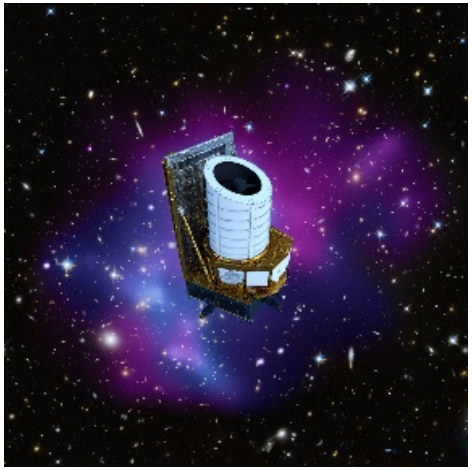
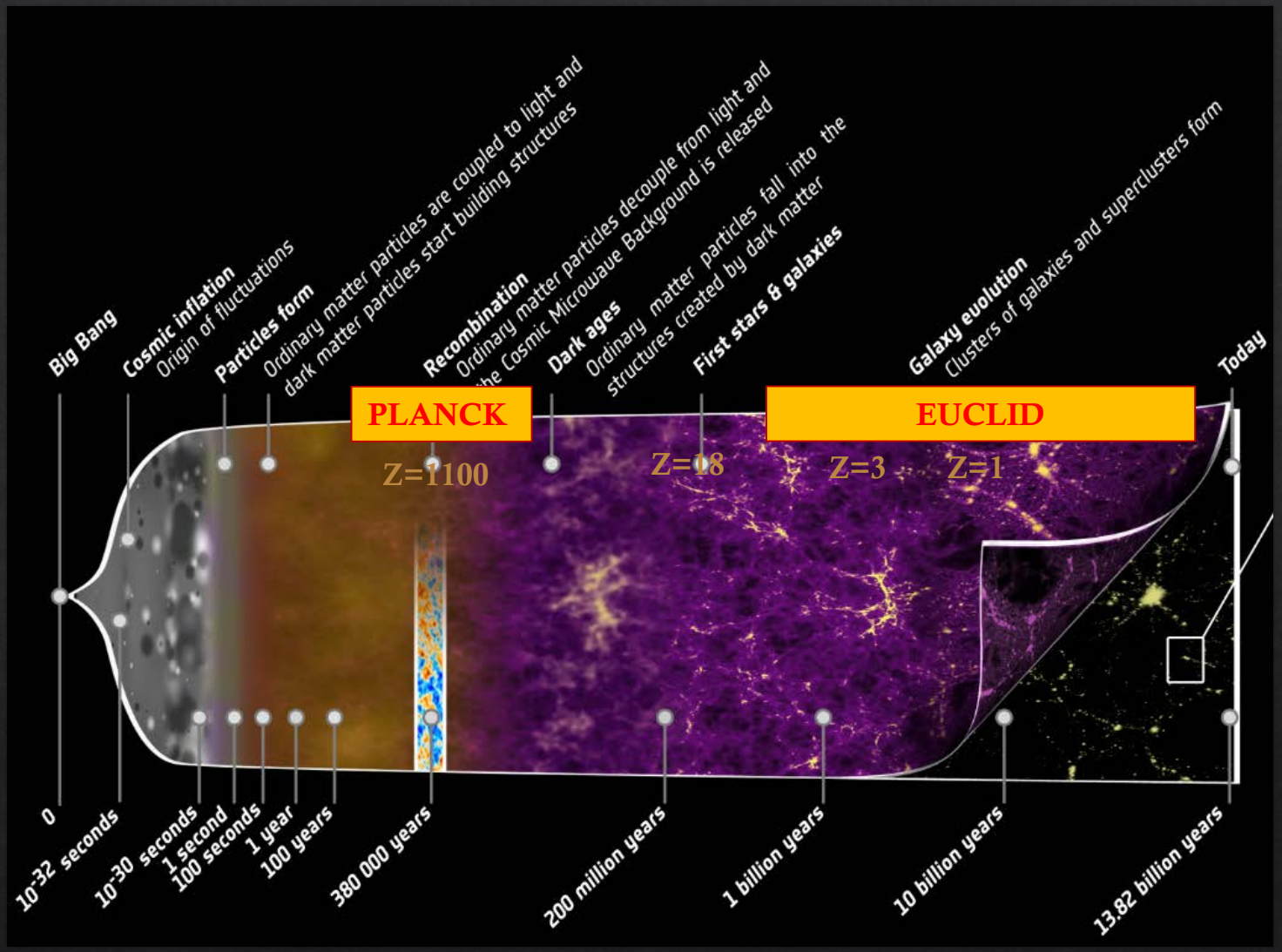
Survey operations for the Euclid mission

Xavier Dupac, on behalf of the Euclid Science Operations Centre

ESA - European Space Astronomy Centre, Spain



ESA cosmology missions / cosmos history

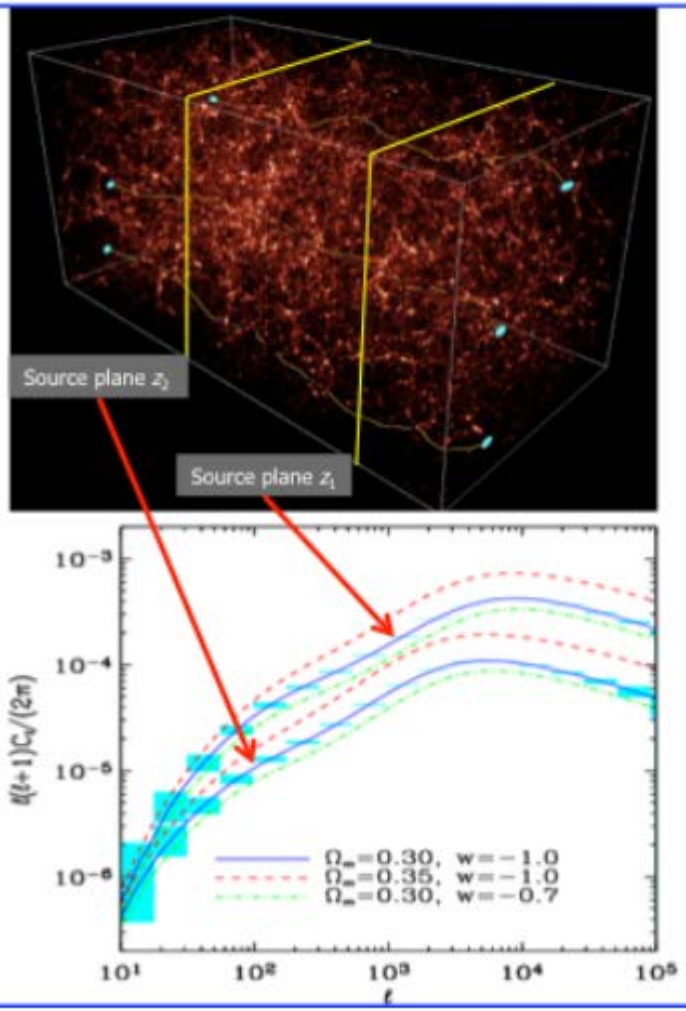


WL probe: Cosmic shear over 0<z<2 :

1.5 billion galaxies shapes, gravitational shear and photometric redshifts (u,g,r,i,z,Y,J,H) with 0.05 (1+z) accuracy over 15,000 deg^2

GC; BAO, RSD probes: 3-D positions of galaxies over 0.7<z<1.8 :

35 million spectroscopic redshifts with 0.001 (1+z) accuracy over 15,000 deg^2



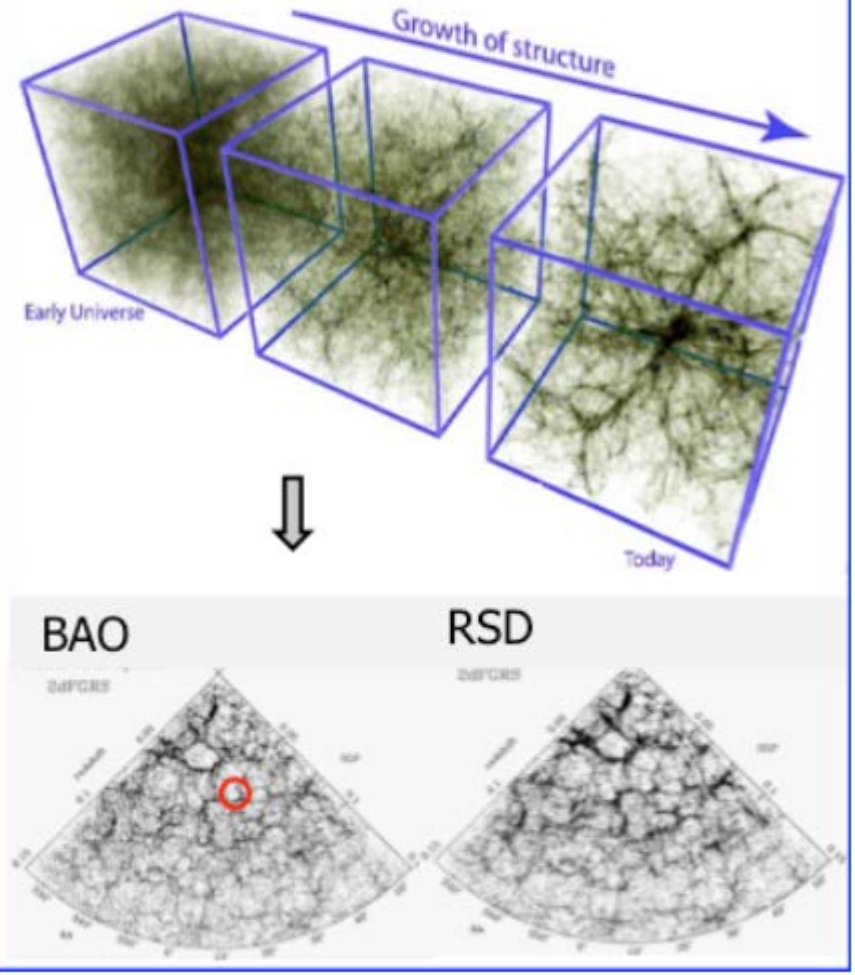


Illustration of the primary probes of the Euclid mission. Right: Galaxy Clustering (GC), including Baryon acoustic oscillations, (BAO), Redshift Space Distortion (RSD). Left: Weak Lensing (WL)- Courtesy Euclid Consortium/Science Working Group.

The Euclid mission

- ESA is implementing the Euclid mission in order to study Dark Energy through its imprint on the cosmic evolution of Dark Matter distribution
- 1.2 m space telescope with two focal instruments: Visual Imaging channel (VIS) and the Near-Infrared Spectrometer and Photometer (NISP).
- Each field of view is a 0.8 x 0.7 deg. tile with four dithers, with each dither in turn split into VIS imaging, NISP imaging and NISP spectrometry observations.
- Euclid will be launched in 2022 by Soyuz from Kourou, French Guiana, to the Sun-Earth L2 point.
- 6-year nominal mission duration
- 15000 sq. deg. wide survey coverage

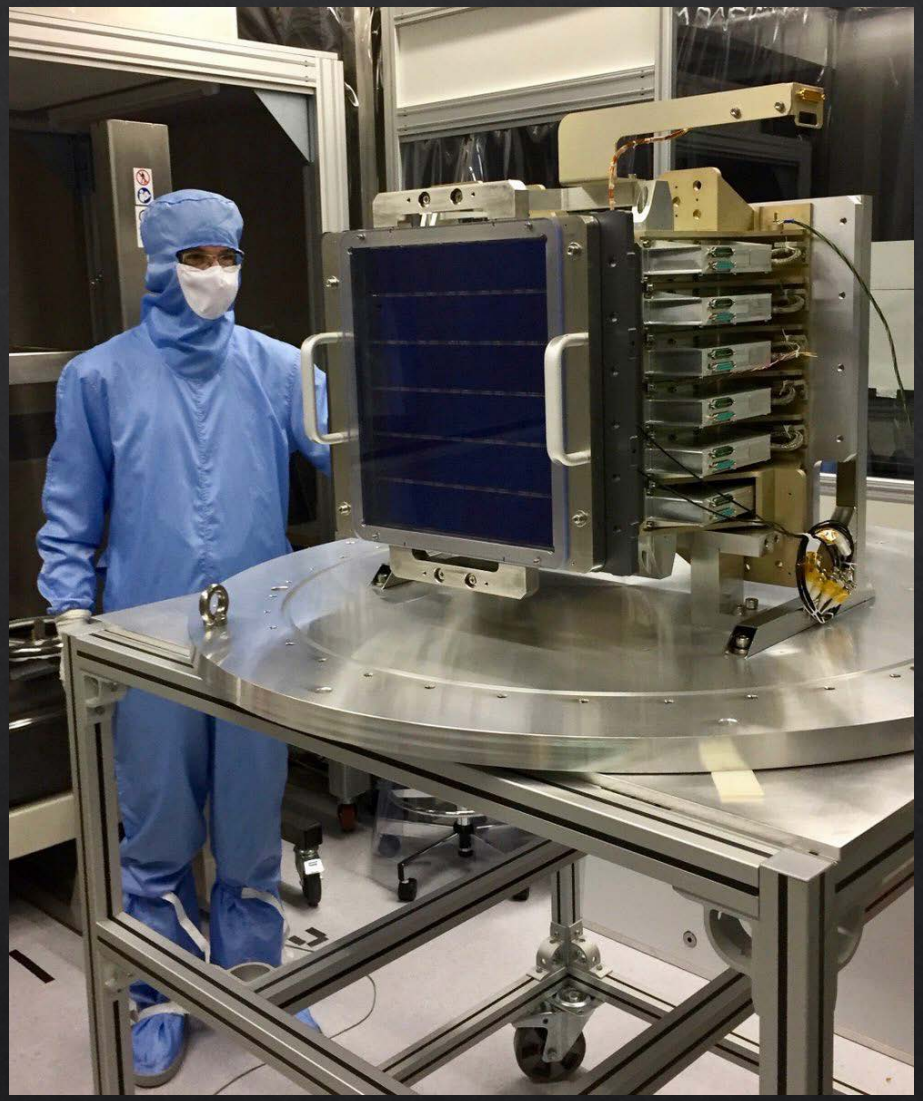
Courtesy Thales Alenia Space

VIS instrument

- Visible wide-band imager
- 0.1”pix: precision galaxy shape measurement

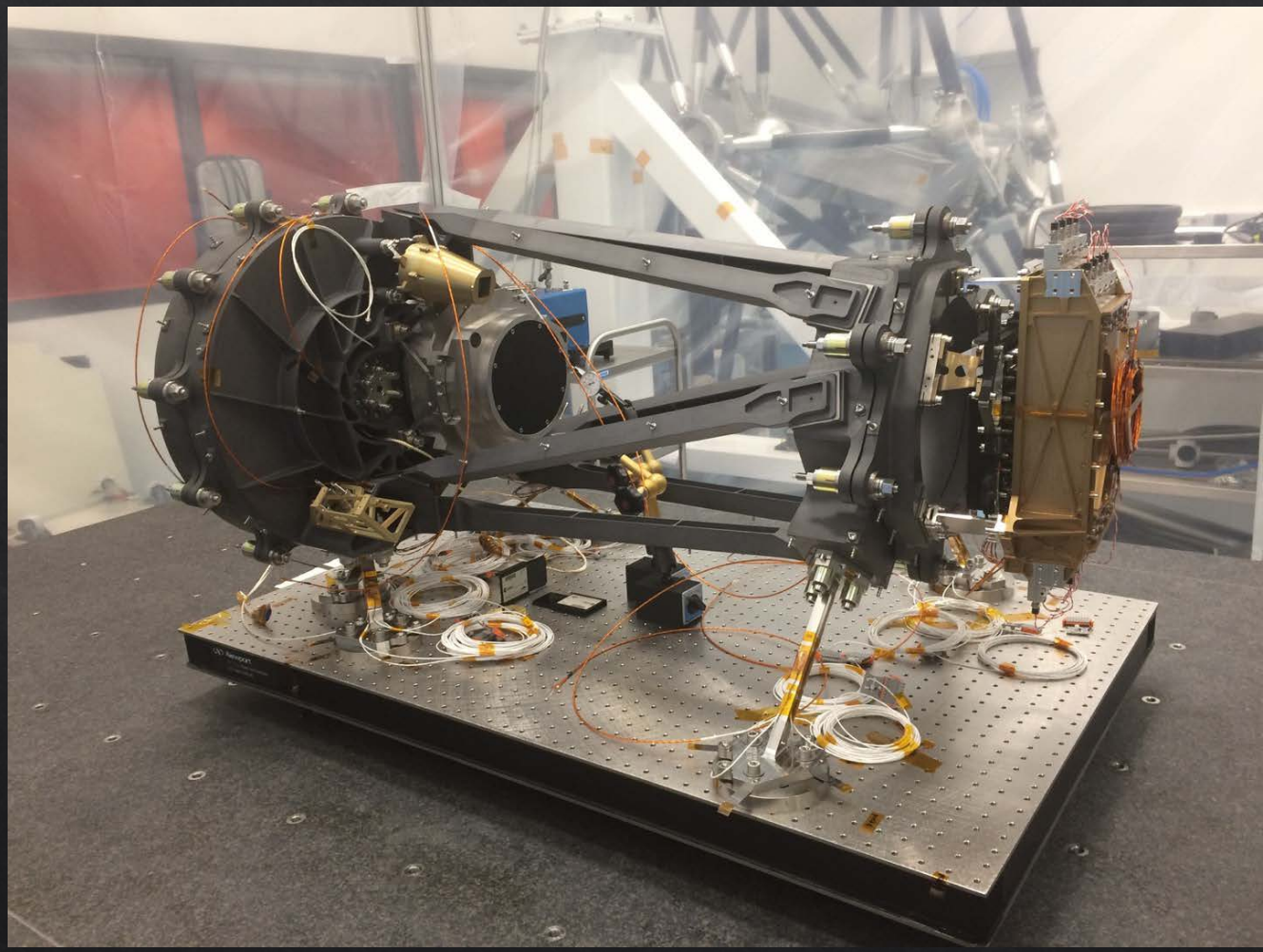
- VIS observes in a large unique visible band (0.55 – 0.9 μm) with a 24.5 mag (10 σ ext.) sensitivity thanks to 36 4kx4k CCD arrays

- UK led, MSSL



NISP instrument

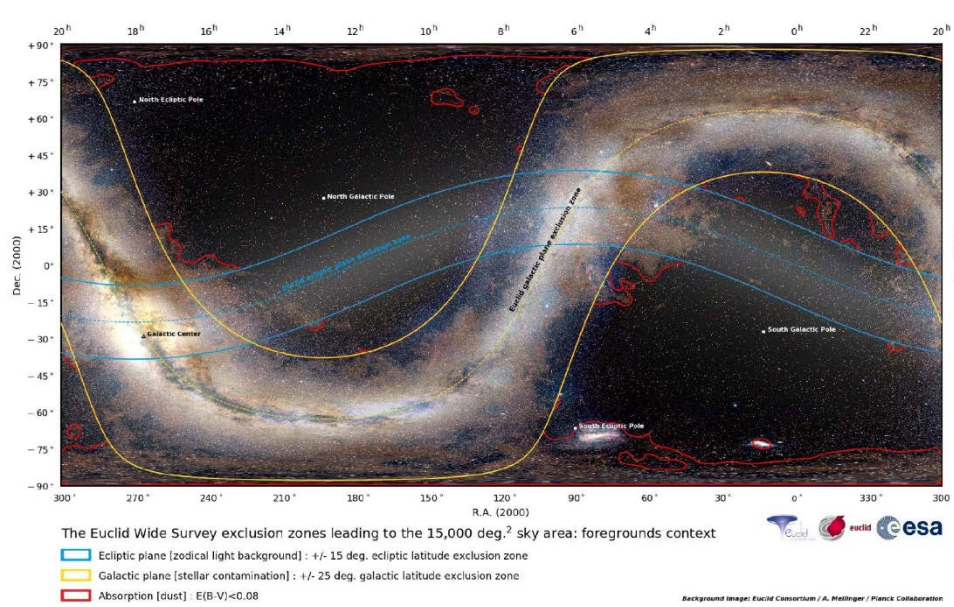
- Near Infrared spectrometer & photometer
- NISP photometry consists of three wide near-infrared bands (Y: 0.9 – 1.1 μm, J: 1.1 – 1.4 μm, H: 1.4 – 2 μm) with a sensitivity of 24 mag (5 σ point source) and 0.3” pixel size.
- The NISP slit-less spectrometer works in the 0.9 – 1.85 μm range with a spectral resolution > 380 assuming a 0.5” aperture.
- Accurate measurement of galaxy redshifts: $\Delta z/(z+1)<0.1\%$
- France led, CNES/LAM

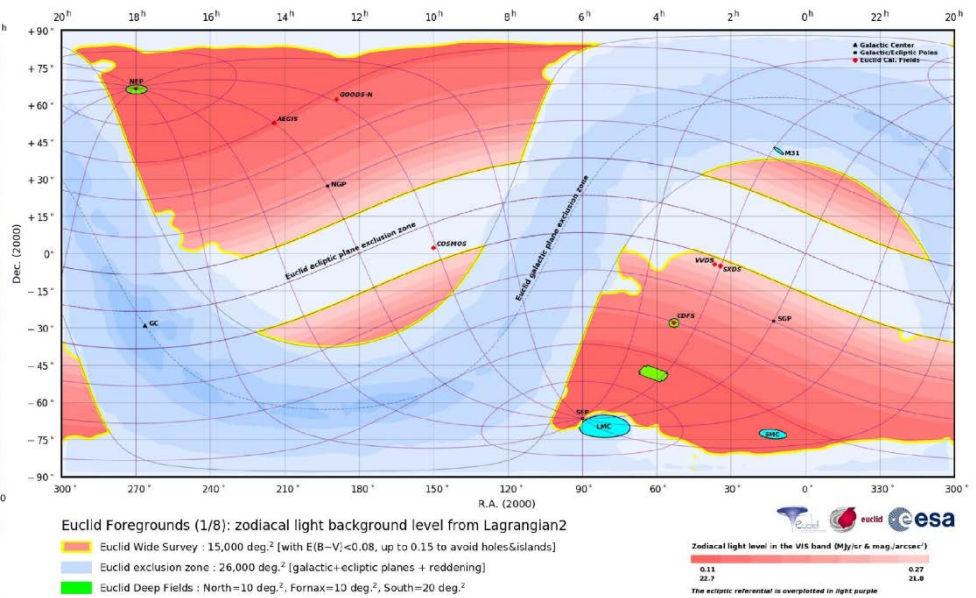


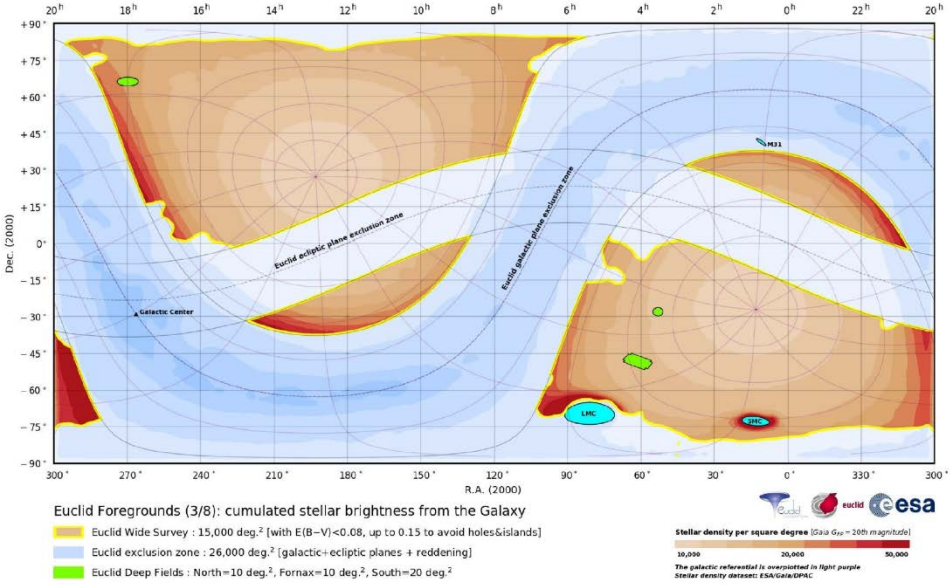
The Euclid survey

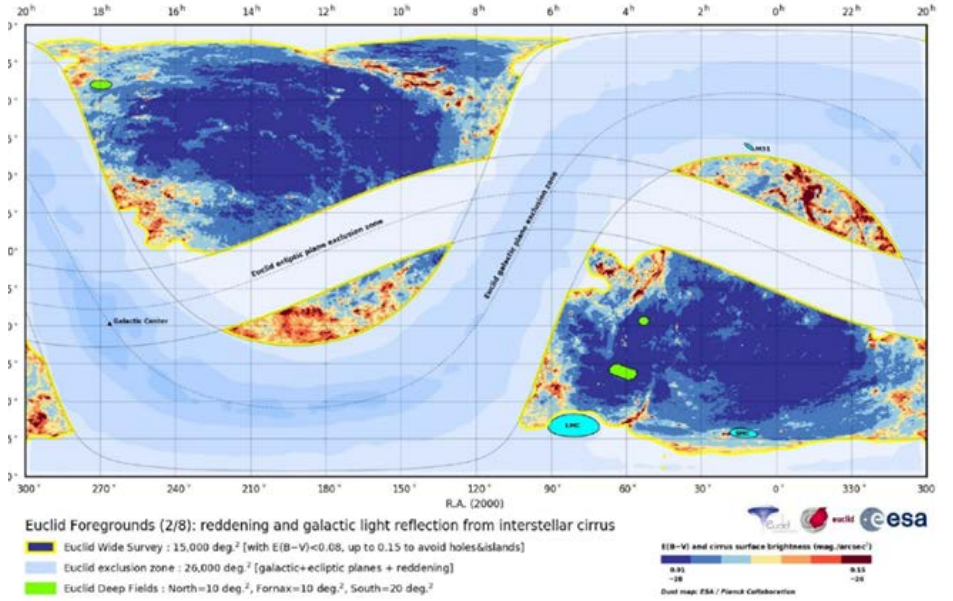
- The Euclid Survey, as designed by the Euclid Consortium Survey working group (EC-SURV), is built in order to ensure the scientific goals of the mission are achieved after 6 years of observations.
- The visibility of sky areas strongly depends on angular constraints (solar aspect angle, etc).
- The survey consists of a Wide Survey (15000 sq. deg.) and three Deep Fields, covering 40 sq. deg. in total, near the North Ecliptic pole, near the South Ecliptic pole, and one in Fornax coinciding with the Chandra Deep Field.
- It is required that the three deep fields are at least 2 magnitudes deeper than the wide survey.
- A number of calibration fields also need to be observed and re-observed throughout the 6-year survey

What area to observe ?



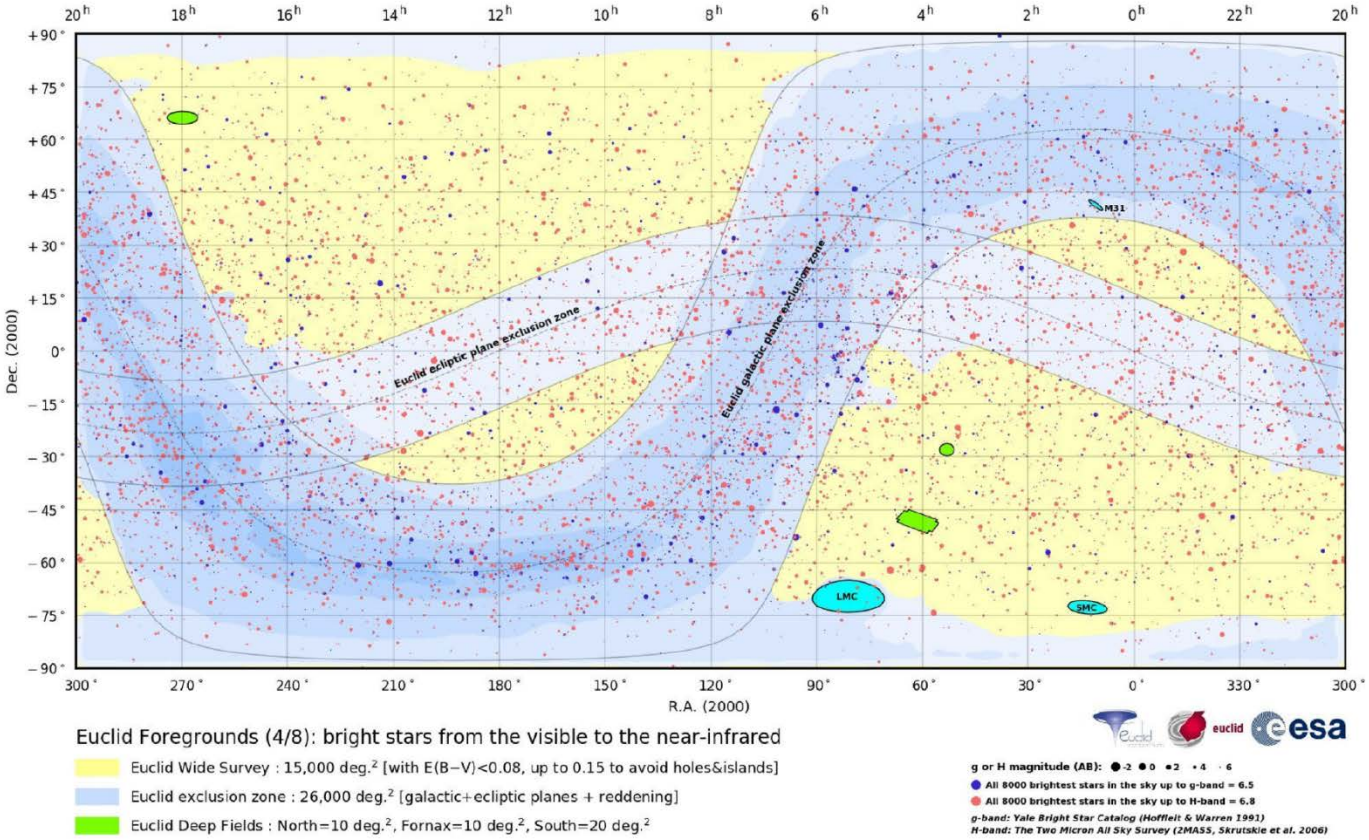






Courtesy J.-C. Cuillandre

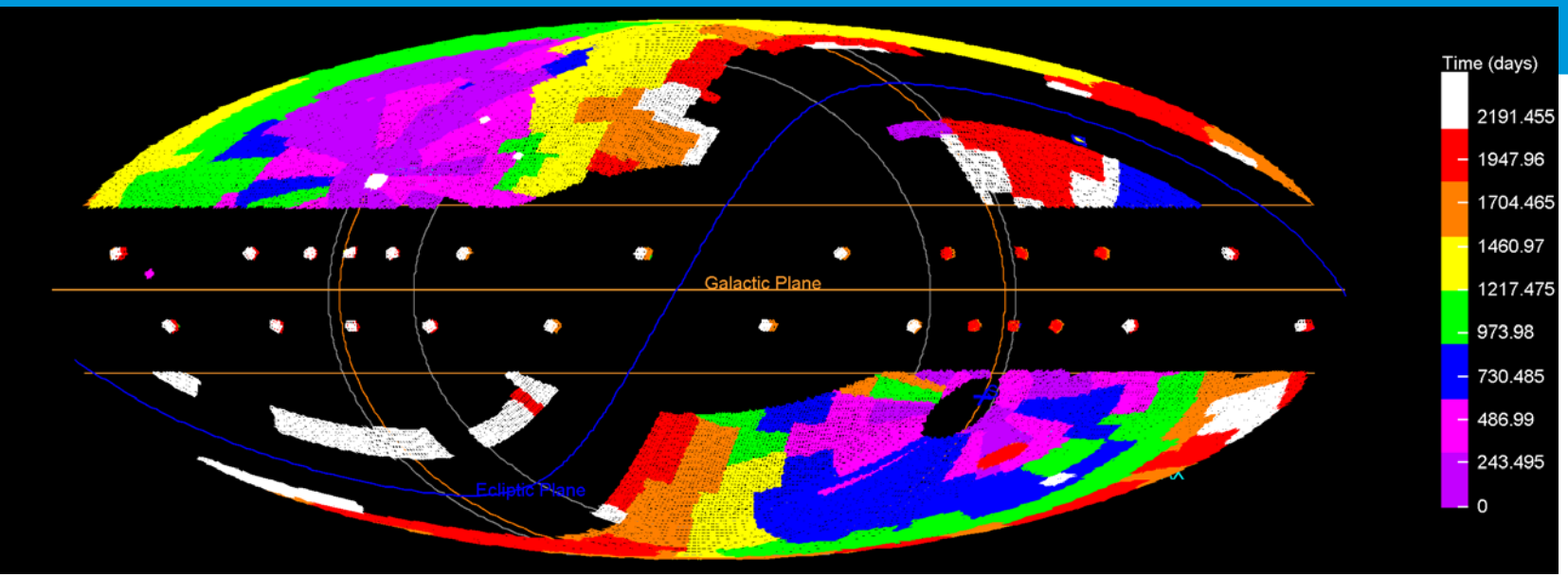
Building the Euclid 6-year nominal survey



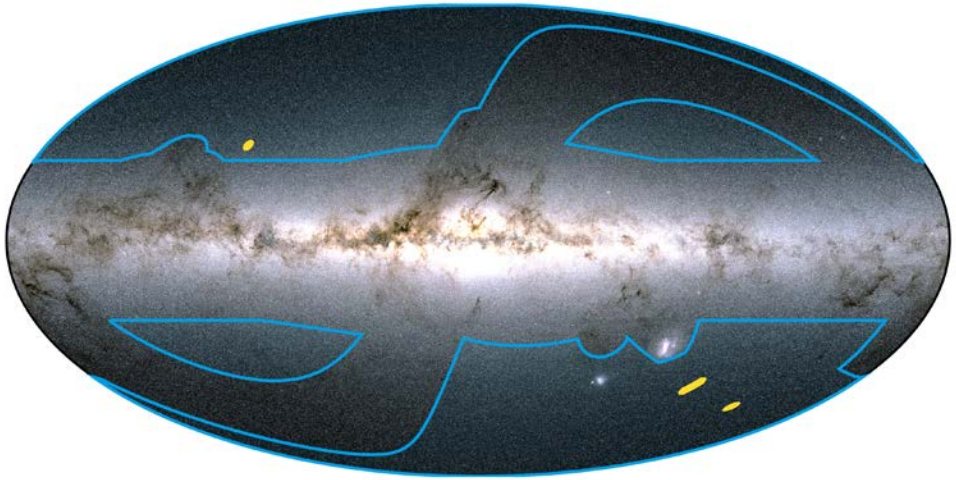
euclid European Space Agency

Courtesy J.-C. Cuillandre

The “Helsinki” survey (June 2019)



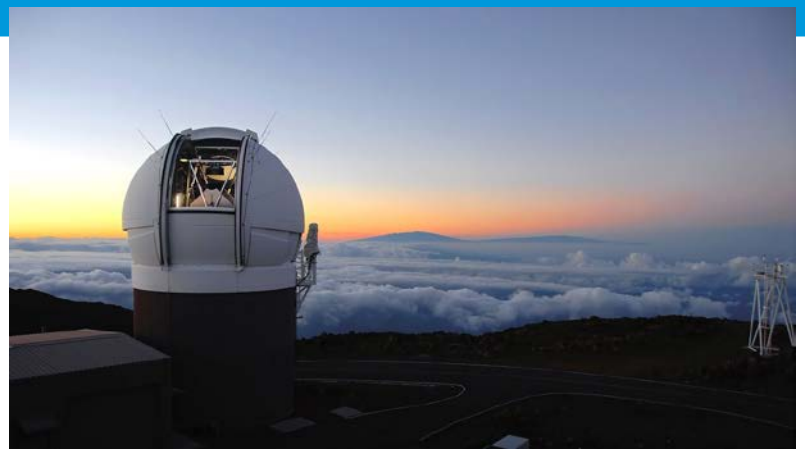
The Helsinki wide survey with calibration fields (colors correspond to different observing epochs)

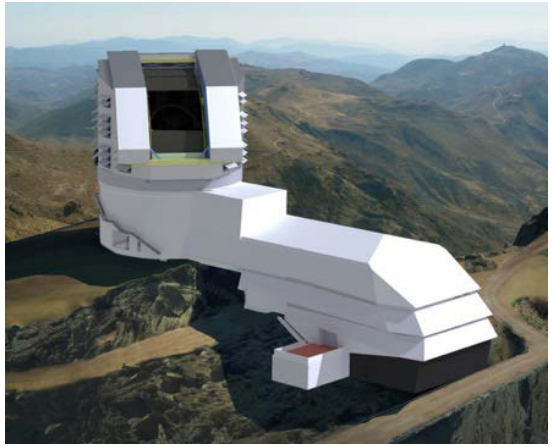


Location and shape of the three deep fields in Galactic coordinates

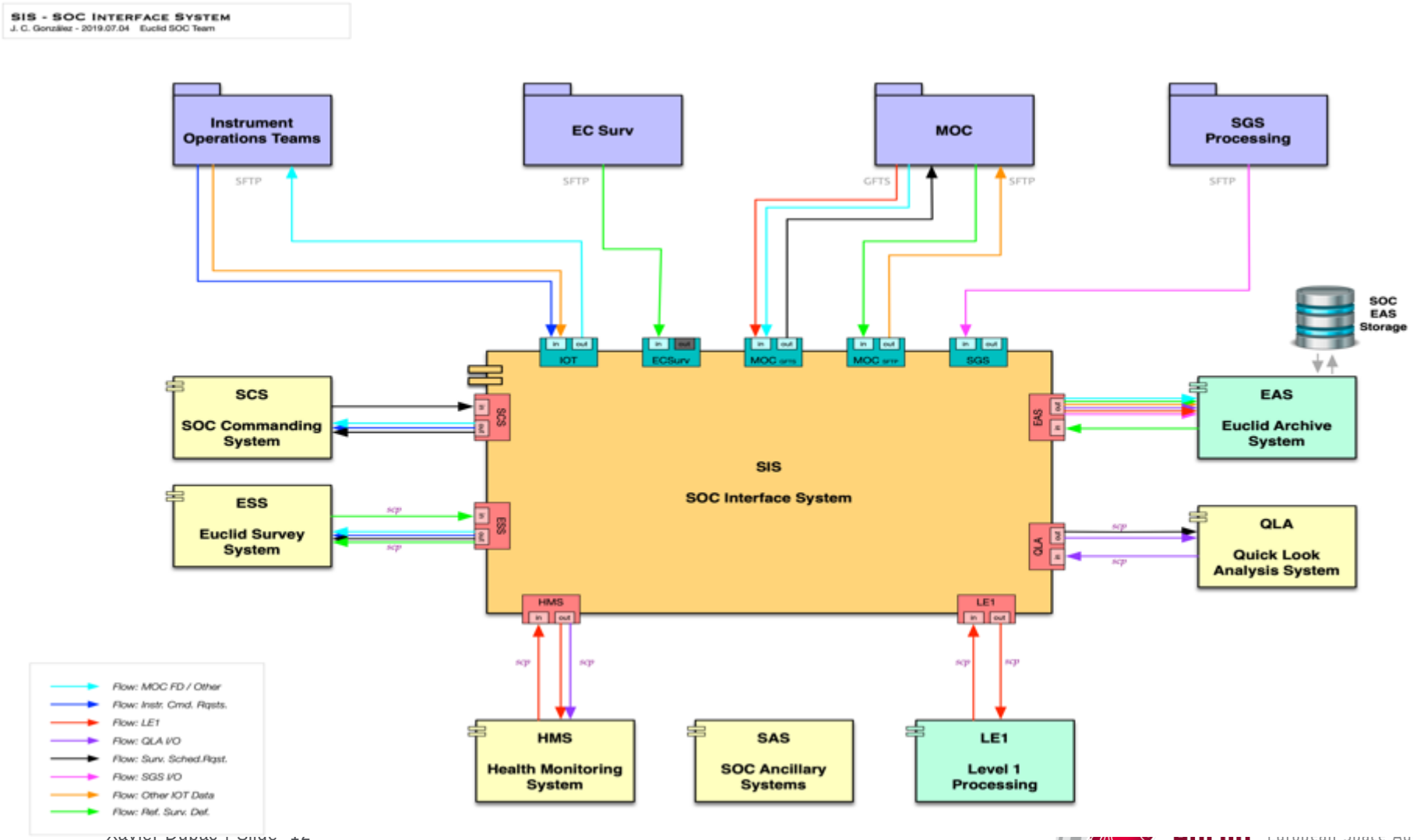
Cross-facility collaboration

- Additional **4 band** (u)griz photometry: Pan-STARRS 1&2, CFIS (CFHT), CEFCA-JST
- Needed for photometric redshift and PSF modelling for individual galaxies
- LSST: 8.4m telescope (~2023)
- Volume of additional external data >> Euclid data





The Euclid Survey System at SOC: context



SOC tasks for the survey

SOC responsibilities for the survey :

- Support the Survey optimization
- Verification of the Reference Survey Definition: integrity checks, compliance checks (celestial constraints, consumables…)

- Making and maintaining the Operational Sky Survey from the RSD
- Operating the survey in case of contingencies and change requests
- Survey CCB
- Issuing Survey Schedule Requests to MOC

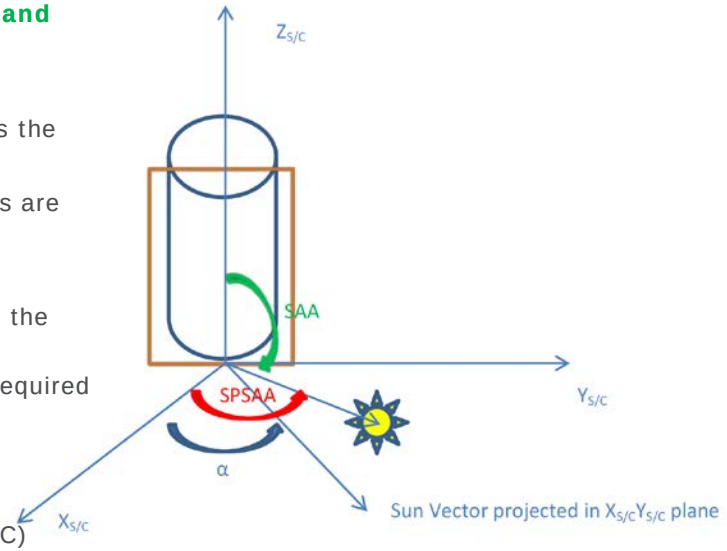
- Monitoring of the survey
- Reporting on the state of the survey

SOC integrity checks of the RSD

- Format checking: check that the RSD is provided in the correct format and readable by the ESS
- Operation-overlap checking: check that all the operations (slews and observations) are disjoint in time and that there is no significant gap between them
- Duration checking: check that the duration of each observation is always positive and consistent with the provided start/end times
- Slew checking: check that slew times are long enough for the observation start and end pointings
- Number checking: verify that all numbers provided in the RSD are within boundaries (e.g. latitude within -90 and 90 deg., etc)
- ...

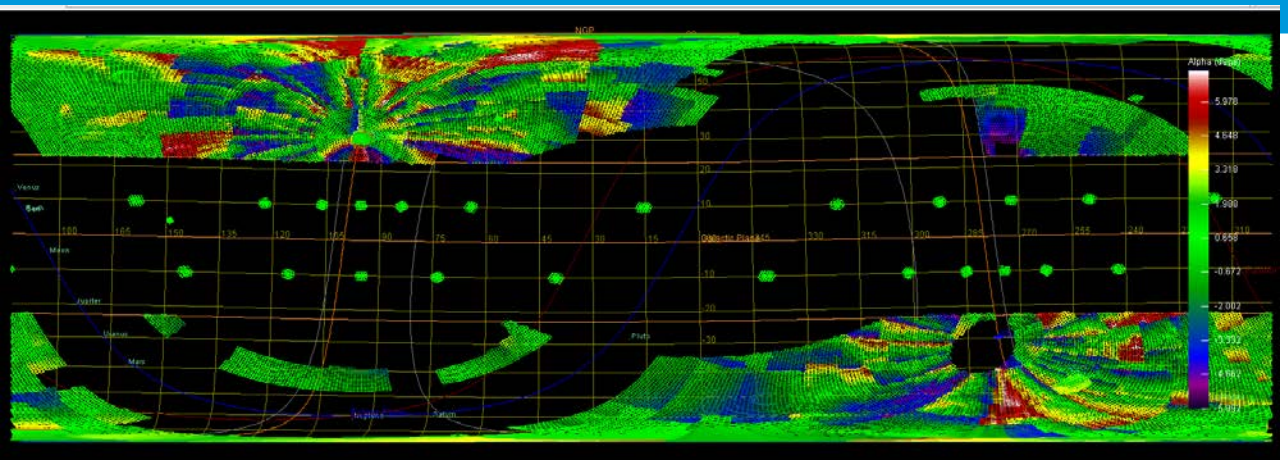
Compliance checks of the RSD

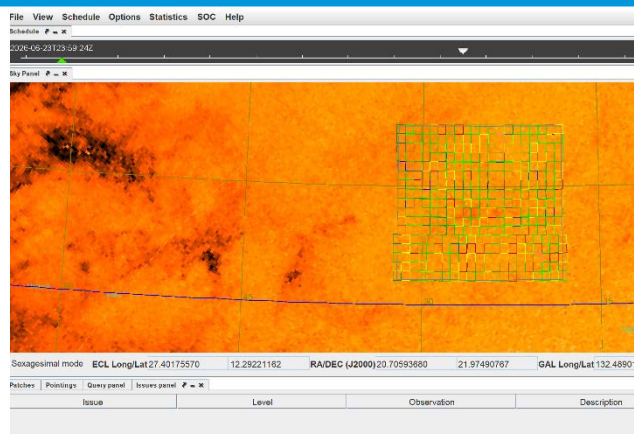
Goal is to verify the RSD with respect to MOD-A requirements and the Constraints and Limitations doc.

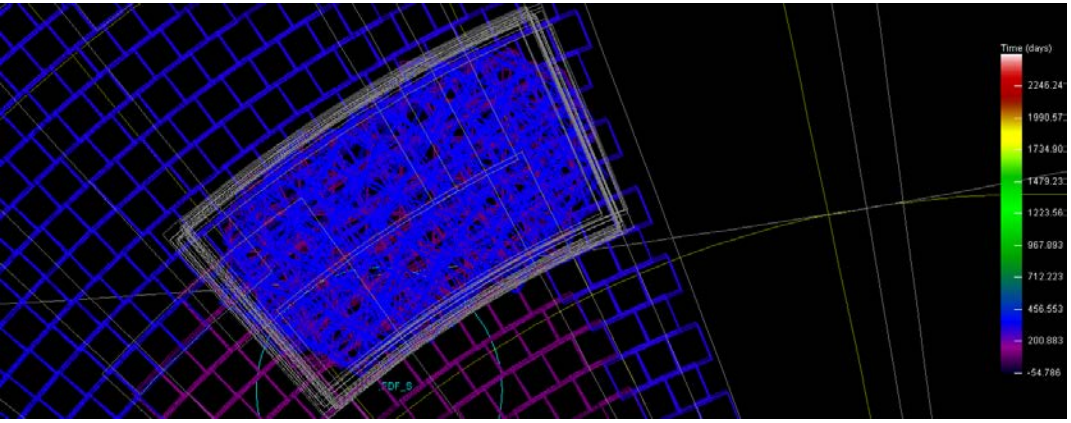


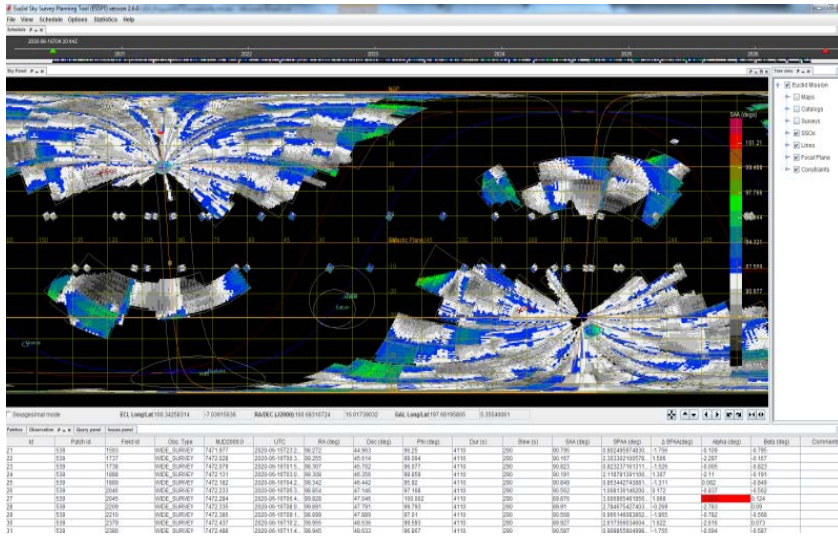
- MOCDA-SYS-001 check that the survey duration does not exceed 6 years and includes the “adequate” margin.
- MOCDA-SYS-002 Solar Aspect Angle (SAA) verification: check that all the observations are within current SAA limits (87 – 105 deg.)
- MOCDA-SYS-003 check that the alpha angle is always between ±6 deg.
- MOCDA-SYS-005 Check that the survey, including calibration fields, is performed with the consumable resources associated equivalent to a maximum of 48000 (TBC) Scientific Observations, including all the necessary slews between Scientific Observations, the required dither steps per Scientific Observation and the total number of mechanism actuations
- MOCDA-SYS-005a Check that the calibration field sequences do not require enhanced spacecraft performance with respect to Science Observations
- MOCDA-SYS-006 Check that field-to-field slew amplitudes do not exceed 1.2 deg. (TBC)
- MOCDA-SYS-007 Check that in total the survey contains no more than 950 large slews for science purpose
- MOCDA-SYS-008 Check that large slews have maximum amplitude of 180/23/12 deg. (TBC) about the X/Y/Z axes
- MOCDA-SYS-009 Check that science observation sequences do not exceed 4400 s
- MOCDA-SYS-012/013 Check that slews of 0.8 deg. take 290 s in the survey and that slews between dithers take 60 s
- MOCDA-SYS-019 Check that one day is scheduled every 28 days (TBC) for spacecraft orbit and platform maintenance
- MOCDA-SYS-027 Check that the Sun-S/C-Earth angle is not greater than 33 deg.
- MOCDA-SYS-030 Planet avoidance: check that the observations do not violate the currently defined planet constraints
- Data volume checks

ESS operational tool



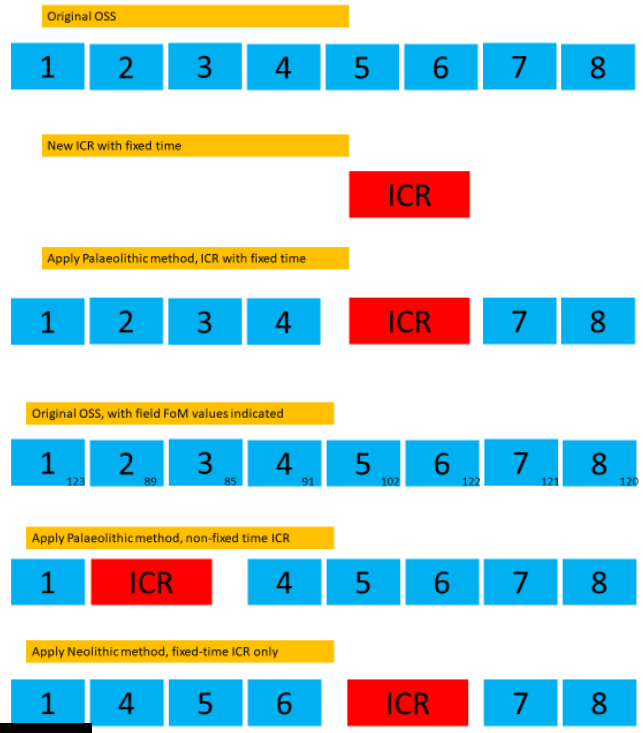


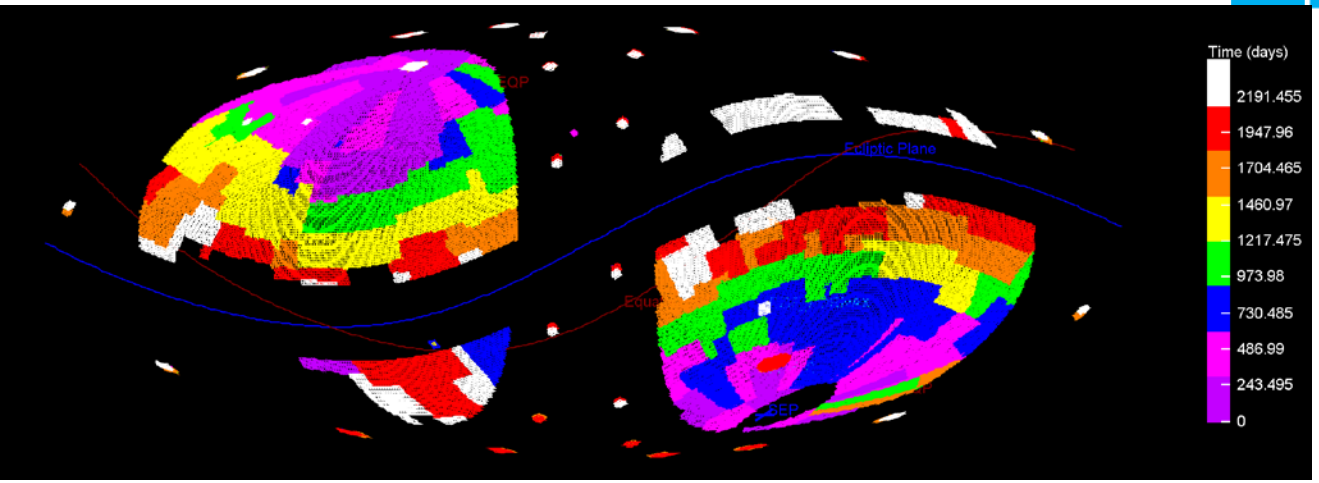




Euclid Survey System status (Nov. 2019)

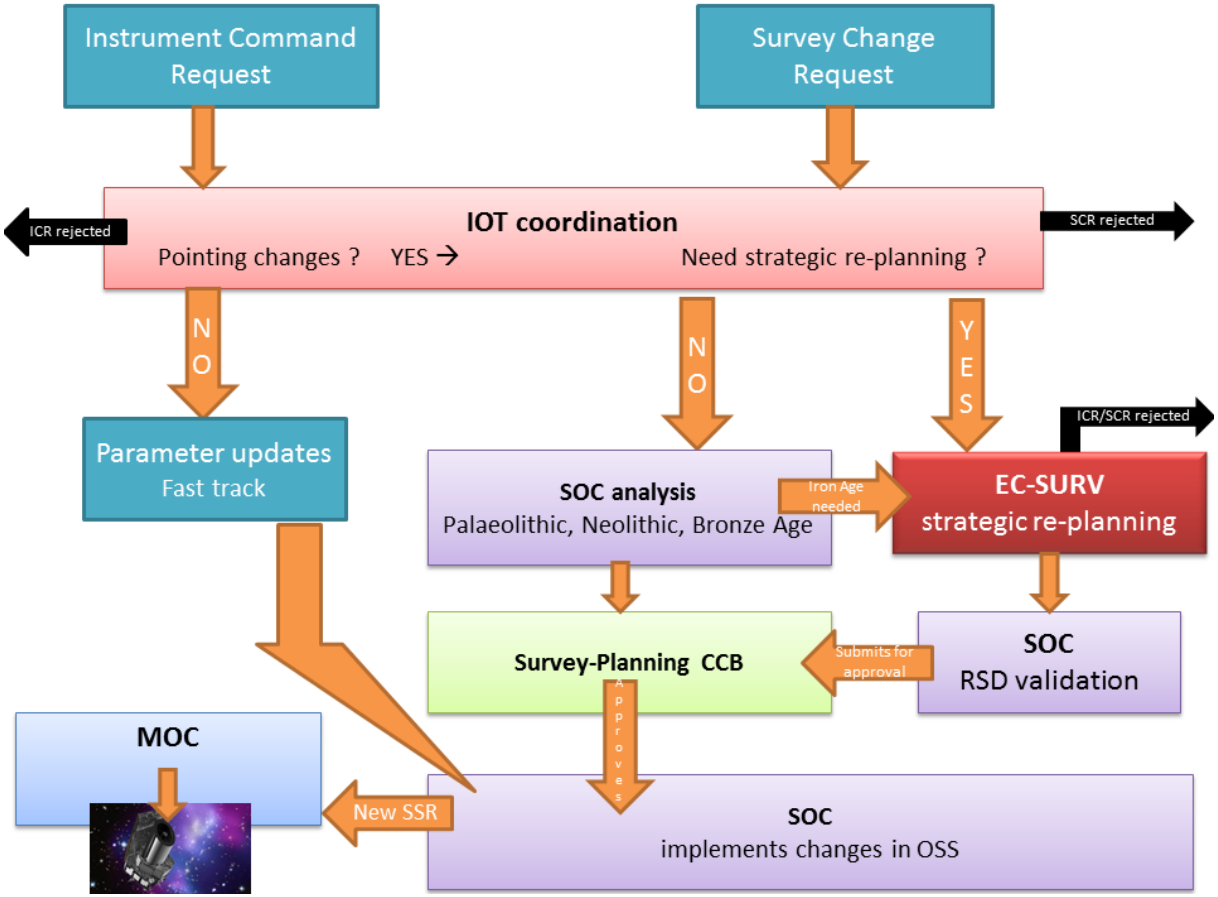
- The Euclid Survey System v4.2.0 has been fully tested and validated as part as the SOC v2.2 test campaign
- It includes the SOC re-planning functionalities (“Palaeolithic” and “Neolithic”) to quickly react to survey change requests (local optimized re-planning)
- The ESS includes various Figure-of-Merit proxies: GAIA star density maps in 3 colors, extinction and reddening, Schlegel extinction model
- These FoM proxies are placeholders until we get the updated FoM map from the Consortium, based on WL and GC FoM combined
- ESS can now produce a draft of a quarterly SOC survey report
- The Survey Performance Verification functionalities at SOC level are now largely defined
- ESS will fetch QLA reports for quick and crude survey quality estimates, and Level 2 (catalogs) information from SAS for more refined analysis (galaxy counts per field…)





euclid European Space Agency

CCB for survey changes during operations



ESA Euclid Science Operations Centre

Photo B. Altieri