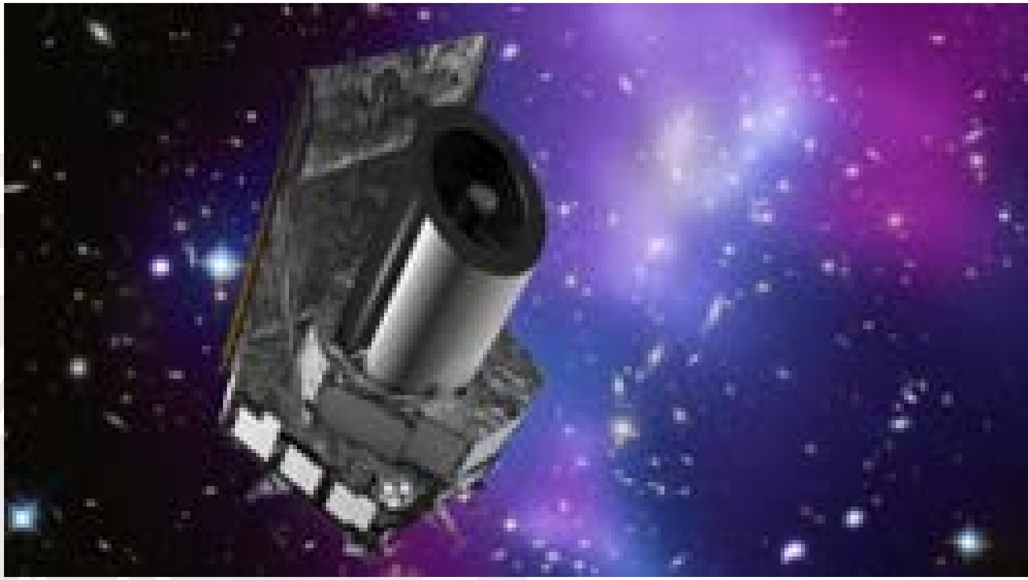
euclid



Euclid Survey Operations

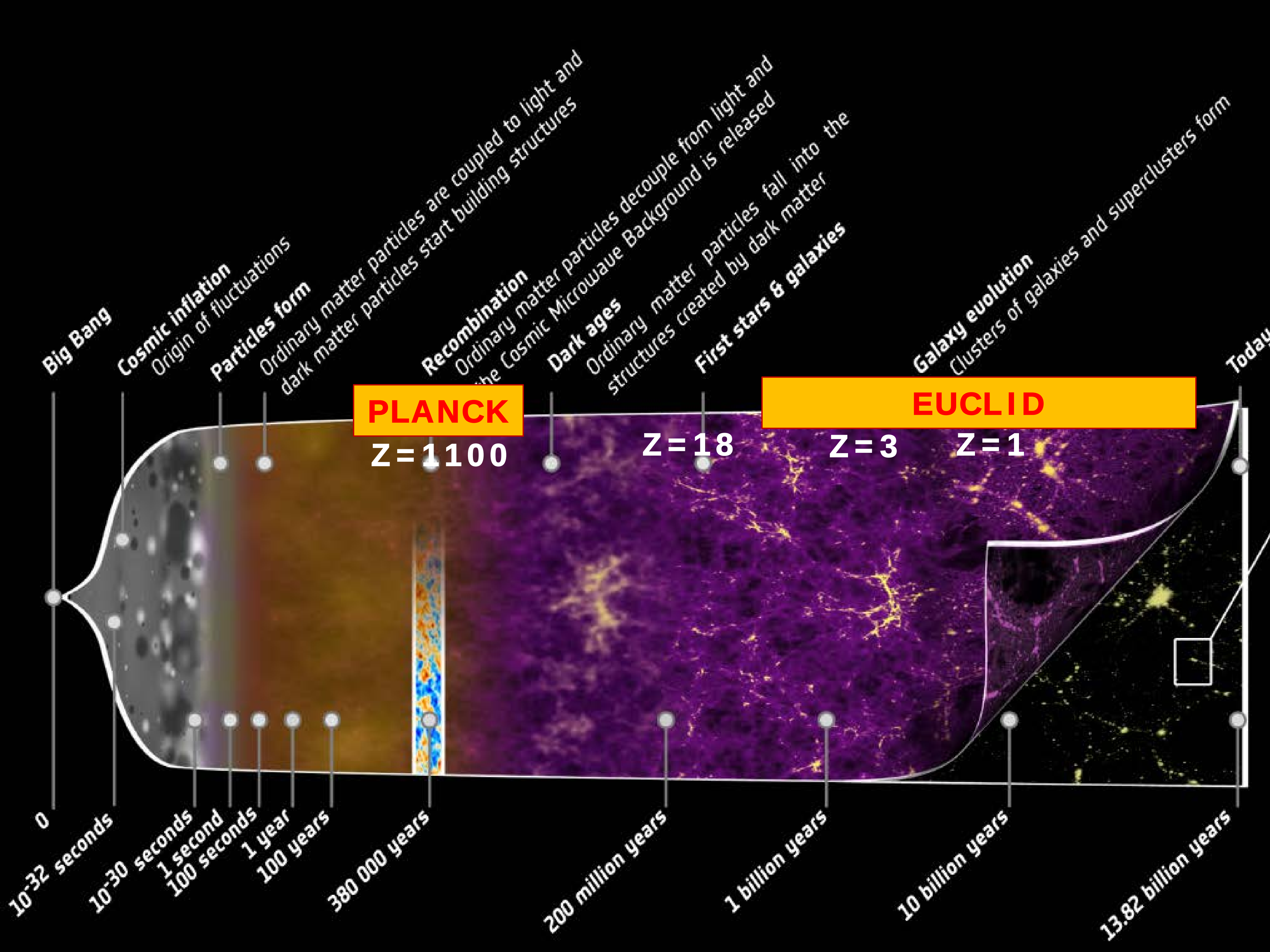
Xavier Dupac, on behalf of the Euclid Science Operation Centre

ESA / ESAC

European Space Agency

Summary

- 1. Brief introduction (Euclid & its science goals)
- 2. The Euclid Survey
- 3. Survey operations at ESAC
- 4. Procedures for survey changes



Big Bang
Cosmic inflation
Origin of fluctuations
Particles form
Ordinary matter particles are coupled to light and dark matter particles start building structures
Recombination
Ordinary matter particles decouple from light and the Cosmic Microwave Background is released
Dark ages
Ordinary matter particles fall into the structures created by dark matter
First stars & galaxies
Galaxy evolution
Clusters of galaxies and superclusters form
Today
PLANCK
Z=1100
Z=18
EUCLID
Z=3
Z=1
0
10^{-32} seconds
10^{-30} seconds
1 second
100 seconds
1 year
100 years
380 000 years
200 million years
1 billion years
10 billion years
13.82 billion years

What is Euclid ?

- Euclid is the next ESA cosmology mission, to provide catalog of > 10^9 galaxies, in order to constrain Dark Matter, Dark Energy and other cosmological parameters, through **Weak Lensing and Galaxy Clustering** probes
- WL needs ~1% accuracy in apparent galaxy ellipticities, which imposes stringent requirements on the PSF ellipticity reconstruction
- GC requires a very accurate measurement of galaxy clustering power spectrum based on spectroscopic redshifts
- The Euclid payload consists of a 1.2 m Korsch telescope and two focal instruments: **the 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.
- VIS observes in one wide visible band (0.55 – 0.9 µm) with a 24.5 mag (10 σ ext.) sensitivity thanks to 36 4kx4k CCD arrays, and reaches a pixel size of 0.1 arcsec.
- 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 spectrometer works in the 1.1 – 1.85 µm range with a spectral resolution of 250 and a pixel size of 0.3”.
- Euclid will be launched in May 2021 by Soyuz from Kourou, French Guiana, to the Sun-Earth Lagrange 2 point.
- 6 yr nominal mission

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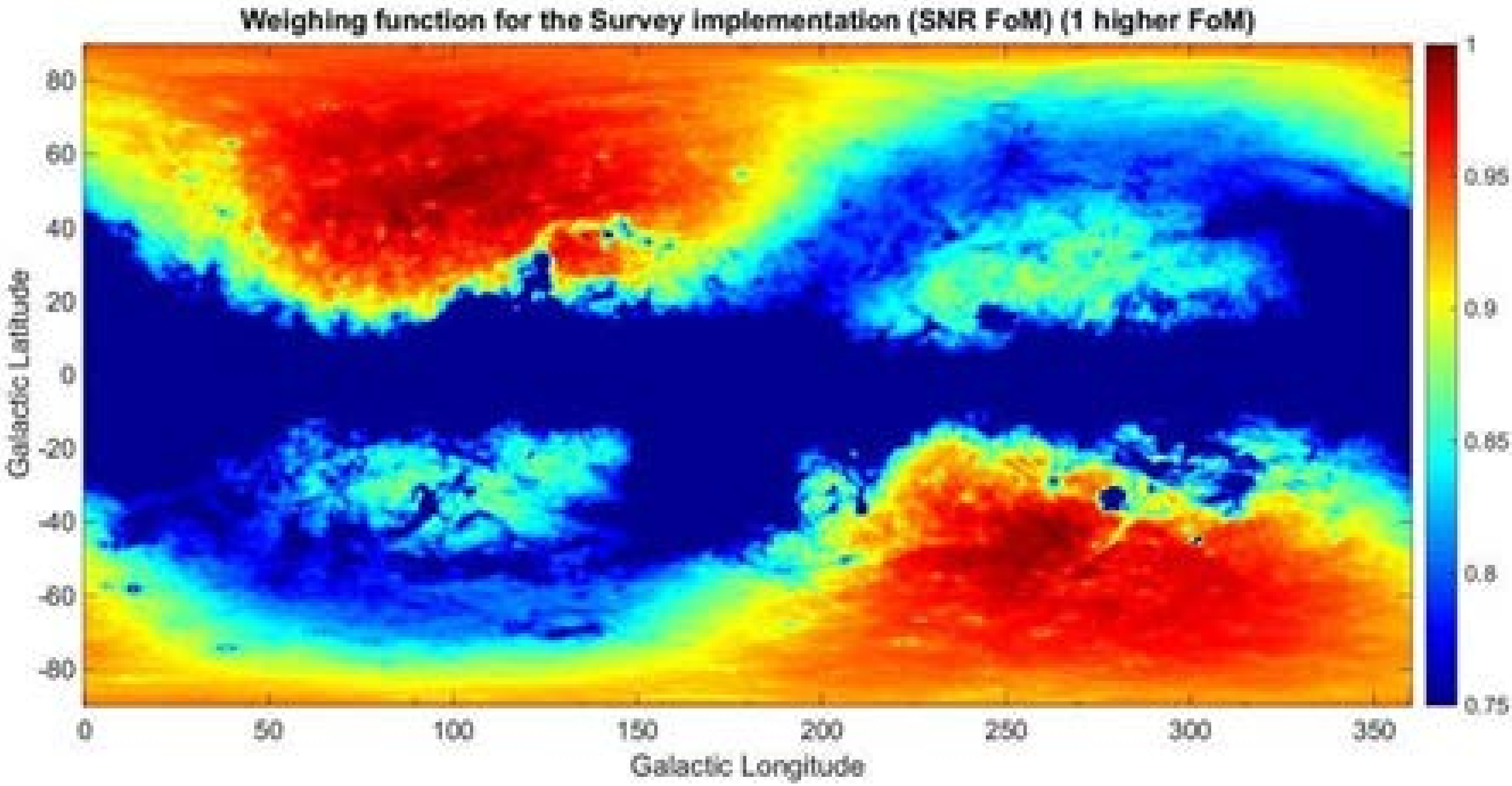
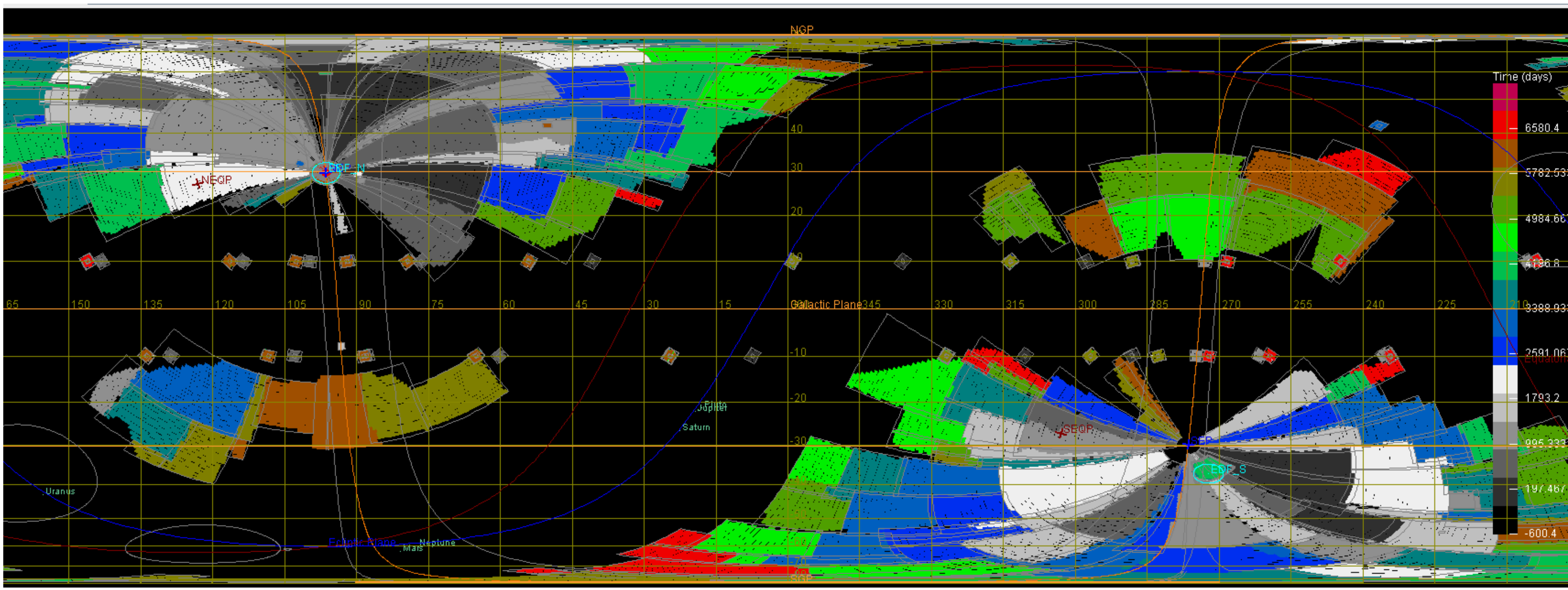
Euclid Survey constraints

- **Weak lensing** figure of merit ~ flat over the Extragalactic sky
- → We have to observe a LARGE ENOUGH area for weak lensing survey
- **Galaxy clustering** figure of merit varies a lot over the Extragalactic sky
- → We have to observe an area with ENOUGH GALAXIES PER AREA for galaxy clustering
- Compromise in area and depth: 15000 deg^2 wide survey
- We also want to do 3 DEEP FIELDS for special cosmology analyses (high-redshift galaxies, etc)

Figure of merit for Euclid survey



The Euclid Wide Survey



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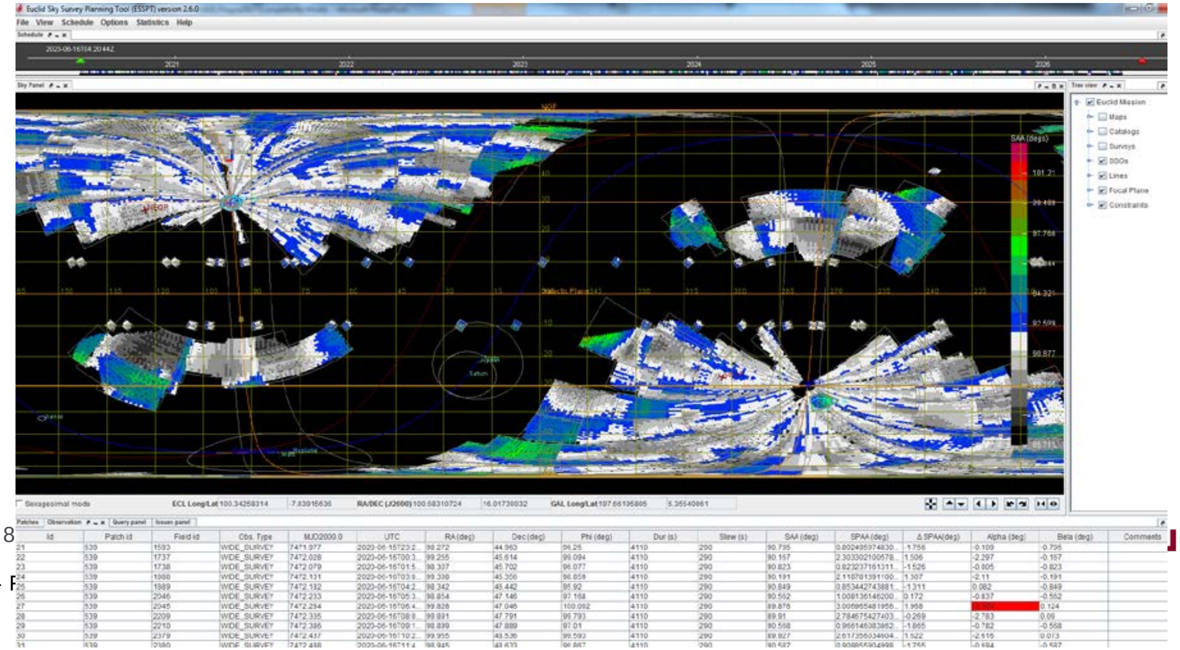
The Euclid Survey System @ ESAC

- The Euclid Survey System at SOC consists of various modules, including the Operational Tool (ESSOT) and the external Planning Tool (ESSPT). There is a web-based visualisation service as well (ESSWVS), currently being developed.
- The ESSPT is available for the whole Euclid collaboration (> 1000 scientists) to use freely in order to understand and visualize the Euclid survey. Here is a screenshot of the ESSPT below, with the Solar Aspect Angle highlighted (color coded) for each Euclid observation field.



Survey operations summary

- Survey operations at SOC include:

- Verification of the Reference Survey Definition: **integrity checks**
- Verification of the RSD: **compliance checks** (celestial constraints, consumables...)
- **survey performance verification**

- Making and maintaining the Operational Sky Survey from the RSD
- “Operate” the survey in case of contingencies and change requests (ICR, SCR)
- SOC leads the Euclid survey CCB for any change in the survey
- Issuing Survey Schedule Requests to MOC

- Monitoring of the survey with QLA and L2 data
- 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 Constrains 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

Performance verification

- Once the RSD is validated with respect to the requirements, SOC will study it in terms of performance verification.
- The main criterion on which to verify the performance of the survey is the **comparison of the coverage and integration time with one or more "figure of merit" maps** that will be delivered from EC to SOC. These figure of merit maps will highlight the areas of the sky that must be observed in priority in order to ensure a successful cosmological outcome of the mission.
- SOC will perform the following checks, among others:
- \- ... % (TBD) of the high-merit areas (threshold TBD) are observed during the first year / first two years of the mission
- \- At the end of the nominal survey, all desired areas are indeed observed
- \- Integration time for all areas is compatible with wishes
- \- Spatial continuity verification: check that there is an orientation continuity between adjacent operations (observations & slews) in a schedule ?
- Performance verification shall also take into account the footprint of available and planned **external surveys**
- The results of the performance verification will be transmitted to EC-SURV and the EST so that the survey reference can be finally adopted or challenged.
- In case it is challenged, it may lead to another RSD being built by EC-SURV and delivered to SOC again, after being approved by the EST.

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Nominal survey ops – routine phase
Survey monitoring

- During routine operations, SOC will perform the regular monitoring of the survey completion and quality, in order to be able to report to all interested bodies, and to be able to raise concern / alert when something deviates from nominal plans.
- The monitoring will take place using 2 different sources:
- **QLA**: The main goal of this step is to **ensure the survey can continue according to plan**. Any contingency or severe performance drop that could indicate that the survey is not progressing adequately anymore should be revealed by QLA and propagated to ESS to allow a survey-level assessment of the issue. In case the problem is serious enough or long enough to significantly degrade the survey quality, SOC will inform IOTs accordingly
- **Level 2**: The main goal of this activity is to **check that the achieved Figure-of-Merit on a given survey field is good enough**. Requirements in terms of FoM shall be expressed as a fraction of the expected FoM map to be delivered together with an RSD and its MOCD-B (TBC)

Survey operability

- The OSS built to be the optimal survey solution, optimized for in-flight system performance
- However, it is expected that SOC will receive various types of requests (through ICRs) that will have an impact on the OSS.
- These survey operations will be performed by SOC : evaluate the impact of requested deviations from the OSS, take corrective actions and implement schedule updates.

Survey operability scenarios

- Option I : **palaeolithic approach or fast re-planning**

- The simplest outcome of the ICR or SCR when studied by the CCB is the Palaeolithic approach or fast re-planning

- In this case, the change request is implemented as such (fields supposed to be observed at that time are removed, for now). No gap recovery applies on the damaged part of the survey.
- Some level of performance optimization is possible if SCR is time-constrained and not fixed-time. SOC can find the least-damaging time within the ICR/SCR time window and apply it (e.g. the field(s) with least FoM will be removed)
- Some of the spatial gaps introduced in this approach could be recovered at a later time (~ at the end) in the survey, possibly within existing large survey time gaps, but long slews are required.

Neolithic approach

- Option II: **Neolithic approach or local optimized re-planning**

- Once the CCB has approved an ICR or SCR, SOC will analyze the consequences of such change locally. SOC may propose a consolidated re-planning solution to the CCB. If the CCB approves, SOC then implements the changes in the OSS and issues a new SSR to MOC. This applies to the "fast re-planning" within 14 days (TBC).

- The Neolithic approach may take the following form: change the starting times of fields over a limited time and spatial window, in order to sacrifice the "worst" field(s) of this window in terms of FoM.
- This allows to perform some limited amount of local optimization of the survey even when the change request has a fixed starting time.
- This requires the field "earliest start time" and "latest start time" keywords to be either transmitted in the RSD to SOC or computed by SOC based on constraints.

Bronze age approach

- **Option III: Bronze Age approach, for a survey with margin**

- The viability of this option depends on the operability of the RSD delivered by EC to SOC: some amount of time margin should exist to help operability of the survey and make possible some amount of “Bronze Age” local re-planning.
- Since there are 24 hrs slots for MOC windows, we could take margin from that (TBC).

- When a change request is accepted by the CCB, which requires either a fixed-time or a time-window field to be introduced in the survey, SOC uses this time margin to accommodate it.
- The other fields of this same patch may be re-shuffled around the introduced field, the same way that happens in the Neolithic approach, only this time there is no need to sacrifice any field.
- The great advantage of the Bronze Age re-planning system is that the survey is almost guaranteed to proceed as planned, without any spatial gaps left.
- The great disadvantage though is that the efficiency of the survey is reduced (time gaps).

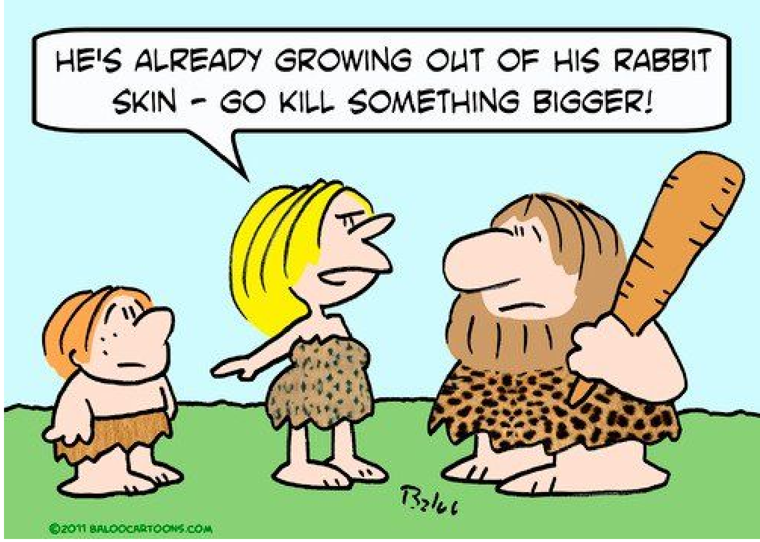
Iron Age approach

- **Option IV: Iron Age approach or strategic survey revision**

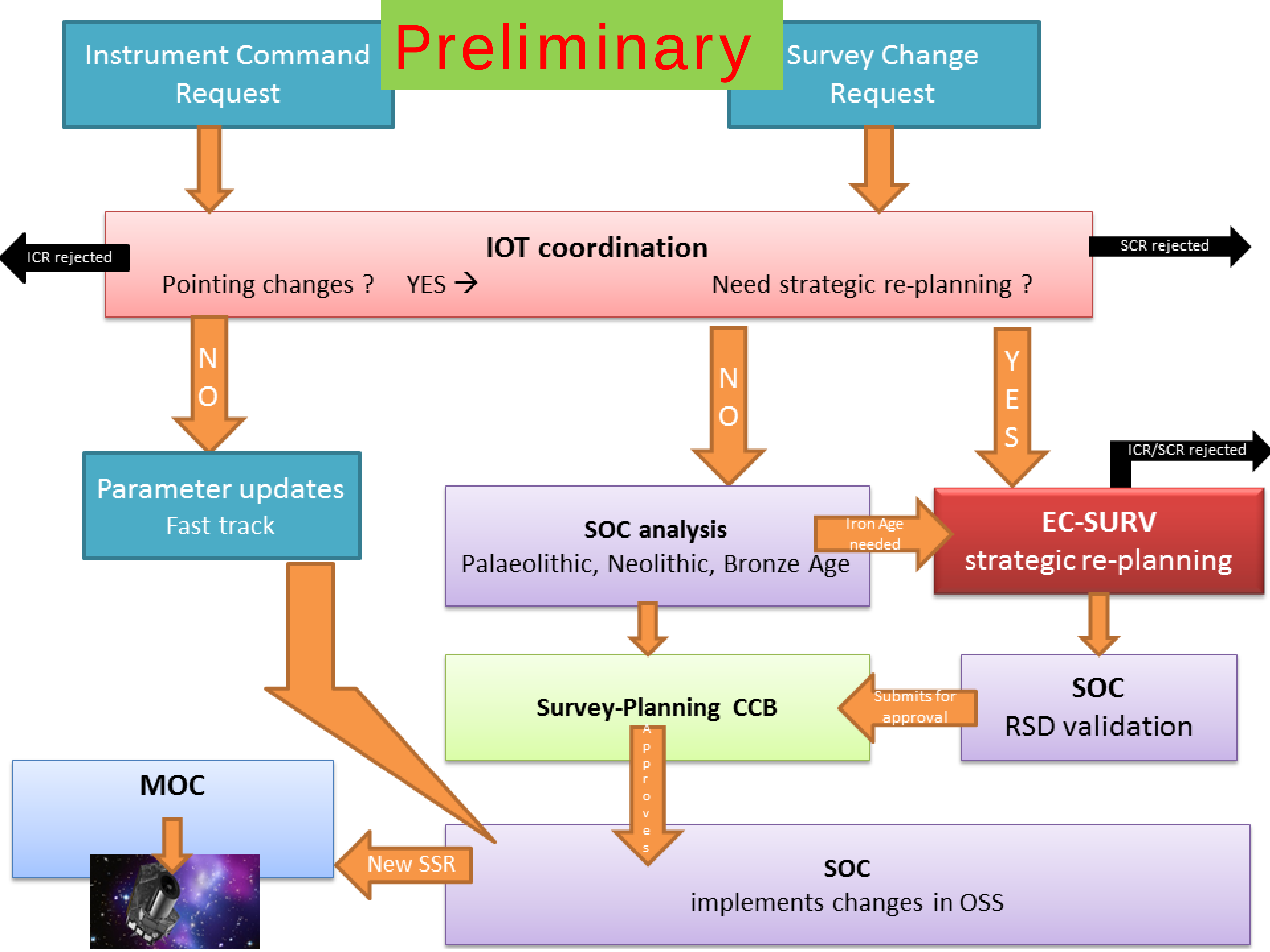
- ESS should be able to predict whether the proposed changes (or similar changes happening in the future) will degrade the survey performance beyond a tolerable limit to be defined.
- If so, SOC may decide to suggest a global re-planning to the IOT coordination group
- EC-SURV may then perform a number of analyses on the survey, optimize the survey based on the remaining survey time, and come up with a final RSD solution.
- They would then get approval from the EST to deliver this new RSD to SOC.
- When getting the new RSD, SOC will perform the same checks as for the first operational RSDs: integrity checks in ESS, compliance checks with MOD-A, and some regression survey performance verification.

Euclid Survey Change Control Board

- A **CCB for the ESS is to be put in place**.
- This CCB will be chaired by the Euclid Mission Manager and will involve at least the following players (TBC):
    - -Mission Manager (chair)
    - -EC Instrument Team Coordinator
    - -One NISP representative
    - -One VIS representative
    - -Project Scientist or Deputy Project Scientist
    - -SOC Survey Scientist
    - -...

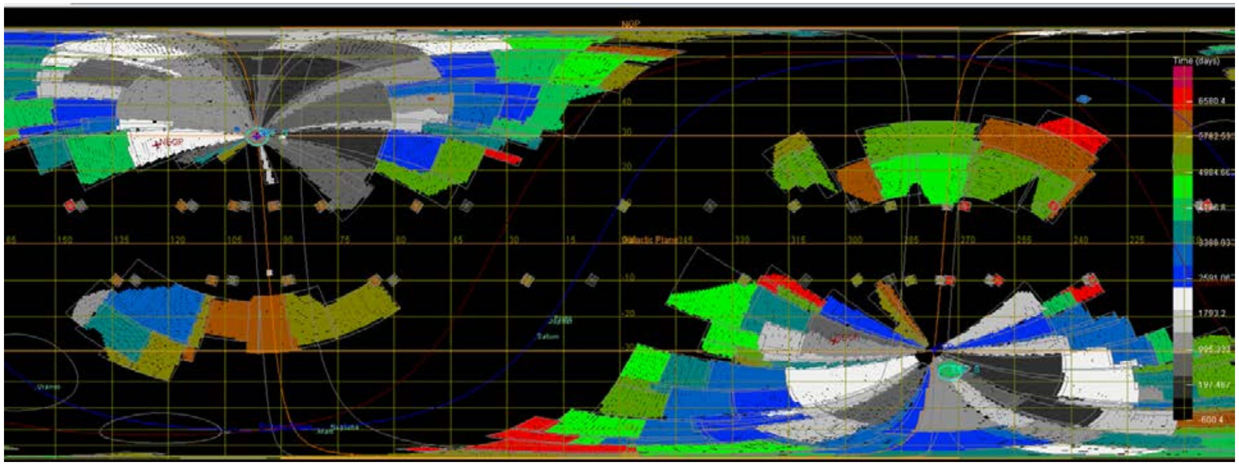


- Any ICR that would result in an interruption or a modification of the Euclid survey, and all SCRs, need to go through the CCB
- ICRs / SCRs can come from the Calibration Operations Group or other sources


Preliminary
Instrument Command Request
Survey Change Request
IOT coordination
Pointing changes ? YES →
Need strategic re-planning ?
ICR rejected
SCR rejected
N O
N O
Y E S
ICR/SCR rejected
Parameter updates
Fast track
SOC analysis
Palaeolithic, Neolithic, Bronze Age
Iron Age needed
EC-SURV
strategic re-planning
Survey-Planning CCB
Submits for approval
SOC
RSD validation
Approves
MOC
New SSR
SOC
implements changes in OSS

Conclusion

- Euclid is the next ESA cosmology mission
- We aim to observe > 10^9 galaxies at z ~ 0.5 – 3 and still significant numbers at z ~ 3 – 8
- The legacy value of Euclid will be huge (cosmology, galaxy evolution, stars, Solar System objects…)
- Constraining power on Dark Matter and Dark Energy is awesome
- **The success of Euclid largely depends on a properly optimized (and operated !) survey**
- **SOC @ ESAC has a leading role in survey operations**
- **We are looking forward to the Euclid launch 3.5 years from now !**



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