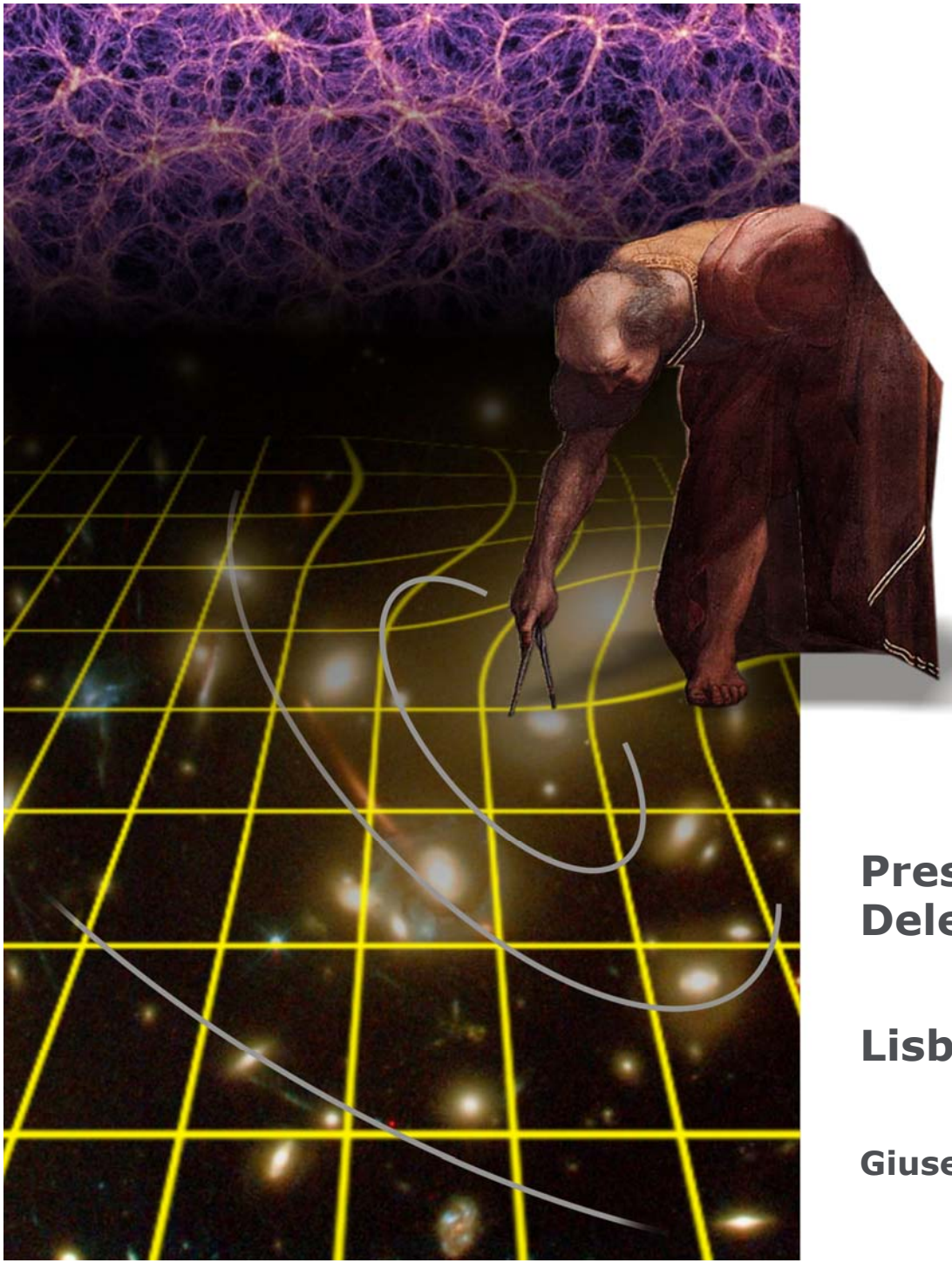


Euclid:
an ESA mission to map the Dark Universe

Presentation to the Portuguese Delegation and Industry

Lisbon, March 19th 2012

Giuseppe Racca

European Space Agency

Outline of the presentation

1. **EUCLID Science Objectives**
2. EUCLID Mission and Payload Module Overview
3. Service Module Overview
4. Schedule

EUCLID Scientific Objectives (1/6)

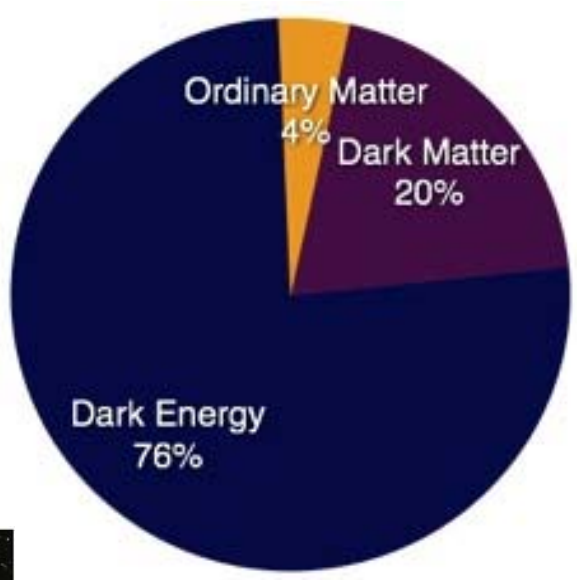
Search for the critical density

- Our Universe is observed to be Euclidean or "flat", best described with the Big-Bang inflation model. This is confirmed by the CMB observation
- **The flatness requires a critical density (Ω=1):**
  - Amount of protons+neutrons (baryons) is constrained by direct observations and the theory of nucleosynthesis
    - **Baryons must be less than 3-5% of critical density**
  - Dark Matter is needed which is "Cold", i.e. the dark matter particles have negligible velocity, but observations show
    - **Cold DM cannot be more than 10x baryonic mass**
  - Remaining missing mass not found, instead, the *cosmological constant* Lambda Λ needed re-introduction
    - **A positive Λ can explain ~80% of the critical density**
- **Supernova observations indicate accelerated expansion of the Universe => Cosmological Constant**

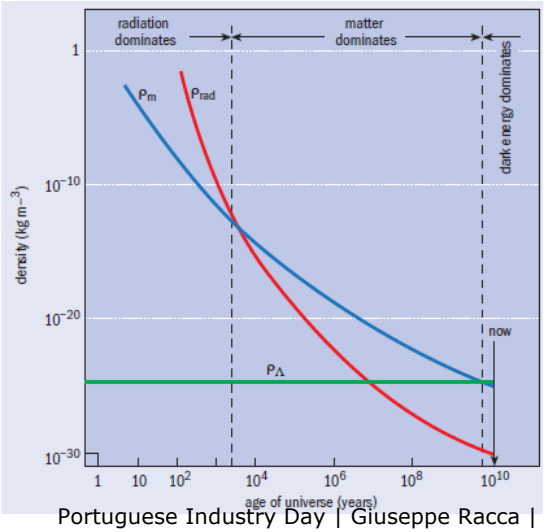
EUCLID Scientific Objectives (2/6)

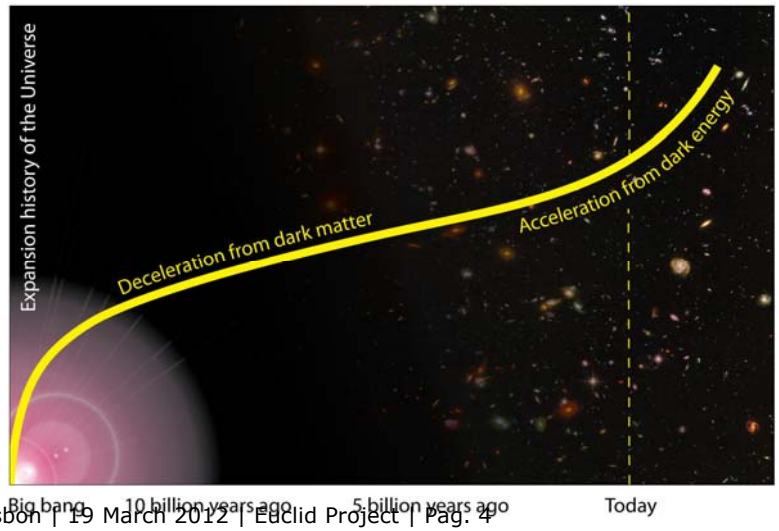
The Concordance model: Lambda Cold Dark Matter - ΛCDM

- ΛCDM is so far the only model within the framework of General Relativity which fit all data at once, including
  - Nucleosynthesis of light elements
  - Cosmic Microwave Background measurements
  - Accelerating expansion of the Universe, from Supernovae observations
  - Cosmic structures, galaxy clustering
- ΛCDM does not explain the physics, it leaves open several fundamental questions, in particular the properties and nature of the dark components



Concordance Model





EUCLID Scientific Objectives (3/6)

Summary

Issue	Euclid's Targets
What is Dark Energy	**Measure the Dark Energy equation of state parameters** w_p and w_a to a precision of 2% and 10%, respectively, using both expansion history and structure growth.
Beyond Einstein's Gravity	**Distinguish General Relativity from modified-gravity theories**, by measuring the galaxy clustering growth factor exponent γ with a precision of 2%.
The nature of dark matter	**Test the Cold Dark Matter paradigm** for structure formation, and measure the sum of the neutrino masses to a precision better than 0.04eV when combined with Planck.
The seeds of cosmic structure	**Improve by a factor of 20 the determination of the initial condition parameters** compared to Planck alone. n (spectral index), σ_8 (power spectrum amplitude), f_{NL} (non-gaussianity)

EUCLID Scientific Objectives (4/6)

Concept

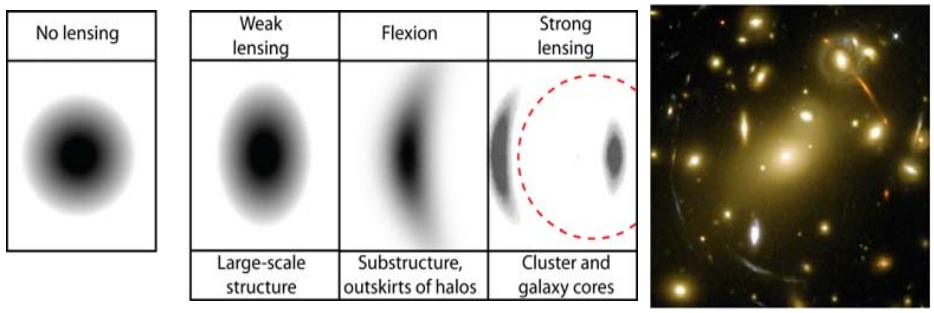
- Euclid will perform a sky survey and is optimised to measure simultaneously two principal dark energy probes:
  - **Weak Lensing**
  - **Baryon Acoustic Oscillations (galaxy distribution power spectrum)**

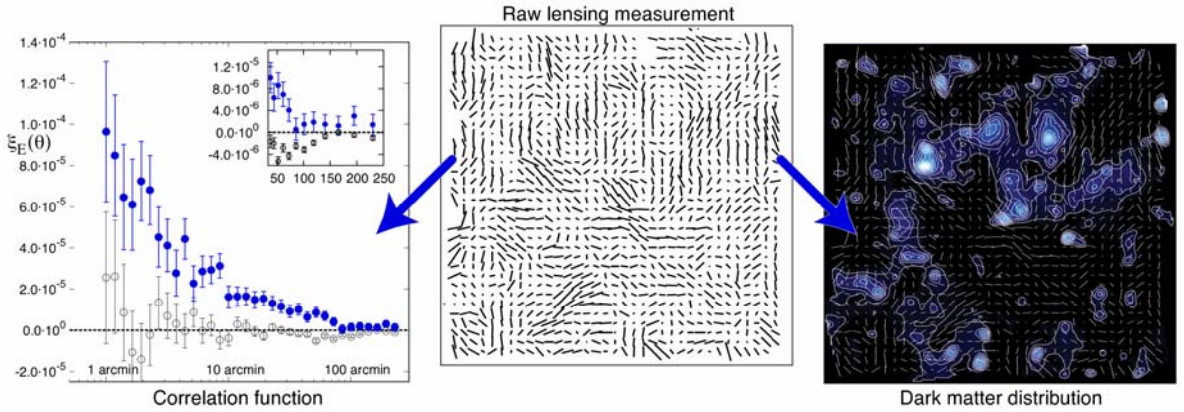
- **Science Requirements**
  - Minimum survey area of 15,000 deg^2 (~1/4 of sky)
  - Determine the shapes and shear of statistical samples of galaxies with a density of 30-40 galaxies/arcmin^2. Total of 1.5 billion galaxies
  - Determine the photometric redshifts of the weak lensing galaxies with dz/(1+z)=0.05 down to 0.03
  - Measure spectroscopic redshifts with dz/z < 0.001 in the same volume.

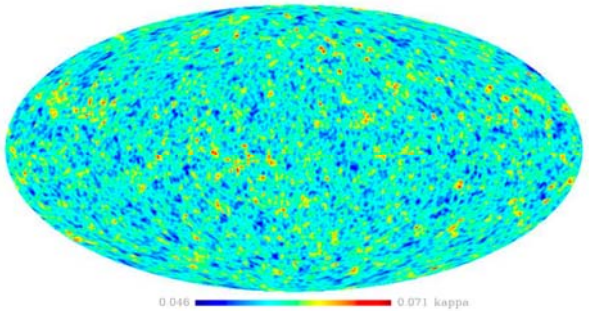
The mission is named in honour of the pioneer of geometry.

EUCLID Scientific Objectives (5/6)

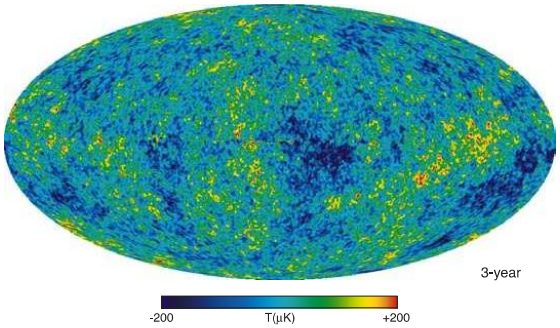
Weak Lensing Probe







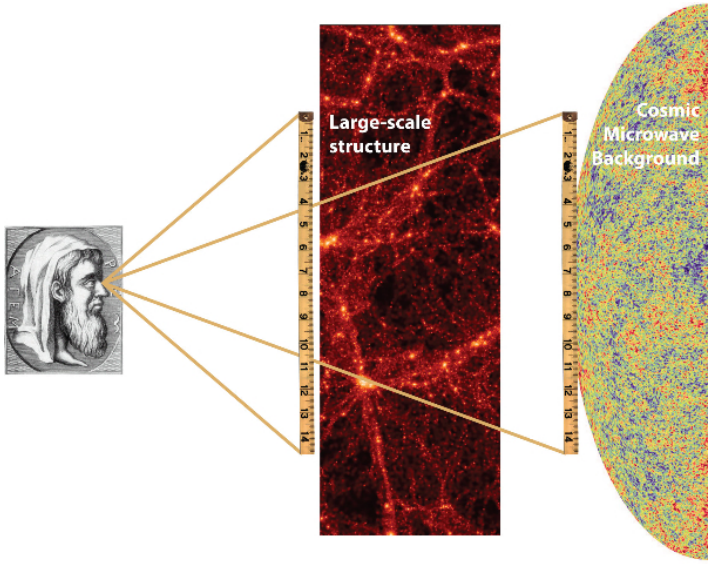
Weak Lensing (simulation) result:
Dark Matter distribution at z=2



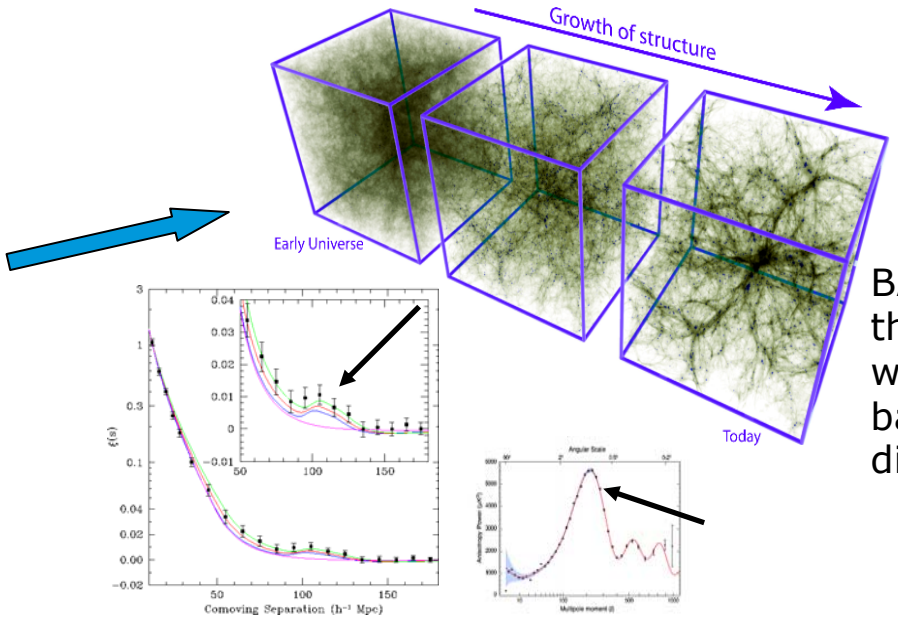
WMAP CMB
Structure at z=1100

EUCLID Scientific Objectives (6/6)

Baryon Acoustic Oscillations

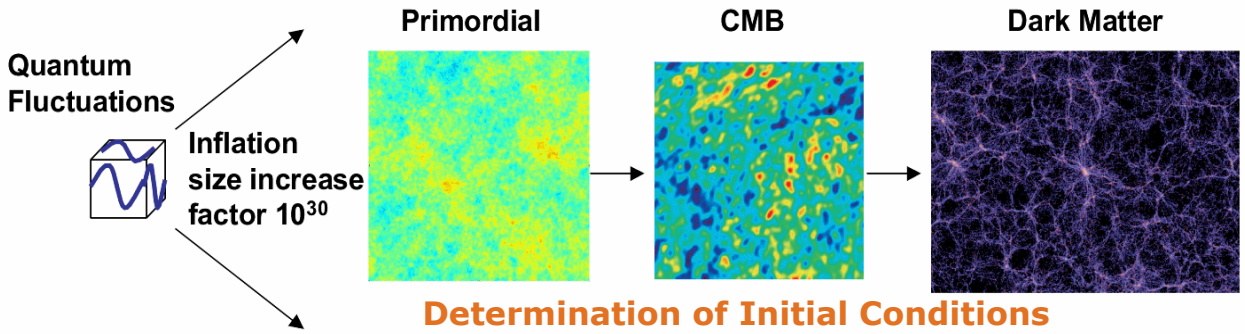


Baryon Acoustic Oscillations: measure typical scales of galaxy structures in comoving frame



BAO will map the cosmic web using baryon distribution

Z=1100 from WMAP



Outline of the presentation

1. EUCLID Science Objectives

2. EUCLID Mission and Payload Module Overview

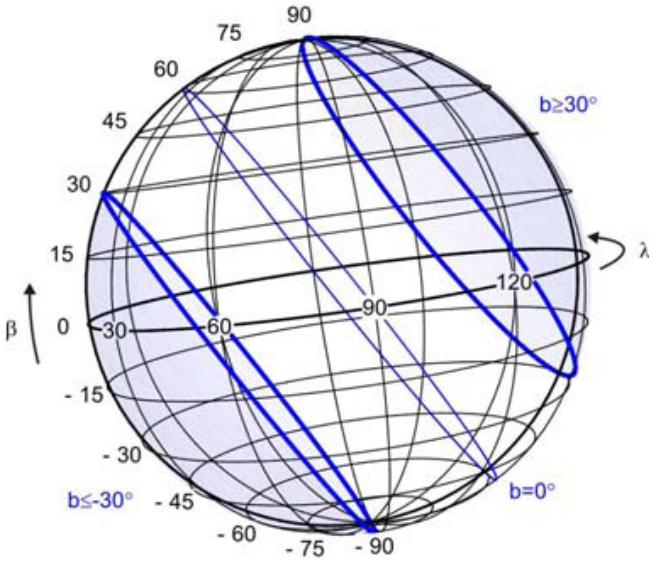
3. Service Module Overview

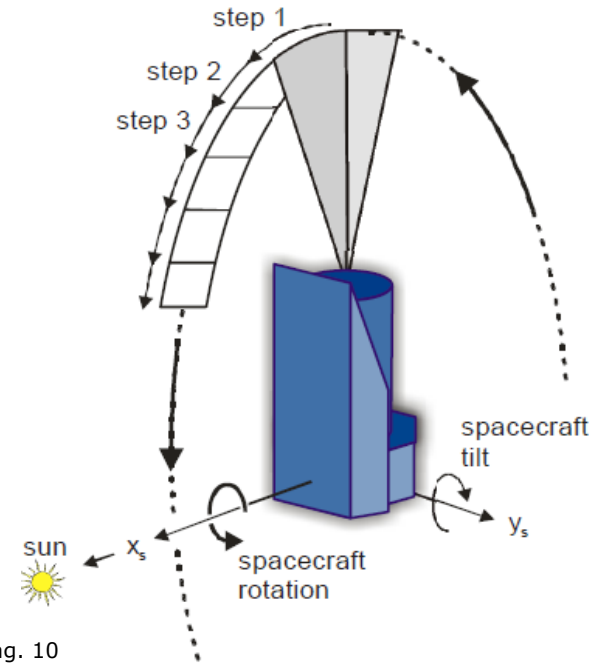
4. Schedule

EUCLID mission overview (1/8)

Mission facts

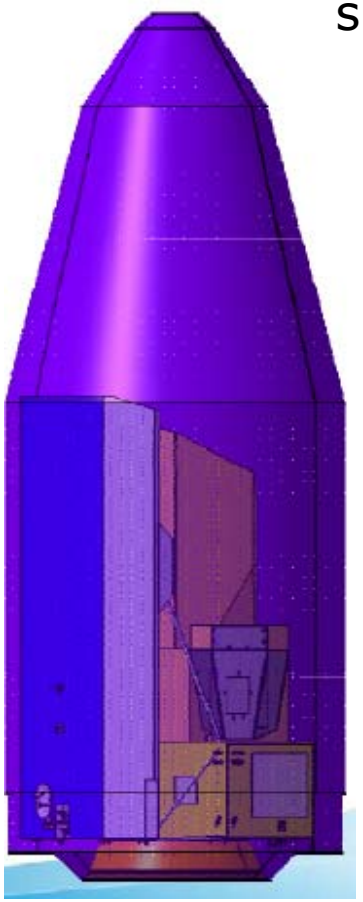
- Survey mission with 6.25 year nominal operation duration.
- The Spacecraft will be launched by a Soyouz ST2-1B from French Guyana to L2, maximum launch mass is 2160 kg.
- The 3 axis stabilized spacecraft is operated in step and stare mode (around the S/C sun axis) to observe the extra galactic latitudes > 30 degrees.

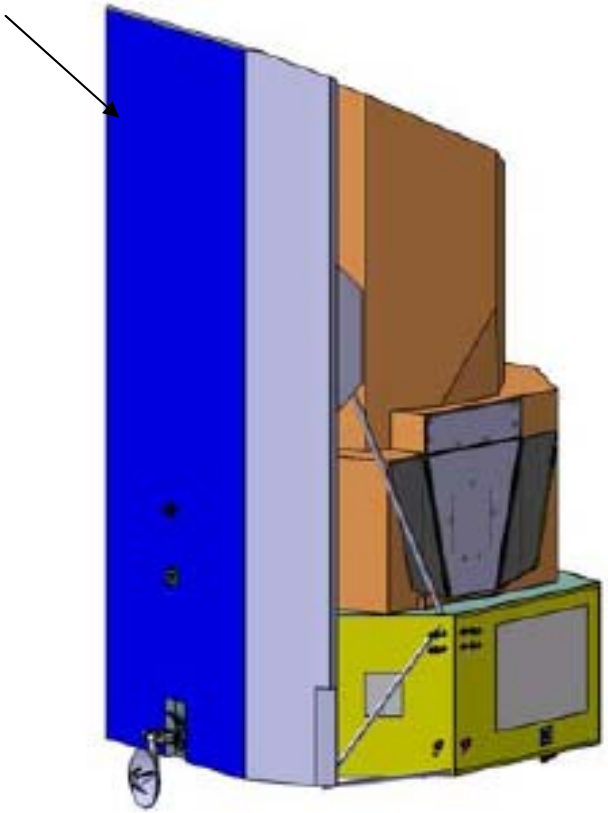


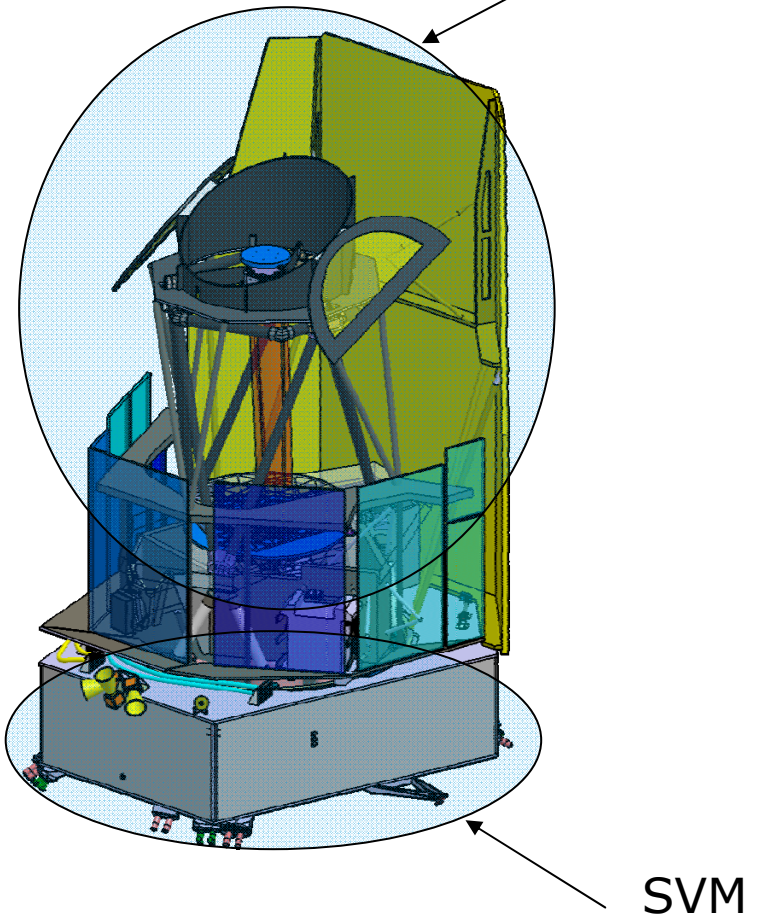


EUCLID mission overview (2/8)

Quick view of the spacecraft







Astrium config (PM6)

TAS config (PM5)

EUCLID mission overview (3/8)

Payload Module facts

The EUCLID payload module consists of:

- Optical configuration: 3-mirrors anastigmatic Korsch
- field of view: 0.763 0.709 deg^2, 0.45deg off-axis
- free aperture: 1.2 m^2
- WFS and M2 mechanism for calibration
- optical quality: WFE ≤ 70nm rms (NISP channel)
- common bench for telescope and instruments, interface to SVM
- Zerodur/carbon or Silicon Carbide SiC-100 technologies
- Dichroic at the exit pupil transmit IR light to NISP and reflects visible light to VIS
- A visible imager (VIS)
- A near-IR instrument (NISP)

EUCLID mission overview (4/8)

VIS Instrument

A visible imager:

- limiting magnitude: magAB=24.5
- redshift resolution: z/(1+z) 3%–5%
- spectral range : 550–920nm
- focal plane: 6 6 CCDs (e2v, 12 12 m^2 pixels, 4096 4096 pixels)
- plate scale: 0.1arcsec/pix
- field of view: FoV=0.787 0.709deg2
- focal length: f=24.5 m

EUCLID mission overview (5/8)

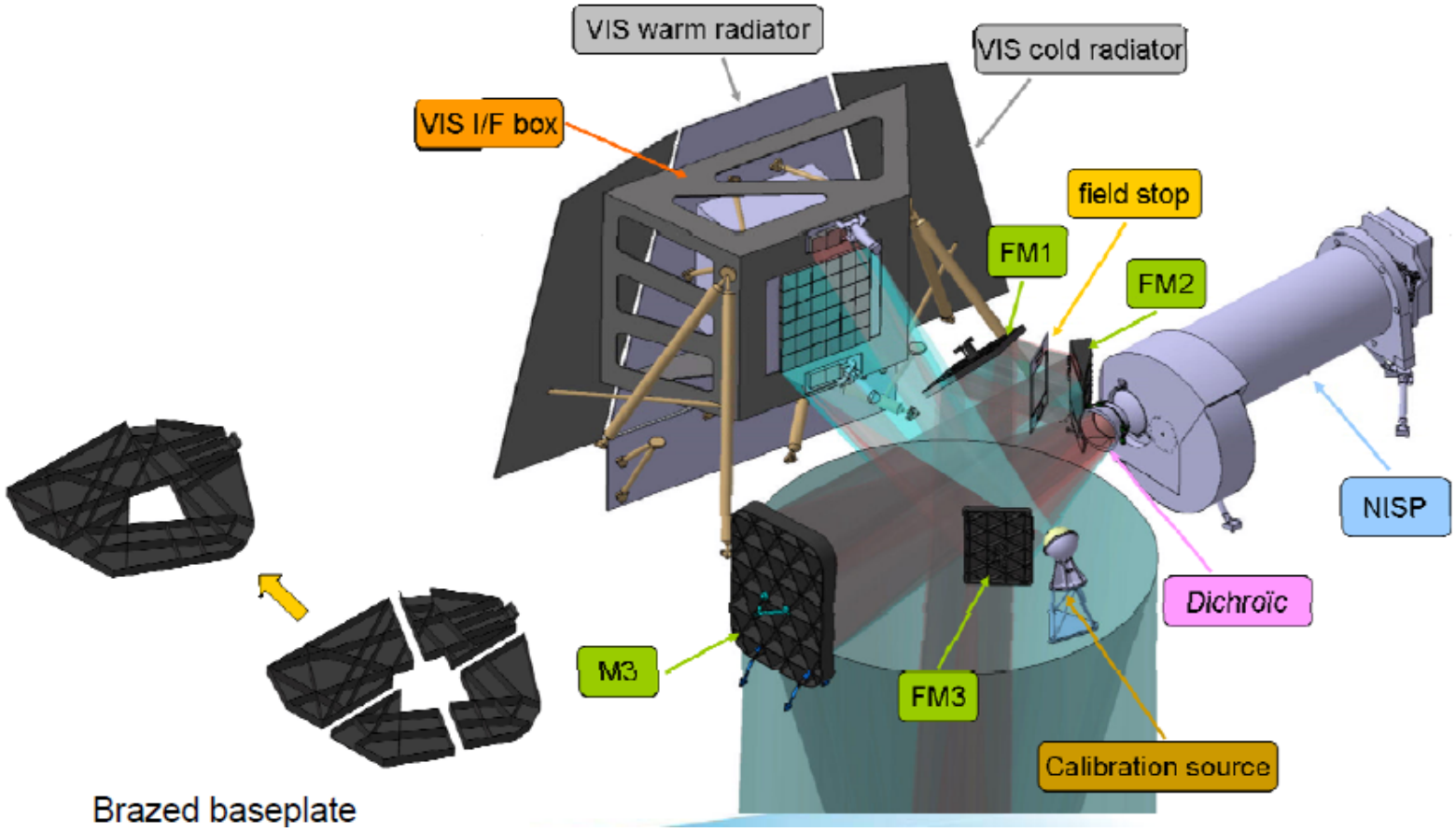
NISP Instrument

A near-infrared spectrograph photometer:

- Photometry
  - limiting magnitude: magAB=24.5
  - redshift resolution: z/(1+z) 3%–5%
  - spectral range : 920–1146nm (Y), 1146–1372nm (J), 1372–2000nm (Hp)
- Spectroscopy
  - limiting magnitude: magAB=19.5
  - redshift resolution: z/(1+z) 0.1%
  - spectral range : 1000–2000nm
  - spectroscopic resolution: ~ =500
- focal plane: 4 4 Hawaii 2RG (Teledyne, 2048 2048pixels, 2.4 m)
- plate scale: 0.3arcsec/pix
- field of view: FoV=0.763 0.722deg^2
- focal length: f~6.1 m

EUCLID mission overview (6/8)

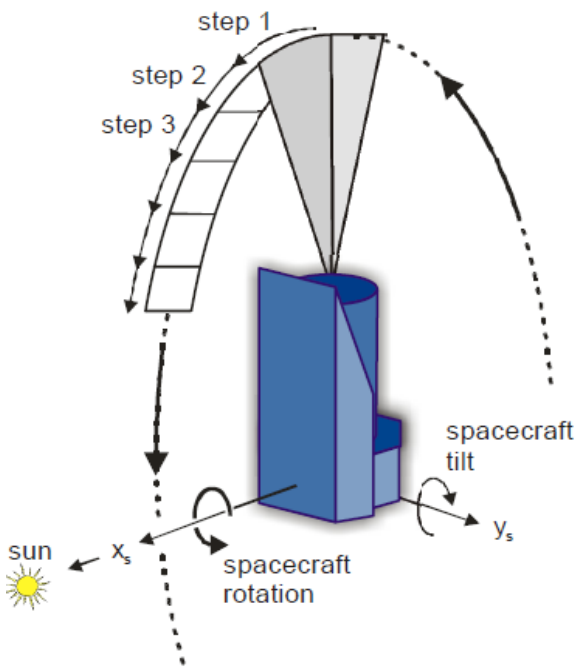
Payload facts



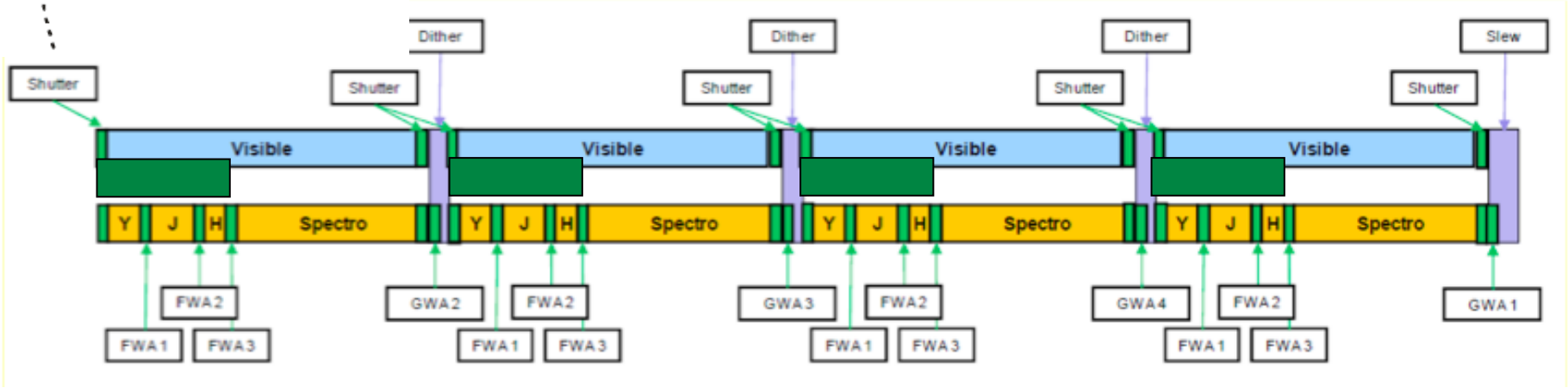
Astrium configuration
(passive thermal control, SiC techno)

EUCLID mission overview (7/8)

Typical operation



- For each step (field), 3 dithers are performed at Spacecraft level leading to a total of 4 frames.
- For each dither the 3 photometric bands are observed thanks to the NI-FWA actuation
- For spectroscopy, a combination of 2 filters and 2 grisms (identical but different dispersion directions) is used for the 4 frames
- VIS is integrating in parallel with the spectro to avoid any disturbances from NI-FWA and NI-GWA
- VIS shutter is kept closed during photometry



EUCLID mission overview (8/8)

Ground Segment

1. Mission Operation Centre
    a. at ESOC (Darmstadt, Germany)

2. Science Operation Center
    a. at ESAC (Villafranca, Spain)

3. Ground Stations:
    a. Cebreros and Malargue antennas
    b. Daily science communication:

        ~ 850 Gbits in K band (26 GHz)

    a. Command and control in X band

Outline of the presentation

1. EUCLID Science Objectives

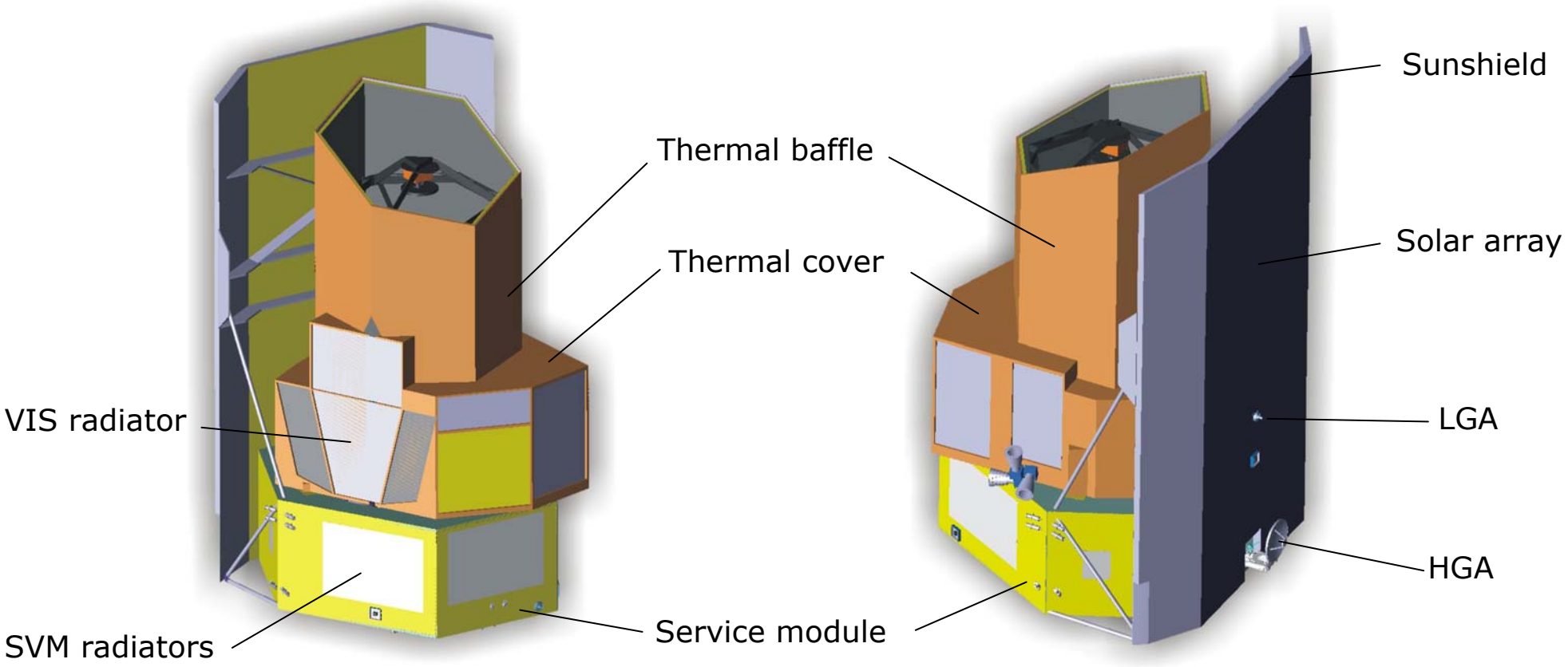
2. EUCLID Mission and Payload Overview

3. Service Module Overview

1. Schedule

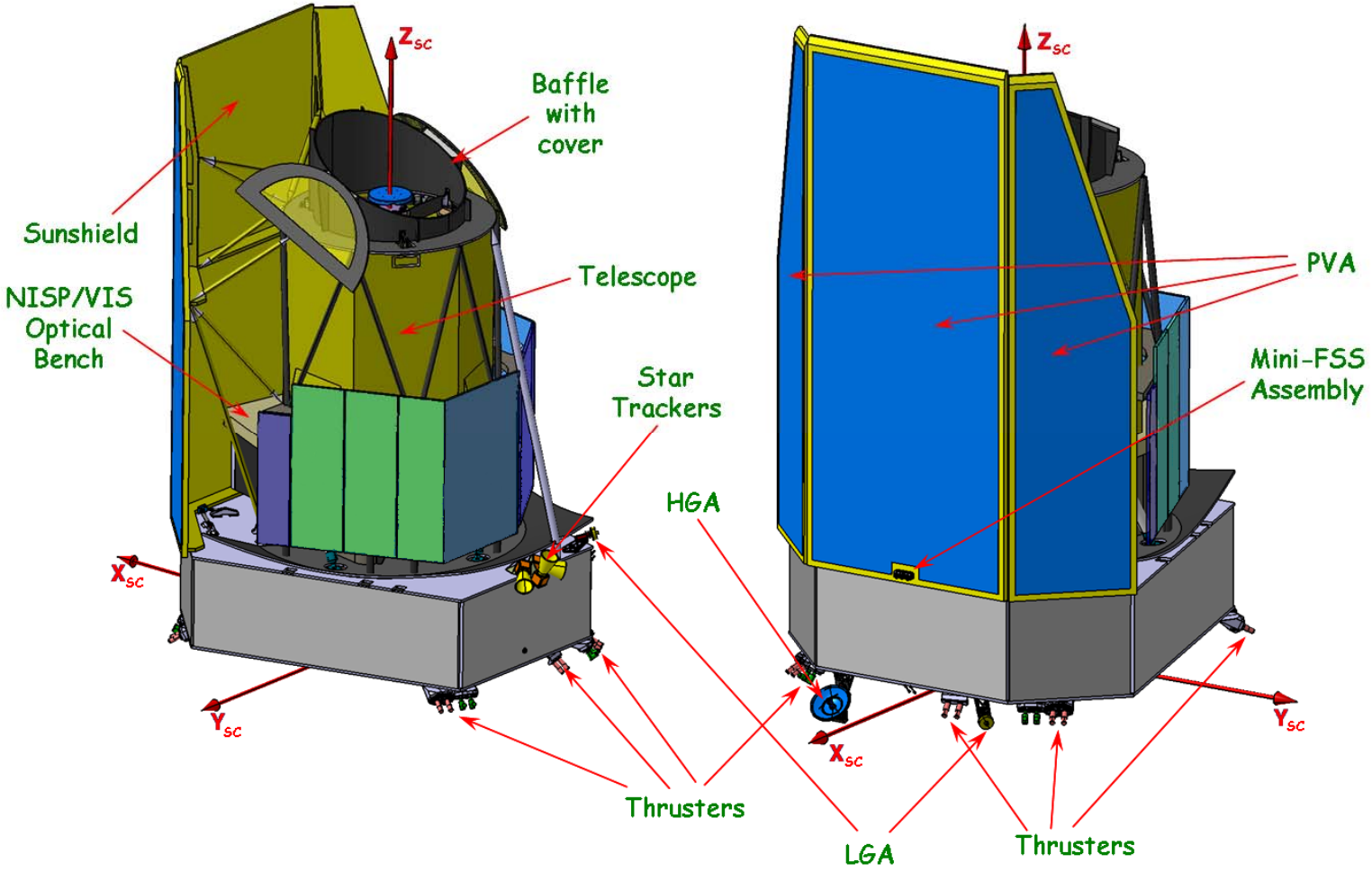
EUCLID spacecraft preliminary design (1/3)

Astrium concept



EUCLID spacecraft preliminary design (2/3)

TAS concept



EUCLID spacecraft preliminary designs (3/3)

ASTRIUM concept

Telescope

1. Primary Mirror: SiC
2. Cold Telescope (T~150K)
3. Passive Thermal Control

AOCS

1. Fine pointing: Cold Gas + FGS & Gyro
2. Slews: Cold Gas + Star Tracker & Gyro

THALES concept

Telescope

- Primary Mirror: Zerodur
- Cold Telescope (T~240K)
- Active Thermal Control

AOCS

- Fine pointing: Cold Gas + FGS & Gyro
- Slews: Reaction Wheel + Star Tracker & Gyro

Euclid Service Module Overview (1/4)

Attitude and Orbit Control Subsystem

- Sensors:
  - fine guidance sensor (half frame transfer CCDs, 1Hz bandwidth, close to VIS focal plane)
  - inertia measurement unit
  - high performance star tracker
  - fine sun sensors
- Micro-propulsion
  - science mode manoeuvres (field step, dither step for AST), attitude control (solar pressure compensation)
  - proportional cold-gas, 6 thrusters (1000 N, cold redundant)
- Reaction Wheels for slew and dither steps (only TAS)
- Chemical propulsion
  - orbit maintenance, transfer correction, safe mode
  - mono-propellant hydrazine (blow-down mode), membrane tank, 6 thrusters (20N, cold redundant)
- Pointing performance
  - RPE < 15/15/150 mas rms per x/y/z-axis (700s)
  - dither step: < 75 s
  - field step: < 350 s

Euclid Service Module Overview (2/4)

Communication Subsystem

- Science data 850 Gbit/day
- Memory 4 Tbit Non volatile flash memory, 3 days storage capability
- Link window 3.5h/day effective downlink time, Cebreros ground station (35m)
- TM/TC
  - 2 X-band LGA,
  - 2 resp. 5 kbit/s downlink,
  - 4 resp. 128kbit/s uplink,
  - hot redundant receiver and cold-redundant transmitter
- Science telemetry
  - K-band (26GHz),
  - steerable HGA, 40cm,
  - 75Mbit/s downlink,
  - GMSK modulation,
  - internally cold-redundant

Euclid Service Module Overview (3/4)

Electrical and Power Subsystem

- Electrical architecture:
  - OBC (e.g. LEON)
  - SSMM 4+2 Tbit
  - packet telemetry/telecommand (PUS compatible)
  - MIL-STD-1553B bus for PLM and SVM unit interfaces
  - SpaceWire link to EIU
- Power subsystem:
  - 28V regulated,
  - MPPT,
  - 75Ah Li-Ion battery
- Solar array:
  - body mounted (on sunshield),
  - GaAs triple junction cells (28% efficiency)
  - 9.8m^2

Euclid Service Module Overview (4/4)

Structure and Thermal Subsystems

- Service Module:
  - hexagonal shape, central cone, 6 shear walls, 6 hard points for PLM interface
  - Al honeycomb, CFRP facets
  - 1666mm SF Soyuz launcher interface
  - radiative cooling, foil radiators
- Unit accommodation
  - position of tanks optimised for science mode manoeuvres
  - high dissipation units on cold side
- Sunshield
  - stiff design (angled wings, ribs, struts)
  - Al honeycomb, CFRP facets
  - planar solar array mounted on Sun-facing side

Euclid Industrial Schedule

Astrium version

Task Name	Duration	Start	Finish
Milestones	1847 days	Mon 07.01.13	Tue 04.02.20
BDCR Kick-off	0 days	Mon 07.01.13	Mon 07.01.13
Core team acting	52 wks	Mon 07.01.13	Fri 03.01.14
SRR	0 days	Fri 21.06.13	Fri 21.06.13
PDR	0 days	Fri 26.09.14	Fri 26.09.14
CDR	0 days	Wed 05.10.16	Wed 05.10.16
QR	0 days	Mon 02.07.18	Mon 02.07.18
FAR	0 days	Thu 02.05.19	Thu 02.05.19
Launch	0 days	Tue 04.02.20	Tue 04.02.20
VIS FM delivery	0 days	Mon 24.07.17	Mon 24.07.17
NISP FM delivery	0 days	Mon 11.12.17	Mon 11.12.17
Procurement	660 days	Fri 26.09.14	Fri 07.04.17
GSE	528 days	Mon 29.09.14	Wed 05.10.16
Payload Subsystem	528 days	Fri 26.09.14	Wed 05.10.16
Structure/ Thermal S/S	528 days	Mon 29.09.14	Wed 05.10.16
Sunshield S/S	264 days	Mon 29.09.14	Thu 01.10.15
AOCS S/S	528 days	Mon 29.09.14	Wed 05.10.16
Reaction Control S/S	660 days	Mon 29.09.14	Fri 07.04.17
Core Data Management S/S	528 days	Mon 29.09.14	Wed 05.10.16
Central S/W	396 days	Mon 29.09.14	Mon 04.04.16
Communication S/S	528 days	Mon 29.09.14	Wed 05.10.16
Power S/S	528 days	Mon 29.09.14	Wed 05.10.16
Harness	528 days	Mon 29.09.14	Wed 05.10.16
Euclid Space segment	1133 days	Fri 02.10.15	Tue 04.02.20
PLM	645 days	Tue 05.04.16	Mon 24.09.18
PLM SM MAIT	157 days	Tue 05.04.16	Wed 09.11.16
PLM PFM AIV	387 days	Fri 31.03.17	Mon 24.09.18
Euclid system AIV	1133 days	Fri 02.10.15	Tue 04.02.20
AVM AIV	500 days	Tue 05.04.16	Mon 05.03.18
SVM AIV	1133 days	Fri 02.10.15	Tue 04.02.20
SVM structural model MAIT	316 days	Fri 02.10.15	Fri 16.12.16
SVM PFM AIV	406 days	Fri 14.04.17	Fri 02.11.18
S/C AIV	817 days	Mon 19.12.16	Tue 04.02.20
S/C STM campaign	74 days	Mon 19.12.16	Thu 30.03.17
S/C PFM qualification/acceptance	127 days	Tue 20.11.18	Wed 15.05.19
Contigency & Launch Campaign	198 days	Fri 03.05.19	Tue 04.02.20
Space segment validation tests	313 days	Tue 31.07.18	Thu 10.10.19