Euclid Update

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On behalf of the NASA project and the Euclid Consortium

Euclid – mapping the geometry of the dark universe

A space-based survey telescope led by the European Space Agency (ESA) and the Euclid Consortium with contributions from NASA.

First space mission dedicated to the study of dark energy.

Measurements include the Dark Energy equation of state, $w(a)$, the growth of structure parameter, γ, the neutrino mass, m_ν, and the universe's initial conditions f_{NL}

Image credit: SpaceX

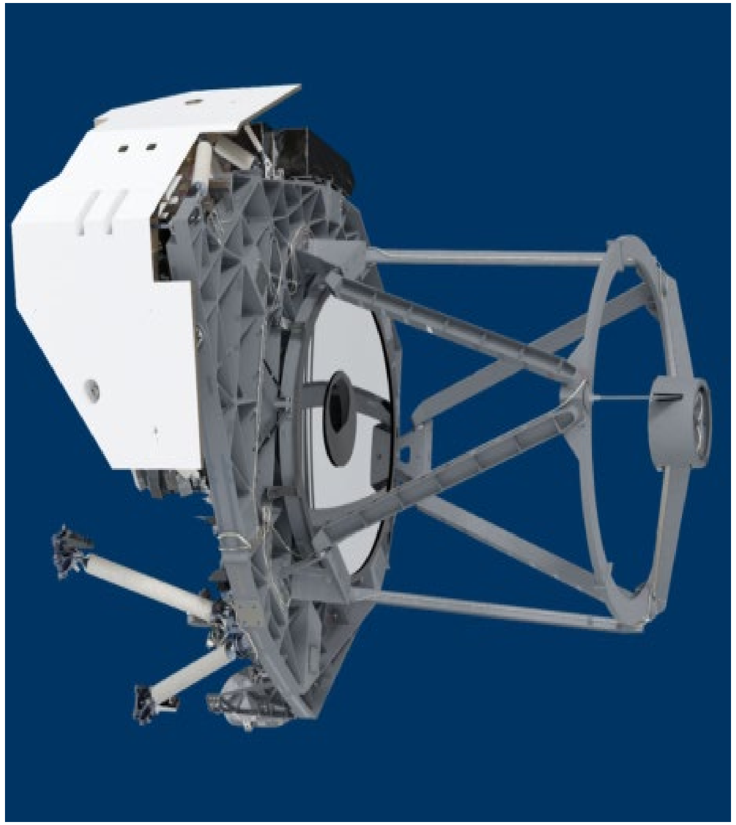
Three NASA-provided elements:

- Hardware contribution to near-IR instrument
- Euclid NASA Science Center at IPAC (ENSCI)
- 3 Science teams selected through peer review:
  - Constraining Dark Energy and Gravity with Euclid (PI J. Rhodes, JPL)
  - Looking at Infrared Background Radiation Anisotropies with Euclid (PI A. Kashlinsky, GSFC)
  - Precision Studies of Galaxy Growth & Cosmology Enabled Through a Physical Model for Nebular Emission (PI R. Chary, Caltech)

Euclid – Telescope and Instruments

Telescope:
1.2 meter primary diameter
Silicon Carbide 3-mirror Korsch anastigmat

Two Instruments:
VIS – wide band visible imaging array instrument
NISP – near-IR spectrometer and photometer



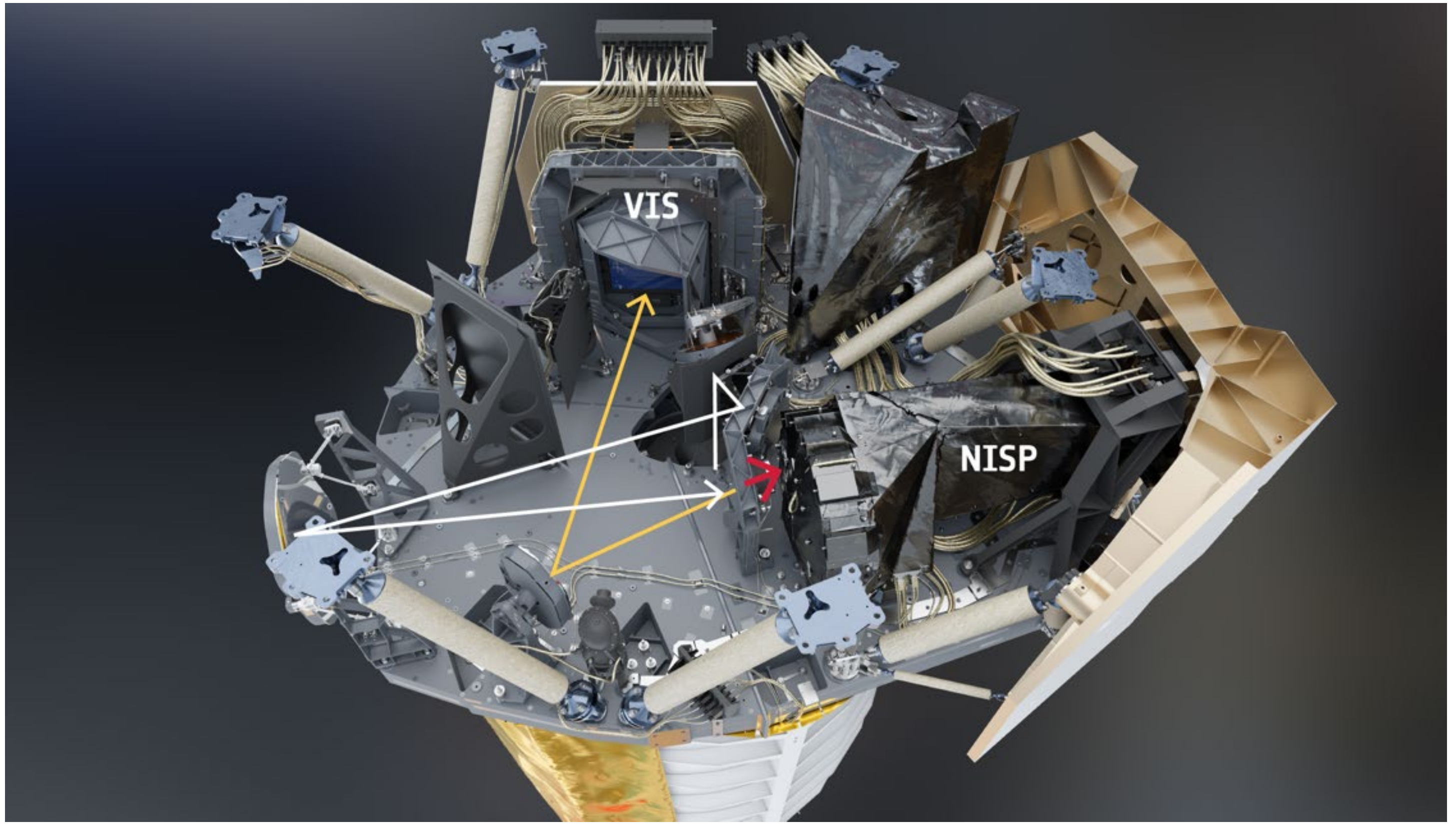


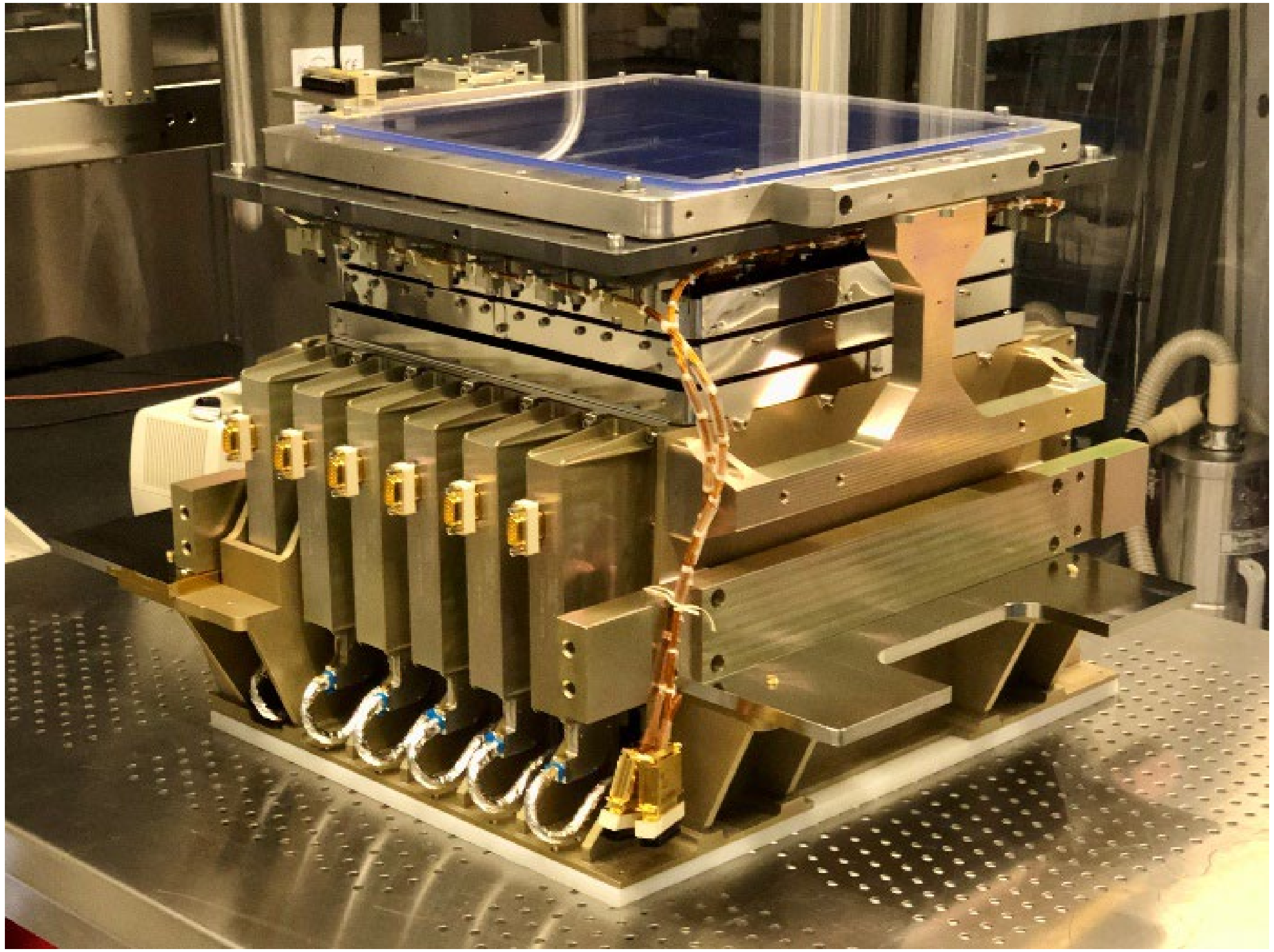
Image credit: Airbus Defense and Space / ESA

Euclid – Visible Instrument (VIS)

Focal Plane Array (FPA) 6 x 6 array
- 4096 x 4132 pixel Teledyne e2v Si CCDs
- 0.1 arcsec/pixel
- 0.53–0.92 µm wide-band imaging

Thermal Isolation Layer
- CCD/FPA = (**153** ± 7) K
- ROE = (**270** ± 20) K

Read Out Electronics (ROE)
- Signal amplifier & Analog to Digital Converter (ADC)
- FPGA for CCD operation



FPA with Perspex cover on top of CCDs for protection
Image: M. Cropper et al. *The* Euclid *Visible Camera VIS* (in prep.)

Euclid – Near-infrared Spectrometer and Photometer

- 16 x 2048 x 2048 pixel 2.3 um cutoff Teledyne HgCdTe arrays
- SIDECAR ASIC detector readout
- 0.3 arcsec/pixel
- 0.95–2.02 µm Y/J/H-band imaging
- R > 400 slitless spectroscopy

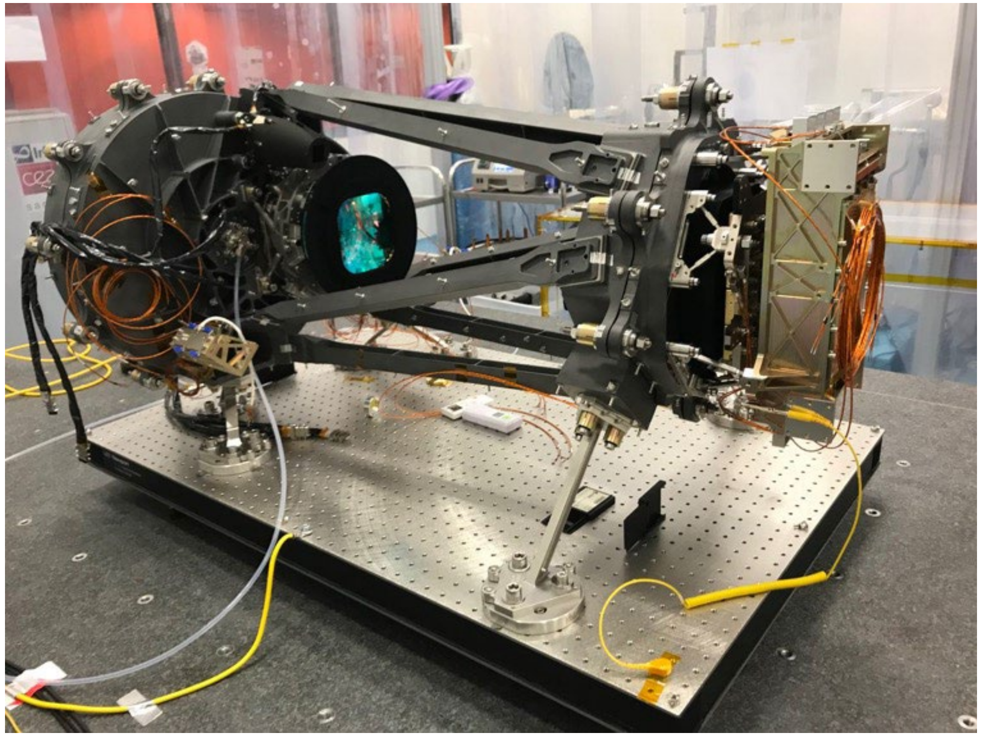


Image credit: Euclid Consortium & NISP instrument team

NISP flight model before being wrapped in Multi-Layer Insulation (MLI).

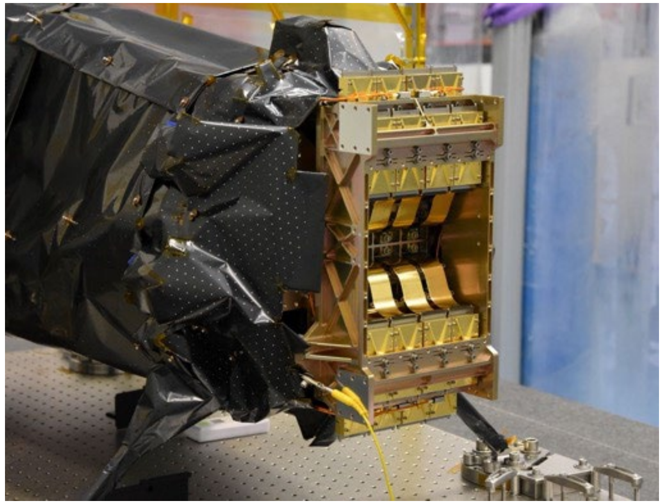


Image credit: Euclid Consortium/CPPM/LAM

NASA flight hardware consists of 16 flight units (+ 4 flight spares) of:

- Detectors
- Readout electronics
- Cryogenic cables

JPL led, with GSFC testing support

Launch and Early Operations

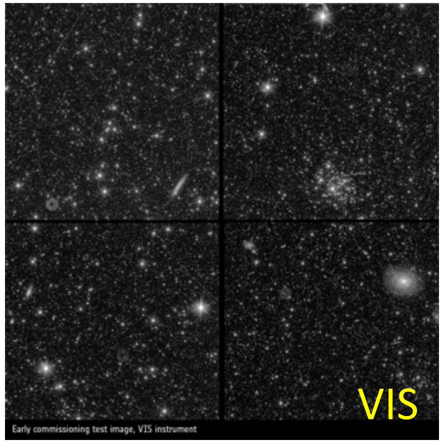
Euclid was launched on July 1, 2023 from Cape Canaveral, FL on a SpaceX Falcon 9.

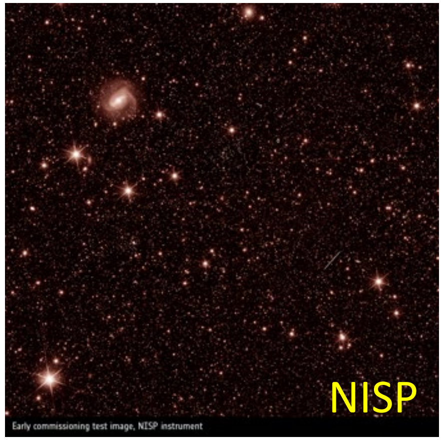
Early observations showed that Euclid's spacecraft and systems, the telescope and scientific instruments were performing well (images at lower right).

A few areas of concern have been identified and mitigated:

- Unexpected straylight at specific spacecraft orientations
- Occasional X-rays from solar flares contaminates some VIS images
- Occasional loss of fine guidance tracking

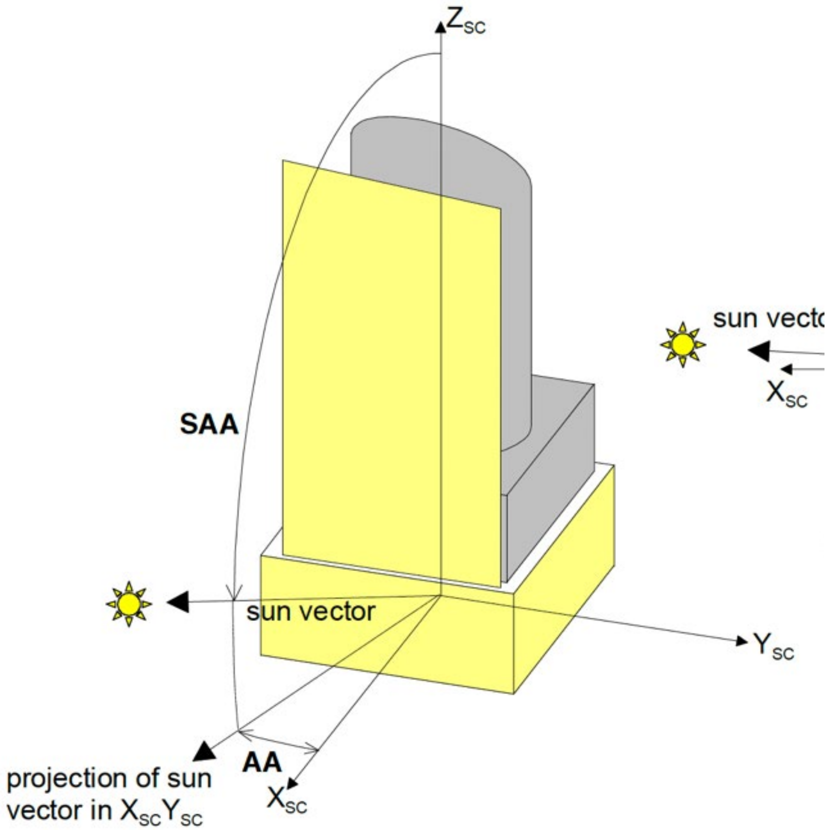
Image credit: SpaceX



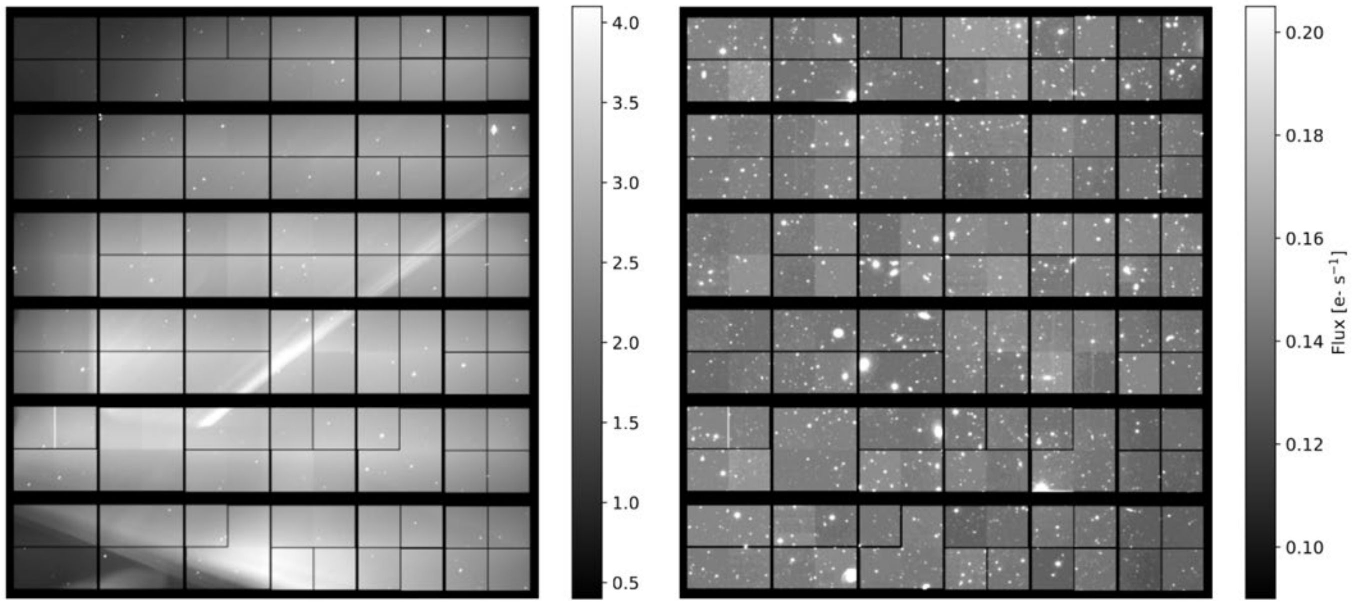


ESA/Euclid/Euclid Consortium/NASA

Euclid Straylight



Euclid Collaboration: R. Scaramella et al.(2021) / ESA



Euclid Collaboration: Y. Mellier et al. (in prep.)

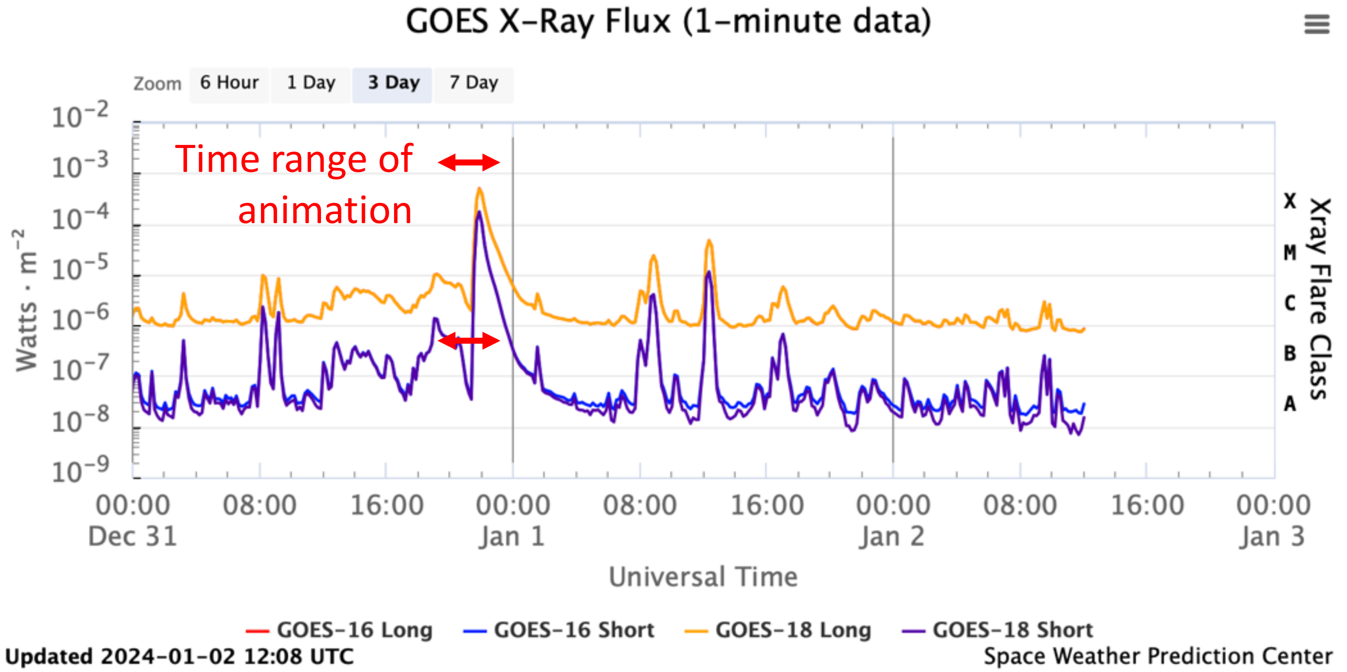
Initial measurements showed excessive solar straylight in VIS at some of the nominal survey spacecraft orientations. NISP unaffected.

To mitigate this, we have altered the range of solar orientations Euclid will operate at during its survey. Euclid's survey strategy has been re-optimized, at a slight penalty to overall survey efficiency.

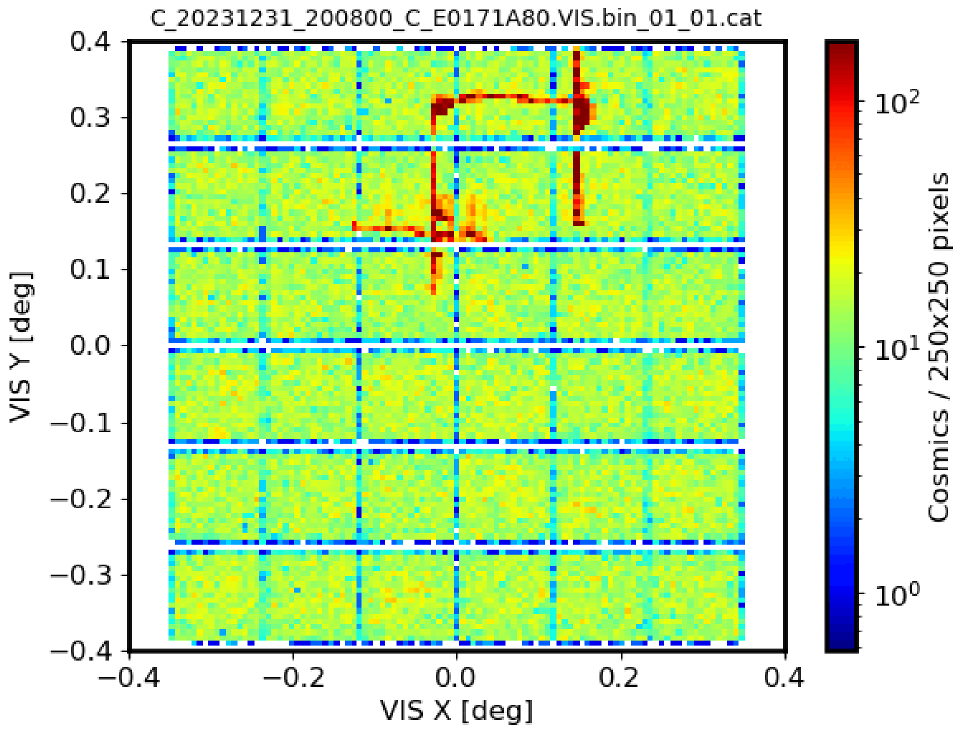
Solar x-ray flare contamination

Due to insufficient shielding, x-rays from solar flares contaminate some VIS exposures. (NISP unaffected).

Affected pixels are flagged and masked from use in science analysis.



https://www.swpc.noaa.gov/products/goes-x-ray-flux



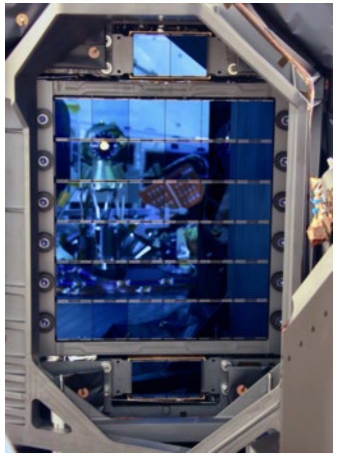
Credit: Koen Kuijken / Euclid Consortium

Intermittent Loss of Fine Guidance Tracking

There was initial, intermittent loss of reliable guiding information from Fine Guidance System (FGS).

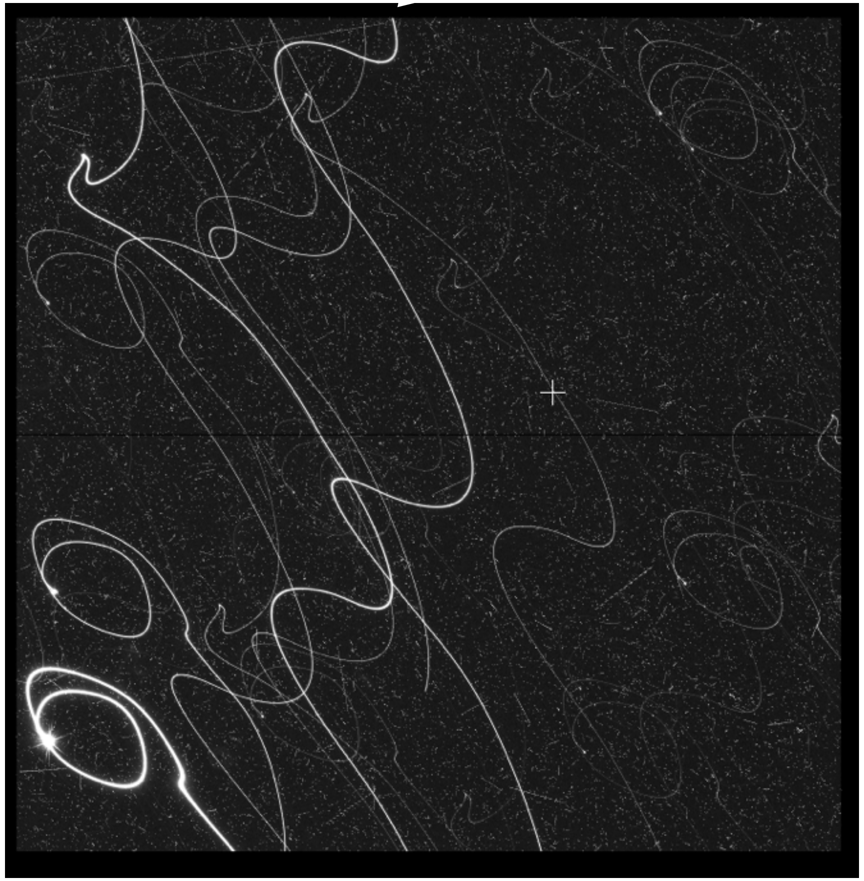
Root cause traced to FGS software. Regions with low stellar density suffered confusion with cosmic rays. Automated rejection of poor pointing solutions was not performing as expected.

The spacecraft commissioning phase was extended, the FGS software was updated and tested on-orbit. The system is now performing well.



FGS sensors consist of 4 CCDs adjacent to VIS focal plane

Image: M. Cropper et al. (in prep.)



One VIS exposure at 2023-08-02 4:35 UTC
Image: ESA

Euclid Early Release Observations

The first science images from Euclid were released in a press event on November 7, 2023. Public data release expected May 23, 2024.

Intent is to highlight Euclid's capabilities. Communications and Outreach merit took precedence over scientific merit.

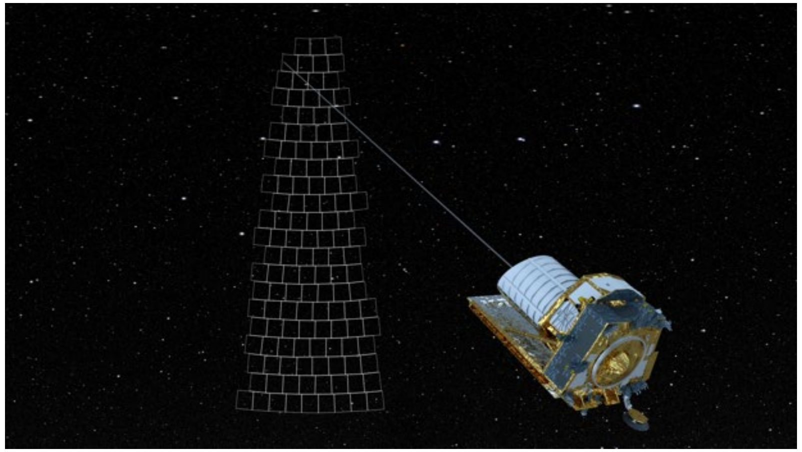
Each target is one standard observing block of 70 minutes covering one FOV of ~ 0.7 x 0.7 deg, with exception of Perseus (4 blocks).

Both imaging data and spectroscopy data were taken. For the EROs, only the imaging data has been fully processed.

Image credit: ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi

https://www.esa.int/Science_Exploration/Space_Science/Euclid/Euclid_s_first_images_the_dazzling_edge_of_darkness

Euclid Data release timeline

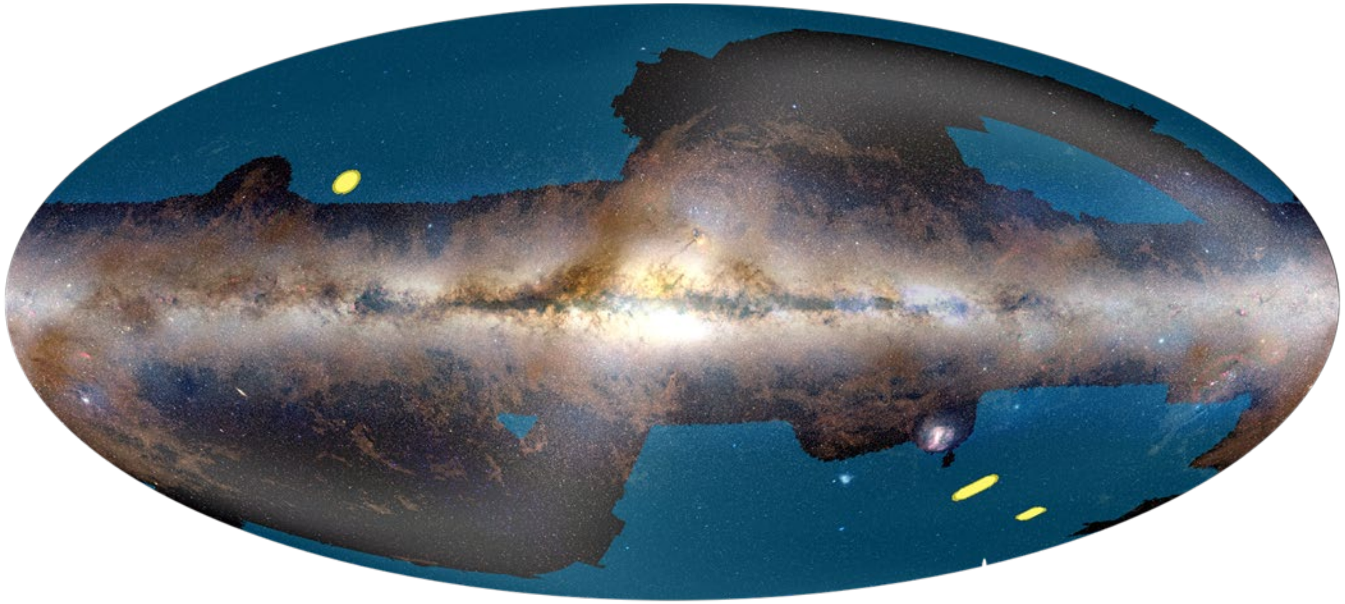


Recent Milestones:
- Mission Commissioning Results Review successfully concluded Feb 8, 2024
- Euclid's Science Survey started on Feb. 14, 2024

Coming milestones:
- May 2024: Public Release of ERO data
  - Initial science and instrument publications
  - Media briefing @ ESAC

- March 2025: Q1 public data release
  - ~ 50 deg^2 of survey data
  - single visit over Euclid Deep fields

- June 2026: DR1 public data release
  - ~ 2000 deg^2
  - 1st year of wide survey data



Credit: ESA/Euclid/Euclid Consortium/NASA/Planck Collaboration/A. Mellinger

Euclid NASA Science Center at IPAC (ENSCI) supports the US Research Community

Contact with research community:

- Conferences/AAS and Workshops
- Special session at Jan 2024 AAS, planning for 2025
- User Panel (started 1 year before launch)
- User Survey planned before first data release
- Push info to community: newsletters, social media, planning opt-in mailing list

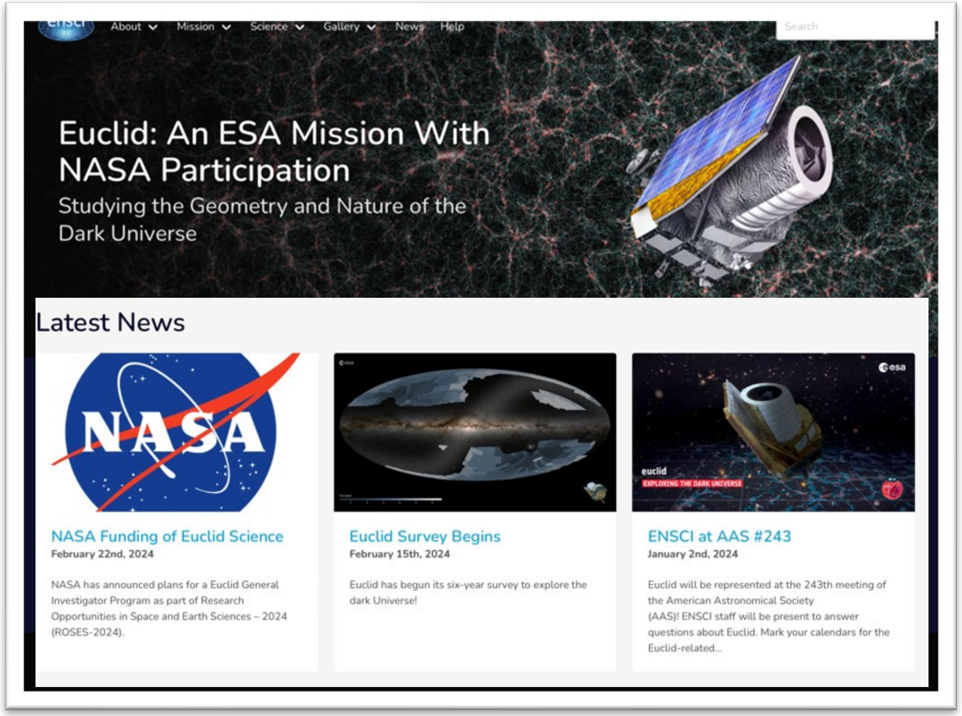
Web presence:

- Help desk (ensci-support@ipac.caltech.edu)
- Mission news and FAQ
- Documents and (planned) tutorials
- Recent document on expected data products
- Advertise data releases and research opportunities

Support US archival research with Euclid:

- Work with NASA/IPAC Infrared Science Archive (IRSA) to design, validate, enhance the complementary US archive
- Data tools and documentation
- Data Analysis workshops after data releases

IPAC/ENSCI director: George Helou
ENSCI science/task lead: Harry Teplitz



ENSCI website

Support for US Science Teams:

- Meetings, developer advice; calibration docs/files

ENSCI prioritizes US, but open to all:

- European researchers will have access to mission knowledge from national centers

Euclid General Investigator Program (EGIP)

NNH24ZDA001N-EUCLID

EGIP solicits research on the analysis of data from the Euclid mission due to be in the public domain by the time the proposed project is funded.

EGIP solicits proposals on development of data analysis techniques.

Investigators will be required to make software or other resources supporting such new analysis techniques publicly available.

- Early Release Observations
- Quick Release 1

IC 342

NGC 6397

Image credit: ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi

Conclusion

After an extended commissioning period, Euclid is performing well and the main survey has started!

Data release in May 2024 will include papers covering the performance of the mission.

The NASA Euclid project office is facilitating a series of “Lessons Learned” meetings between ESA and NASA projects.

> **Optics**: Stray light, on-orbit calibrations (NISP), impact of ice deposition, when to decontaminate, thermal stability
>
> **Operations**: FGS, flight calibration of dispersive elements, scheduling considerations (calibrations vs survey), micrometeorites, and any comments ESA may have on data processing considerations
>
> **NISP detectors**: evolution of performance, persistence, snowballs, operability

Recommendation: have next Euclid update focus on pipeline status, data products and tools.

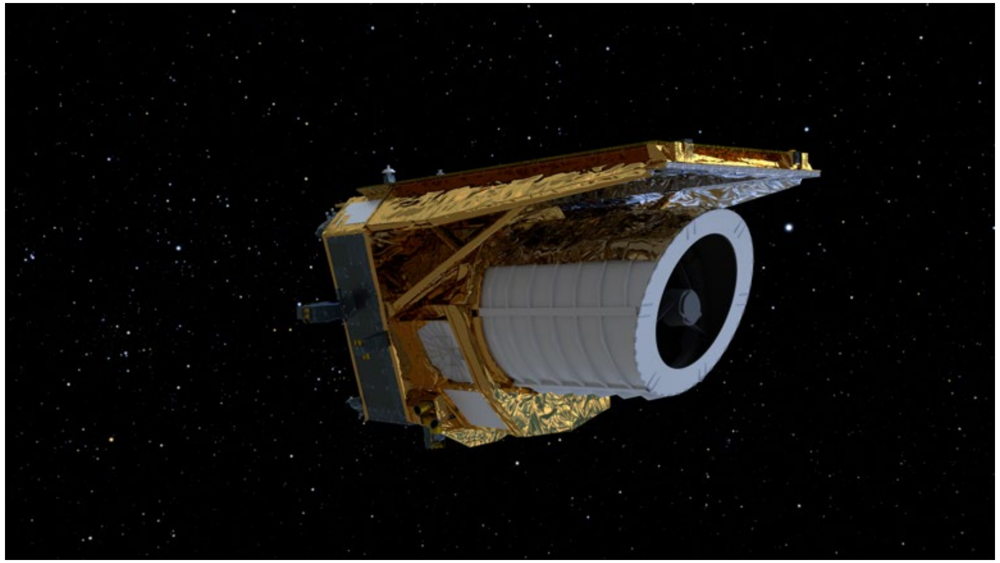


Image credit: ESA.