Euclid @ OAS Bologna:
experimental activities, ground segment and scientific exploitation preparation.
Status and perspective

Natalia Auricchio & Elena Zucca
On behalf of the Euclid Consortium
SUMMARY

➤ The Euclid mission

➤ VIS&NISP

➤ NISP: General Architecture and current status

➤ People
ESA mission dedicated to the study of dark energy and dark matter

- Selected in Oct. 2011 ⇒ Fully funded
- Partners: ESA, TAS, Airbus DS, Euclid Consortium (EC)
- Overall mass: ~2020 kg, Power: 1920 W (E0L),
  Data rate: 850 Gbit/day
- 6.25 years mission

Technology:

- Telescope 1.2m aperture (T=125K)
- 2 cryogenic instruments ⇒ VIS&NISP
  (T=100-150K, passive)

L2 orbit

- Launch Vehicle – Soyuz-Fregat
- Launch date: 2022, from Kourou space port

Euclid Consortium, A space mission to map the Dark Universe: https://www.euclid-ec.org/
36 CCDs, 4kx4k pixels, 12 µm
Pixel size: 0.1 arcsec
Spectral band: 550-900 nm
Data volume: 423 Gbit/day
Temperature: 150-155 K (passive)

16 2kx2k H2RG NIR detectors
Pixel size: 0.3 arcsec
Spectral band: 920-2000 nm
Data volume: 290 Gbit/day
Temperature: 100-140 K (passive)
- **Budgets:** **Box Size:** 1.0x0.5x05 m, **Mass:** 160 kg, **Power:** 200 W

- **3 main assemblies:**
  - **NI-OMA:** Opto Mechanical Assembly
  - **NI-DS:** Detection System
  - **NI-WE:** Warm Electronics

**NISP FM global overview**
OATS is responsible for the Science Ground Segment
- **NI-DPU/DCU**: two Data Processing Units, 8 Detector Control Units for each DPU.

- **NI-ICU**: Instrument Control Unit

- **NI-DPU Application SW**

- **NI-ICU Application SW**
The **NISP EGSE** (including CCS, SCOE and IWS) was moved to LAM (Marseille) to perform the NISP EM TV test at mid–January 2019.
The **NISP EGSE** is a set of Test Equipments that will support all the AIV/AIT campaigns.

The EGSE is composed by **three main HW parts**, and involves **two main SW tasks**:  
**NI-CCS (NISP Central Checkout System)**, provided by ESA: the combination of SW (mission database, other configuration data, and test sequences) and HW (4 servers and 4 client stations) that implement the main control system used in all test campaigns at the NISP instrument level.  
**NI-SCOE (NISP Special Check-Out Equipment)**, provided by ESA: a rack, including two computers and many specialized devices, controlled through the CCS, acting as a spacecraft interface simulator for the payload under test.  
**NI-IWS (NISP Instrument WorkStation)**, provided by INAF/OAS-BO: a standalone workstation, interfaced with the CCS, providing quick-look capabilities, FITS data storage, and off-line analysis tools.
NISP: Current Status

- **Euclid STM**: delivered in 2017
- **NISP Avionic Model**: DPU&ICU EM and NIOMA&NI-DS electrical simulators delivered to TAS-I (Turin) in June 2018 to perform the Integrated PLM Functional Test activities.
- **EGSE/IWS & DPU EQM** delivered to LAM last week to perform the NISP EM TV test in ERIOS.
- **E(Q)M** test: all functional elements, including NI-DS, tested at Operating Temperature on bench. Full functional test. 1 month operations.
- **Flight Model**:
  - NIOMA: ready at LAM
  - DPU/DCU FM already manufactured. Integration phase in progress. FM 1 and 2 will be delivered in March/April 2019
  - ICU FM to be delivered in June 2019
  - DS FM to be delivered in March 2019
  - NISP FM test: July-August 2019. Delivery in September 2019
Italian contribution (II)

NISP Local PM: Luca Valenziano INAF OAS Bo

INAF OAS Bologna: Enrico Franceschi, Massimo Trifoglio, Fulvio Gianotti, John B. Stephen, Stefano Silvestri, Andrea Bulgarelli, Francesca Sortino, Natalia Auricchio, Gianluca Morgante, Adriano De Rosa, Filomena Schiavone, Gian Paolo Guizzo, Luciano Nicastro, Paola Battaglia, Elisabetta Maiorano

INAF OA Torino: Donata Bonino, Vito Capobianco, Leonardo Corcione, Sebastiano Ligori

INAF OA Padova: Andrea Balestra, Favio Bortoletto, Carlotta Bonoli, Maurizio D’Alessandro, Ruben Farinelli, Eduardo Medinaceli

INFN Bologna: Donato Di Ferdinando, Federico Fornari, Francesco Giacomini, Nicoletta Mauri, Laura Patrizii, Gabriele Sirri, Claudia Valieri, Carlo Veri

INFN Padova: Enrico Borsato, Stefano Dusini, Fulvio Laudisio, Chiara Sirignano, Luca Stanco, Sandro Ventura
INFN Genova: Stefano Davini, Sergio Di Domizio

NISP Instrument:

Enrico Franceschi, Massimo Trifoglio, Fulvio Gianotti, John B. Stephen, Stefano Silvestri, Andrea Bulgarelli, Donato di Ferdinando (INFN) ⇒ EGSE/IWS, AIV, support to Project Management;

Francesca Sortino ⇒ Project control, configuration, Contract management, Support to PO;

Natalia Auricchio ⇒ PA & AVM/EM test support;

Gianluca Morgante, Adriano De Rosa ⇒ NISP design and thermal modeling

Filomena Schiavone ⇒ Clean Room support

Gian Paolo Guizzo ⇒ Electrical Architect

Luca Valenziano, Paola Battaglia, Elisabetta Maiorano ⇒ Operations
DPU/DCU ARCHITECTURE

- DPU/DCU functionalities: detector control, data acquisition and processing, science data delivery to S/C
- DPU/DCU units: 2 identical, each composed by 2 DPU sections and 8 DCUs

- Each DPU section hosts:
  - 1 Data Processor board (DPB)
  - 1 Data Router board (DRB)
  - 1 Data Buffer board (DBB)
  - 1 Power Supply board (PSB)

- Cold redundancy

- 8 DCUs powered by the PSB of the active section, not redundant

- Total daily produced data: ~4 TBytes
Euclid will investigate two of the most puzzling quantities in modern cosmology, Dark Energy and Dark Matter, combining two methods:

- **Weak Gravitational Lensing** to map the 3-D Dark Matter distribution in the Universe. This requires extremely high precision measurements of galaxy shapes, realised with the VIS, and the inference of galaxy distances by means of photometric redshifts with the NISP.

- **Baryon Acoustic Oscillations** as a function of time, by measuring galaxy clustering properties. This task will be carried out by the spectroscopic channel of the NISP instrument.
### Euclid Scientific Objectives

<table>
<thead>
<tr>
<th>Issue</th>
<th>Euclid’s Targets</th>
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<tbody>
<tr>
<td><strong>What is Dark Energy: ( w )</strong></td>
<td>Measure the DE equation of state parameters ( w_p ) and ( w_a ) to a precision of 2% and 10%, respectively, using both expansion history and structure growth.</td>
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<tr>
<td><strong>Beyond Einstein’s Gravity: ( \gamma )</strong></td>
<td>Distinguish General Relativity from modified-gravity theories, by measuring the growth rate exponent ( \gamma ) with a precision of 2%.</td>
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<tr>
<td><strong>The nature of dark matter: ( m_\nu )</strong></td>
<td>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.</td>
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<tr>
<td><strong>The seeds of cosmic structure: ( f_{NL} )</strong></td>
<td>Improve by a factor of 20 the determination of the initial condition parameters compared to Planck alone. ( n ) (spectral index), ( \sigma_8 ) (power spectrum amplitude), ( f_{NL} ) (non-gaussianity)</td>
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</table>

+ **LEGACY SCIENCE**
Science Working Groups (SWGs)

Galaxy clustering
Clusters
CMB cross-correlations
Strong lensing
Cosmological Theory
Primeval galaxies
Galaxy/AGN evolution
Cosmological simulations
Weak lensing
Nearby galaxies
Milky Way
Planets
Supernovae and Transients
Solar System Objects
SWG Coordination

Red = primary science
Blue = legacy science
From satellite to science
Euclid Data Flow

SOC

100 Gb/day → 10^{14} B/3-years = 100 TB/3-years

60% 30% 10%

VIS  NIR  SiR

1 PB  0.5 PB  60 TB

x5x3  x5x3  x2x3

100 Mb/s  50 Mb/s  7 Mb/s

MER

2xEuclid + Ground

13 PB

100 Mb/s

SHE

1 PB

x1

10 PB

EXT

SPE

0.4 PB

x2

< 0.1 PB

LE3

0.1 PB

x1

European Space Agency
Science Ground Segment

- Instrument Development Teams
- Instrument Operations Teams
- Science Data Centres
- Organisation Units
- Science Working Groups
- Operations Ground Segment
- Science Operations Centre
- Scientific Community
Ground data

Euclid payload

OU-LE3
Organization Units (OUs)

The OUs are responsible for defining the set of tasks which the SGS must perform.

Organisation Unit for Visible Imaging (OU-VIS)
Organisation Unit for NIR Imaging (OU-NIR)
Organisation Unit for NIR Spectra (OU-SIR)
Organisation Unit for External Data (OU-EXT)
Organisation Unit for Simulation (OU-SIM)
Organisation Unit for Merging (OU-MER)
Organisation Unit for Spectral Measurement (OU-SPE)
Organisation Unit for Shear (OU-SHE)
Organisation Unit for Photo z (OU-PHZ)
Organisation Unit for Level 3 products (OU-LE3)
Euclid OUs @OAS Bologna

**OU-SPE** Spectral feature measurements (5300)
Maiorano, Palazzi, Pozzetti, Vergani

**OU-PHZ** Physical parameters and model templates
Bolzonella, Pozzetti

**OU-LE3** Internal data, External data, Clusters of Galaxies
Bardelli, Bolzonella, Cappi, Cucciati, Sereno, Zucca
GOAL: Provide the **science ready data products** to the science working groups [SWGs].
OU-LE3 structure

Note: each box contains two WPs. One in charge of the implementation of the codes and one in charge of its validation.

Internal Data
- 4 PFs

External Data
- 3 PFs

Gal Clustering
- 6 PFs

Weak Lensing
- 9 PFs

Clusters
- 15 PFs

Time Domain
- 7 PFs

MWNG
- 3 PFs

Requirements from SWGs for 47 processing functions
As an example...

OU-LE3 Internal data is in charge of 4 PFs

VMPZ-ID   survey photometric mask
VMSP-ID   survey spectroscopic mask
SEL-ID    selection function
LMF-ID    luminosity and mass functions

the data products to be delivered are not “simple” outputs, but complex analysis tools
The virtuous circle

Science Requirements → Validated Estimators → Pipeline Integration

SWG → OUs → SDCs

Science ready data products
# Euclid OUs/SWGs @OAS Bologna

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Strength points

Our expertise in this scientific field (in particular galaxy evolution, clusters of galaxies, strong lensing, CMB) and our previous experience in following all the stages of galaxy surveys play a fundamental role.

A number of OAS people not only is working in Euclid but is covering a leading position.
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- Emanuel Rossetti
- Margherita Talia
Critical issues

Need of software engineers for specific support [not necessarily exclusive for Euclid]

Heavy commitment (both in money and in FTE) with no immediate return (in terms of publications) [critical in particular, but not only, for young people]

People with specific expertise moving to Institutes outside the Euclid Consortium and/or leaving the field: their training and their expertise are lost [it is not simply a problem of man power]