The Euclid survey

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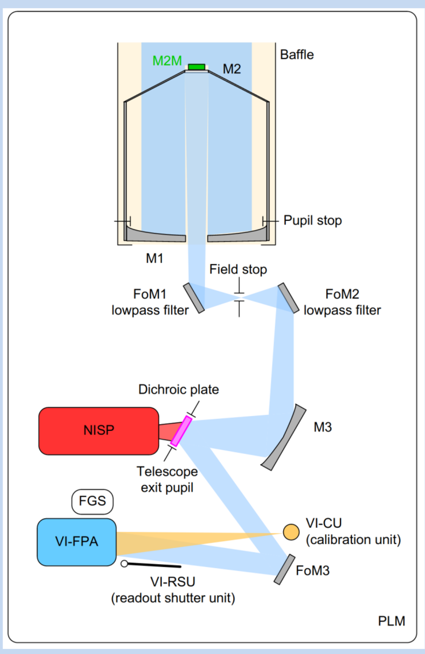
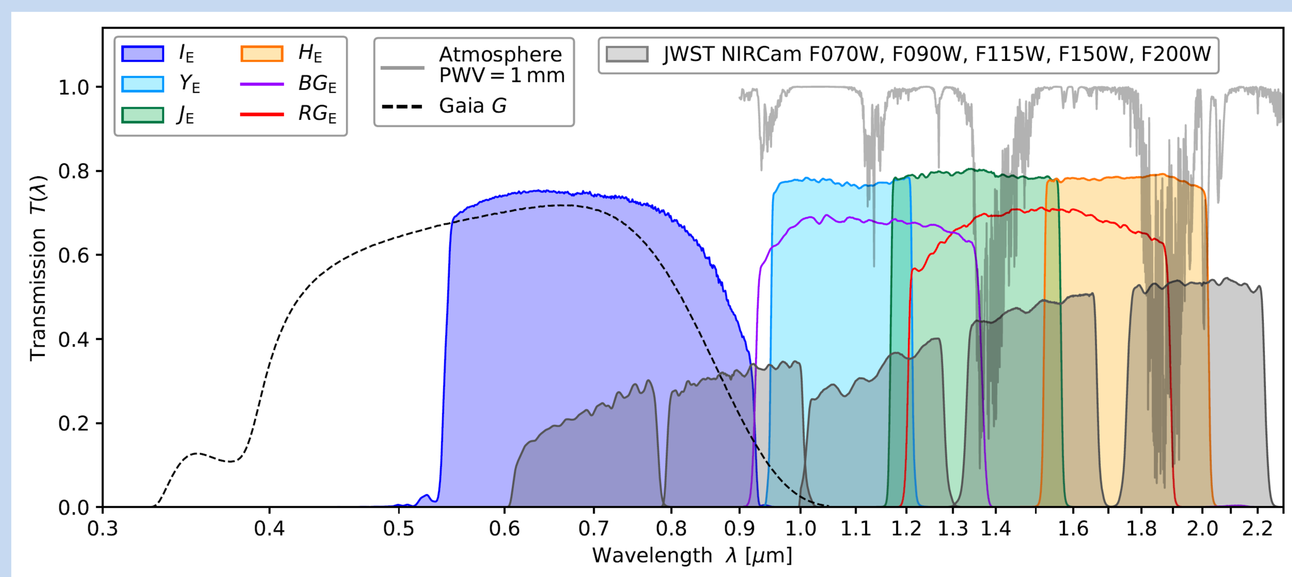
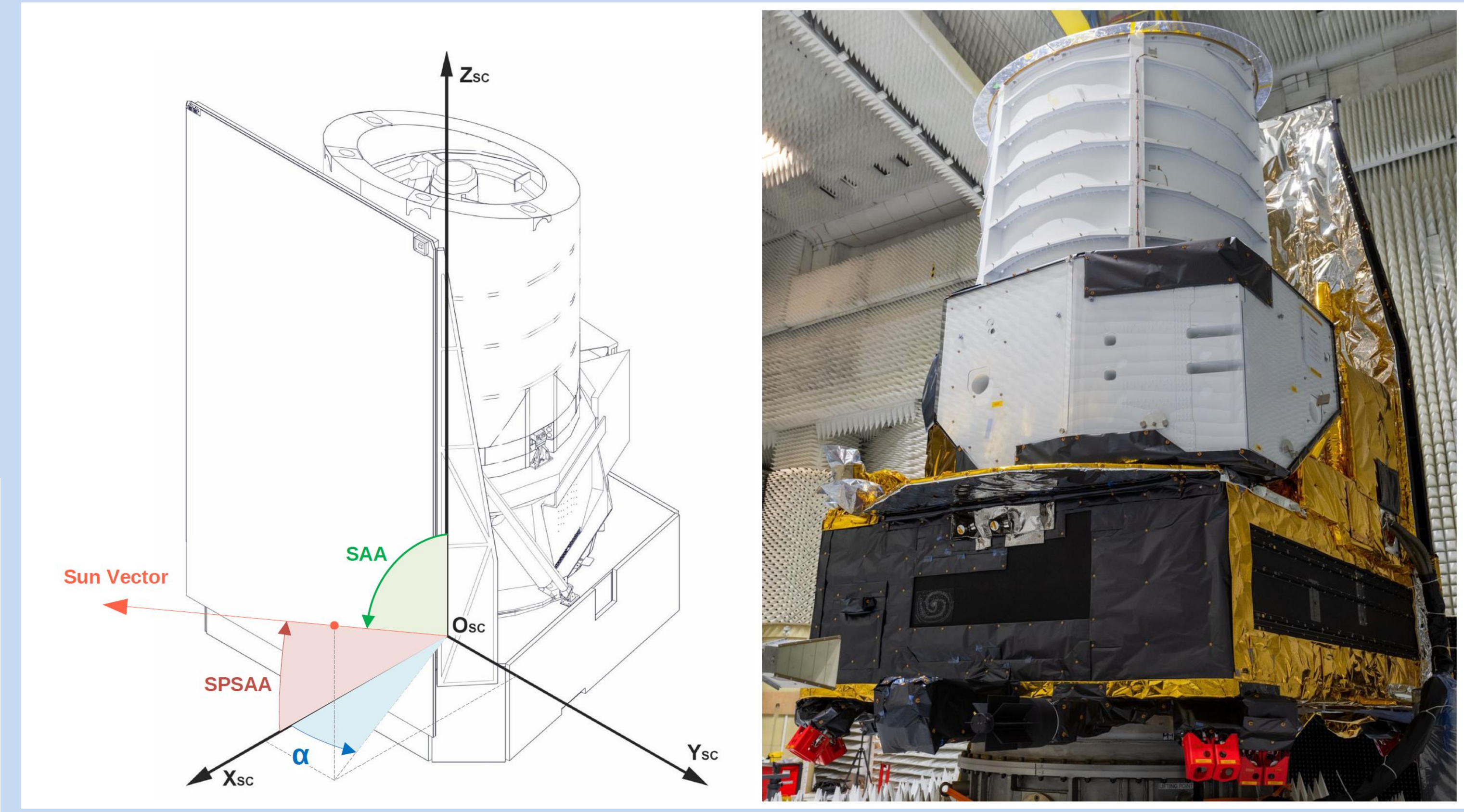
The Euclid mission

Euclid is a medium-class mission in the Cosmic Vision 2015–2025 programme of the European Space Agency (ESA) that will provide high-resolution optical imaging, as well as near-infrared imaging and spectroscopy, over about 14000 square degrees of the Extragalactic sky. In addition to accurate weak lensing and galaxy clustering measurements that probe structure formation over half of the age of the Universe, its primary probes for cosmology, these data will enable a wide range of additional science. Euclid instruments consist of a wide-band visible imager (VIS) and a near-infrared spectro-photometer (NISP).



Left: the Euclid optical path.
Right: the spectral response of VIS and NISP photometry, and of the "blue" and "red" grisms.





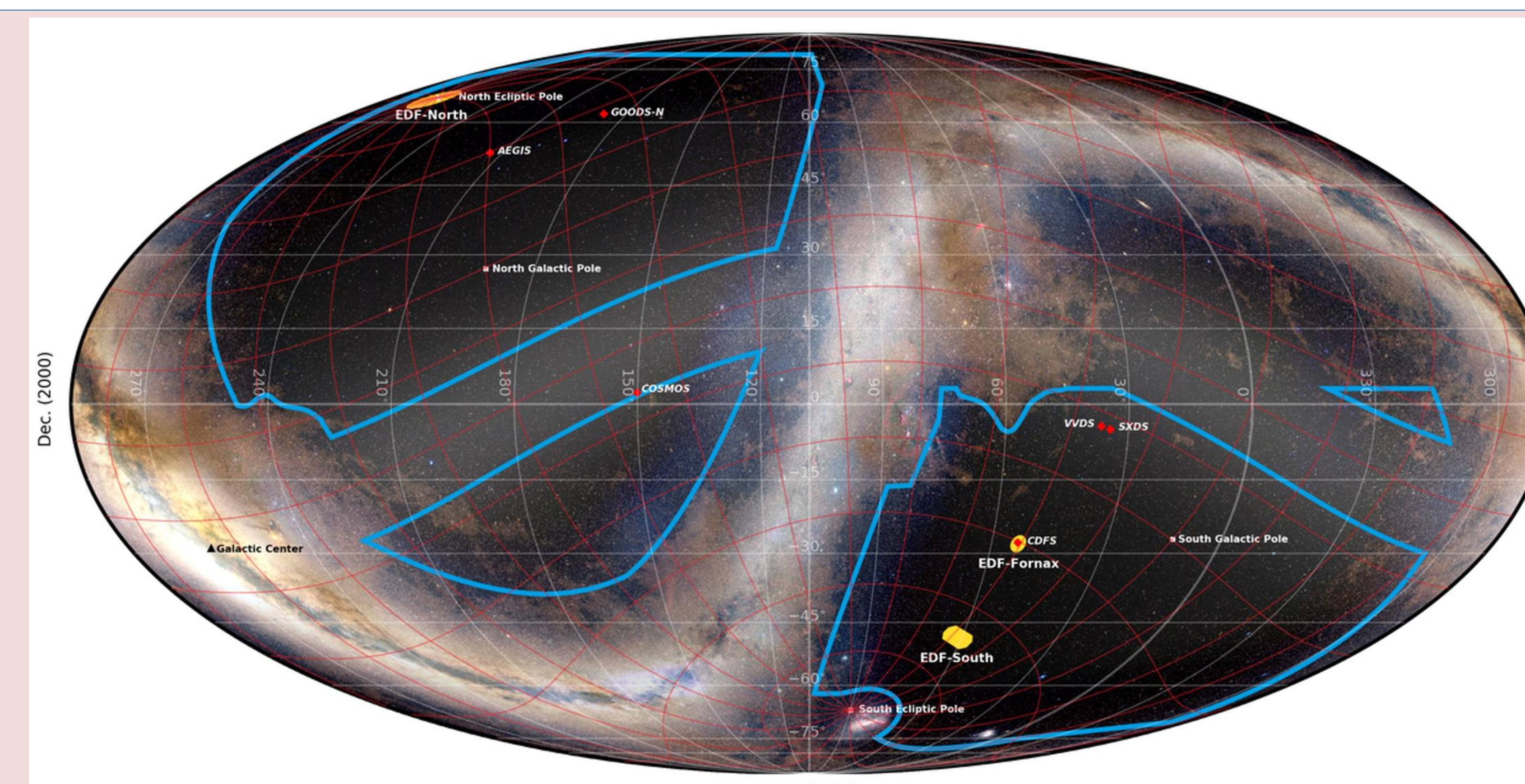
Left: overview of the Euclid spacecraft with the principal axes highlighted. Right: The fully assembled spacecraft in February 2023 in the anechoic chamber of Thales Alenia Space in France, after completing final electromagnetic compatibility tests. Figure credit: ESA – M. Pédoussaut.

Survey design and Region of Interest

To achieve its primary cosmology objectives, Euclid aims to observe a sample of 1.5 billion galaxies for the weak lensing, and measure 35 million redshifts for the analysis of the spectroscopic clustering signal. To do so, it needs to cover about 14000 sq. deg. of Extragalactic sky with low zodiacal background and low Galactic extinction, for which it requires a period of about six years. To do this, it requires the definition of a Region of Interest, which is the maximum area on which Euclid could obtain observations compliant with the scientific requirements. The Wide Survey is scheduled to observe as much as the RoI as possible during 6 years of mission.

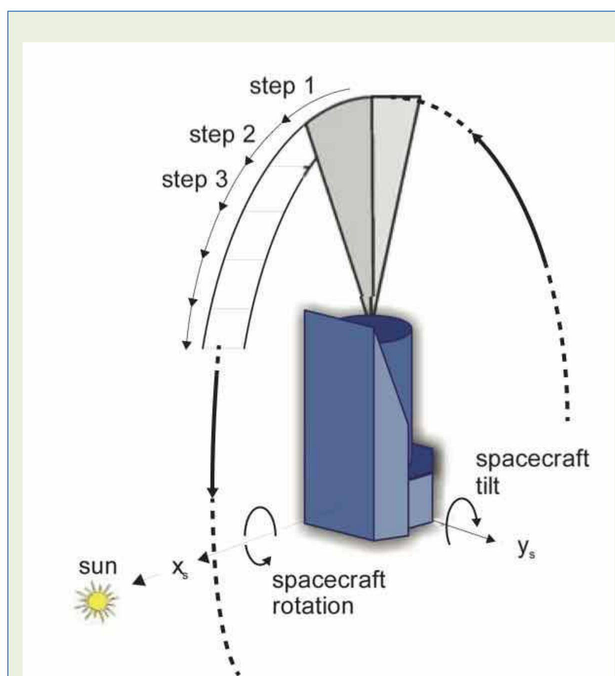
On top of this Wide Survey (EWS), the mission also needs three Deep Fields (EDS): the need to calibrate and monitor the telescope, cameras and electronics requires repeated visits of specific fields that will accumulate substantial depth over time. We also need to characterise the typical EWS source population and systematic effects, requiring deep data over a large area. About 12% of Euclid's on-sky observations are spent on the EDS, for which we target a six-fold increase in S/N compared to the EWS, or a gain in depth of about 2 magnitudes.

The EDS is complemented by the Auxiliary Fields, used for calibration of photometric redshifts and to quantify the impact of colour gradients within galaxies on shape measurement in the presence of a chromatic PSF. These include the COSMOS, AEGIS, SXDS, VVDS, CDFS and GOODS-N fields. Most of the other Euclid calibration observations are performed in the self-calibration field near the Ecliptic North pole.



Above: Mollweide projection of the whole sky, with the Wide Survey Region of Interest (RoI) delimited in blue. The blue borders enclose the RoI, which is the maximum area considered for the Wide Survey. The RoI excludes the Galactic and Ecliptic planes. The triangular southern 'island' near RA = 330° is restricted in size, since the Rubin Observatory does not extend to more Northern latitudes. The Euclid Deep Fields are shown in yellow and the auxiliary fields with red marks (not to scale).

Survey scheduling



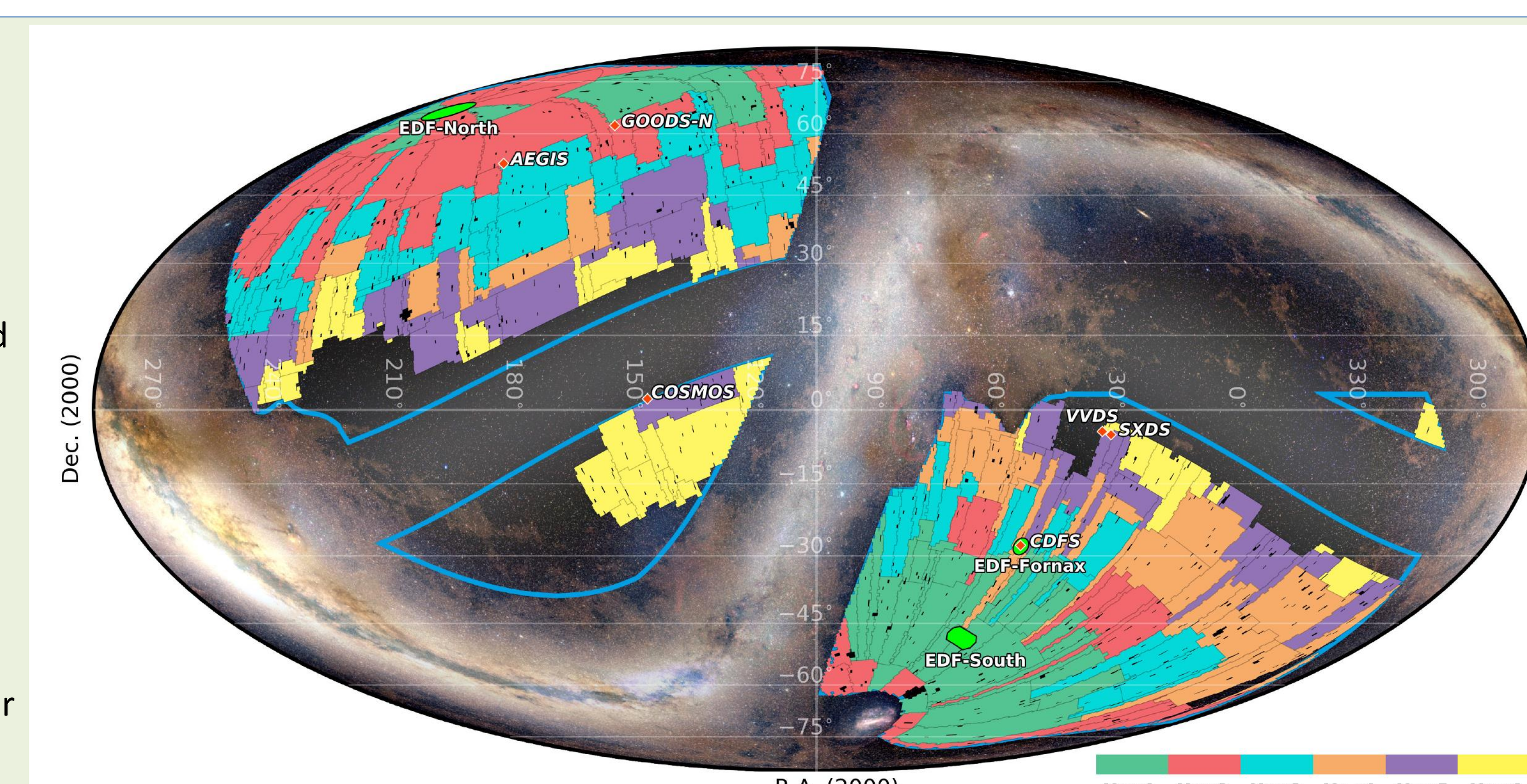
Above: Euclid's step-and-stare observing mode.

On the right: the Figure of Merit of the Wide Survey observations along the six years of mission, and the first year of the operational survey, with different colours exhibiting different types of surveys and calibration fields. Orange triangles mark the two re-planning starting points.

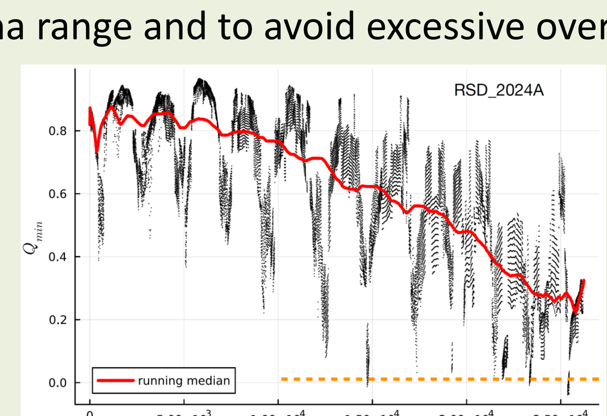
Euclid's main step-and-stare observing mode is shown on the left, showing north-south steps along a circle as rotations around the X-axis. Euclid can tilt to another circle by rotating around the Y-axis.

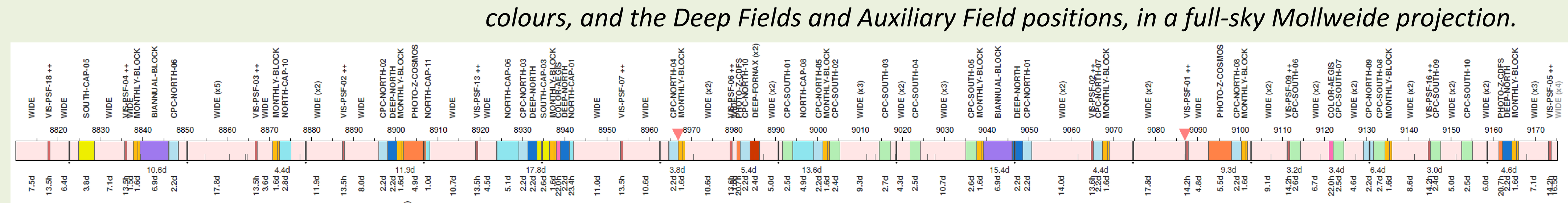
The EWS tessellates the RoI with FoVs aligned with the Ecliptic meridians, distributed along parallels of latitude. This configuration minimises overlaps and maximises survey efficiency. The natural observing mode is to step-and-stare along the transit meridian, sweeping the sky at an approximate rate of 1° per day as Euclid progresses on its yearly orbit around L2.

FoVs are observed in sequences called 'patches', usually covering a latitude-longitude rectangle of the RoI. Two parameters, Alpha and Solar Aspect Angle, allow the telescope to point away from transit. The scheduling algorithm ensures pointings never go outside the parameters allowed range ([-2.9°; -8.5°] for Alpha, [87°; 120°] for SAA), by always observing close to transit. For the polar caps (Elat > 78°), a different tiling strategy is used to cope with the limits of the Alpha range and to avoid excessive overlaps due to converging meridians.



Above: the first operational survey realization, with Wide Survey observation years in different colours, and the Deep Fields and Auxiliary Field positions, in a full-sky Mollweide projection.





Survey operations and re-planning

The celestial and spacecraft constraints are compiled by ESA Project and Science Operations Centre (SOC) and taken into account by the Survey Operations Support Team (SOST) to produce a valid Reference Survey Definition (RSD). This file contains the Wide Survey, Deep Survey and calibration fields for the whole nominal mission (5 years and 10 months starting on Feb. 14th, 2024). SOC validates the RSD and processes it for operational use, then generates from it the pointing requests and instrument activities to be transmitted to the Mission Operations Centre (MOC), who operates the spacecraft.

The fastest way to change the survey plan while in operations in through the SOC local re-planning, as described schematically on the figure on the right. This happens typically when there is a one-off change that needs to be performed quickly, sacrificing temporarily a small part of the scheduled survey. For more complex changes to the survey plan (such as changes in a recurring calibration block, or details in the scheduling in the Deep Field passes), a strategic re-planning of the survey by SOST is needed. Such strategic re-plannings resulting in the issuing of a new RSD for operations typically occur twice a year. Bi-weekly meetings between SOST and SOC allow smooth decision-making and planning to take place.

Strategic re-planning of the survey already occurred twice in 2024, in order to correct and optimize some of the calibration blocks, and to re-observe some missed observations. Ice deposited on the telescope mirrors degraded VIS sensitivity, which led to the decision to perform two few-day decontamination sessions (in March and in June), where parts of the telescope were heated for a short time, in order to sublimate the deposited ice. Some of the Wide Survey data taken prior to the second decontamination session are significantly affected by the ice, and may need to be re-observed in the near future. Current efforts on survey re-planning are focusing on this possibility and on further calibration corrections and improvements.