Euclid Imaging Instrument

“Observing the dark Universe with Euclid”

18 November 2009

Jerome Amiaux
CEA Saclay
EIC System Manager

On Behalf of the Euclid Imaging Consortium
Weak Lensing Instrument philosophy

- Euclid Science Objectives: Fundamental cosmology: Dark Energy, Dark Matter, Gravity, Cosmic initial conditions + Legacy science

- Euclid Probes: **Weak Lensing (Imaging Instrument)**, Baryonic Acoustic Oscillation (Spectro Instrument)

- Euclid Imaging: Optimised for weak gravitational lensing and also provides additional probes (Cluster, ISW) and legacy science

- Weak Lensing: map the dark matter and measure dark energy requires:
  
  - high precision galaxy shape measurements in the visible (only feasible from space)
  - accurate NIR photometry for photometric redshifts (space + ground observations)

**Galaxy shape measurements (visible visible light)**

**Photometric redshifts (Near IR light)**
Euclid Imaging Consortium developed a set of tools that allow:
- flow down of requirement from science to instrument
- evaluation of instrument performance with respect to science objectives
- Refinement and trade off requirement flow down
Radiometric Performance and Observation strategy

- Observation strategy (goal 20000 deg² in 5 years):
  - Step and Stare mode
  - 36 fields per days
  - Dithering at Satellite level
  - 4 dithers per fields
  - 100” steps per dither
  - 2.8 compression VIS
  - 500 Gbits/day of VIS data
  - 2.5 compression NIP
  - 200 Gbits/day of NIP data

<table>
<thead>
<tr>
<th>band</th>
<th>Object Magnitude AB</th>
<th>exposure time (s)</th>
<th>radiometric SNR in 3 exposures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riz</td>
<td>24.5</td>
<td>450</td>
<td>14.3</td>
</tr>
<tr>
<td>Y</td>
<td>24</td>
<td>82</td>
<td>7.1</td>
</tr>
<tr>
<td>J</td>
<td>24</td>
<td>111</td>
<td>7.1</td>
</tr>
<tr>
<td>H</td>
<td>24</td>
<td>61</td>
<td>7.1</td>
</tr>
</tbody>
</table>
Field of View Filling

Continuous Scanning Visible
- Instrument FoV: \(\sim 1^\circ \times 0.5^\circ\) on sky
- Visible Pixel Plate Scale: 0.1” on sky
- NIR Pixel Plate Scale: 0.3” on sky

➢ 9×4 CCD to fill an 0.47\(^2\) instrument FoV
Visible e2v CCD 203-82 4kx4k 12 \(\mu\)m pixels

➢ 3x6 NIR FPA to fill an 0.52\(^2\) instrument FoV
NIR Hawai-2 RG 2kx2k 18 \(\mu\)m pixels
**Image Performance evaluation**

- **PSF System Performance evaluation through shear simulation process:**
  - CCD effect
  - Optical PSF
  - Jitter

<table>
<thead>
<tr>
<th>Requirement (goal)</th>
<th>FWHM (arcsec)</th>
<th>Ellipticity (FWHM definition)</th>
<th>Ellipticity (quadrupole definition)</th>
<th>EE50 (°)</th>
<th>EE90 / EE50 (Alternate req. replacing EE83/FWHM)</th>
<th>Shear Error $\delta \gamma$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.18-0.23</td>
<td>&lt; 0.1 (&lt;0.05)</td>
<td>none</td>
<td>none</td>
<td>&lt;5.0 (&lt;4.5)</td>
<td>&lt;3.2x10^{-4}</td>
</tr>
<tr>
<td>Nominal</td>
<td>0.16</td>
<td>0.034</td>
<td>0.025</td>
<td>0.22</td>
<td>5.0</td>
<td>2.7x10^{-4}</td>
</tr>
</tbody>
</table>

- Through Euclid Imaging Consortium simulation pipeline we can estimate the impact of a system PSF on measurements
Opto-Mechanical architecture proposal

- EIC instruments starts after M3, at VIS / NIP separation on the dichroic (dichroic included)
- Based on the optical design, the EIC opto-mechanical encompass:
  - A visible Channel (VIS)
  - A NIR Photometry channel (NIP)
  - A Common Opto Mechanical Assembly (COMA)

- COMA will provide thermal Mechanical I/F towards the P/L via hexapods
Opto-Mechanical architecture proposal

- EIC instruments start after M3, at VIS / NIP separation on the dichroic (dichroic included)
- Based on the optical design, the EIC opto-mechanical encompass:
  - A visible Channel (VIS)
  - A NIR Photometry channel (NIP)
  - A Common Opto Mechanical Assembly (COMA)

- COMA will provide thermal Mechanical I/F towards the P/L via hexapods
**Opto-Mechanical architecture proposal**

- EIC instruments starts after M3, at VIS / NIP separation on the dichroic (dichroic included)
- Based on the optical design, the EIC opto-mechanical encompass:
  - A visible Channel (VIS)
  - A NIR Photometry channel (NIP)
  - A Common Opto Mechanical Assembly (COMA)

- COMA will provide thermal Mechanical I/F towards the P/L via hexapods
COMA Design Description

- COMA (Common Opto-Mechanical Assembly) will support:
  - Visible Channel
  - NIP channel
  - Dichroic (NIP / VIS spectral separation)
  - Visible path fold (alignment capability)
  - Shutter (to prevent trail during CCD read out)
  - Calibration unit (flatness better than 5%)
  - Baffling walls
  - P/L interface struts

Mass estimation: 107 kg (incl. 20% margin)
VIS Channel Design

CCD, Read Out Electronics and Power Supply Units are currently baselined

Vis Channel:
- 36 CCD 203-82 (9x4)
- 12 ROE (1 per 3 CCD)
- 12 PSU (1 per ROE)

Focal Plane Architecture in two blocks to ensure thermal decoupling between warm electronics (<300 K) and Detectors operated at <160 K.

**Thermal design completed**
- CCD: \( T = 150 \text{ K} \) with gradient < 3K

**Mechanical Design completed**
- quasi static load 26 g design

**AIV sequence studied in details**

Mass estimation: 65 kg (incl. 20% margin)
Visible Unit Reference Design

- Reference unit is 3 CCDs + 1 ROE + 1 PSU

- CCD and ROE flagged as “Critical Items”.
- Early ROE Bread Boards and representative CCD under test to feed the criticality analysis

**Visible Unit Block Diagram**

**CCD and ROE Diagram**

- e2v CCD203-82
- ROE Bread Board
CCD related critical item

- ESA-provided CCD204 (4kx1k) test on-going at CEA and MSSL:
  - CCD characterisation
  - PSF measurements

- Significant programme has been put in place to understand and quantify radiation effect on CCD:
  - contract from ESA to SSTL (Surrey) with Open University, CEA Saclay and UCL-MSSL participation for radiation characterisation of 6 CCD204
  - characterisation of p-channel CCDs, and procurement by ESA from e2v for p-channel CCD204 devices
  - detailed modelling of CCD radiation damage effects at ESA, Open University and CEA Saclay

- Learning the lessons from the Gaia PEM programme, prototype Euclid flight design Read Out Electronics have been designed and fabricated
  - same electronic components as flight but commercial packaging

Test Bench at MSSL

Early PSF at MSSL

Undamaged (left) / damaged (right) CCD PSF

First image with representative CCD and ROE

Early effort to ensure that CCD damage radiation will be manageable in the frame of Euclid
Mass and Power Budget

- Mass Budget ongoing work of mass reduction:
  - So far only one design loop with sub systems, margin are accumulated on both sides of each subsystems interfaces

- Power Budget:
  - Average power budget. For constant power dissipation, additional 10%.
  - Power estimation of VIS electronics is based on measurements on representative bread board

<table>
<thead>
<tr>
<th>S/S</th>
<th>EIC Mass (margin 20% in kg)</th>
<th>EIC Average Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIS imager</td>
<td>62 kg</td>
<td>~112 W</td>
</tr>
<tr>
<td>NIP imager + CCU</td>
<td>96 kg + 17 kg</td>
<td>~31 W</td>
</tr>
<tr>
<td>COMA</td>
<td>107 kg</td>
<td></td>
</tr>
<tr>
<td>PDHU + PMCU</td>
<td>16 kg + 14 kg</td>
<td>~62 W + 18 W</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>~312 kg</strong></td>
<td><strong>~223 W</strong></td>
</tr>
</tbody>
</table>
NIP
The Near Infrared Imaging Photometer Channel for EUCLID

18/11/2009

Mario Schweitzer
EIC National Study Manager Germany

(Max Planck Institute for Extraterrestrial Physics)
### NIP Overview

<table>
<thead>
<tr>
<th></th>
<th>NIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>detectors</td>
<td>3 x 6 = <strong>18</strong> H2RGs</td>
</tr>
<tr>
<td>FOV</td>
<td>~ 0.5 deg²</td>
</tr>
<tr>
<td>band(s)</td>
<td>Y: 920-1146 J:1146-1372, H:1372-2000 (2500) nm</td>
</tr>
<tr>
<td>PSF FWHM</td>
<td>0.3ʼʼ @ 1259 nm</td>
</tr>
<tr>
<td>pixel scale</td>
<td>~ 1 pix. per PSF FWHM (J)</td>
</tr>
</tbody>
</table>

| limit. magAB     | wide survey (20000deg²) 24 (5 sigm. point source) |
|                  | calculation: J-band S/N=5 with 3 x 68s images (max. 140s / image) |

| limit. magAB     | Deep survey (> 40 deg²) 26 (5 sigm. point source) |

*NIP (with thermal shield (yellow))

---

Euclid Imaging Consortium— 18/11/2009

Diffusion restriction as stated on page 1
- **optical base plate:**
  - 2mm CFRP LTM 123 M55J
  - 96mm Honeycomb (Al)
  - 2mm CFRP LTM 123 M55J
Mechanical Design

- **optical base plate:**
  - 2mm CFRP LTM 123 M55J
  - 96mm Honeycomb (Al)
  - 2mm CFRP LTM 123 M55J
Mechanical Design

- Backside of VIS shutter
- Calibration source for NIP
Electronics Design

- Electrical architecture schematics
  - (with Astrium Ottobrunn)

- Assume: 4 channel mode (up the ramp) @ 200 kHz:
  - 26 non destr. reads per ramp

- Data processing:
  - Assume algorithms for:
    - slope generation + glitch detection + saturation detection

  ➔ no critical issues identified
    - (w.r.t. comp. power, memory, data rate)

- In total:
  ➔ 105 MOPS/s
  ➔ required intermediate memory: 15 Gbit
    - (incl. storage of EDAC info.)

- Total downlink rate per day (2.5 compression): 207 Gbit
Assessment phase Study

- demonstrated feasibility of:
  - optical design
  - mechanical design
  - thermal design
- identification and investigation of critical parameters:
  - Radiator Sizing
  - Small PSF FWHM
  - Cryolenses
  - Filter(holder)
  - Eigenfrequencies
  - Structural Stability
  - Mass

Critical issues have been identified but no show stopper and demonstration of feasibility
Instrument AIV and Test

- CCD characterisation test bench at MSSL and CEA (Cryogenic / before after radiation)
- NIR FPA characterisation test bench at MPE and JPL
- Class 100 clean room
- Metrology Facility
- Bake out Facility
- Vacuum Chamber (from component to instrument size)
- Vibration and shock test facility
- Great experience in all those AIV sequence within the consortium