument cavity- not visible in the picture. Due to the close vicinity to the optics the brackets have been designed to be dismountable from the external side, using a simple but efficient bracket. Furthermore, to avoid risk of damage to the PLM, such brackets with the witness samples have been dismounted only during the mechanical test campaign and during the transport. The frequency of the monitoring has been at each main step of the integration, e.g. at each integration of an optical surface, and before and after each test sequence. On the right, as protection versus on-ground contamination Euclid utilised extensively hard covers with more than 99% protection efficiency and soft covers, made of SCC1000 supported by an aluminium frame, which are mechanical testing compatible. The rear cavity of the instrument is closed and fully protected by the MLIs, designed with dedicated venting paths and by the instruments radiators. The efficiency of the covers has been verified using a specifically built mock-up of the external baffle.

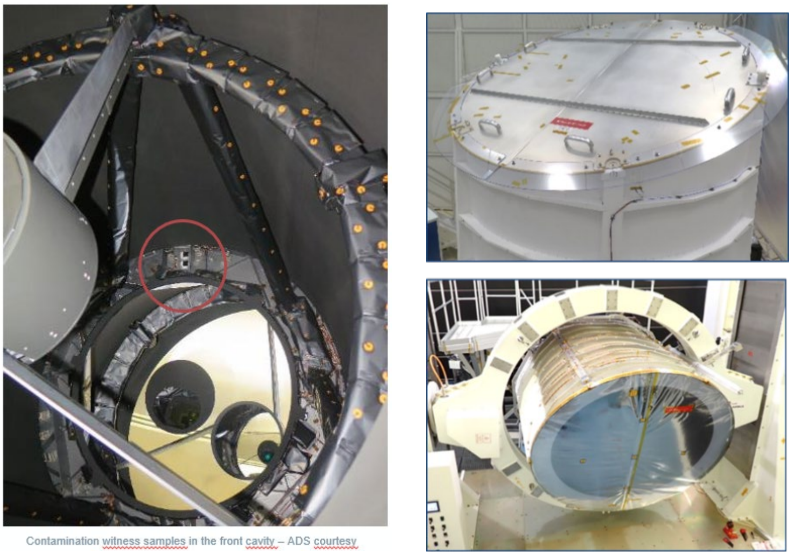


Figure 10. Left: Internal side of baffle, showing M1 and the witness samples installed; right: hard cover installed on PLM baffle and soft cover for mechanical testing.

Finally, heaters are implemented in the PLM, especially on the back side of the mirrors, and instruments have in-flight decontamination capabilities. Even though being negligible in term of mass, the heaters have been submitted to bake-out before their installation on the structure of the mirrors to limit their outgassing during decontaminations phases. In addition, the heaters' location, materials, and outgassing behaviour have been modelled with in-orbit analysis, the impact has been very limited. Water ice growth kinetics and risks affecting the optical performance have been studied [4][5][6] and decontamination strategies are implemented to remove ice by heating.

Mounted on the SiC baseplate, VIS units have been treated as integrated part of the system PLM with no physical separation. Knowing that the VIS CCDs cannot be cleaned, a PLM challenge has been to design each AIT step to avoid impact on VIS cleanliness budgets principally. To depict this aspect following PLM thermal test a potential cleanliness anomaly has been declassed as non-impacting thanks to the PLM mitigations and monitoring managed at PLM level rather than VIS level.

On the other hand, NISP instrument can be considered until a certain extent standalone. NISP contains its own volume which is linked to the optical cavity through ventings and the externally directed perforated MLI. Decisions at NISP level not necessarily have an effect on the PLM (and VIS) and vice versa. The highest risk however on this set-up is in case water ice keeps bouncing inside the NISP cavity or within the filter wheel.

Figure 11. PLM instrument cavity picture being integrated at ADS Toulouse, in front middle the VIS focal plane, right side the NISP instrument.

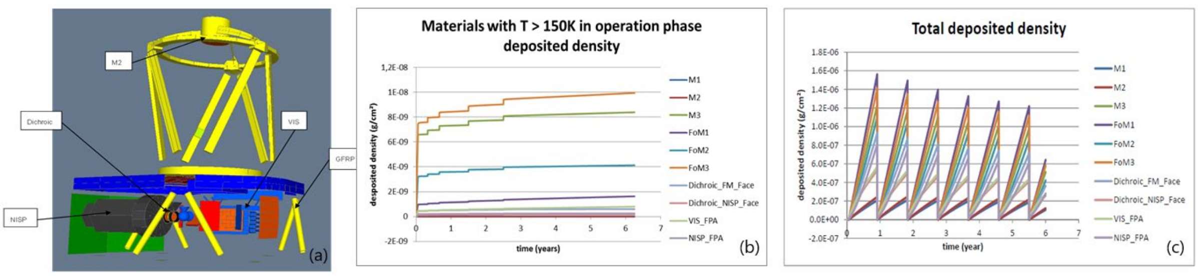
The cleanliness status of the Payload Module at delivery to Spacecraft has been outstanding, in particular regarding molecular contamination, which confirms the efficiency of all implemented design choices or mitigations during AIT. The only exception was the particulate contamination level of the M1, due to its location in the bottom of the baffle and its dimension, the cleaning was not easily feasible. Nevertheless, it has been demonstrated by updated Scatter Sensitivity Analysis, that this particulate contamination level has no detrimental effect on the performances. Below the summary status at PLM delivery to spacecraft, concluding one of the major milestones of Euclid. At Euclid spacecraft level, no cleanliness deviations have been identified at this date, in fact considering the remaining AIT until BOL and EOL. Future publications will include the actuals monitored values by the Euclid spacecraft including the launch campaign

Table 2. PLM contamination levels at delivery to S/C

	M1	M2	M3	FoM1	FoM2	FoM3	Dichro	VIS	NISP	FGS
MOC ($x10^{-7}$ g/cm^2)	2.50	2.03	1.58	2.20	2.51	2.07	2.16	3.53	6.49	5.95
PAC (ppm)	1599	636	770	970	970	870	770	874	620	620

2.4. In-orbit contamination analysis – organic and water-ice contamination
The PLM in-flight outgassing has been studied using Systema Outgassing software. On this tool, Dynamic outgassing data of materials, in accordance with VBQC ECSS-Q-TM-70-52A, are injected in a 3D model which considers surface temperatures at all phases, during cruise and during operations. Emission and re-emission of molecules from different nodes of the model are then computed using mass transfer factors. A Monte-Carlo Ray-tracing approach has been used.
The focus has been the potential outgassing at cold and cryogenic temperature following an early decontamination phase. Two scenarios have been studied:

- Extrapolation of the outgassing data from standard dynamic outgassing tests, where no outgassing below 150K occurs, both in terms of emission and re-emission, the result is positive and no decontamination will be needed during the entire operation phase, Figure 12b.
- Extrapolation of the outgassing data from standard dynamic outgassing tests, the result is less optimist and identifies that one decontamination per year will be necessary, Figure 12c.

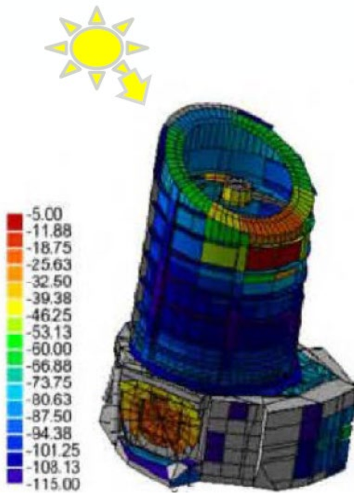


Courtesy Airbus Defence and Space

Figure 12. left PLM 3D with applied materials, the baffle and MLI has been removed to facilitate visualisation, middle: total deposited best case results; right: worst case results requiring one decontamination a year.

2.5. In-orbit contamination analysis - decontamination phase

The decontamination phase profile is planned during early commissioning phase. It consists of an initial transient warming phase based on electrical heaters, located on the rear cavity sensitive elements and by a sun illumination phase, the scope is to outgas light organic molecules and remove water ice. The profile has been defined using the in-flight contamination analysis. supported also by an in-situ ice kinetic testing and scattering effects on flight representative materials and conditions, the work has been presented by B. Bras on [5] and [6] (see 1.8.1). The early decontamination phase is planned to be as long as six days, four under isothermal conditions, where temperatures of sensitive items, such as optics and detectors, will be maintained between 200K to 273K.



To support the required heating power, Euclid will be tilted slightly towards the Sun (Figure 13). This consequence of the is an increase temperature, on the external baffle where the lower surfaces will still be cryogenic, for such reason the risk of having ice has been studied. The dynamics of water release from the cryogenic parts of the external baffle have been characterised by testing different thicknesses of water-ice deposited on a MAP black PNC paint.

Figure 13. Sun illumination phase thermal map, the achieved minimum peak temperatures at the bottom external baffle surfaces, increased the risk of water ice condensation, which has been studied in details with in-situ water-ice measurements.

The ice time-dependency re-emission behaviour has been derived both with quartz crystal microbalances (QCMs) and by in-situ reflectivity testing [5]. The tests have been carried out at ESA-ESTEC and the ice kinetics have validated for the duration of the ice decontamination phase, see Figure 14.

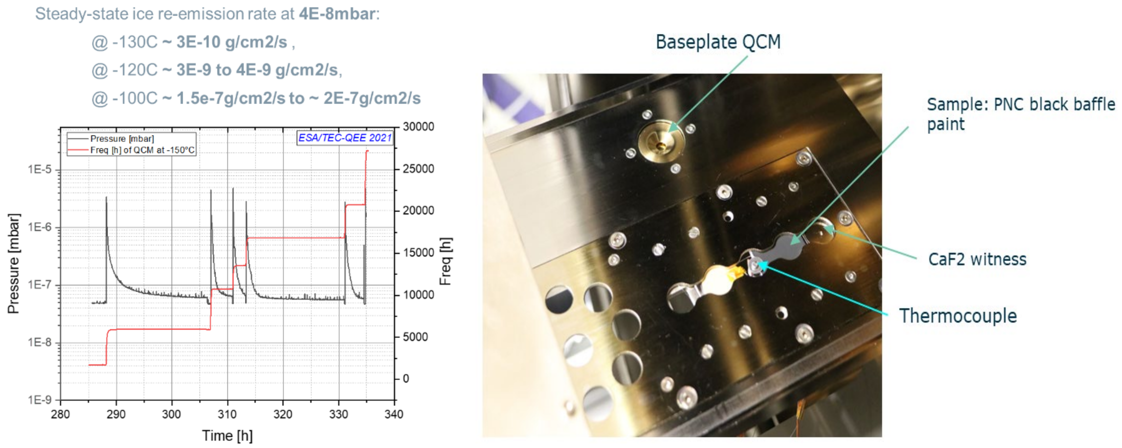


Figure 14. left: Ice re-emission rates at different temperatures; right: picture of set-up, for more details see presented work [5].

2.6. In-orbit contamination analysis – ice straylight impact on performance

No specific ground phase water absorption mitigation has been possible on Euclid, although an extensive vacuum bake-out campaign has been carried out. Since water is reabsorbed by materials when reexposed to ambient conditions, the strategy to control water on Euclid relies on in flight decontamination phases. In order to predict ice performance impact on flight optics and use this information as a potential trigger for decontamination and for data model calibration purposes, a series of in-situ ice straylight characterisations on flight representative mirrors and optics have been tested at ESTEC, the results are presented by B.Bras et al. [6].

2.7. Service module and Euclid spacecraft

The big challenges relevant to the Euclid S/C design related to the contamination control engineering were mainly aimed at avoiding any contamination of the PLM sensitive surfaces coming from the Service Module (SVM), to assure all the SVM support to the decontamination phases and to maintain a very low contamination budget, especially for particles, during all phases from the mating of the two modules until launch.

In order to avoid any contamination coming from the SVM towards the PLM, a stringent and constraining materials selection process based on low outgassing properties was implemented. Furthermore, an extensive TQCM monitored bake-out campaign, involving the majority of items containing non-metallic materials has been performed, using the common and agreed Euclid bake-out protocol and procedure applicable to the PLM parts. It is interesting and important to highlight that, differently from the PLM, the mass and volume of SVM parts containing non-metallic materials is substantial. All the SVM harness, the entire sunshield, all SVM panels and MLIs, were submitted to bake-out. In order to further protect the S/C sensitive surfaces from outgassing, the same approach was followed during the Euclid S/C TVAC test planning, where all GSE items containing non-metallic materials were requested to be submitted to bake-out.

In parallel to an overall design aimed at avoiding any possible contamination coming from the SVM towards the PLM, the biggest challenge at S/C level was creating a contamination control program able to maintain a very limited contamination budget from the PLM and SVM mating to launch on sensitive surfaces. The main critical aspect was that all AIT phases from that moment on, including the whole environmental testing campaign, were planned to occur under ISO 8 conditions and without the support from purging. For this reason, the PLM had to be protected with a series of specifically designed baffle covers as mission development matured. The initially designed cover provided a 98% of efficiency and later it has been dramatically improved to values well above 99% in efficiency. Nevertheless such cover, which was fundamental during the nominal AIT phases and made by a metallic honeycomb structure, wasn't compatible with the three most critical tests under a particulate contamination point of view: the acoustic test, the vibration test and the thermal vacuum test.

https://mobile.twitter.com/Thales_Alenia_S/status/1542806123513880576

Figure 15. Euclid spacecraft mated and ready for environmental and mechanical tests

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Thus, two covers were further designed: a “soft cover”, consisting of an aluminium circular ring holding a plastic foil, fully compatible with acoustic and vibration loads, and a “thermal cover”, to be used during the S/C thermal vacuum test, made by a hexagonal metallic ring, on which 6 metallic black anodized extremely low outgassing petals are mounted. These two covers have a 98% of efficiency against particulate contamination and on a case it was validated during the S/C STM itself. Following this philosophy, to avoid performing the vibration and acoustic tests with star trackers lens and baffles internal surfaces unprotected, as normally done, a dedicated soft cover has been designed to be mounted during mechanical testing.

In order to allow all covers swaps and installations, implying optics exposure to the external environment, a brand new dedicated fully portable ISO 5 has been procured by TAS-I. Other than the portability, this facility can create an ISO 5 environment of specific parts of the satellite. In this view, it has the peculiarity to be movable with the Euclid S/C horizontal axis, supporting localised implementation of extremely clean conditions. The Euclid ISO 5 portable tent will be utilised also during the launch campaign.

The detailed contamination control programme defined at design phase, has been later validated during the Euclid S/C STM AIT campaign. The STM has been used to prove the CCC programme efficacy, to validate hypotheses and contamination rates used in the contamination predictions, to prepare procedures and fine tune them for the PFM campaign, to optimize the cleanliness inspections plan and monitoring plan and to train personnel to constraints related to contamination control. Such validation phase has been of the outmost importance prior to PFM and highly recommended for any scientific satellite.

Concerning the orbit phase, a contamination analysis has been carried out for both outgassing and for thruster plume. The favourable geometry of the SVM has been of benefit to avoid cross contamination with the PLM. In a matter of fact, while common spacecraft architectures present major contamination sources in field of view of radiators or instruments, on Euclid the PLM is fully shielded from the SVM outgassing, being the SVM overall view factor with the PLM baffle aperture reduced to zero. About potential self-contamination impacting the SVM sensitive items, both extremely limited view factors, and the bake-out campaign effect brings molecular depositions in-orbit to negligible values. About thruster plume possible contamination, covers have been installed to avoid cross contaminating thermal control paints and OSRs, as shown on Figure 16.

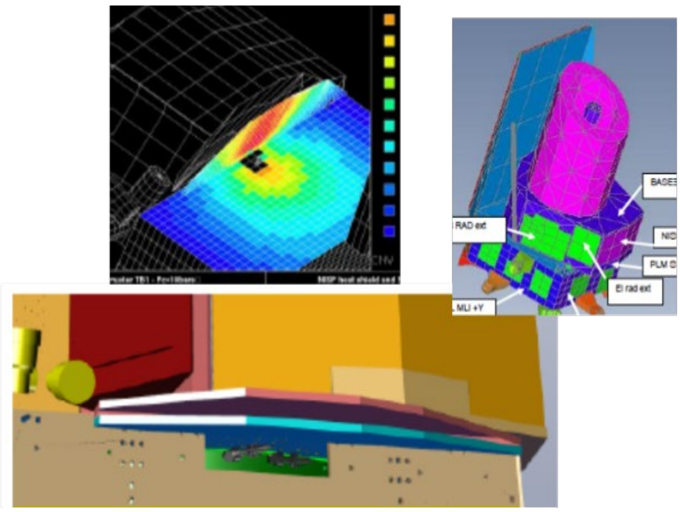

Figure 16. Upper left: thruster plume in-orbit analysis; upper right: PLM to SVM in-orbit outgassing analysis, and bottom: implemented plume shield used to protect radiative surfaces.

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2.8. Pre-launch and launch phase

As already mentioned in the above, one of the most critical part of the Euclid design is that the PLM presents a very large aperture towards the external environment, bringing it to be prone to contamination, mostly particulate. While this disadvantage can be managed during phases until encapsulation by means of high efficiency covers, once the S/C is under the fairing its configuration becomes very critical. First, during the days before lift-off, the PLM mirrors and instruments sensitive surfaces are directly exposed to the internal fairing air, with its natural particulate fall-out. Then, from the launcher engines switching-on, vibrations and acoustic loads start causing particles detaching from the fairing internal surfaces, which a high portion is directly facing the PLM aperture. Then, from lift-off, air starts to move, hazardously transporting those particles possibly in the sensitive surfaces direction. In this view, even if a large portion of the particulate contamination budget was allocated to this very limited phase, the launch phase imposes important constraints to Euclid contamination engineering. To mitigate cross contamination during launch, the entire Euclid external surfaces will be cleaned to a VC-HS + UV level, and at the very last accessible moment before fairing encapsulation. Considering the pressure and constraints of the launch campaign, this activity is expected to be a challenge. The launch provider will see its share of critical activities. Two main improvements are required when compared to typical missions. Firstly, an extensive cleaning of all items facing Euclid when encapsulated, the fairing internal surfaces are required to achieve a level of particulate of only a few hundreds parts per million. Secondly, an improved control of the fairing air quality to reduce ingress of contamination comparable to an ISO 5.

Figure 17. CAD of Euclid in launch configuration.

In terms of release mechanism contamination, the second stage adaptor clamps aren't exposed to sensitive surfaces, thus no specific effects are planned at early launch phase.

All in all, despite these precautions, the particulate contamination predictions are relatively high. Analysis shows that from combined operations to separation, a minimum of 1300 ppm will enter the PLM aperture. Although this contamination represents a noticeable amount with respect to the overall Euclid budget allocations, such level is considered sufficient to comply with the Euclid needs.

3. Conclusions

The Euclid observatory is a demonstration of a successfully integrated contamination control management at Scientific Instruments set, Payload Module and Spacecraft level. The challenges and efforts in contamination control engineering have been described as well as their implementation. Once in-orbit, molecular and water-ice condensation effects have been evaluated, in particular water ice has been characterized with unique testing capabilities and facilities at ESTEC [4][5][6]. End of 2022 – early 2023 will cover final spacecraft acceptance testing followed by kick-off of launch preparations, currently planned for early 2023. All these collected efforts throughout the Euclid development until flight operations will contribute to produce unique dark energy and matter scientific discoveries.

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