
The Euclid Mission
M. Sauvage
(Science Ground Segment)
on behalf of the Euclid
Consortium
with slides from Y. Mellier
www.euclid-ec.org

Euclid Top Level Science Requirements

Sector	Euclid Targets
Dark Energy	• Measure the cosmic expansion history to better than 10% in redshift bins $0.7 < z < 2$. • Look for deviations from $w = -1$, indicating a dynamical dark energy. • Euclid *alone* to give $FoM_{DE} \geq 400$ (1-sigma errors on w_p, & w_a of 0.02 and 0.1 respectively)
Test Gravity	• Measure the growth index, γ, with a precision better than 0.02 • Measure the growth rate to better than 0.05 in redshift bins between $0.5 < z < 2$. • Separately constrain the two relativistic potentials Ψ, Φ. • Test the cosmological principle
Dark Matter	• Detect dark matter halos on a mass scale between 10^8 and $>10^{15}$ M_{Sun} • Measure the dark matter mass profiles on cluster and galactic scales • Measure the sum of neutrino masses, the number of neutrino species and the neutrino hierarchy with an accuracy of a few hundredths of an eV
Initial Conditions	• Measure the matter power spectrum on a large range of scales in order to extract values for the parameters σ_8 and n to a 1-sigma accuracy of 0.01. • For extended models, improve constraints on n and α wrt to Planck alone by a factor 2. • Measure a non-Gaussianity parameter : f_{NL} for local-type models with an error < +/-2.

- DE equation of state: $P/\rho = w$, and $w(a) = w_p + w_a(a_p - a)$
- Growth rate of structure formation: $f \sim \Omega^{\gamma}$;
- FoM=$1/(\Delta w_a \times \Delta w_p) > 400 \rightarrow$ ~1% precision on w's.

Euclid is driven by requirements!

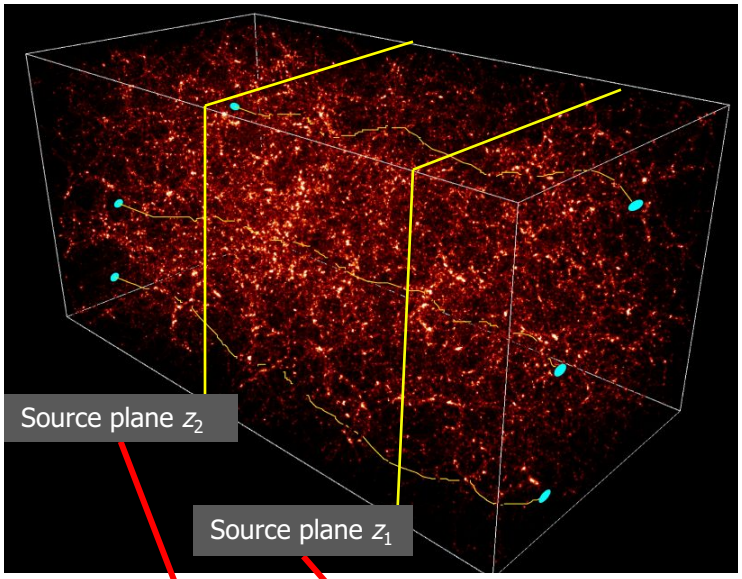
See Euclid theory living reviewhttp://link.springer.com/article/10.12942/lrr-2013-6

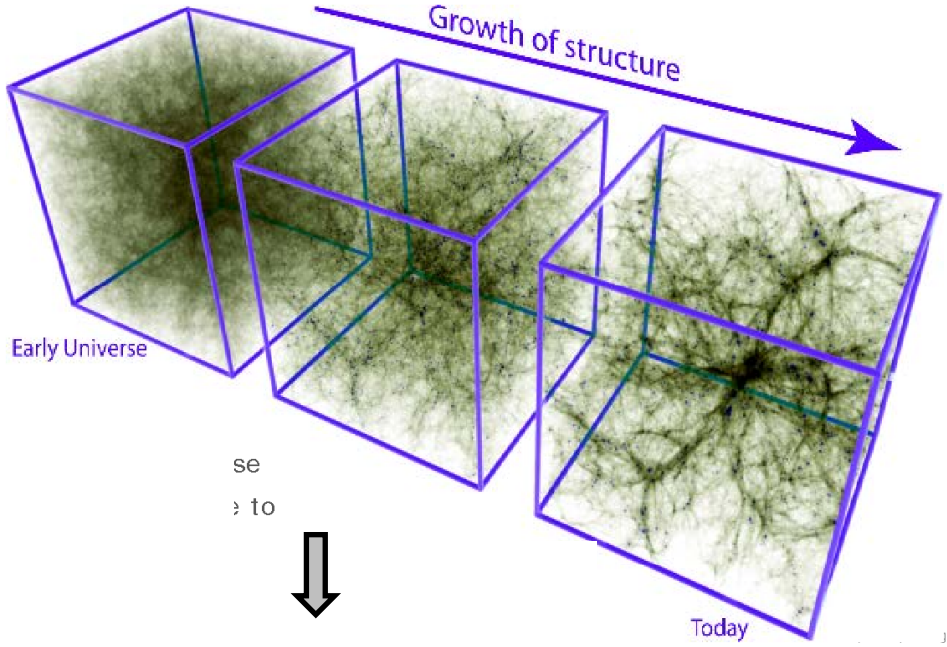
WL probe: Cosmic shear over 0<z<2 :

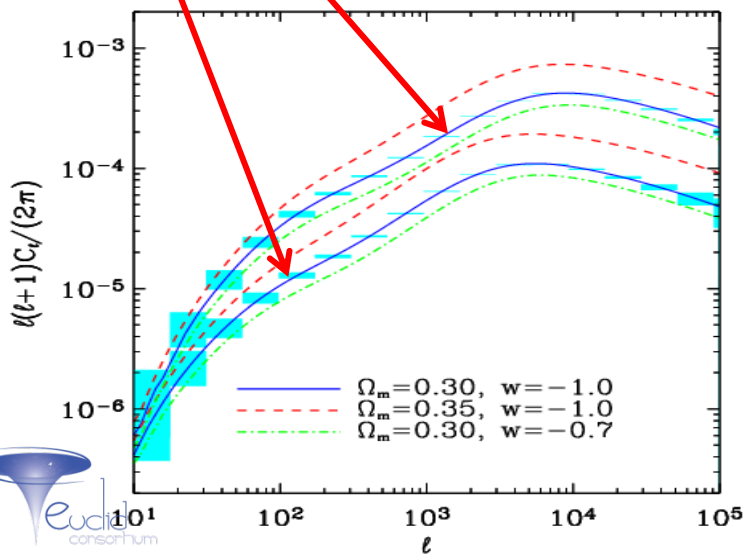
1.5 billion galaxies shapes, shear and phot-z (u,g, r,i,z,Y,J,H) with 0.05 (1+z) accuracy over 15,000 deg^2

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

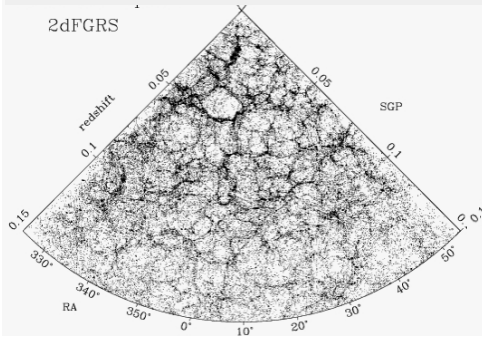
35 million spectroscopic redshifts with 0.001 (1+z) accuracy over 15,000 deg^2



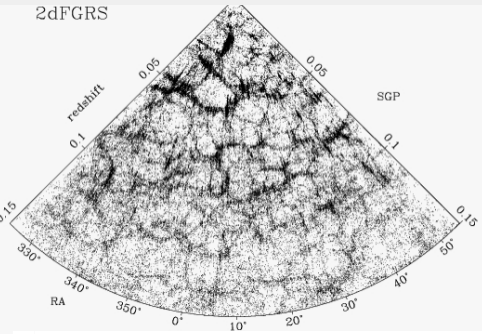




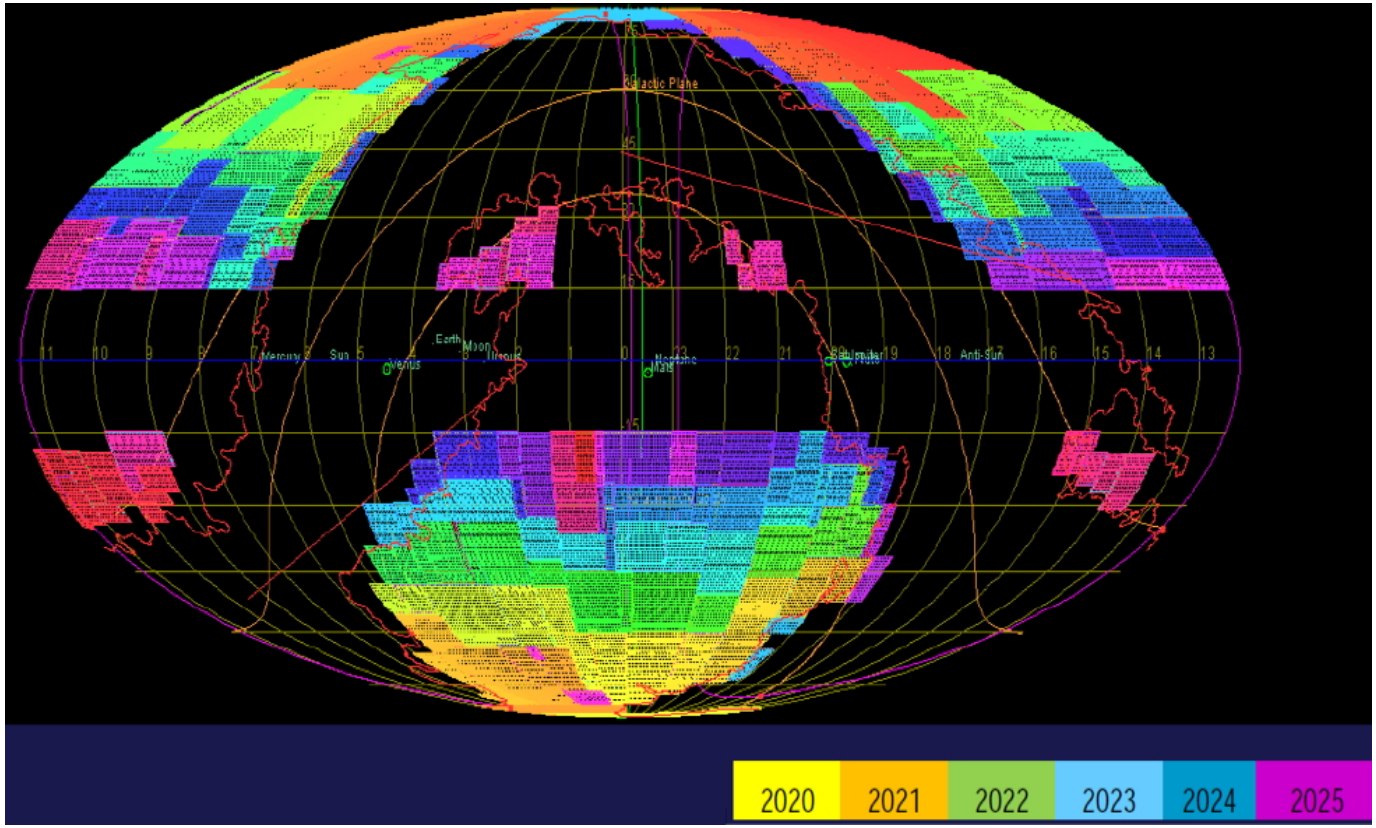
BAO



RSD



Euclid Survey and data



Euclid is a cosmological survey mission, but unlike CMB experiments, it will only do its survey once!

Survey strategy is extremely constrained by ”non-scientific” considerations, e.g.the number of times we can point the satellite!

VIS:
- Imaging
- 36 4k x 4k CCD
- 0.54 deg^2 per field
- 0.1” pixels on the sky
- limiting magnitude: 24.5 AB @10σ
- 520 Gbit/day

NISP:
- Imaging and slitless grism spectroscopy
- 16 2k x 2k NIR arrays
- 0.55 deg^2 per field
- 0.3” pixels on the sky
- limiting magnitude: 24 AB @5σ
- 240 Gbit/day

→ **800 Gbit/day for 6 years**

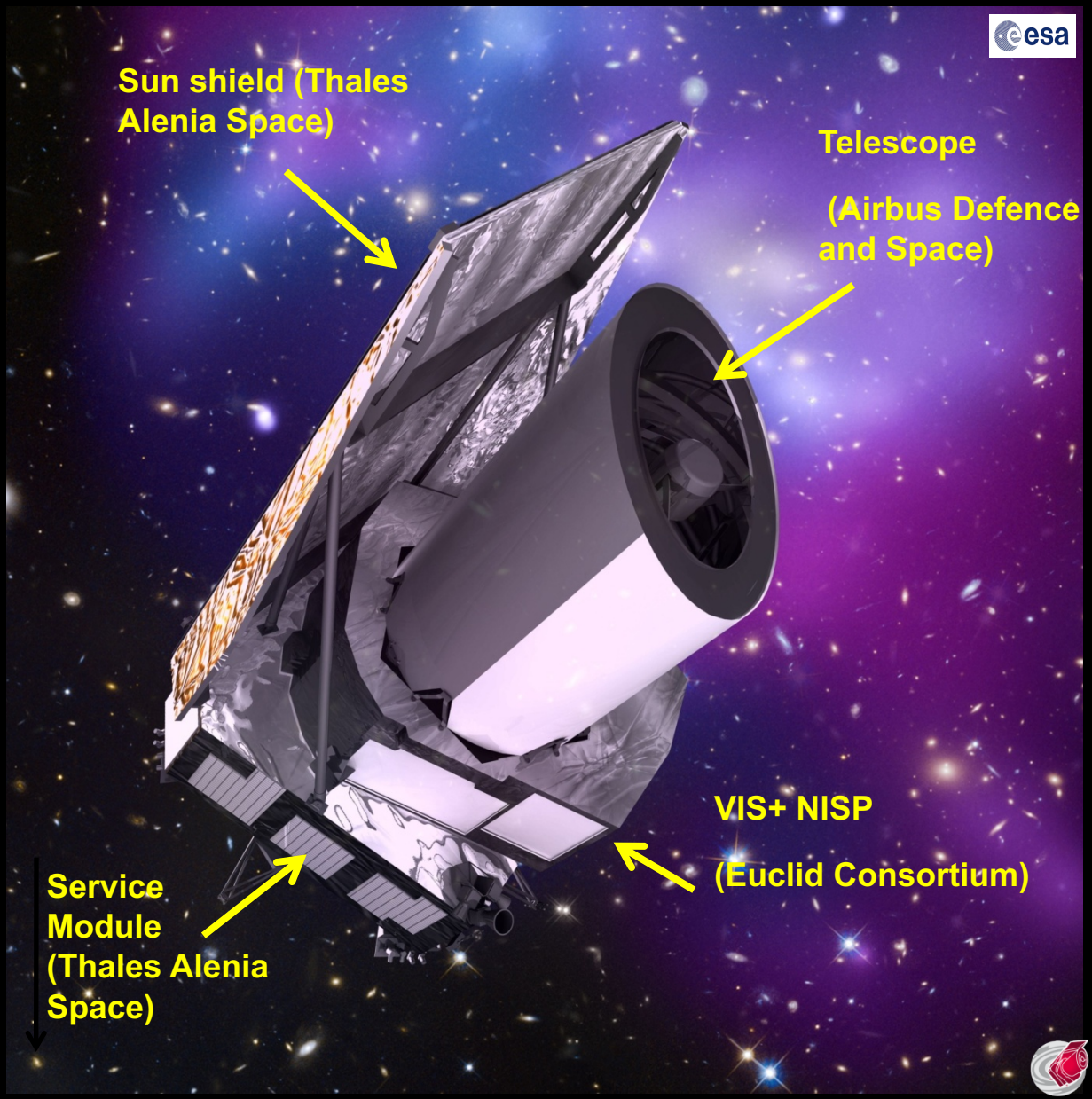
Visible and infrared imaging, as well as infrared spectroscopy are obtained “simultaneously”

ESA Euclid mission

- - Total mass satellite :
- 2 200 kg
- - Dimensions:
- 4,5 m x 3 m

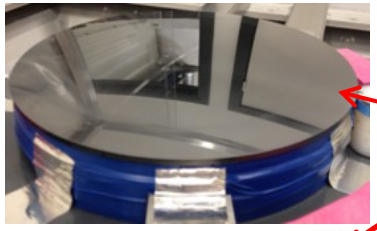
- - Launch: May 2021 (or later) by a Soyuz rocket from the Kourou space port
- - Orbit: Euclid placed in L2

- - Survey: 6 years

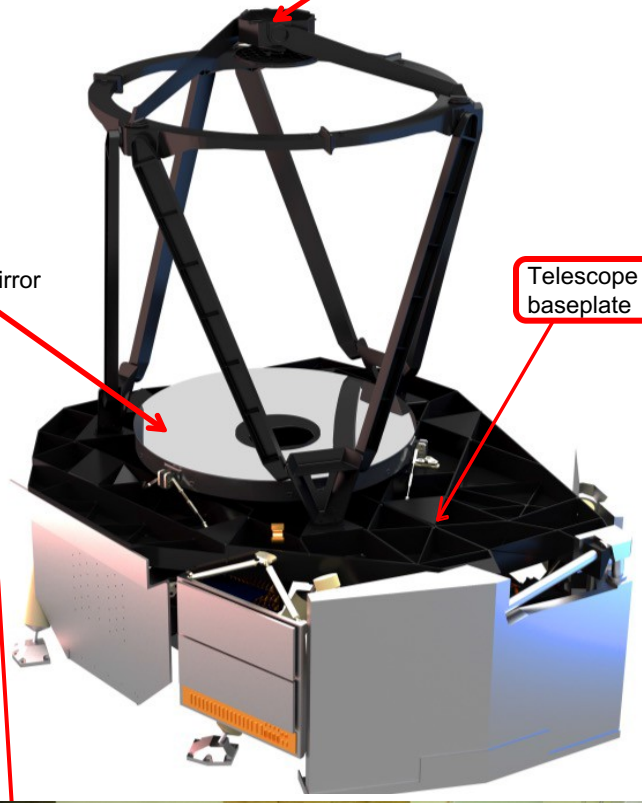


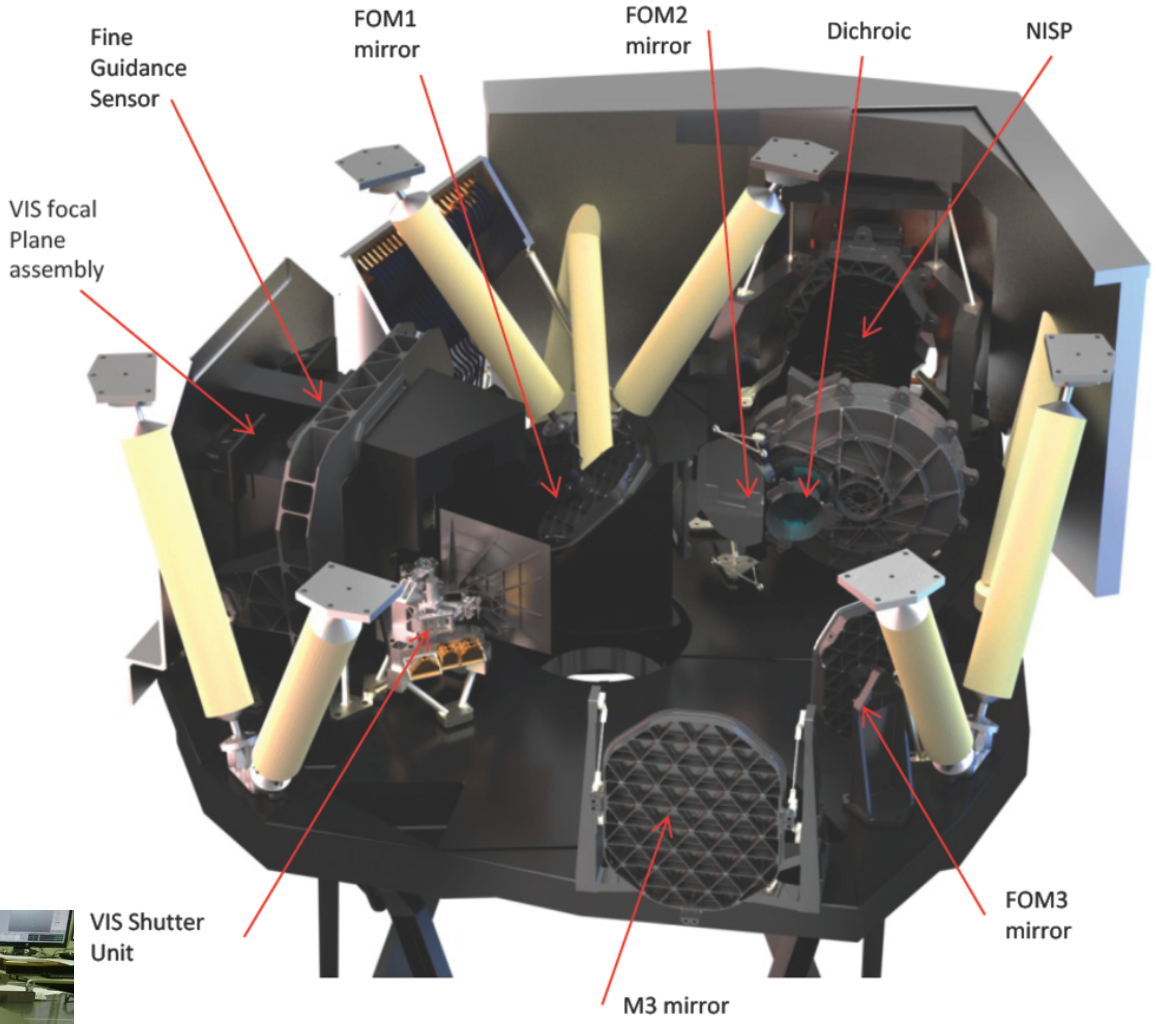
PLM, flight hardware, scientific instruments

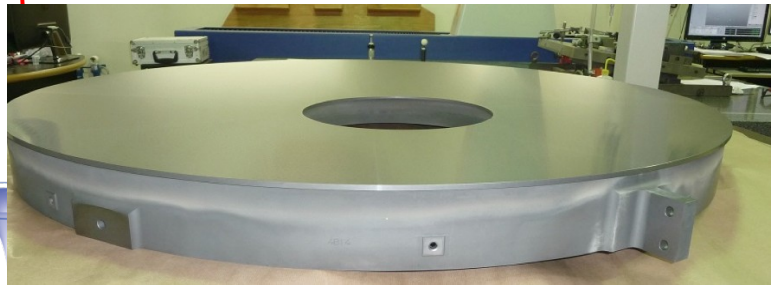
From Thales Alenia Italy, Airbus DS, ESA Project office and Euclid Consortium



M2 mirror



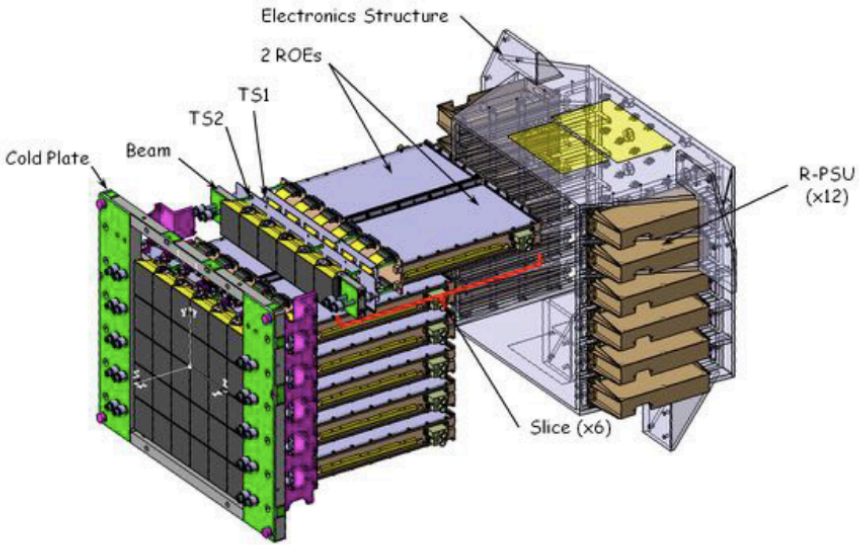




PLM CDR in July 2017, kick-off last week

VIS

VIS CDR on-going…

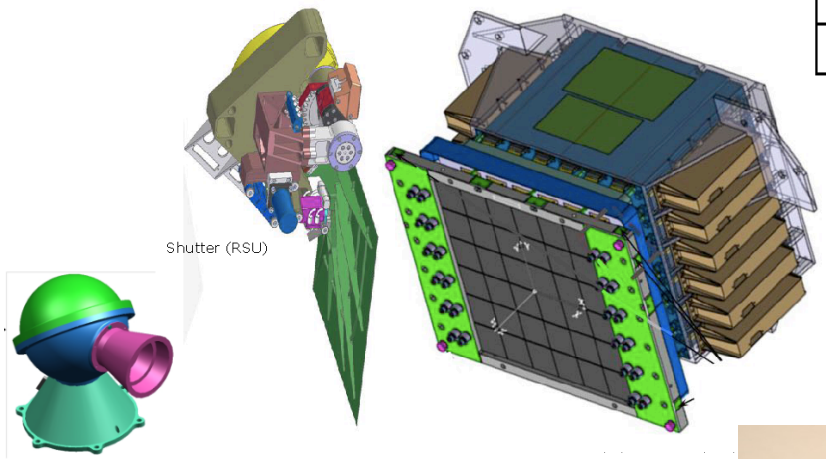


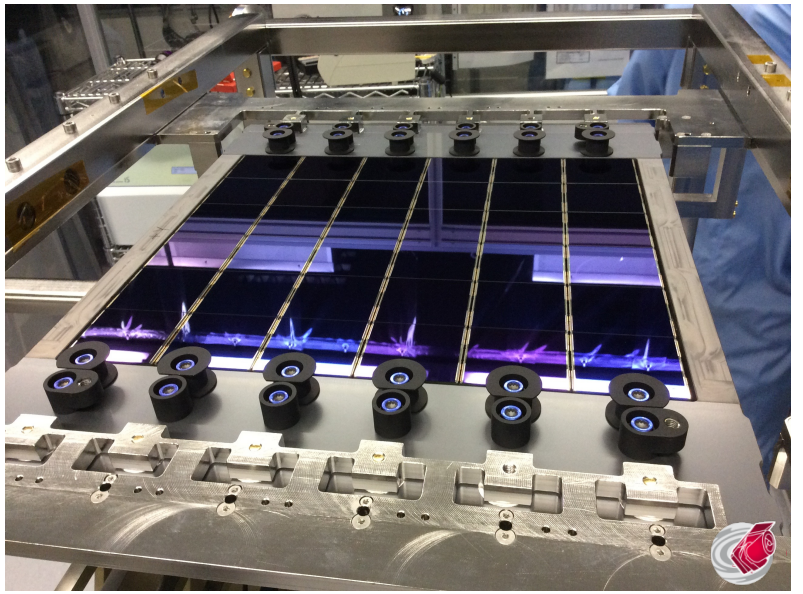
Courtesy: S. Pottinger, M. Cropper and the VIS team

Table 1: VIS and weak lensing channel characteristics

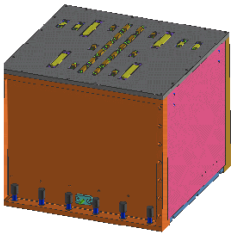
Spectral Band	550 – 900 nm
System Point Spread Function size	≤0.18 arcsec full width half maximum at 800 nm
System PSF ellipticity	≤15% using a quadrupole definition
Field of View	>0.5 deg^2
CCD pixel sampling	0.1 arcsec
Detector cosmetics including cosmic rays	≤3% of bad pixels per exposure
Linearity post calibration	≤0.01%
Distortion post calibration	≤0.005% on a scale of 4 arcmin
Sensitivity	$m_{AB} \geq 24.5$ at 10σ in 3 exposures for galaxy size 0.3 arcsec
Straylight	≤20% of the Zodiacal light background at Ecliptic Poles
Survey area	15000 deg^2 over a nominal mission with 85% efficiency
Mission duration	6 years including commissioning
Shear systematic bias allocation	additive $\sigma_{sys} \leq 2 \times 10^{-4}$; multiplicative $\leq 2 \times 10^{-3}$

Cropper et al 2016.SPIE

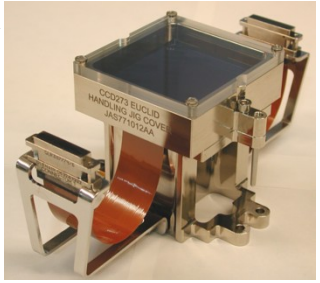


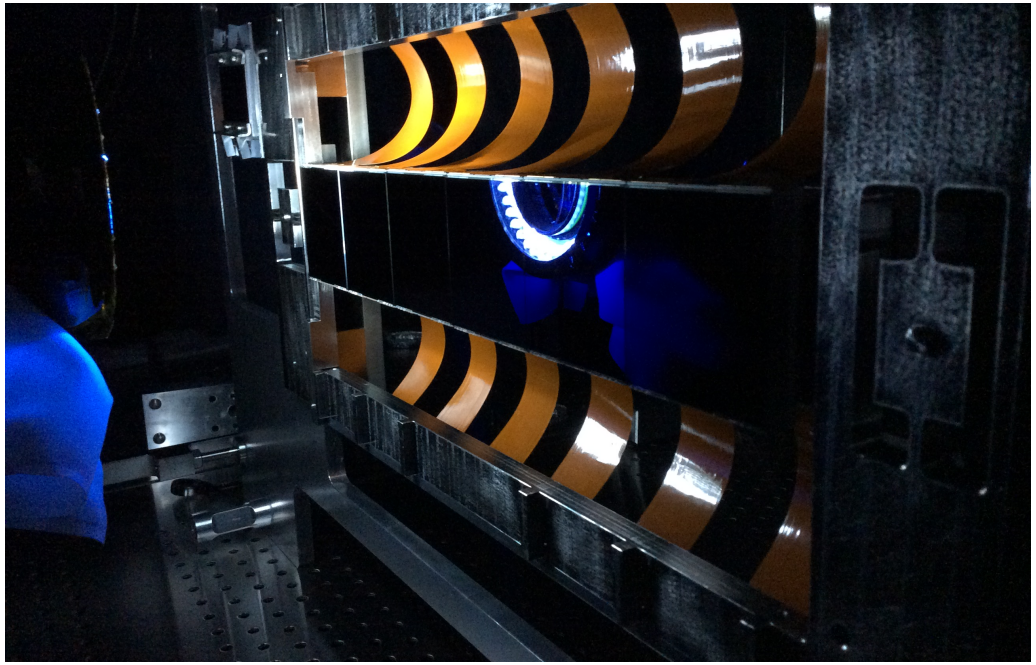


Warm Units
in Service Module

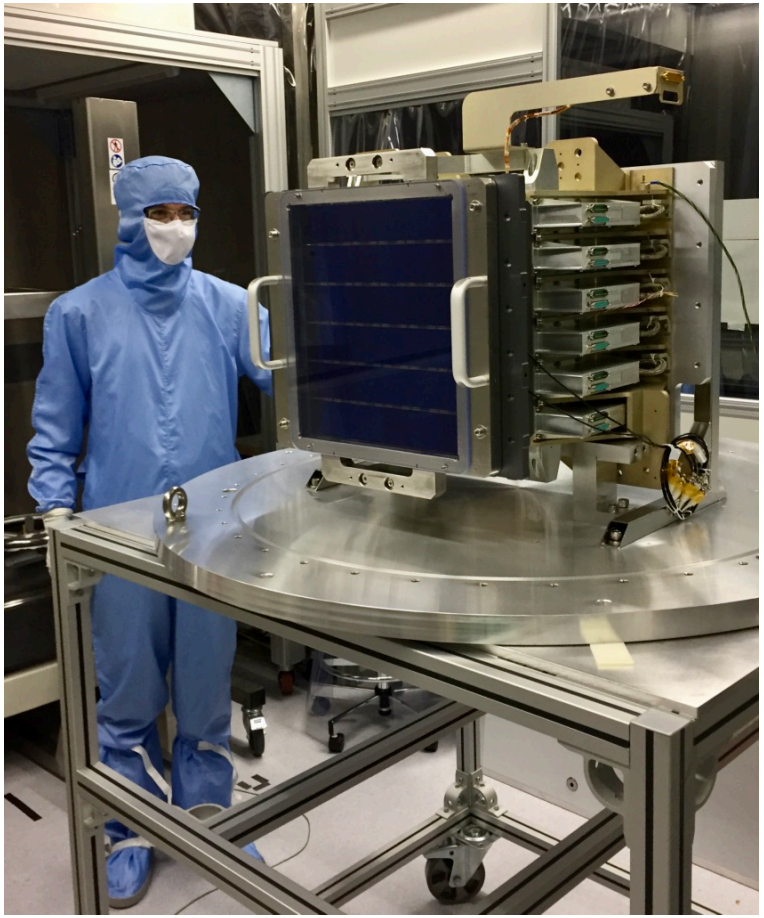


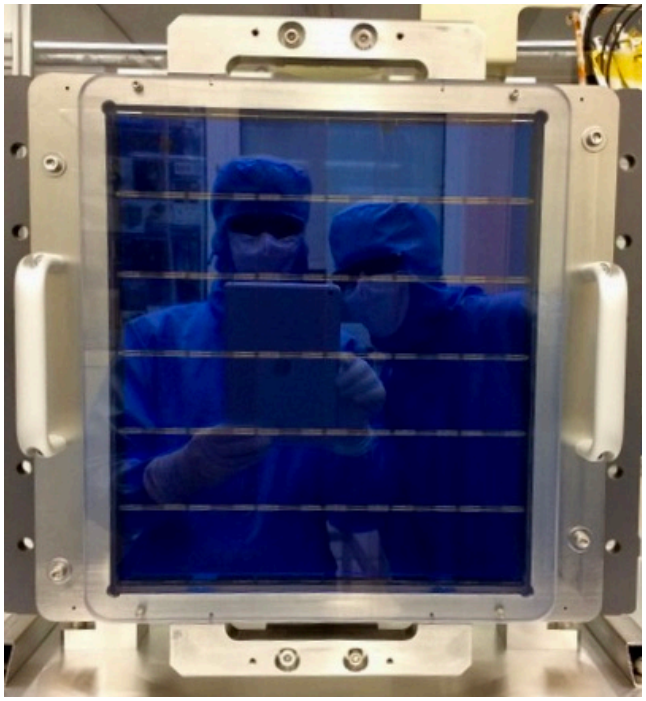
Payload and Mechanism
Control Unit (PMCU)





Measure of focal plane geometry



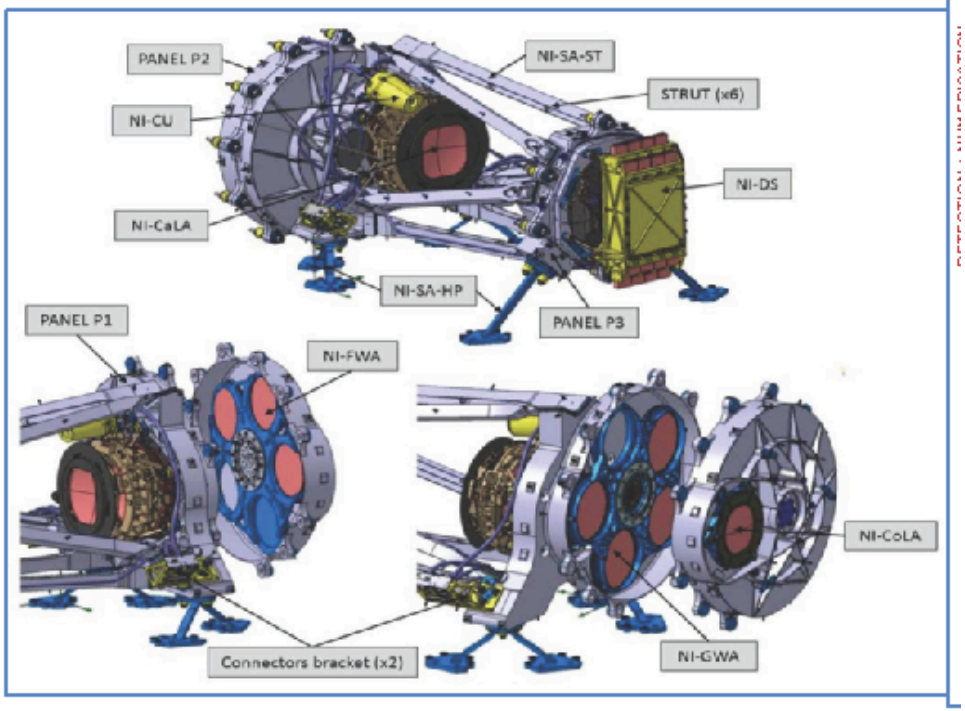


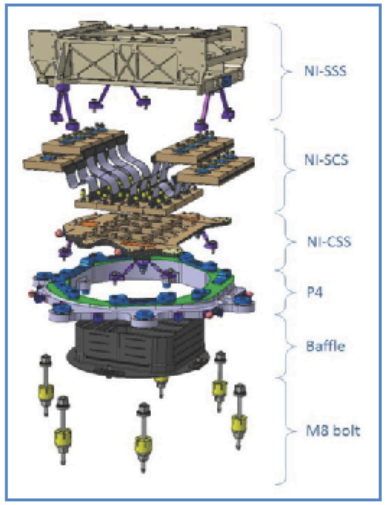
Delivery of the Structural & Thermal Model (May ’17)

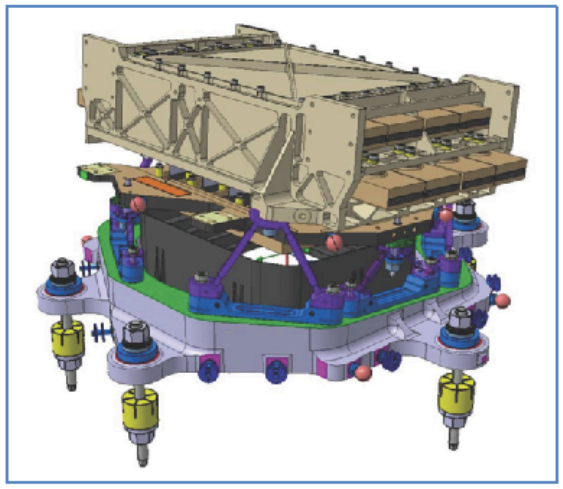
NISP

NISP CDR successful in Nov 2016

Courtesy: T. Maciaszek and the NISP team

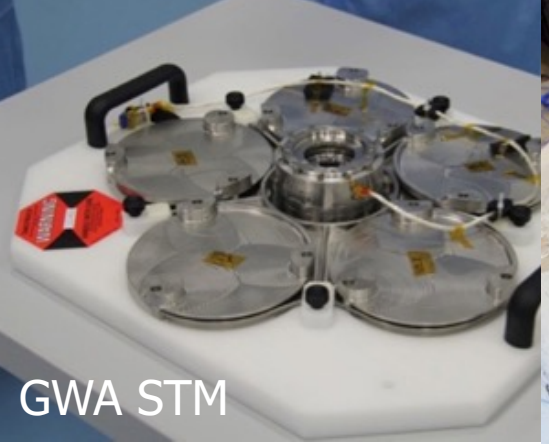


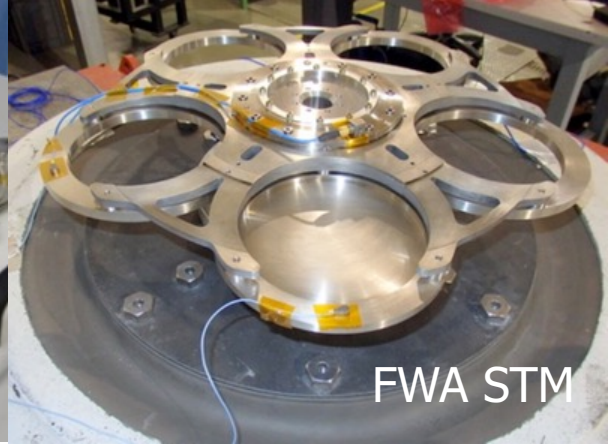




- FoV: 0.55 deg^2 Maciaszek et al 2016:SPIE
- Mass : 159 kg
- Telemetry: < 290 Gbt/day
- Size: 1m x 0.5 m x 0.5 m
- 16 2kx2K H2GR detectors
- 0.3 arcsec pixel on sky
- Limiting mag, wide survey AB : 24 (5 σ)
- **3 Filters**:
- Y (950-1192nm)
- , J (1192, 1544nm)
- , H (1544, 2000nm)
- **4 grisms**:
- 1B (920 – 1300) , 1 orientation 0°
- 3R (1250 – 1850), 3 orientations 0° , 90° , 180°

Reliability issues with cold electronics, FM delivery of detectors halted

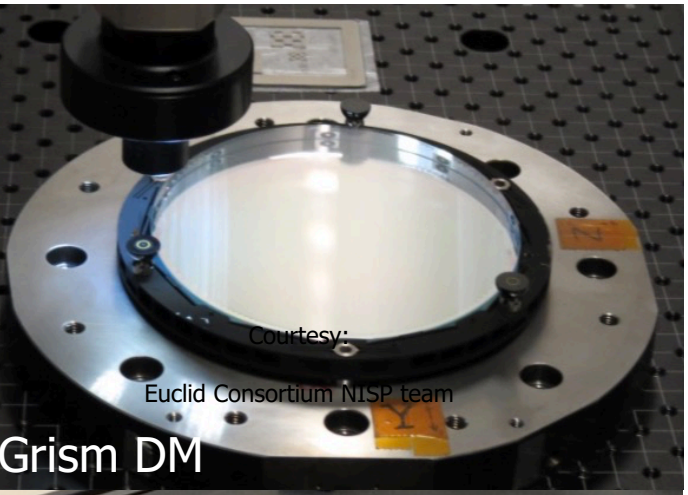

GWA STM


FWA STM

NISP

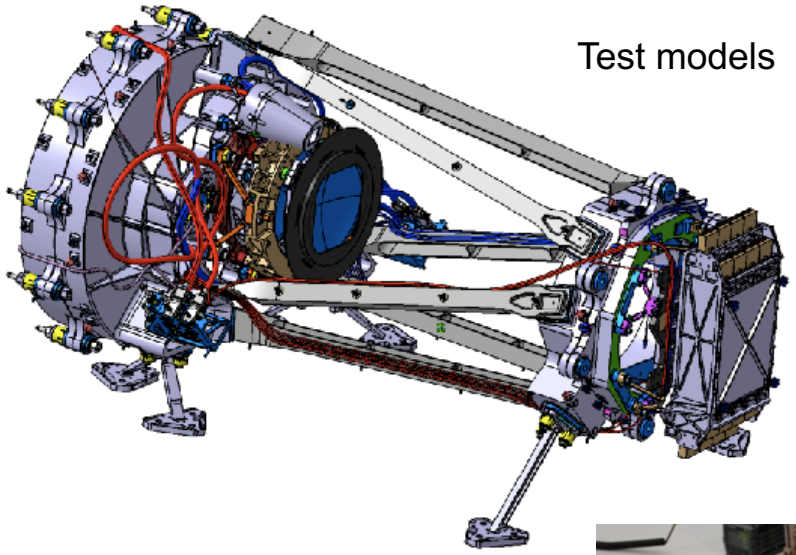
Test models

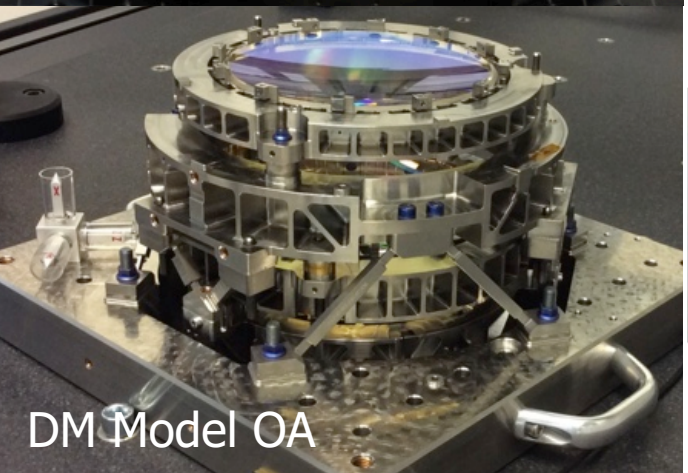

NI-WE

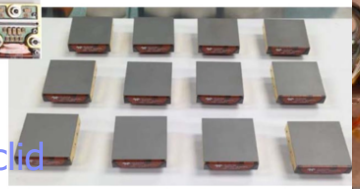

Courtesy:

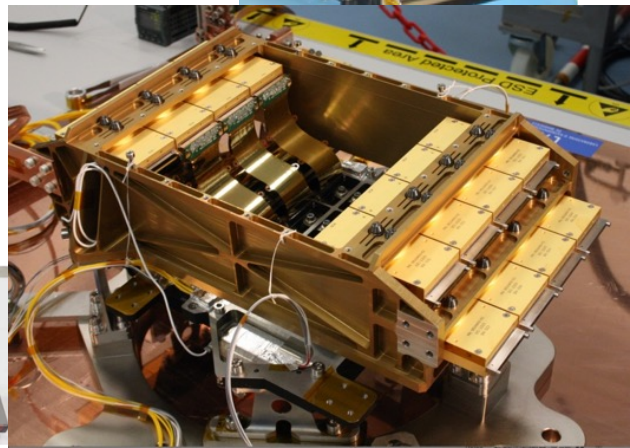
Euclid Consortium NISP team

Grism DM




DM Model OA


Euclid



Performance Status on Dec 2016

Technical Performance Measure		Requirement	CBE Current
Image Quality			
VIS Channel	FWHM (@ 800nm)	180 mas	160 mas
	ellipticity	15.0%	9.4%
	R2 (@ 800 nm)	0.0576	0.0551
	ellipticity stability σ(εi)	2.00E-04	1.90E-04
	R2 stability σ(R2)/<R2>	1.00E-03	1.00E-04
	Plate scale	0.10 "	0.100 "
NISP Channel	rEE50 (@1486nm)	400 mas	225 mas
	rEE80 (@1486nm)	700 mas	584 mas
	Plate scale	0.30 "	0.299 "
Sensitivity			
VIS SNR (for mAB = 24.5 sources)		10	16.99
NISP-S SNR (@ 1.6um for 2xe-16 erg cm-2		3.5	4.81
NISP- P SNR (for mAB = 24 sources)	Y-band	5	5.89
	J-band	5	6.69
	H-band	5	5.34
NISP-S Performance			
Purity		80%	72%
Completeness		45%	52%
Survey			
Wide Survey Coverage		15,000 deg2	15,000
Survey length [years]		5.5	5.4

From R. Laureijs and ESA PO

Euclid performances very close to meeting the scientific and survey requirements

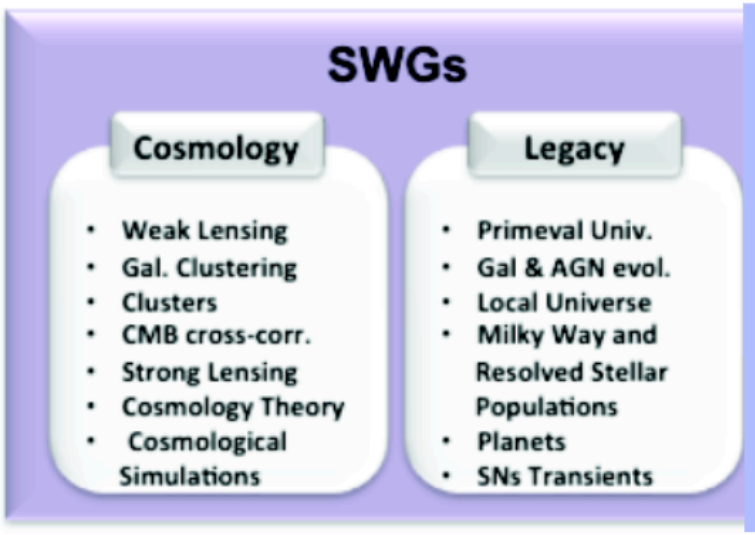
- Image quality of the system fully in line with needs.
- Ellipticity, R^2 stability and non-convolutive errors performance dictated mainly by ground processing.
- *Purity* not compliant with current data processing methods but on-going work to recover it with combination of survey modification and specific data processing.

The EC is now running "Science Performance Verification #2" an exercise to verify the mission performance, starting from a consistent cosmological simulation (released last week), using instrument simulation based on CDR, and emulating the actual data processing chain.

Science Working Groups

Science exploitation of the Euclid data is coordinated by the topical science working groups.

It is within the SWGs that science projects will be designed and papers organized.



J. Brinchmann,

C.Conselice,

H. Hoekstra,

L. Guzzo,

T. Kitching,

L. Percival,

J. Weller

SGS

ESS: Survey planning

SCS: Instrument commanding

QLA: Quick look analysis

HMS: Scientific health monitoring

LE1: Level 1 processing

VIS: VIS image processing

NIR: NISP photometry image processing

SIR: NISP spectroscopy image processing

EXT: External data ingestion

MER: Euclid and External data merging

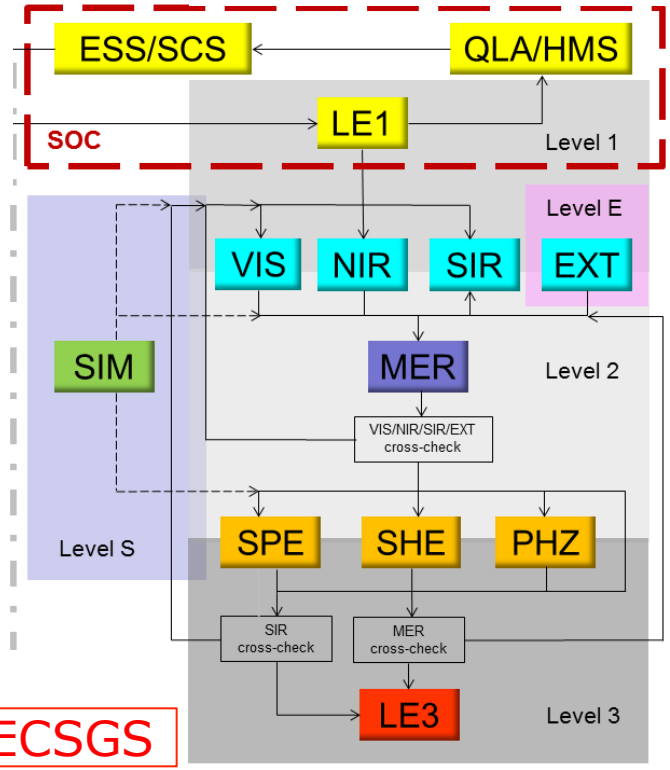
SPE: Spectroscopic redshift and spectral properties

SHE: Shear and weak lensing measurements

PHZ: Photometric redshift measurements

LE3: Level3 scientific processing

SIM: Image simulations



ECSGS

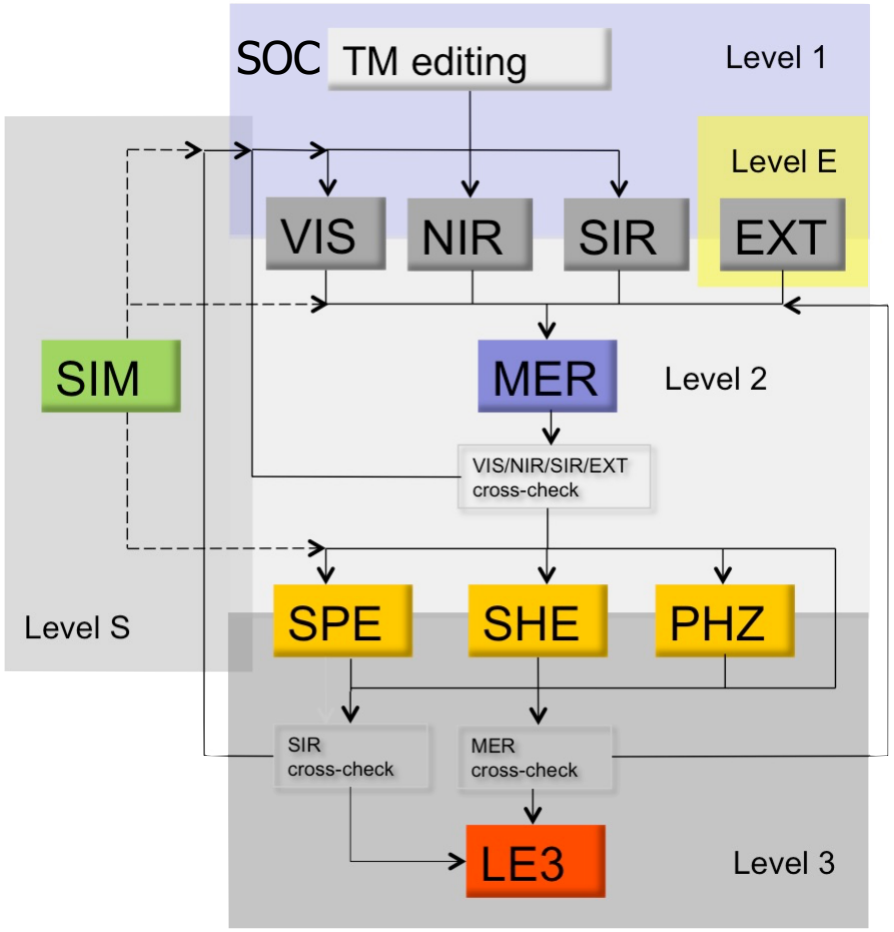
Science Ground Segment

Data processing is broken down in logical units, developed by the Organization Units of the SGS.

The Ground Segment will undergo its Design Review at the end of 2017.

It is currently integrating its various elements through challenges

The mapping of OUs on the pipeline

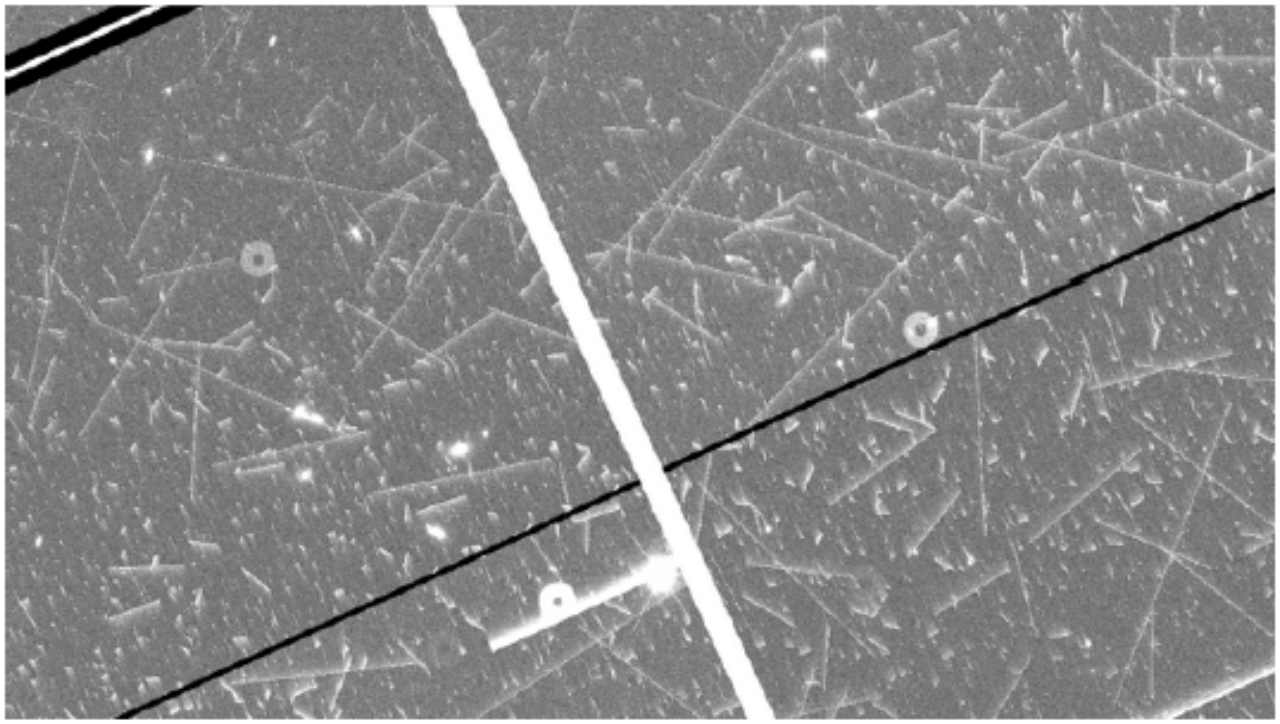


- VIS, NIR, EXT: production of fully calibrated photometric exposures from Euclid and ground-based surveys
- SIR: production of fully calibrated 1D spectra extracted from the NISP spectroscopic exposures.
- MER: production of a source catalog containing consistent photometric and spectroscopic measurements.
- PHZ: production of the photometric redshift for all catalogued sources.
- SPE: production of spectroscopic redshifts for all sources with spectra.
- SHE: measurements of galaxy shapes.
- LE3: production of all high-level science products.
- SIM: production of all the simulated data necessary to validate the data processing stages, and to calibrate observational or method biases.

Scientific Challenges cycle

#	Primary objective	Start	End
Scientific Challenge #1: SIM	Produce samples of Euclid FoV (0,7°) of VIS/NIR/SIR simulated images and spectroscopy images consistent with a single input catalogue (galaxies, stars), instrument model, cosmic rays injected into the simulation code.	Completed	Completed
Scientific Challenge #2: SIM/VIS/NIR/SIR	Produce VIS/NIR/SIR output data products which are consistent with the Data Model: calibrated exposures, stacks, masks, catalogues, 1D spectra, 2D spectra (detection of transients not needed, level Q not needed).	Completed	Completed
Scientific Challenge #3: VIS/NIR/EXT/MER	Production of a merged photometric catalogue of sources from a consistent true universe of stars / galaxies acquired with VIS/NISP Euclid instruments and KIDS/DES ground based surveys	Completed	09/2017
Scientific Challenge #4: VIS/NIR/SIR/EXT/MER/SHE	Production of galaxy shape measurement and optimal VIS PSF model refinement	1/2018	07/2018
Scientific Challenge #5: VIS/NIR/SIR/EXT/MER/PHZ	Production of photometric redshifts measurement and PDF.	1/2018	07/2018
Scientific Challenge #6: VIS/NIR/SIR/EXT/MER/SPE	Production of spectroscopic redshifts measurement	1/2018	07/2018
Scientific Challenge #7: VIS/NIR/SIR/EXT/MER/SPE/PHZ/SHE (micro pipeline)	Update pipeline releases to meet more consistent requirements coverage w.r.t. the previous challenges	09/2018	06/2019
Scientific Challenge #8: VIS/NIR/SIR/EXT/MER/SPE/PHZ/SHE/LE3 (full processing)	Quality of LE3 data products shall be challenged according to the corresponding scientific requirements	09/2020	06/2020

Scientific Challenge 3 : Simulation

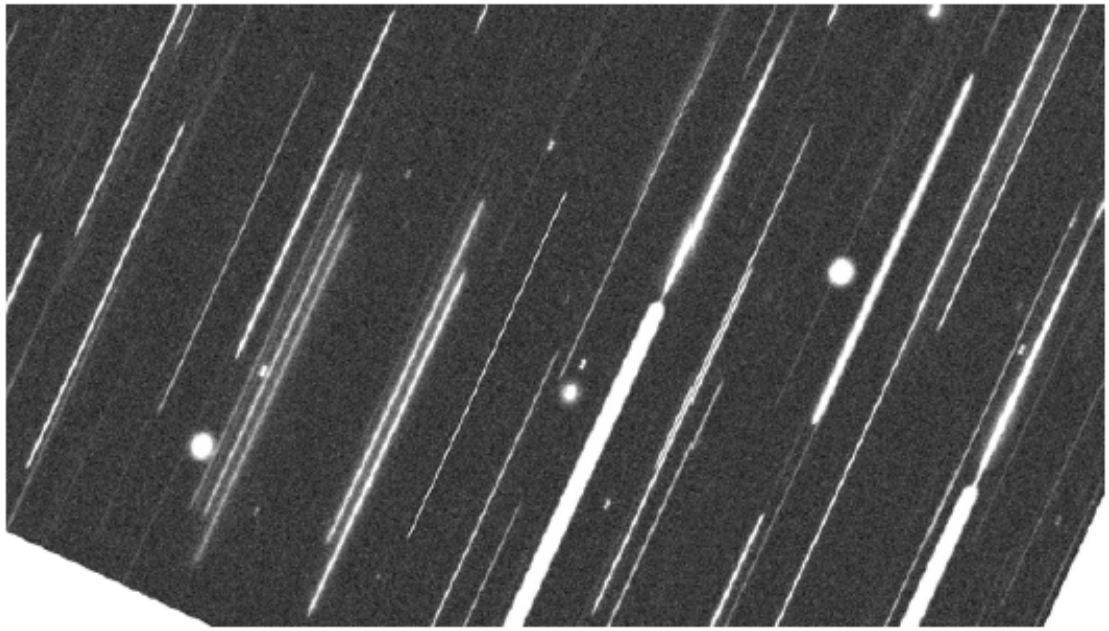


VIS
(Science + Flats + Bias)

Stars (r<24.0 - 24.5)
Galaxies (r<24.0 - 24.5)
Cosmic Rays
Photon Noise
Optical Ghosts
Zodiacal Light
AOCS PSF
Optical PSF
Geometric Distortions
Calibration Lamp
ADC Conversion
ADC Offset
Discretization
ROE non linearity
PRNU
CTI
Saturation Bleeding
Pre/Overscans
Readout Noise

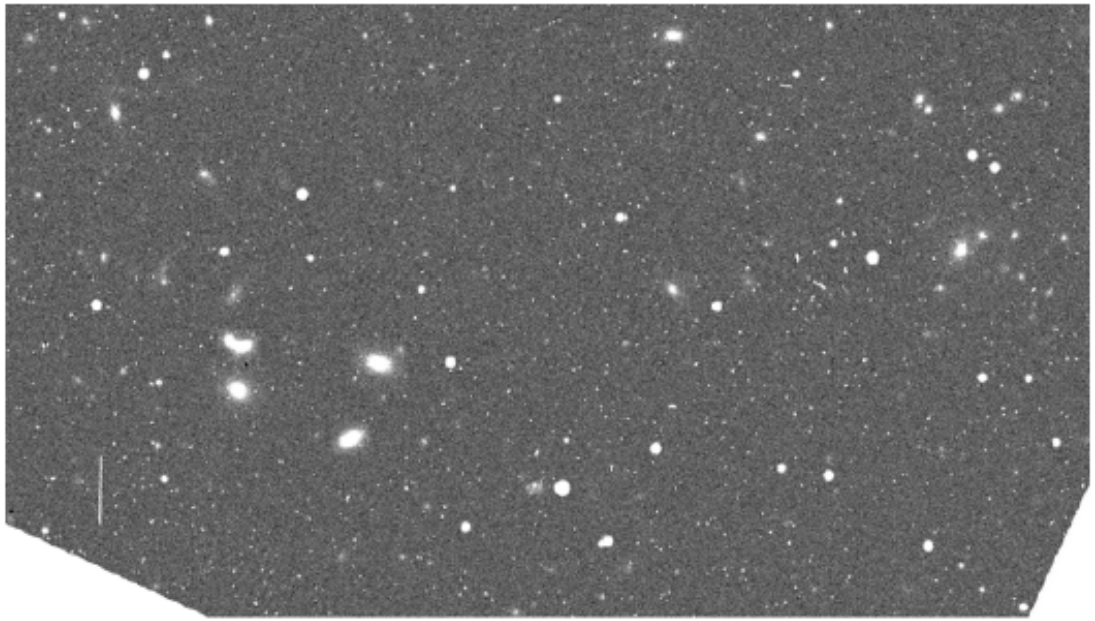
All simulation data from OU-SIM

Scientific Challenge 3 : Simulation



NISP-S
(Science+chi2)

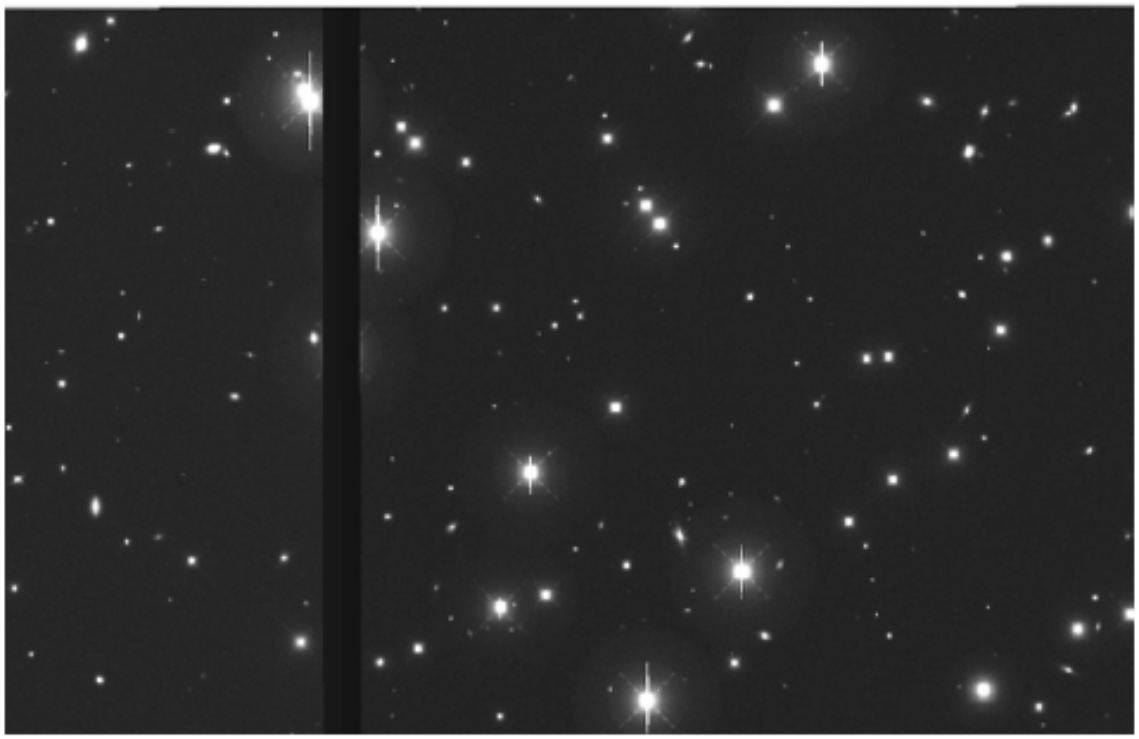
Stars (H<22.5 - 23.0)
Galaxies (H<22.5 - 23.0)
Diffuse Scattered Light
Thermal BG
Zodiacal Light
Optical PSF
0th, 1st and 2nd Grism orders
FPA Metrology
Shutter
QE non linearity
Cosmetic Defects
Dark Current
Saturation
Readout Noise
Poisson Noise



NISP-P
(Science + Dark + Flats)

Stars (r<24.0 - 24.5)
Galaxies (r<24.0 - 24.5)
Cosmic Rays (integration and readout)
Diffuse Scattered Light
Thermal BG
Zodiacal Light
AOCS PSF
Optical PSF
Geometric Distortions
FPS Illumination
Crosstalk + IPC
QE non linearity
Discretization
IntraPixel QE variation
Cosmetic Defects
Dark Current
Saturation Bleeding
Readout Noise
Poisson Noise

Scientific Challenge 3 : Simulation

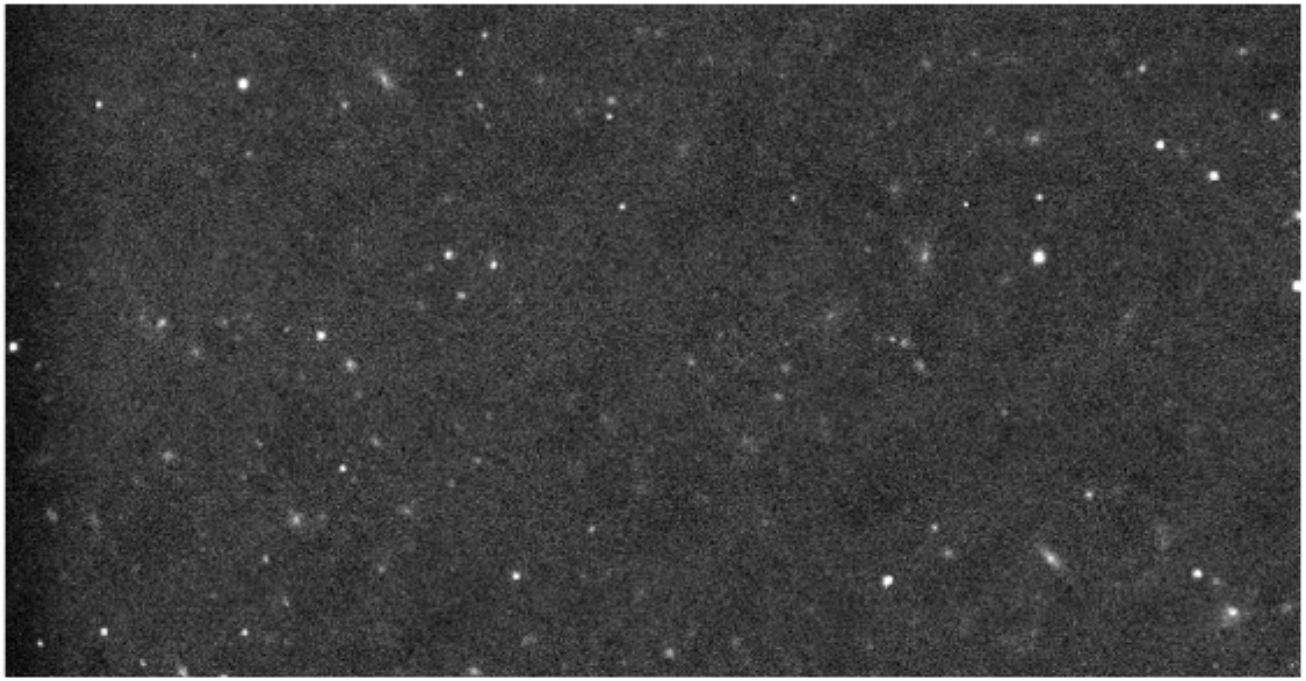


EXT DES
(Science + Flats + Bias)

Stars (r<24.0 - 24.5)
Galaxies (r<24.0 - 24.5)
Sky brightness*
Atmospheric Extinction*
Optical Variable PSFs*
Optical Distortions*
FPA metrology
Bleeding
Cosmetic defects*
Readout noise
ADC conversion
Poisson Noise
Survey Strategy*

* from real observed data

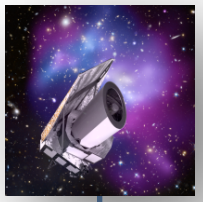
Scientific Challenge 3 : Simulation

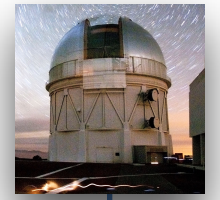


EXT KIDS
(Science + Flats + Bias)

Stars (r<24.0 - 24.5)
Galaxies (r<24.0 - 24.5)
Sky brightness*
Atmospheric Extinction*
Optical PSFs
Optical Distortions*
FPA metrology
Bleeding
Cosmetic defects*
Readout noise
ADC conversion
Poisson Noise
Survey Strategy*

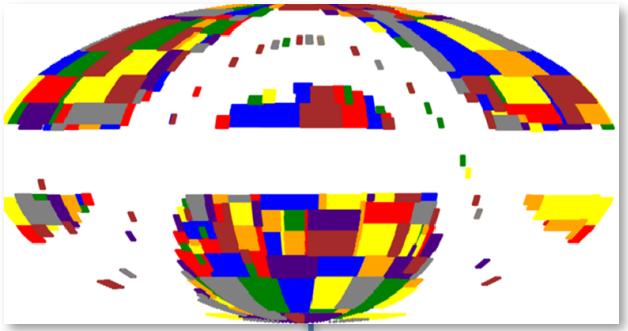
* from real observed data





Mission Operations Centre

External Data Providers



Possible scenario: per-determined SDC-Sky allocation

Science Operations Centre	SDC-NL	SDC-DE	SDC-FR	SDC-CH	SDC-ES	SDC-US	SDC-UK	SDC-FI
Public Data	Raw EXT Data	Raw EXT Data	Raw EXT Data (TBC)					
Level 1 Data Files	Data Files	Data Files	Data Files	Data Files	Data Files	Data Files	Data Files	Data Files
Metadata (prime)	Metadata (backup)							

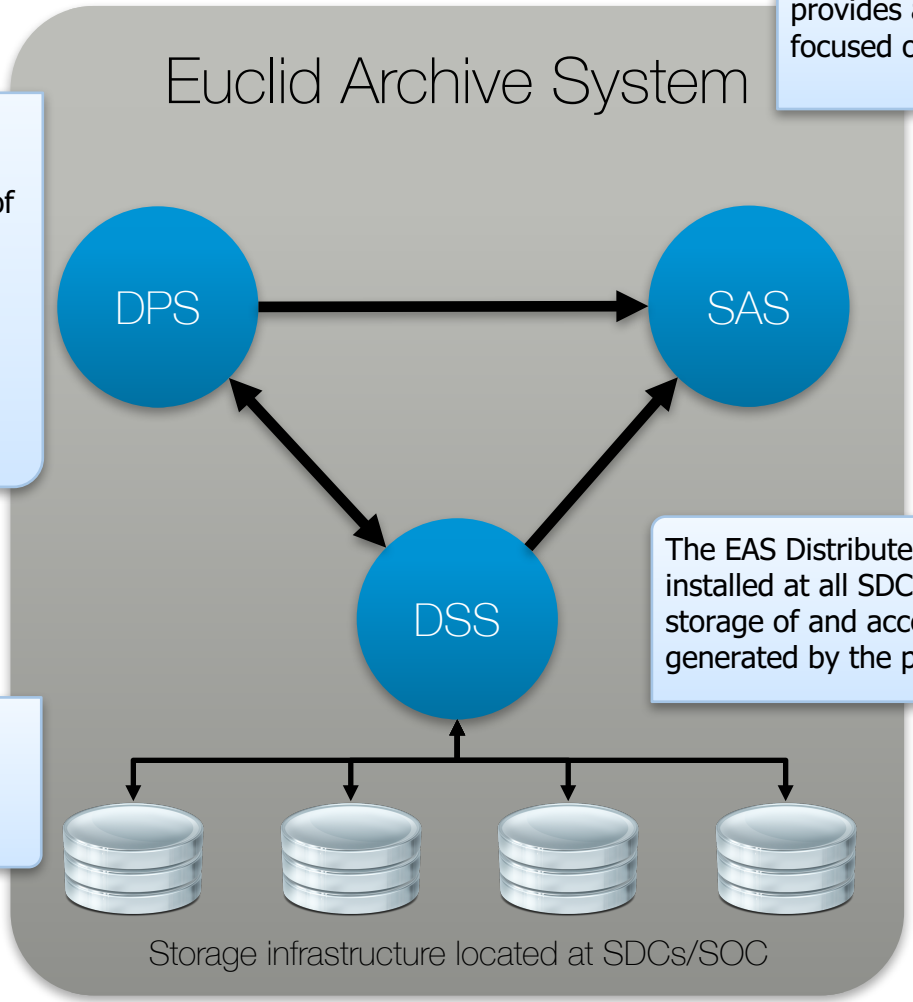
Redundant storage of the data

Archive overview

The EAS Science Archive System (SAS) provides access to the Euclid data focused on the scientific use of the data.

The EAS Data Processing System (DPS) stores the data product metadata including the locations of the data files.

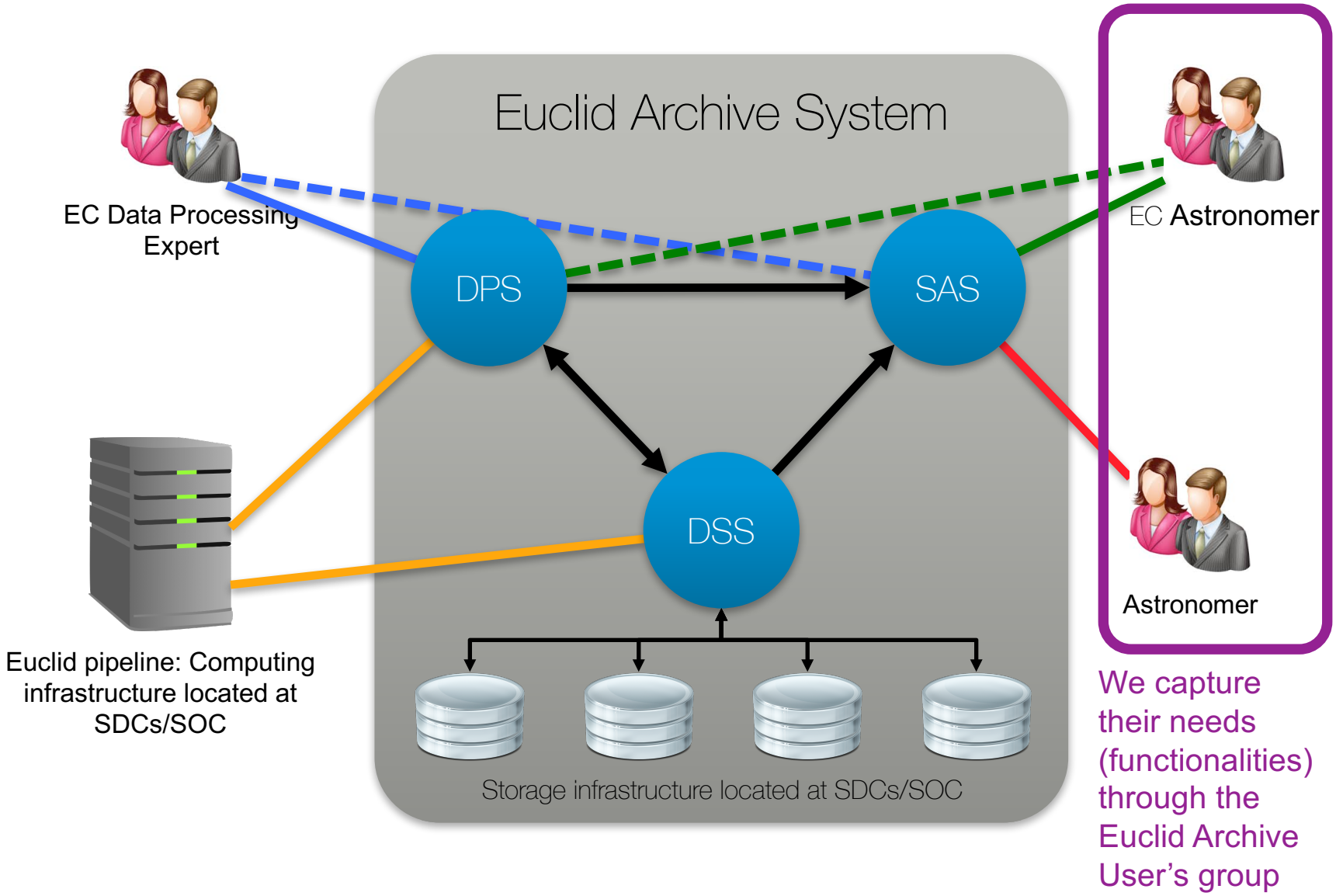
It provides access to the data products to the EC members, including processing coordination, quality control and processing history tools.



The EAS Distributed Storage System (DSS) is installed at all SDCs & SOC and manages the storage of and access to the data files generated by the pipelines.

Storage systems are provided by all the SDCs & SOC. All public data will be located at ESAC.

Major Archive users



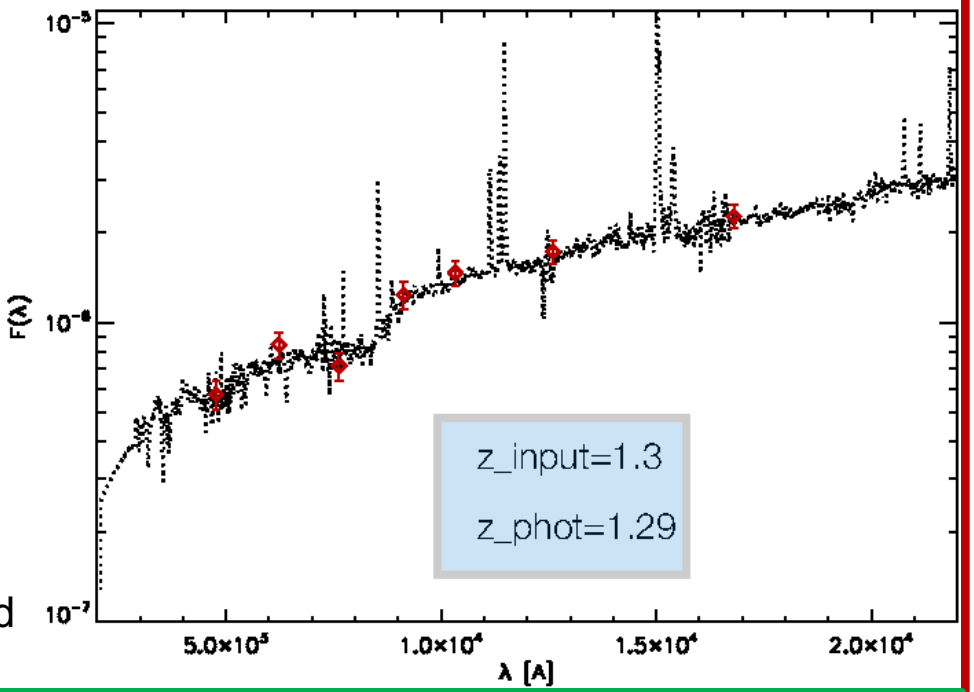
Euclid+ground: photo-z of 1.5 billion galaxies

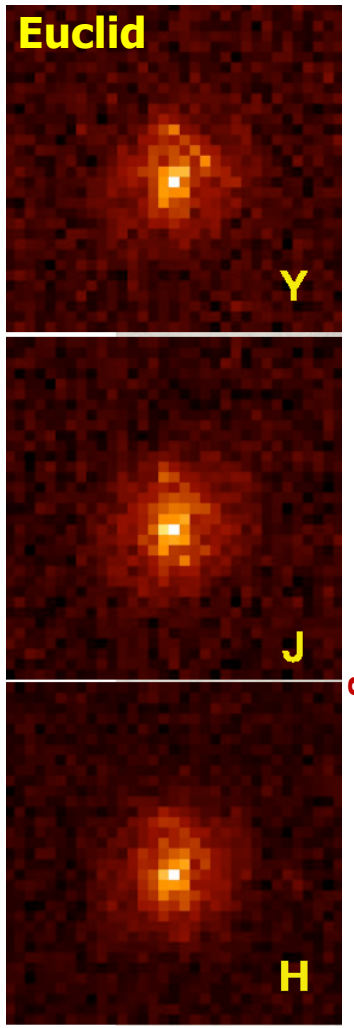
Ground based imaging over 15,000 deg^2 in 4 bands + spectroscopy

Requirements:

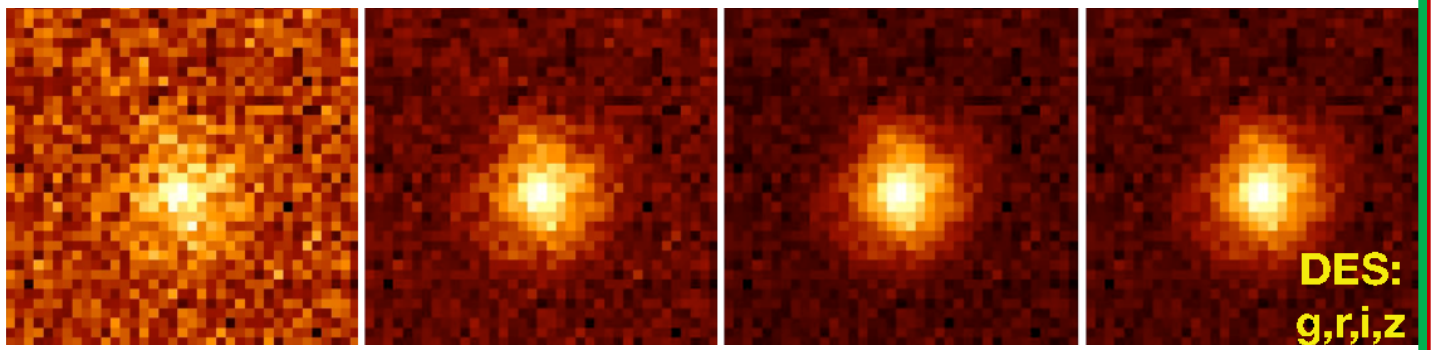
- get photo-z for ~all WL galaxies
- cover the whole Euclid sky (15000 deg^2)
- accuracy: 0.05x(1+z)
- strong(er) requirement on N(z)

→ 4 optical bands needed





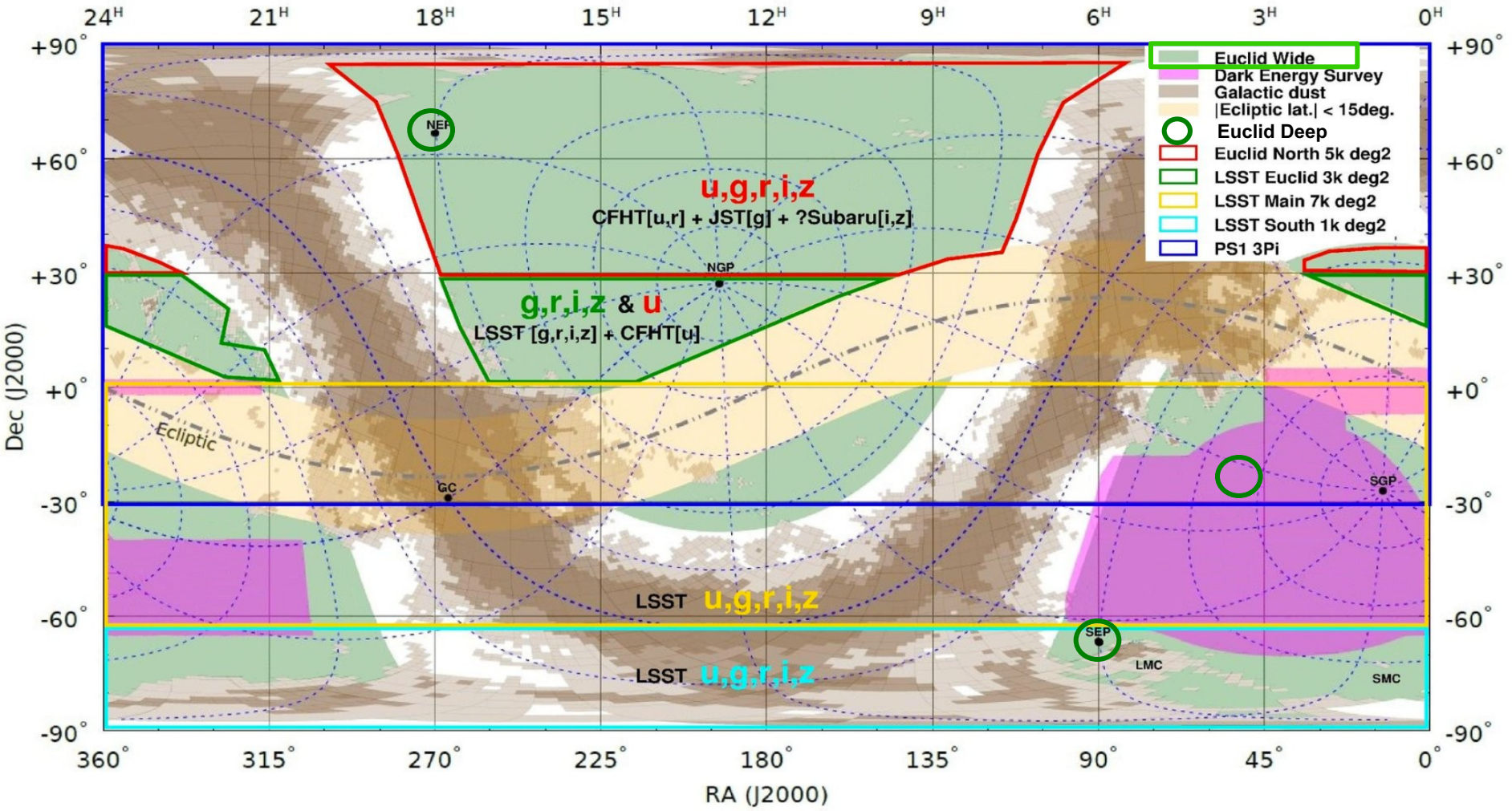
NIR data from Euclid NIR images.



From Euclid SWG Photo-z and OU-PHZ

Euclid Wide and Deep Surveys

(including not yet approved plans)



From J.-C. Cuillandre and the Survey WG

>30° : Subaru will very likely turn into Pan-STARRS

<30° : Depends on LSST-Euclid negociations

Euclid Wide and Deep Surveys

- **Euclid Wide:**
  - 15000 deg^2 outside the galactic and ecliptic planes
  - 12 billion sources (3-σ)
  - 1.5 billion galaxies with
    - Very accurate morphometric information (WL)
    - Visible photometry: (u), g, r, i, z , (R+I+Z) AB=24.5, 10.0 σ +
    - NIR photometry : Y, J, H AB = 24.0, 5.0σ
    - Photometric redshifts with 0.05(1+z) accuracy
  - 35 million spectroscopic redshifts of emission line galaxies with
    - 0.001 accuracy
    - Hα galaxies within $0.7 < z < 1.85$
    - Flux line: $2 \cdot 10^{-16}$ erg.cm^{-2}.s^{-1} ; 3.5σ

- **Euclid Deep:**
  - 10 deg^2 at North Ecliptic pole
  - 20 deg^2 near South Ecliptic pole
  - 10 deg^2 on CDFS (EDF-Fornax).
  - 10 million sources (3-σ)
  - 1.5 million galaxies with
    - Very accurate morphometric information (WL)
    - Visible photometry: (u), g, r, i, z , (R+I+Z) AB=26.5, 10.0 σ +
    - NIR photometry : Y, J, H AB = 26.0, 5.0σ
    - Photometric redshifts with 0.05(1+z) accuracy
  - 150 000 spectroscopic redshifts of emission line galaxies with
    - 0.001 accuracy
    - Hα galaxies within $0.7 < z < 1.85$
    - Flux line: $5 \cdot 10^{-17}$ erg.cm^{-2}.s^{-1} ; 3.5σ

External data for Euclid

In the Euclid Consortium 2 structures deal with external data for science:

- The Complementary Observations Group:
  - In charge of all the managerial interface aspects with external collaborations.
  - Members of each external collaborations (enlisted in the EC) belong to the COG.
  - Deal with all programmatic aspects with respect to data availability for data releases.
  - Prepares proposals for external data acquisition when requested by the Science Working groups.
- The EXT Organization Unit:
  - Ensures that data quality requirements coming from the science objectives are met by the external data set:
    - Either by performing the actual data processing from the raw data up to the fully calibrated exposures (DES model)
    - Or by putting in place the necessary data processing expert interface to transfer the requirements to the external team (CFIS model).
  - Develops methods to perform external data validation before ingestion in Euclid System.
  - Organizes re-processing activities when needed.

Euclidization ground-based external data

Goal	Requirement	External data
Photo-z	Δmag < 10 mmag (relative, single filter)	**Ground-based optical imaging** CFIS, DES, JEDIS-g (PS, LSST tbc)
VIS PSF modelling	Δcolor < 2 mmag (TBC) (relative, model scale)	**Ground-based optical imaging** CFIS, DES, JEDIS-g (PS, LSST tbc)

”Euclidization”:

- Achieve consistency between External Surveys and Euclid Space data:
  1. Photometry: consistent SEDs and absolute scaling SEDs
  2. Consistent intrinsic light distribution (PSF modelling)
  3. Consistent astrometry (for forced photometry)
- Produce identical data product formats for External Surveys

Euclid-compliant calibration

Consistency	VIS reference	EXT reference
Photometry	Gaia-G	- Gaia-G for EXT-r - EXT-giz relative to EXT-r & 2MASS-J[1]
Intrinsic light distribution	PSF modelling (per exposure)	PSF modelling
Astrometry for forced photometry	Gaia-G	Gaia-G[2]

[1] expand to G+BP+RP photometry, then spectra and finally add VIS.
[2] replace eventually by Gaia+VIS as astrometric reference.

The specific case of LSST

LSST and Euclid have similar science objectives and schedule. There is added value for both in reaching a data sharing/exchange agreement.

- Euclid side of the interest:
  - ugriz de-trended individual exposures down to the Euclid depth.
  - Filter transmission curves (down to the accuracy needed for photo-z, including spatial dependence).
- LSST side of the interest (likely biased view):
  - High resolution VIS images for de-blending (calibration/training), from the wide and/or deep survey.
  - NIR photometric coverage for photometric redshifts.

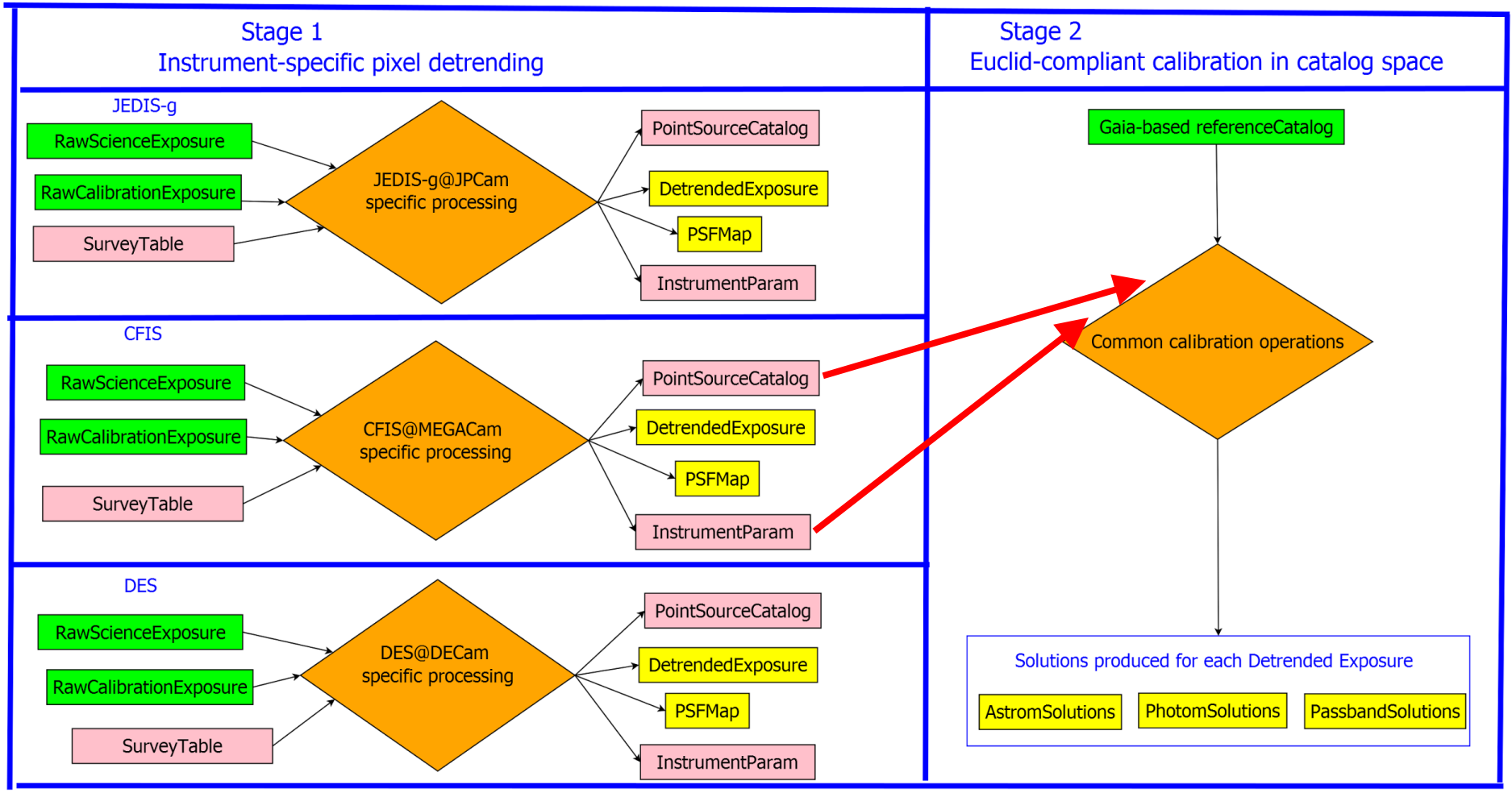
Notes:

Euclid is significantly shallower than LSST:

- The LSST data that Euclid would need is a small fraction of total LSST.
- The Euclid data that LSST would need is a small volume w.r.t. LSST data and processing.

- A white paper outlining the science cases for collaboration will be issued shortly, then Euclid and LSST management will make the decision

Two-staged production

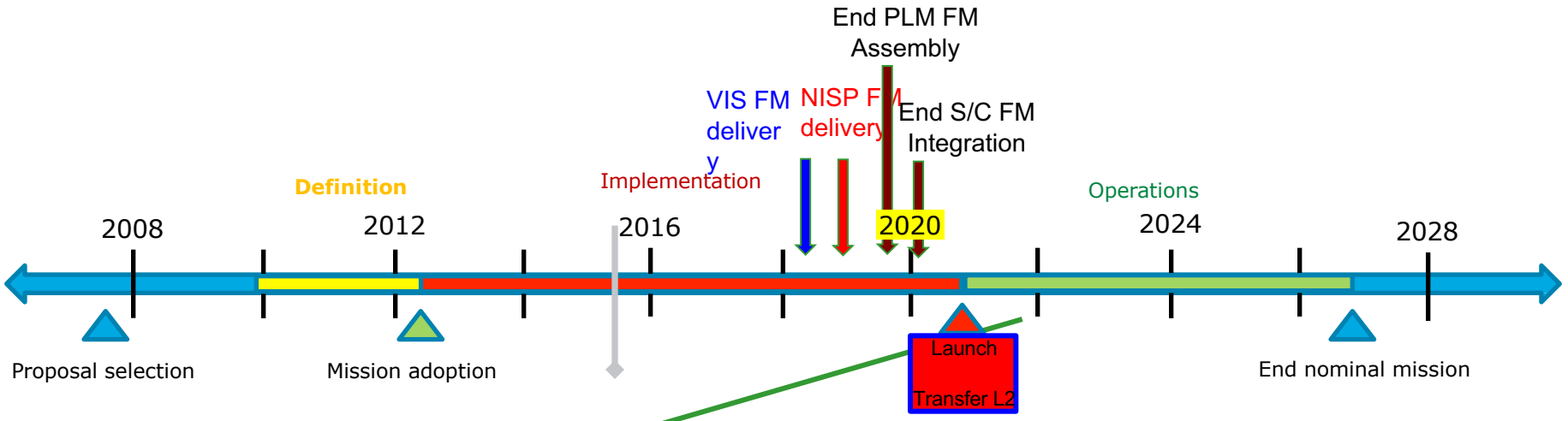


EXT delivery to MER

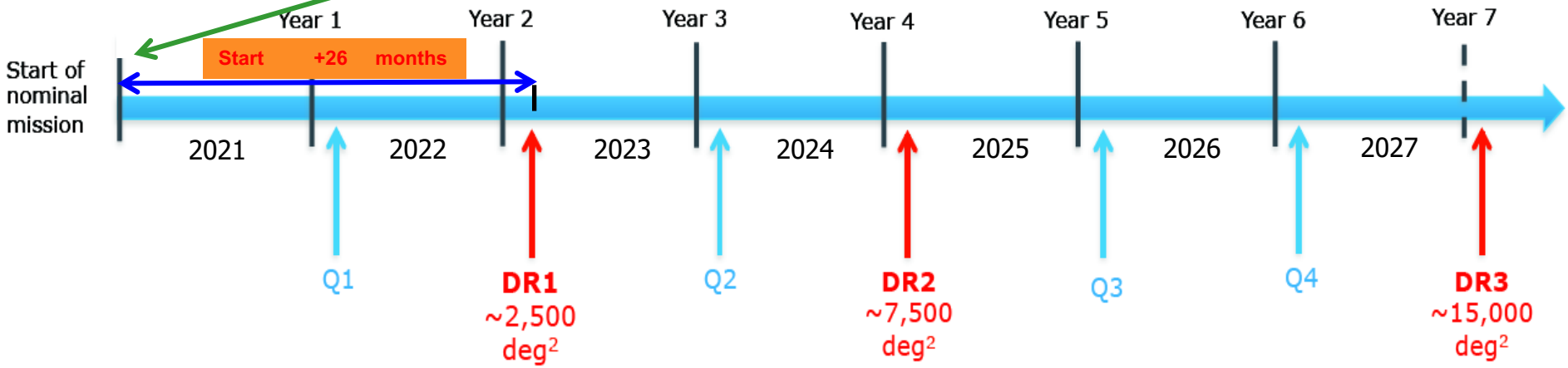
EXT-PF1 Data Products delivered to MER-PF	
Name	**Description**
DetrendedExposure	Detrended exposures. No photometric or astrometric solution or PSF homogenization is applied to the pixels.
PSFMap	PSF characterization for each position in each detector in a DetrendedExposure. One PSFMap is for one DetrendedExposure.
AstromSolution	Astrometric solution for each pixel coordinate position in each detector in one DetrendedExposure. One AstromSolution is for one DetrendedExposure.
PhotomSolution	Photometric solution for each pixel coordinate position in each detector in a DetrendedExposure. One PhotomSolution is for one DetrendedExposure.
PassbandSolution	A solution mapping the variation of the passband over the field of view. One PassbandSolution for all DetrendedExposures..
Coadds: TBC	

Evolution of baseline to account for the fact that intrinsic edge-to-edge transmission variations are incompatible with the photo-z accuracy requirement.

Mission Timeline and Data Releases



Add six months to post-launch dates



Science with Euclid will start in 2022 with Q1 and in 2023 with DR1