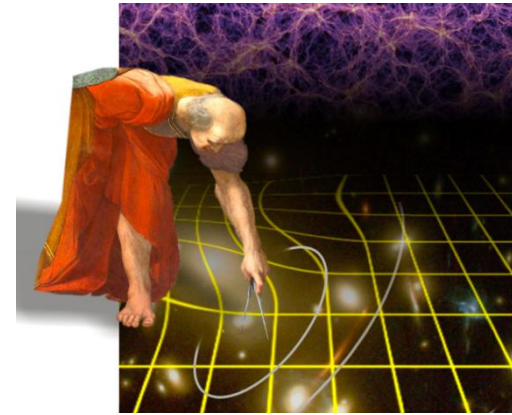




Large science space projects development at CEA illustrated by the Euclid mission

Michel Berthé (CEA Astrophysics Department, France)



02/10/2026 SPACE-Crete Info Day

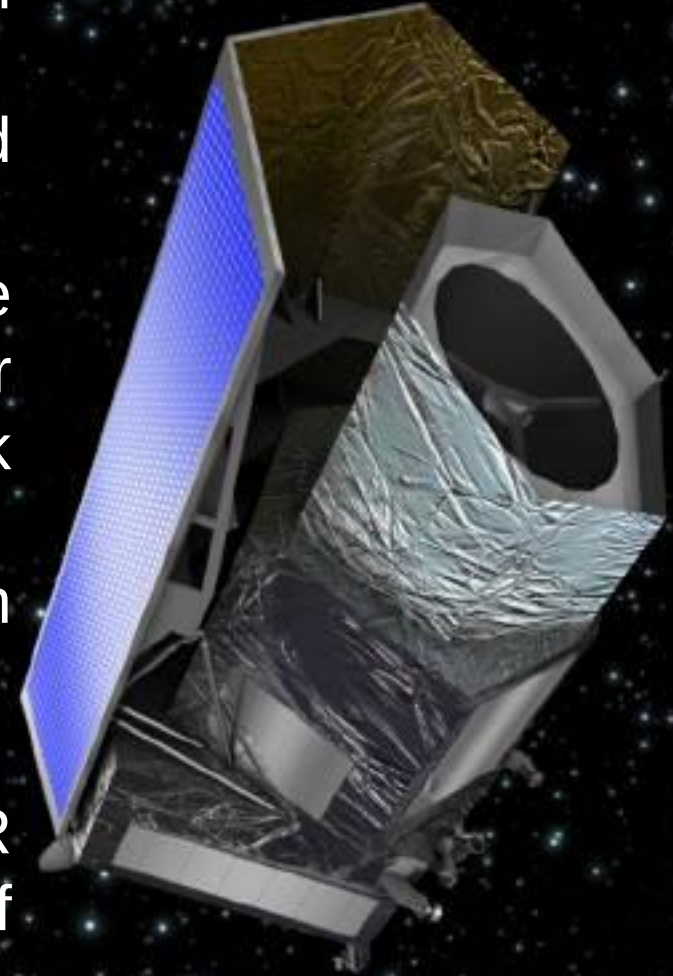


1. Organization of scientific space programs
2. The Euclid mission of the European Space Agency
3. CEA's role in the Euclid mission
4. Product Assurance and Risk Management
5. Mission planning and development plan
6. Budget and human resources

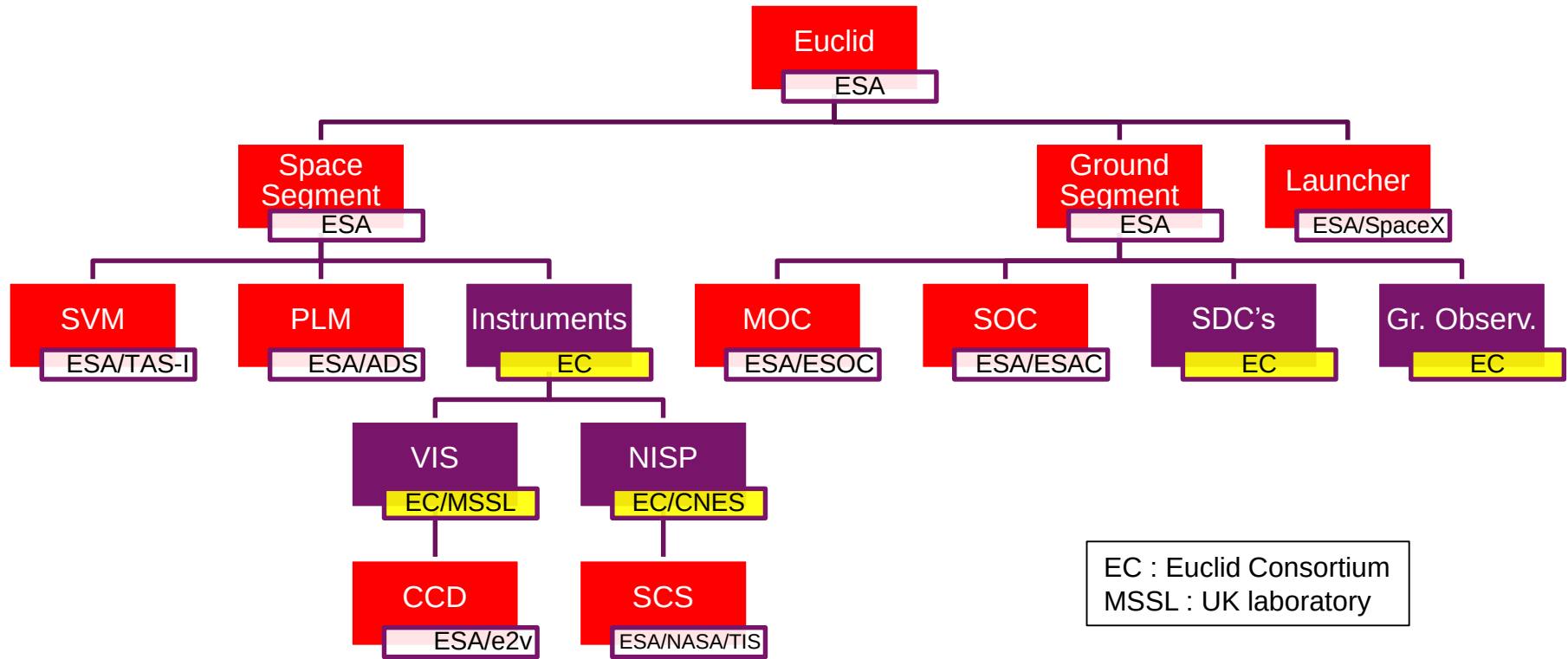
SCIENTIFIC SPACE PROGRAMS

- Most scientific space programs are led by one or more space agencies (ESA, NASA, CNES, etc.)
- Missions are selected based on scientific objectives, proposed by the scientific communities (bottom-up process)
- For ESA science missions :
 - ESA is funding all mission costs (platform, launch, operations, etc.) from its mandatory program budget, except the scientific elements
 - The scientific communities provide the scientific elements (instruments, ground segment facilities and data processing) based on national funding (independence of scientific performance, Principal Investigator)
 - In most cases, ESA asks a single organization in each country to take responsibility for all national contributions (Lead Funding Agency) => Multilateral Agreement. In France, CNES is the national space agency
 - PRODEX (PROgramme de Développement d'Expériences scientifiques) offers institutions and industry the chance to work on ESA experiments. The program works to help countries to get returns on their investments, and to promote scientific and industrial excellence and competitiveness.
 - Greece became a participating state in the PRODEX program in November 2008

- Euclid is an ESA cosmology mission (M2), launched on 1 July 2023 to L2
- Characterization of dark energy and dark matter
- Three-dimensional mapping of the large-scale structure of the Universe for galaxies (Galaxy Clustering) and dark matter (weak-lensing effect):
 - ✓ High-precision images of more than one billion galaxies
 - ➡ **Visible imager (VIS)**
 - ✓ Photometric measurements in 3 IR bands + infrared spectra of approximately 50 million galaxies
 - ➡ **Near-infrared spectro-photometer (NISP)**



RESPONSABILITIES IN THE EUCLID MISSION



Euclid cost at completion: €1.3 billion

- **€800M ESA**
- **€500M Consortium**

Euclid Spacecraft

3,70 m

PLM

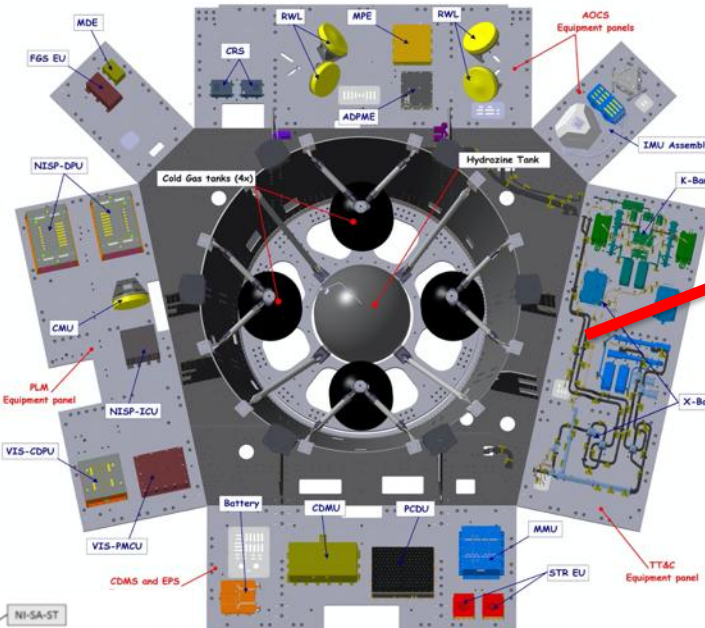
AIRBUS
DEFENCE & SPACE

P/L Module: telescope and cold compartment with P/L cold units

850 kg

sunshield
& solar array

4,80 m

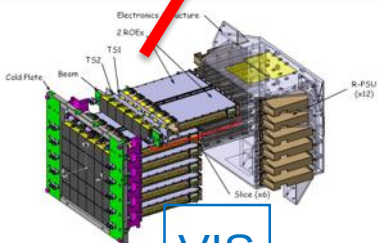


SVM ThalesAlenia
Space

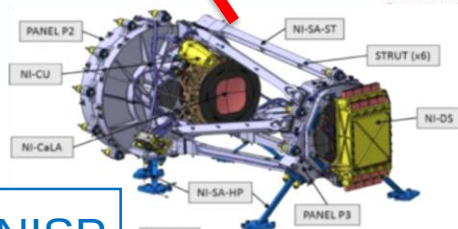
Service Module S/S units
and P/L warm units

1160 kg

total mass : 2160 kg



VIS



NISP

CEA responsibilities in Euclid

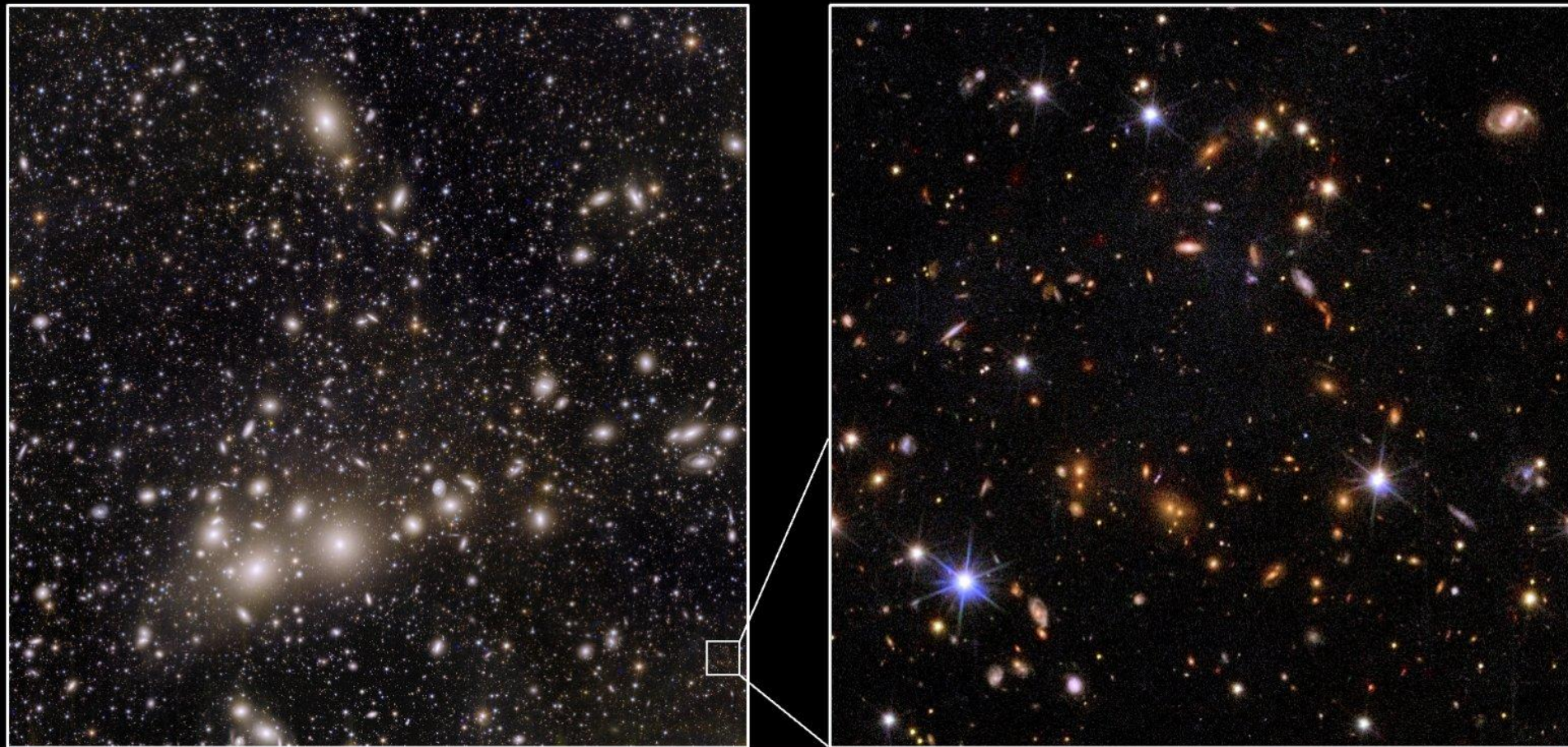
CEA has the following responsibilities in the Euclid project:

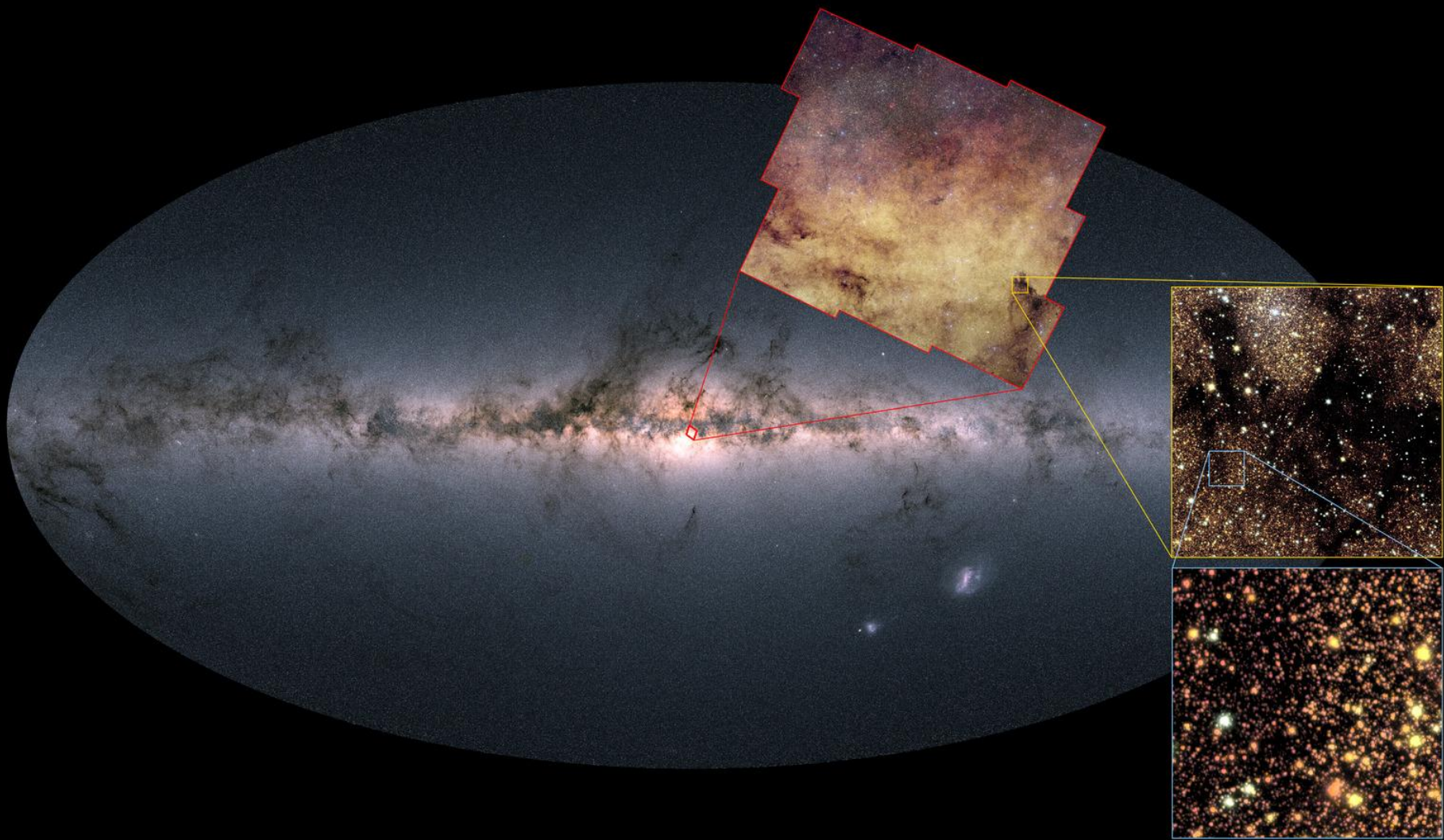
- Design, manufacture and tests of equipments:
 - focal plane assembly (FPA) and motor and power control electronics (PMCU) for the VIS instrument
 - Cryo-mechanism equipment for the filter wheel (CM-FWA) and grism wheel (CM-GWA) for the NISP instrument. These two units are strictly identical in every respect
- Participation in the Euclid Consortium Lead (ECL) group, with in particular the following responsibilities:
 - Technical coordination and support in consortium management
 - Participation in systems engineering activities at Euclid mission level
 - Participation as experts in ESA reviews
- Scientific coordination of the Science Ground Segment (SGS)
- Lead of Euclid scientific activities for data-processing prototyping (Organization Units) “OU Level 3” and participation in the “OU VIS” and “OU Sheer” activities
- Participation in the Science Working Groups (SWG)

The VIS instrument

- Objective: obtain visible-light images of galaxies with extremely high quality (stringent requirements on shape measurements, stability and photometry)
- 1.5 billion galaxies ($m < 24.5$) measured with $\text{SNR} > 10$
- Approximately 50,000 galaxies measured in each 10-minute exposure
 - Measurement of distortions at the 0.01% level
- 36 CCDs of 4000×4000 pixels (600 million pixels over 877 cm^2) with a 0.1 arcsec pixel scale on the sky
=> instantaneous field of view: $0.54 \text{ square degrees } (0.709^\circ \times 0.787^\circ)$
- Large instrument: total mass $\approx 135 \text{ kg}$
- Data rate: $\leq 520 \text{ Gbit/day}$
- “Distributed” instrument made up of several physically independent units in the Payload Module (PLM) of Airbus DS
- VIS instrument responsibility: MSSSL / UK
- **Strong French participation: 3 of the 5 subsystems**

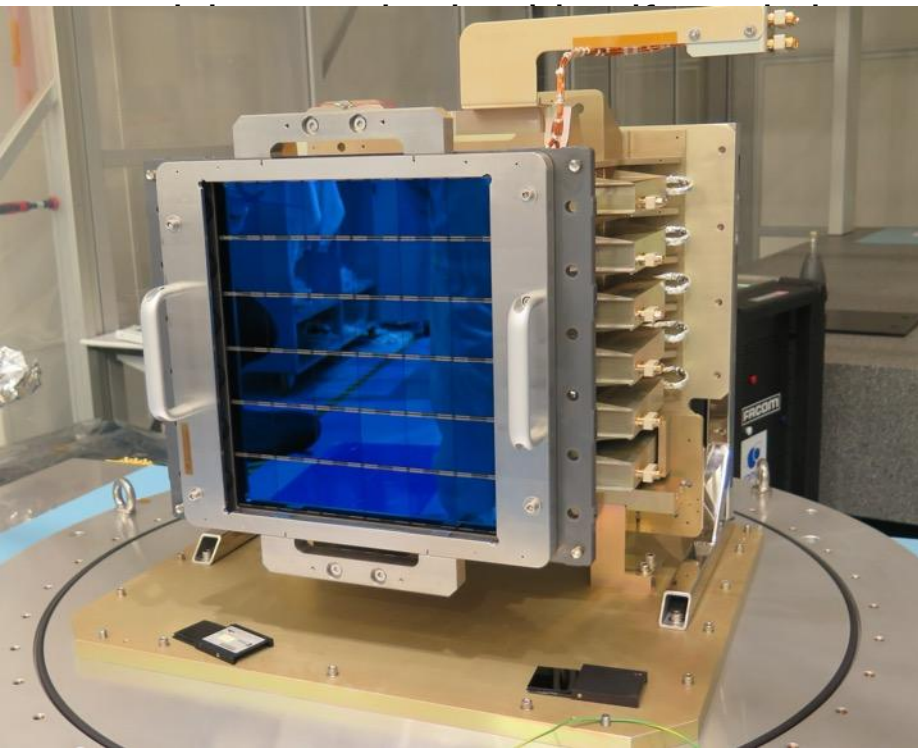
The VIS instrument





THE EUCLID FOCAL PLANE FLIGHT MODEL

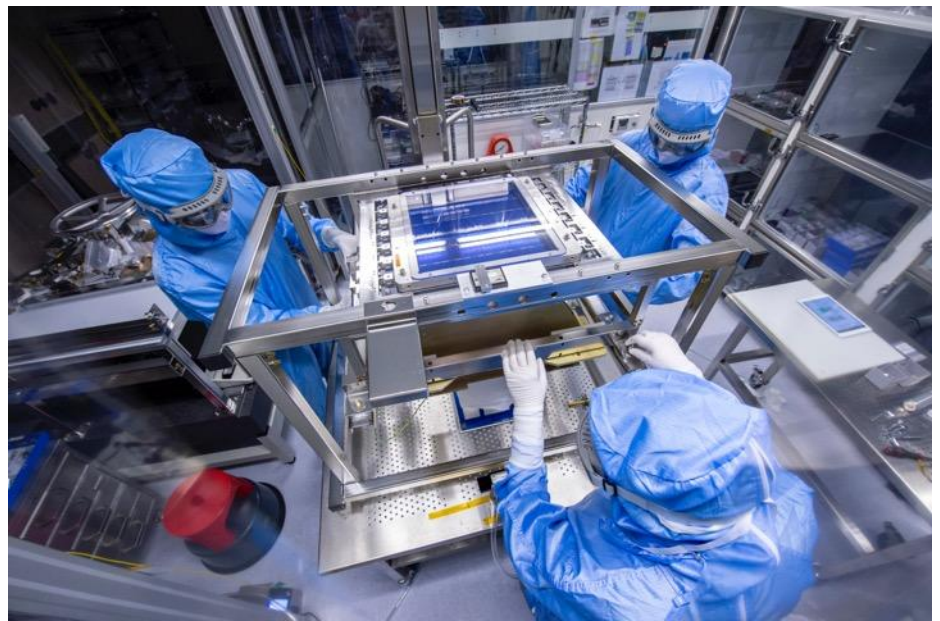
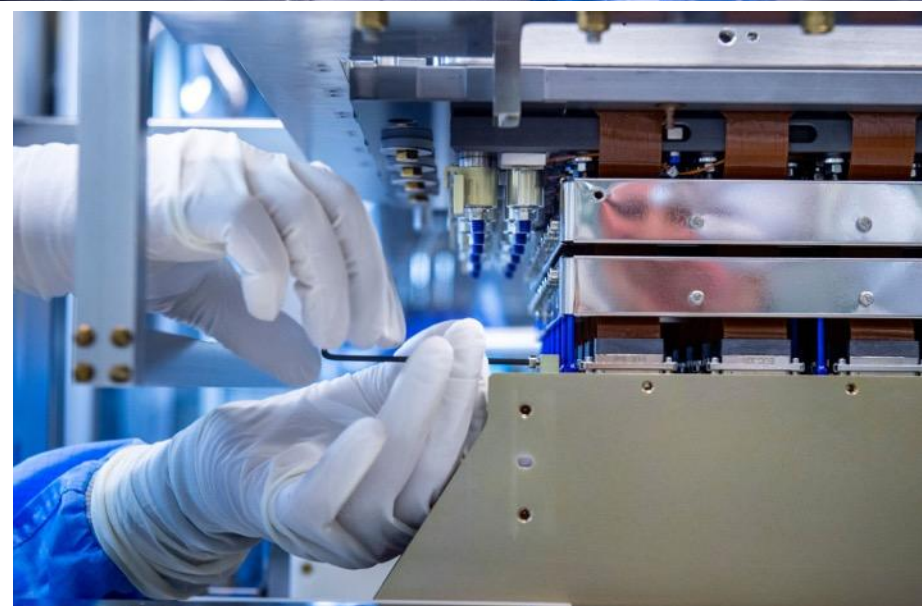
- On 10 January 2020, responsibility for the Euclid focal plane of the VIS instrument was transferred from CEA / IRFU to the laboratory responsible for the instrument (MSSL / UK)
- This focal plane was designed, built, assembled and tested by CEA / IRFU. It consists of 36 CCDs totalling more than 600 million pixels
- Each image acquired in flight by this focal plane will detect approximately 400,000 galaxies, including more than 50,000 with a very high signal-to-noise ratio, enabling their shapes to be measured and therefore cosmic shear to be determined with the



INTEGRATION OF THE EUCLID VIS FOCAL PLANE



- This focal plane was assembled at the CEA Astrophysics Department during summer 2019 under exceptionally clean conditions
- It consists of structural elements supplied by CEA, 36 CCD detectors supplied by the European Space Agency, and electronics for controlling these detectors supplied by MSSL (UK)



TESTING OF THE VIS FOCAL PLANE

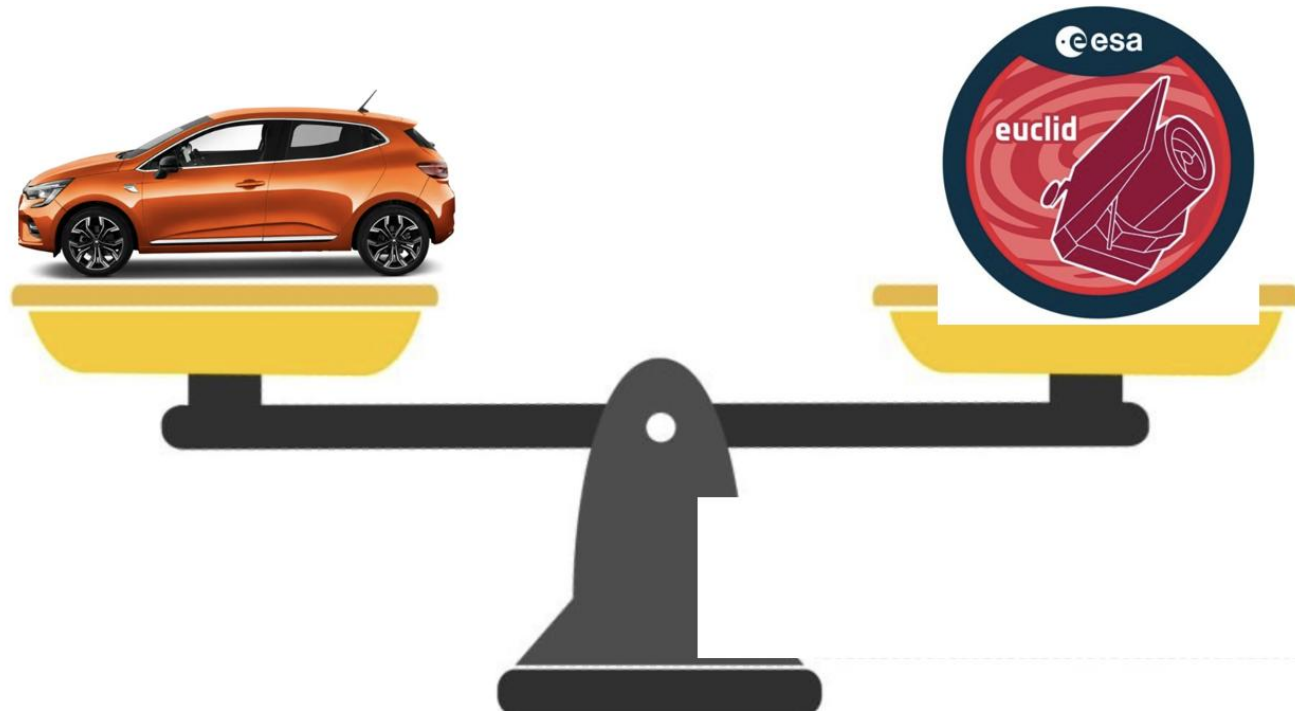


Before delivery, it was tested under CEA responsibility to verify that it would withstand launch vibrations and operate nominally under the operational thermal conditions, with the detectors cooled to -120° while the electronic chains remain at room temperature.

Metrology measurements were performed to ensure the precise position of each detector



PRODUCT ASSURANCE : EUCLID VS CAR



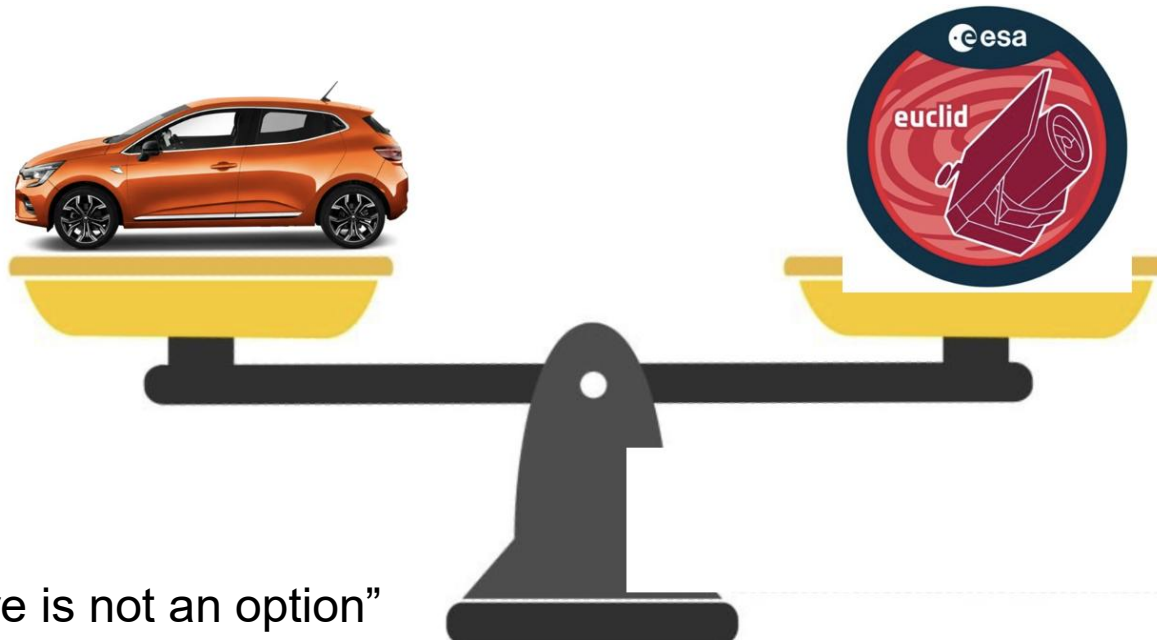
Small car, e.g. Renault Clio

- Travels an average of 150,000 km at 50 km/h = 3,000 hours
- Regular maintenance and repairs
- 450,000 Clio vehicles produced per year (> 15 M total)
- Continuous evolution of the vehicle range from previous models

Euclid (instruments & satellite)

- Operates continuously for at least 6.25 years = 55,000 hours
- No in-flight maintenance possible
- One flight unit manufactured (plus development and qualification models)
- Little direct heritage

PRODUCT ASSURANCE : EUCLID VS CAR



- In flight: “Failure is not an option”
- A ground failure = schedule slippage: either impossible to recover from (launch window, e.g. Rosetta) or very costly (approx. **€50M/year** during the final phases of the program)
- High-reliability requirements for this type of mission
- Very detailed analysis and test program with early verification: “What has not been tested does not work”
- Work in a reference framework (collection of standards and best practices), e.g. ESA ECSS : **innovation is difficult, rules are highly conservative**

- Creation of a risk register during Phase B1
- **Risk register** under the control of the **Product Assurance Manager**, not the Project Manager
- Ensures **independent control** and separation of responsibilities
- Reviewed every 2 months, transmitted to CNES and ESA, with major or new risks escalated during CEA Project Meetings

RISK MANAGEMENT

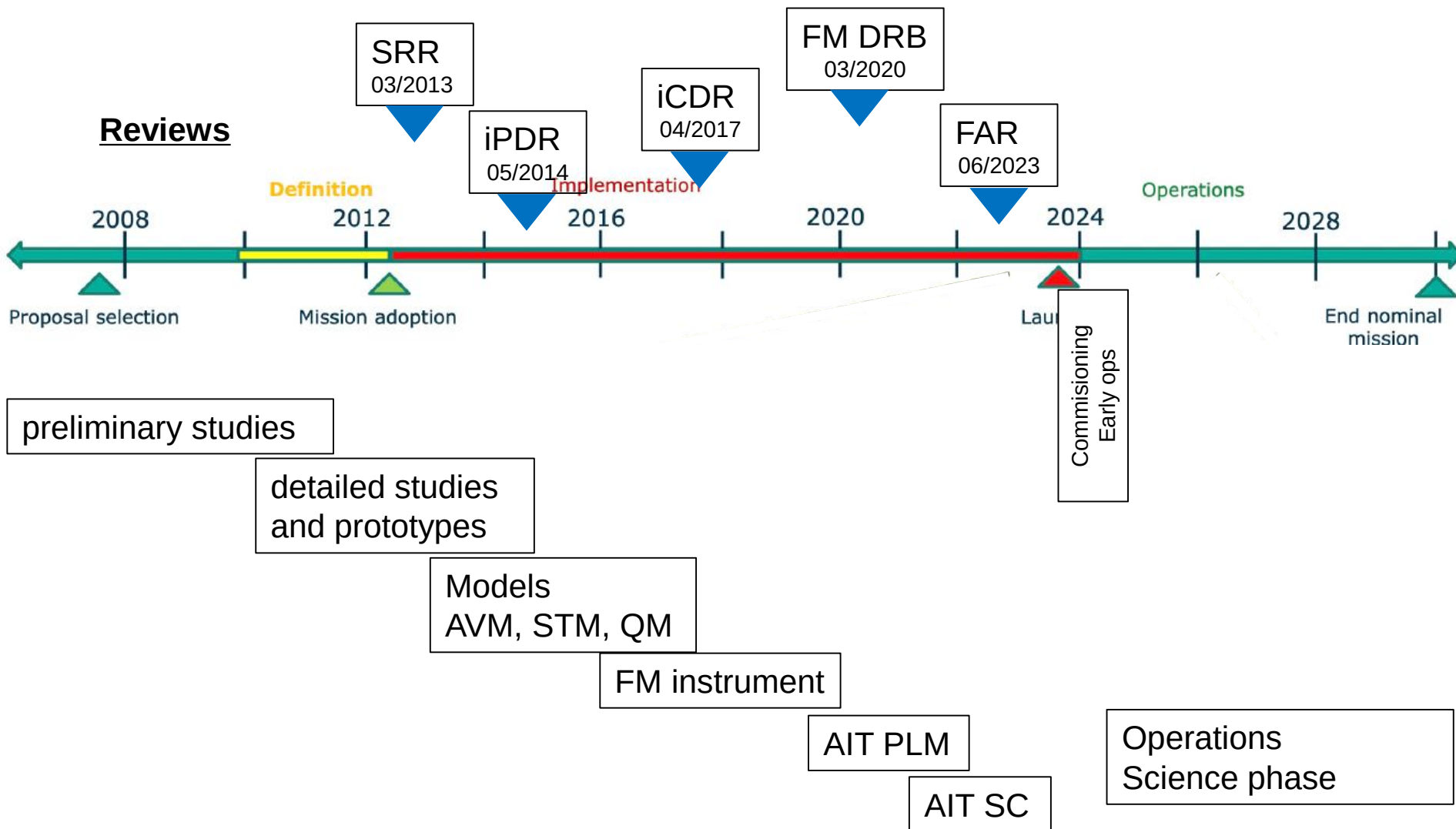
Risk Severity Level (I x P)		Probability (P)				
		Very low $P \leq P1$	Low $P1 < P < P2$	Average $P2 < P < P3$	High $P3 < P < P4$	Very probable $P \geq P4$
Impact (I)	Very High $I \geq I4$	H2 Significant (5x1)	H2 Significant (5x2)	H1 Critical (5x3)	H1 Critical (5x4)	H1 Critical (5x5)
	High $I3 < I < I4$	H2 Significant (4x1)	H2 Significant (4x2)	H2 Significant (4x3)	H1 Critical (4x4)	H1 Critical (4x5)
	Average $I2 < I < I3$	H3 Minor (3x1)	H2 Significant (3x2)	H2 Significant (3x3)	H2 Significant (3x4)	H1 Critical (3x5)
	Low $I1 < I < I2$	H3 Minor (2x1)	H3 Minor (2x2)	H2 Significant (2x3)	H2 Significant (2x4)	H2 Significant (2x5)
	Very High $I \leq I1$	H3 Minor (1x1)	H3 Minor (1x2)	H3 Minor (1x3)	H2 Significant (1x4)	H2 Significant (1x5)

RISK MANAGEMENT

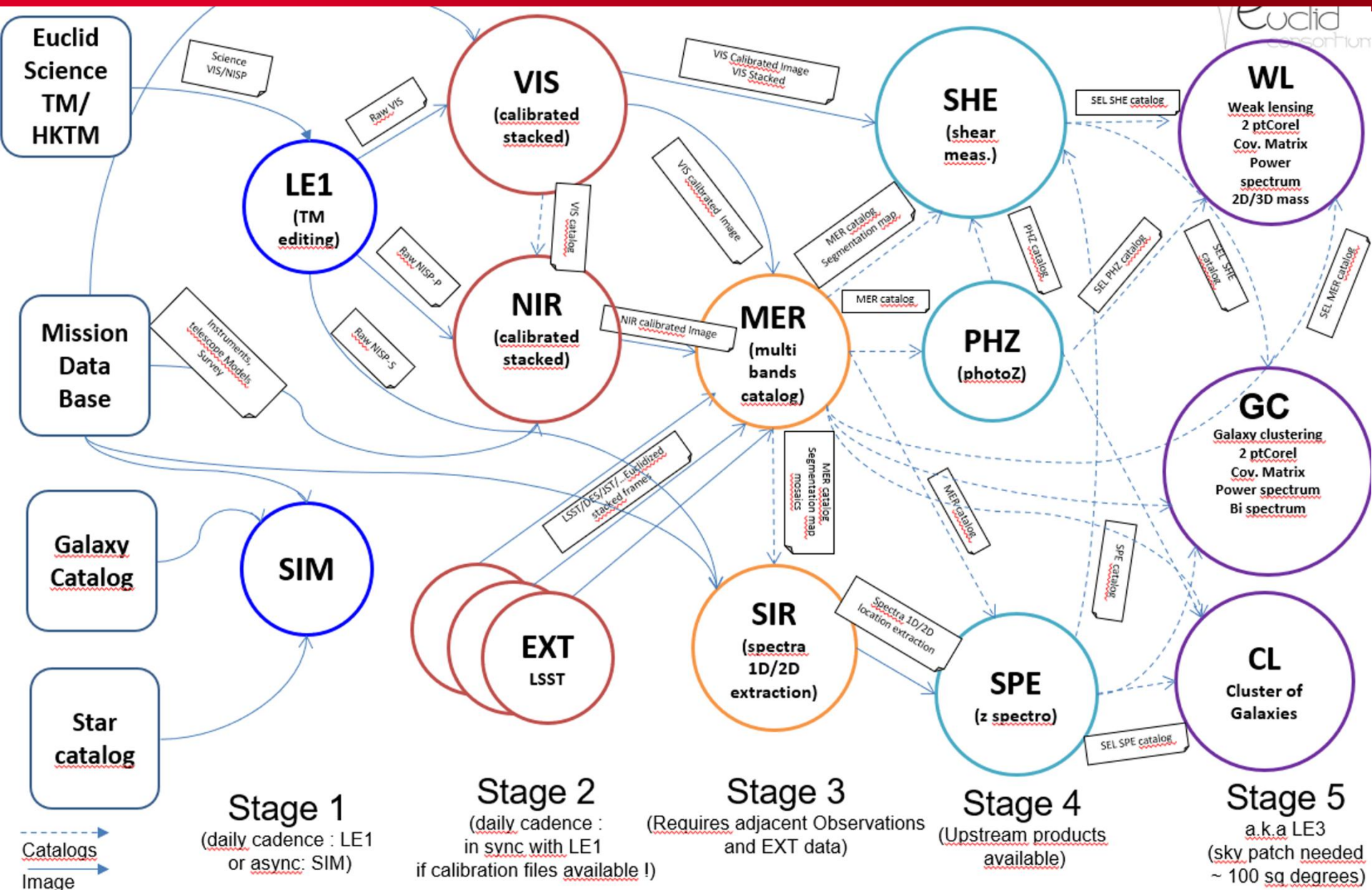
- Creation of a risk register during Phase B1
- Risk register under the control of the Product Assurance Manager, not the Project Manager
- Ensures independent control and separation of responsibilities
- Reviewed every 2 months, transmitted to CNES and ESA, with major or new risks escalated during CEA Project Meetings
- **Risk mitigation**
 - As early as possible (study of alternative solutions)
 - Call on technical experts: CEA / CNES / ESA
- **In the event of a confirmed contingency**
 - Immediate notification of CEA (+ CNES & ESA)
 - Set up regular CEA follow-up meetings

Risk Severity Level (I x P)		Probability (P)				
		Very low P ≤ P1	Low P1 < P < P2	Average P2 < P < P3	High P3 < P < P4	Very probable P ≥ P4
Impact (I)	Very High I ≥ I4	H2 Significant (5x1)	H2 Significant (5x2)	H1 Critical (5x3)	H1 Critical (5x4)	H1 Critical (5x5)
	High I3 < I < I4	H2 Significant (4x1)	H2 Significant (4x2)	H2 Significant (4x3)	H1 Critical (4x4)	H1 Critical (4x5)
	Average I2 < I < I3	H3 Minor (3x1)	H2 Significant (3x2)	H2 Significant (3x3)	H2 Significant (3x4)	H1 Critical (3x5)
	Low I1 < I < I2	H3 Minor (2x1)	H3 Minor (2x2)	H2 Significant (2x3)	H2 Significant (2x4)	H2 Significant (2x5)
	Very High I ≤ I1	H3 Minor (1x1)	H3 Minor (1x2)	H3 Minor (1x3)	H2 Significant (1x4)	H2 Significant (1x5)

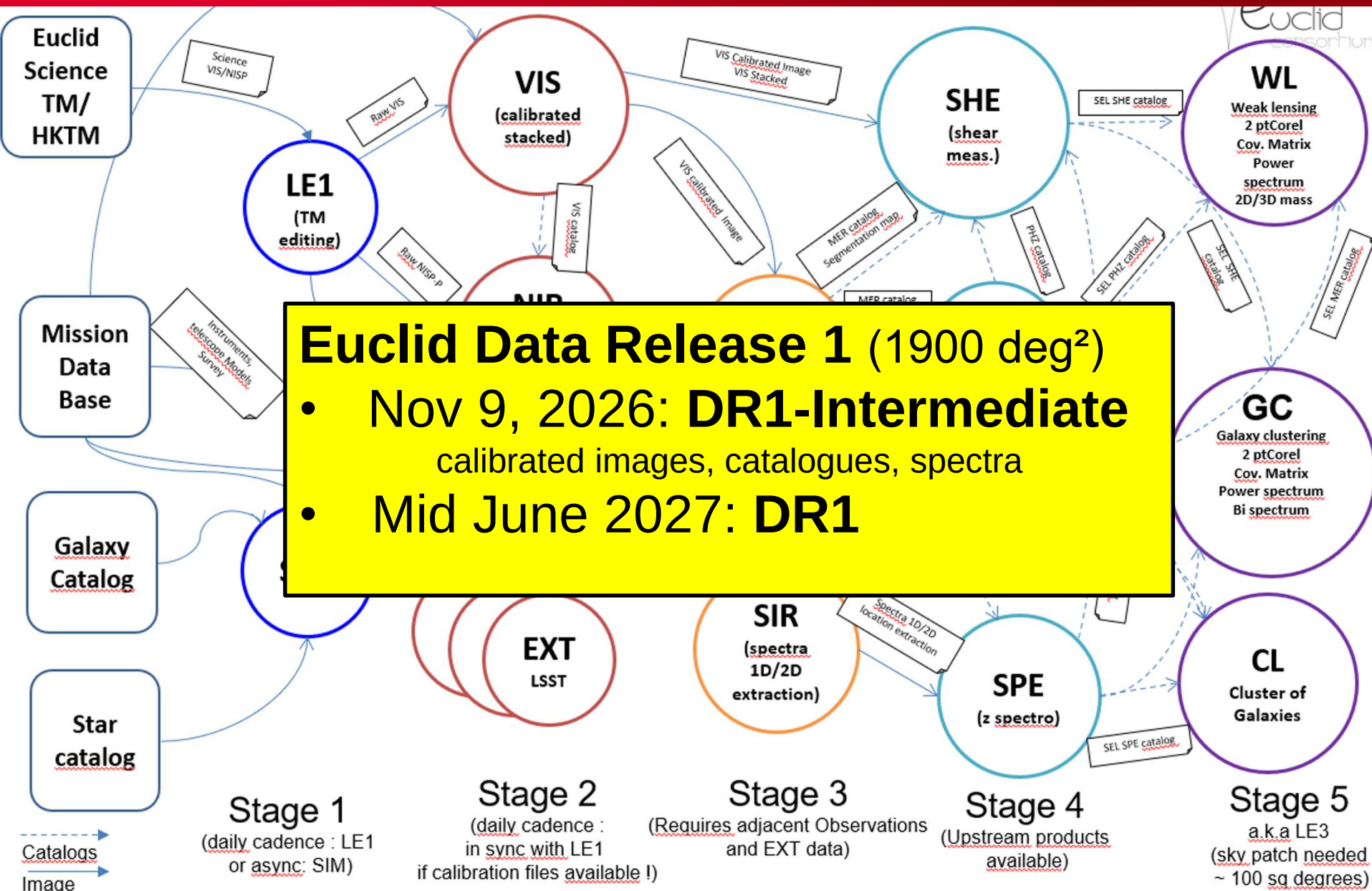
EUCLID MISSION SCHEDULE



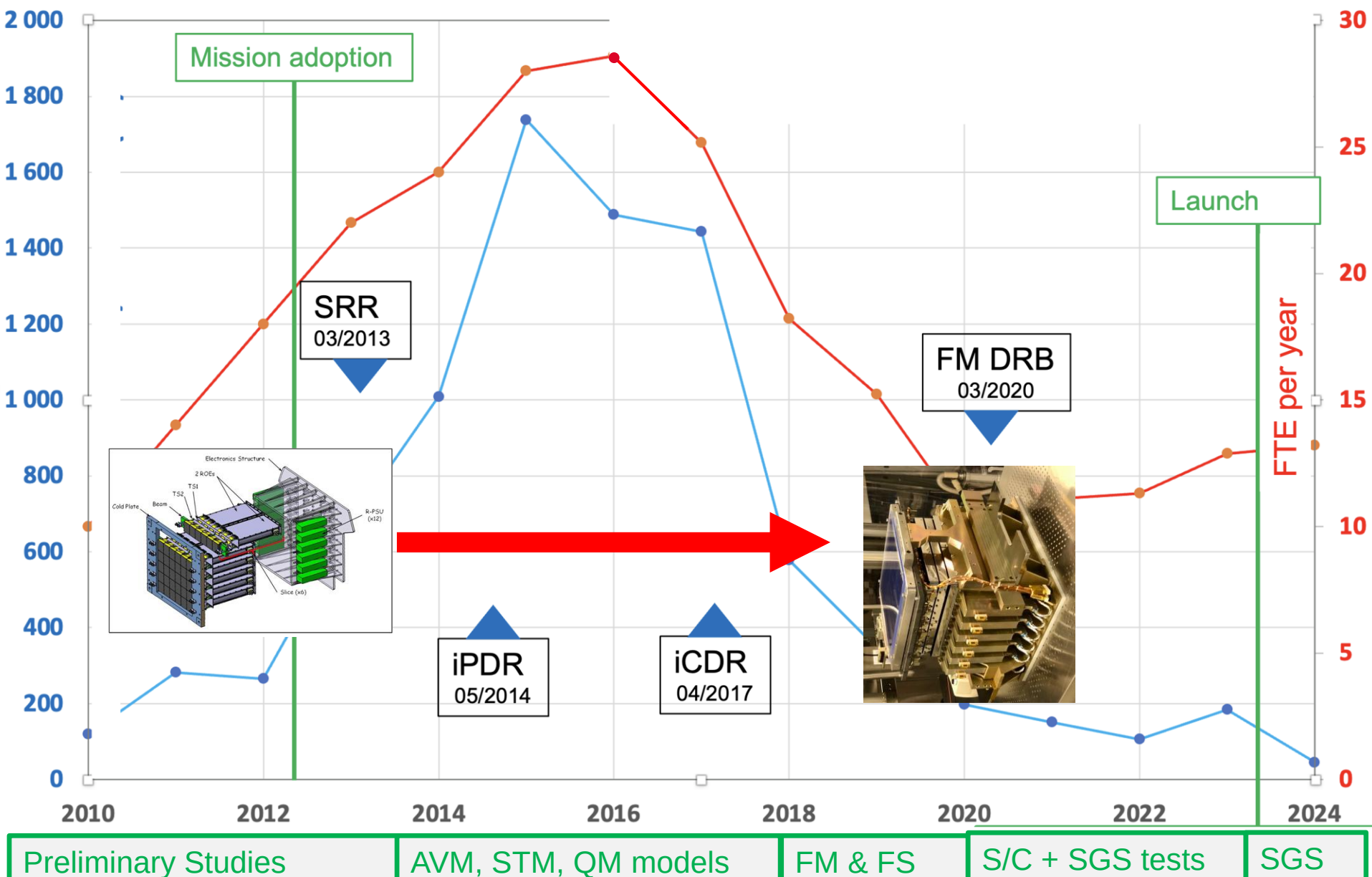
EUCLID SCIENCE GROUND SEGMENT (SGS)



EUCLID SCIENCE GROUND SEGMENT (SGS)

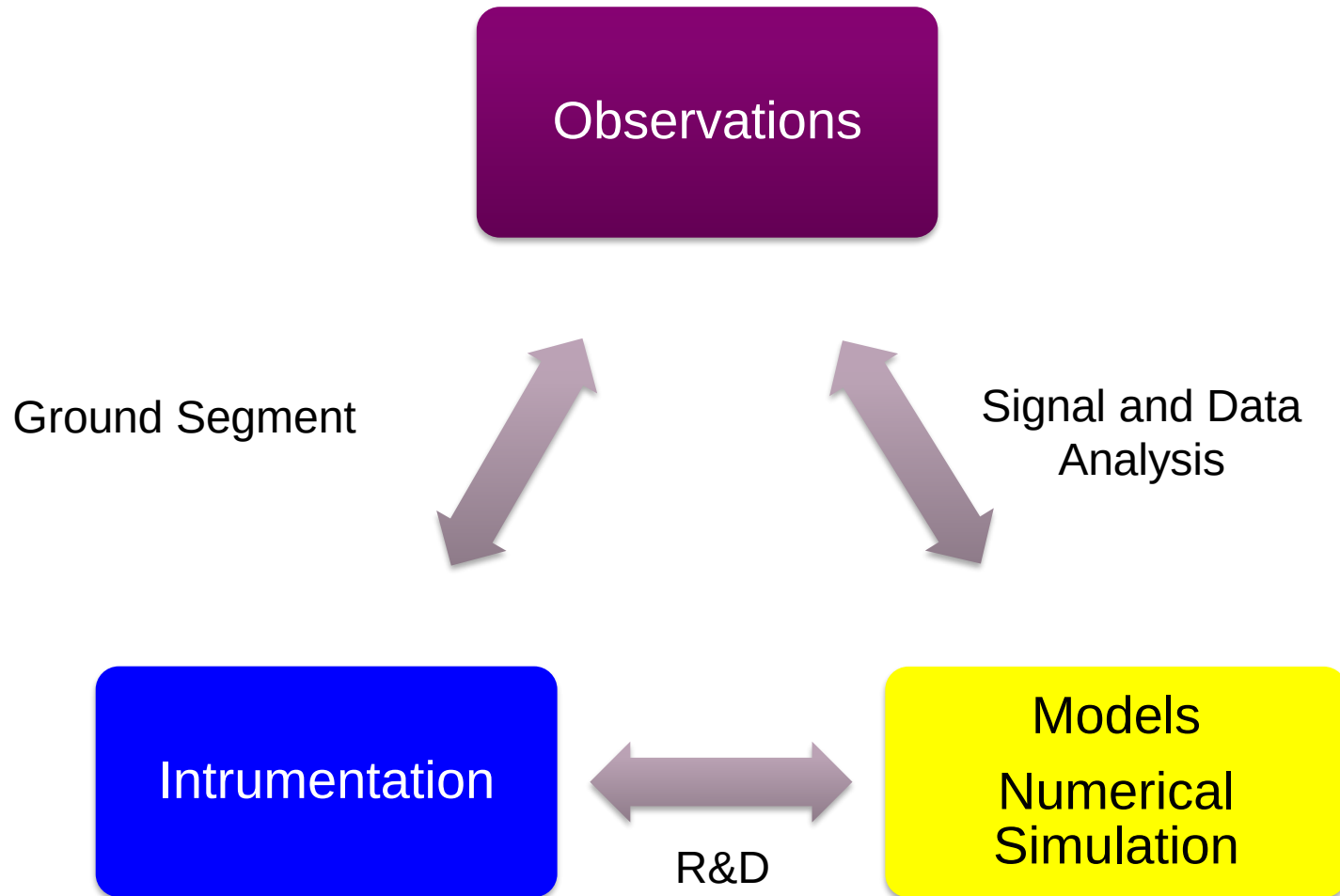


BUDGET AND HUMAN RESSOURCES ASPECTS @ CEA



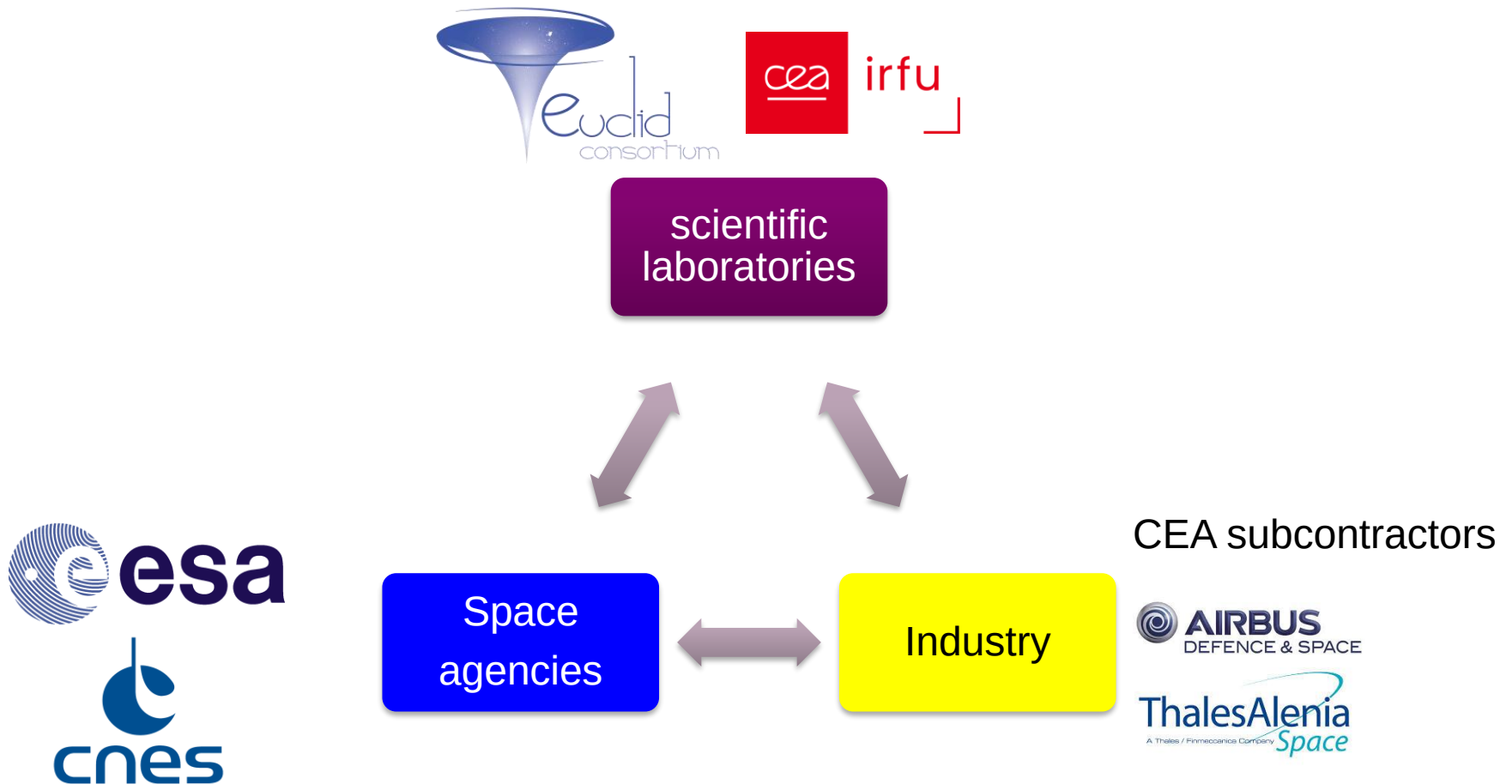
THE 2 TRIANGLES

The Scientific Triangle



THE 2 TRIANGLES

The Programmatic Triangle



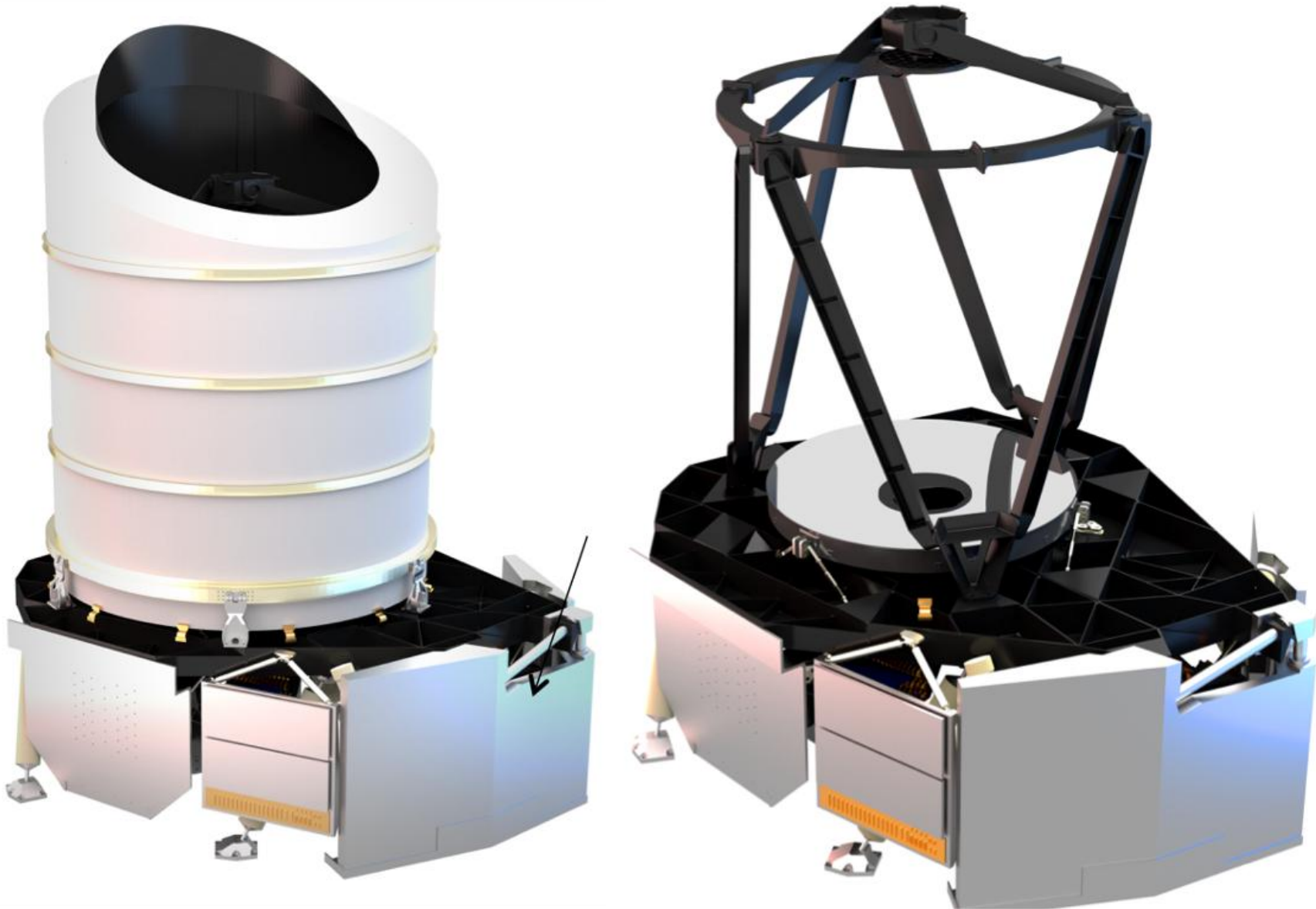
Thank you for your attention



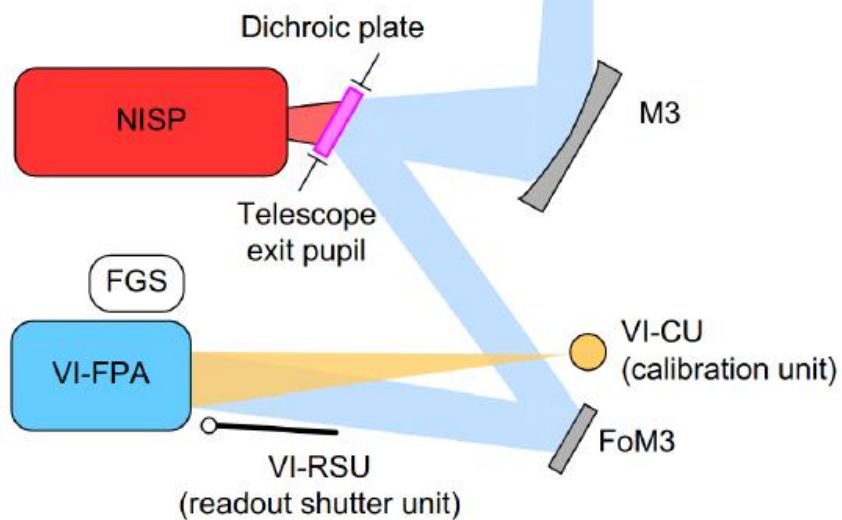
Backup slides

Euclid Payload Module

(Airbus Defense and Space)



A schematic diagram of a two-mirror optical system. Light from a source on the left enters a tube bounded by a yellow 'Baffle'. The light passes through a green 'M2M' component and reflects off a small green 'M2' mirror. The light then reflects off a larger 'M1' mirror at the bottom. The 'Pupil stop' is located at the M1 mirror. The light then passes through a 'Field stop' and is focused by two mirrors, 'FoM1' and 'FoM2', which are labeled as 'lowpass filter'. The light is then directed towards a detector on the right.



A 3D CAD model of the internal structure of the M3 instrument. The model shows the arrangement of various components: VIS (blue), FoM1 (green), FoM2 (green), FoM3 (red), Dichroic (yellow), and NISP (orange). A dashed white line indicates the central axis of the instrument.

M1+M2
(+M3+FoM3) FoM1+2 M3 Dichroic NISP filters
+ NI-OA

> 2.15 μm undetected

0.92-2.15 μm NISP science

0.54-0.92 μm VIS science

0.42-0.54 μm

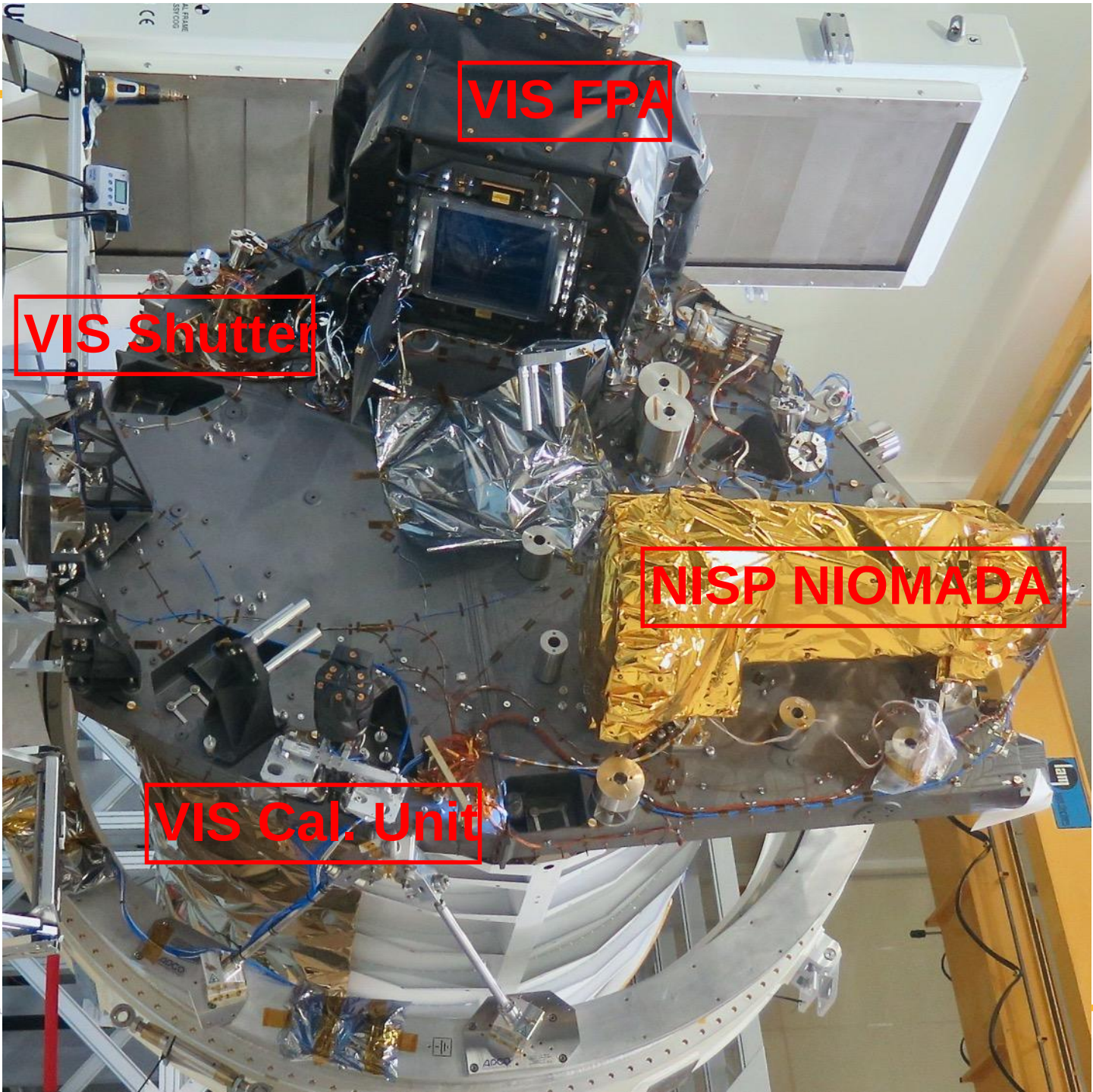
< 0.42 μm

< 0.33 μm

NISP FPA

VIS FPA

FoM3



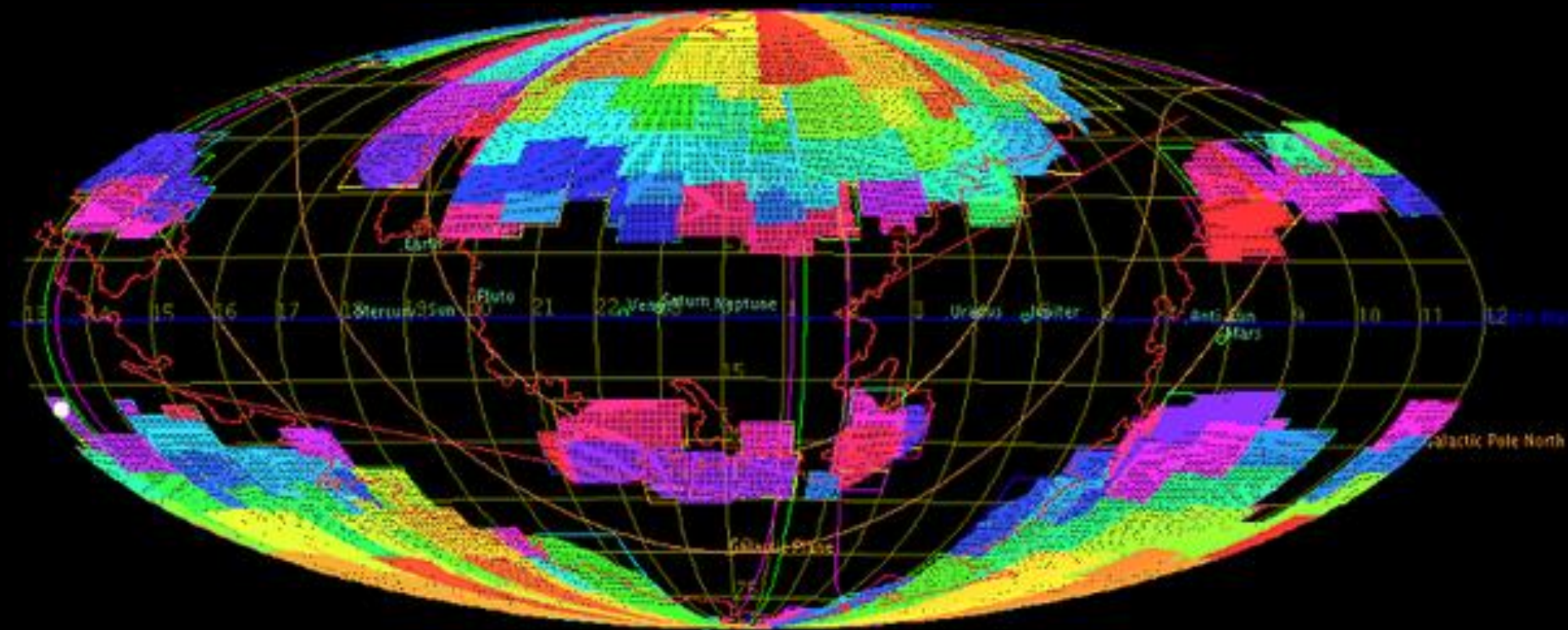
VIS FPA

VIS Shutter

NISP NIOMADA

VIS Cal. Unit

Euclid Survey



Definition phases

- Phase A : Feasibility – paper studies – key technology validation model (TRL ↗) – variable duration (>1 year)
 - Validation by the Department Scientific and Technical Council

Mission selection

- Phase B1 : continuation of Phase A + requirements definition: approx. 18 months
 - SRR of system requirements (ESA)
 - CNES resources review + CEA assessment review

Mission adoption = financial commitment by ESA, national space agencies and scientific organizations

Implementation phases

- **Phase B2** : preliminary design, interfaces, numerical modelling, development of prototypes and ground support equipment (GSE): duration 12 to 24 months
 - PDR preliminary design review (ESA + CNES)
 - CEA/IRFU kick-off review + finalisation of the initial project baseline
 - Regular IRFU Project Meetings (approximately every 2 to 3 months)

start of major financial commitment
- **Phase C** : detailed design, development models (STM / EM): duration 30 to 36 months
 - CDR critical design review (ESA + CNES)
- **Phase D** : qualification (QM), production of flight models (FM/PFM): duration 24 to 18 months
 - Delivery of instrument flight models

Operational phases

- **Phase E1 : post-delivery activities (satellite integration & testing):**
duration 12 to 24 months
 - **Flight Readiness Review (ESA)**
 - **Launch**
- **Continuation of Phase E1: in-flight commissioning (3 to 6 months) + handover (variable from industry to ESA)**
- **Phase E2 : scientific operations**
 - Every day, during a 4-hour window, Euclid sends its 100 GB of daily data to ESA's "Deep Space" antennas. The data rate is approximately **9 MB/s** from **L2 (more than 100 Million km away)**
 - In total, over 6 years, **170 petabytes** of compressed data will be sent by Euclid to Earth