



MOAO design specificities and performance for EAGLE

the high resolution multi-object spectrograph for the E-ELT

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and the EAGLE team

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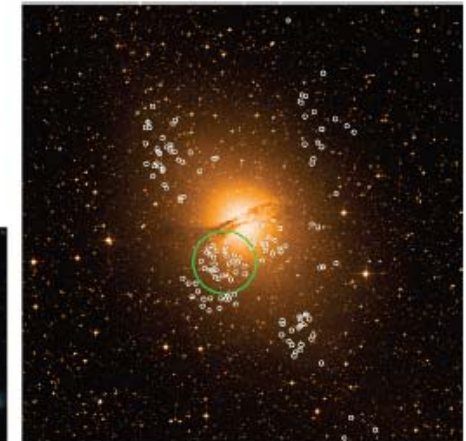
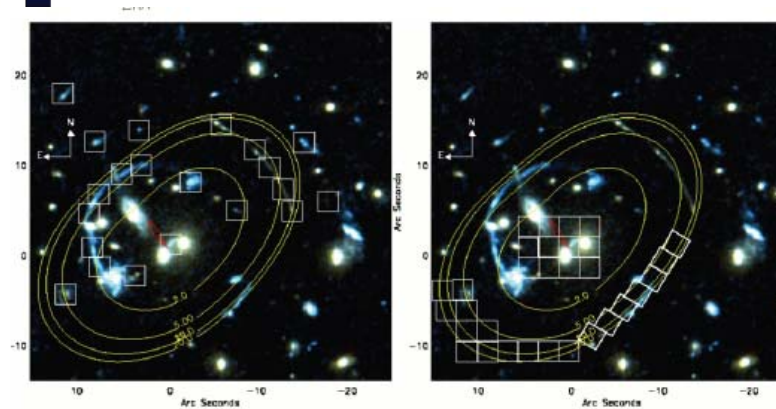
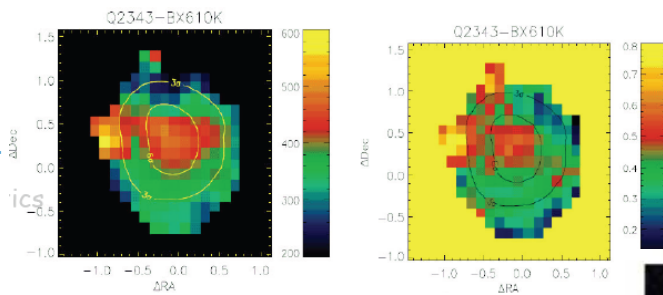




EAGLE science cases

- EAGLE will be the instrument of choice for several E-ELT science projects, in synergy with JWST:
 - Spatially resolved properties of distant galaxies
 - Detection and characterisation of the Highest Redshift Galaxies
 - Physics of galaxy evolution from stellar archaeology

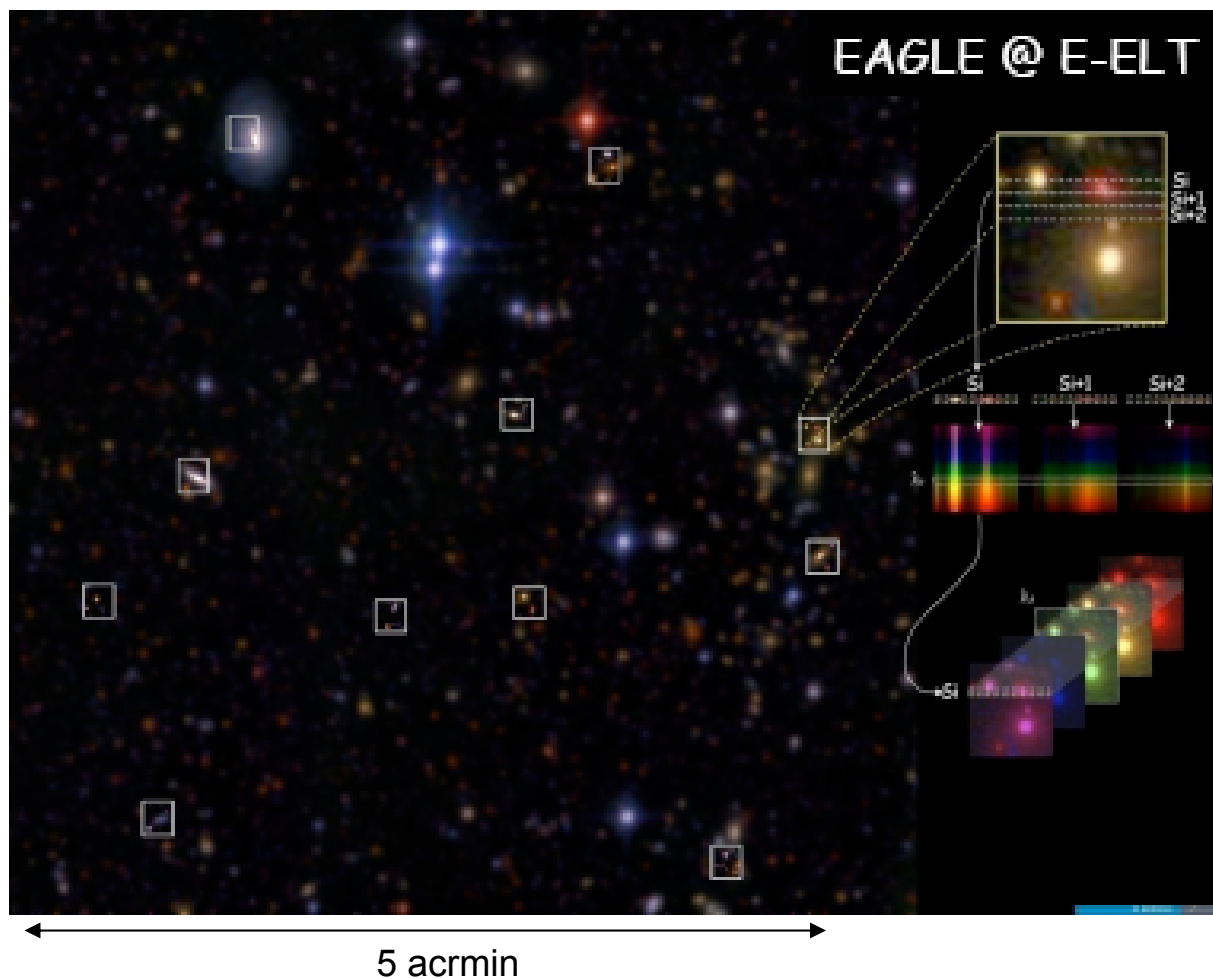
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EAGLE: multi-IFU AO-fed near IR spectrograph

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Main Functions:

- Target Acquisition
- Adaptive Optics
- Image slicing & spectroscopy



EAGLE: Main system Requirements

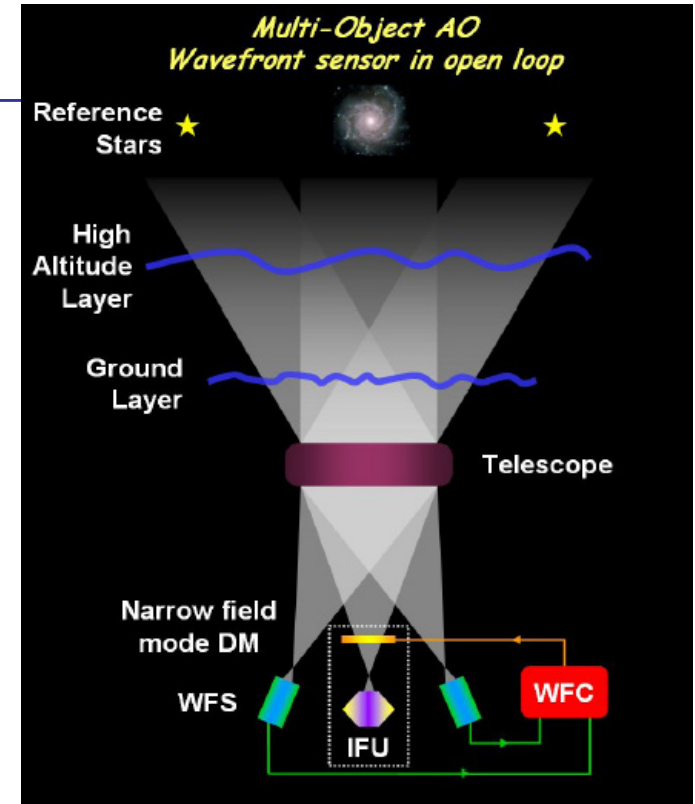
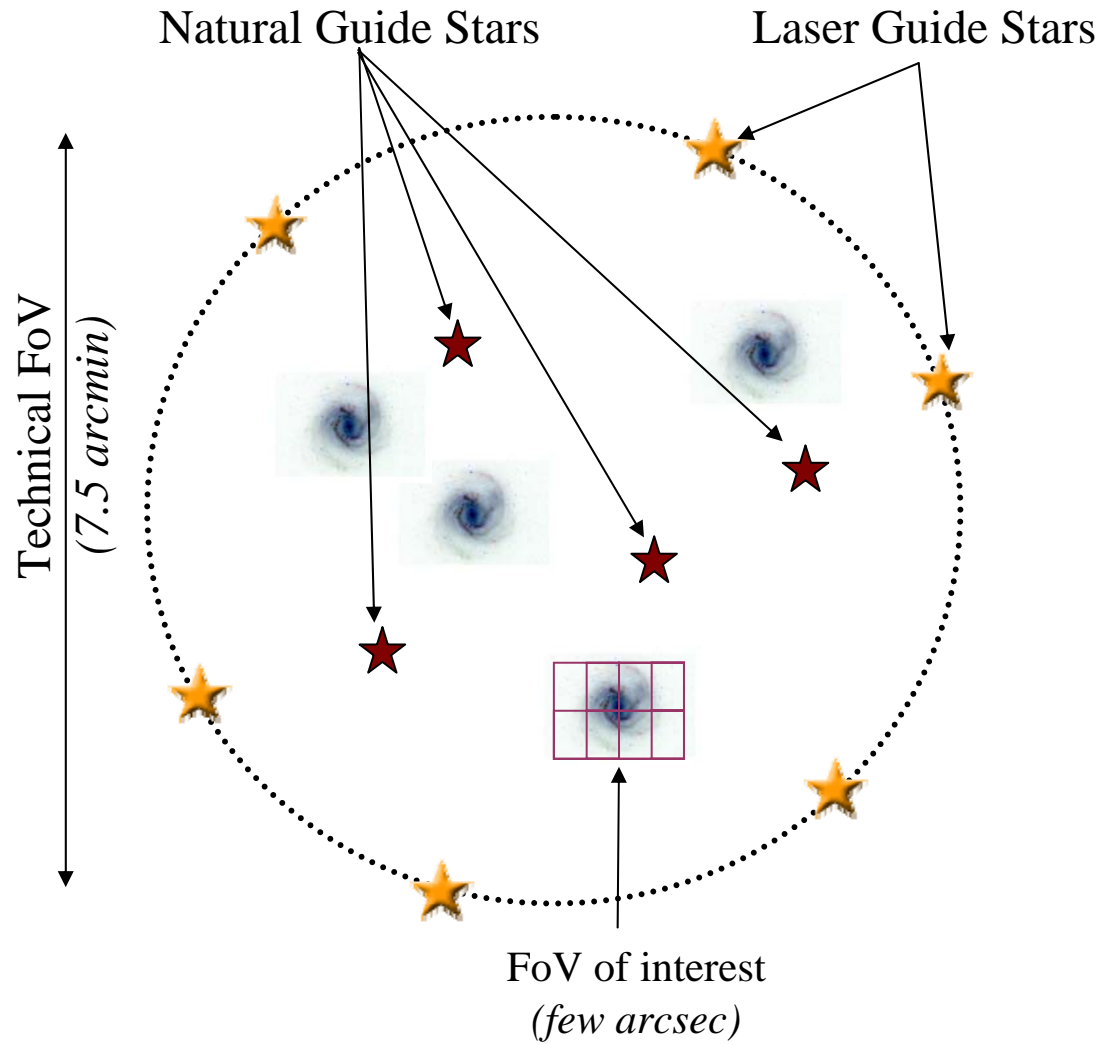
Parameter	Requirement
Field of View	> 5' diameter
Integral Field Unit (IFU)	> 1.5" x 1.5" each
Multiplex	> 20
Spatial resolution	> 30% Ensquared Energy (EE) in 75 mas (H-band)
Spectral resolution	4,000 10,000
Wavelength Coverage	0.8 - 2.4 μm
Clustering / tiling	Distributed & clustered targets + ability to map

Requires Adaptive Optics!

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MOAO concept



- Several off-axis GSs (in the technical FoV)
⇒ perform a full tomographic estimation
- Optimal correction applied locally
⇒ on each FoV of interest

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MOAO error budget

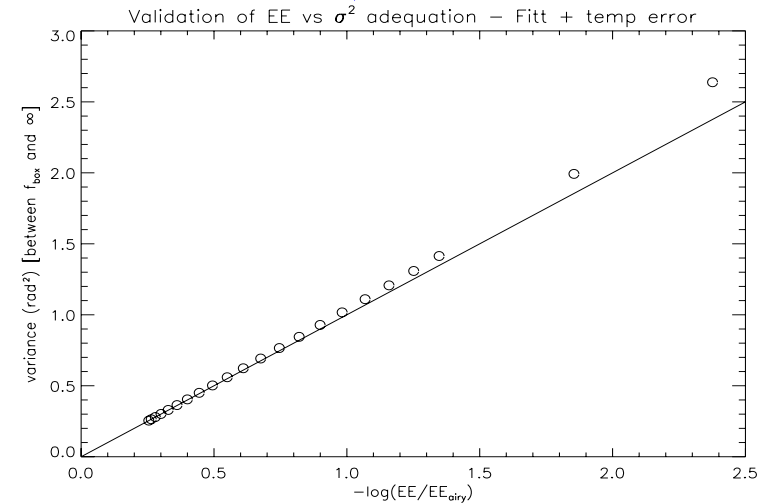
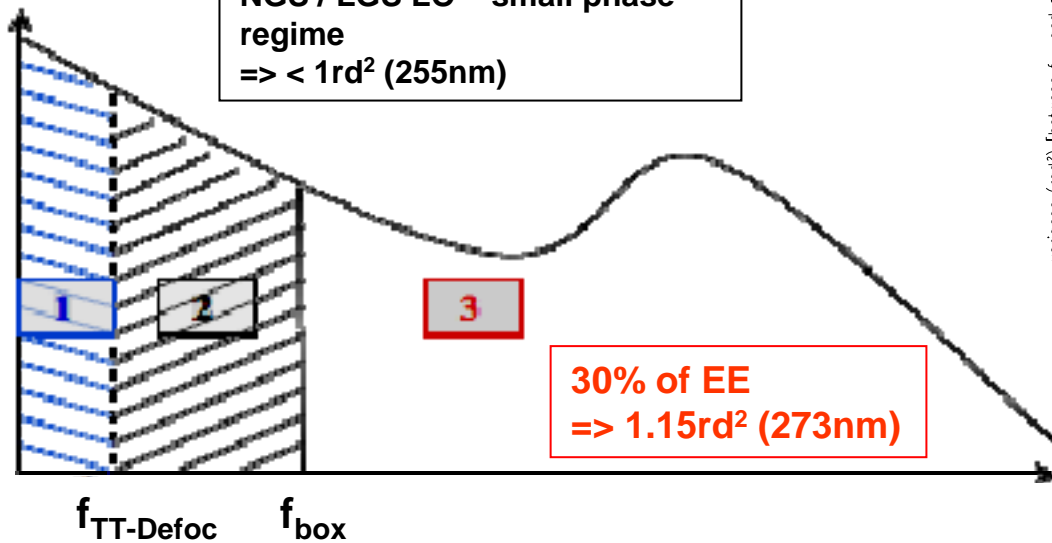
Definition of pertinent metrics

EAGLE spec : > 30 % of EE \Rightarrow Good AO correction regime

\Rightarrow Direct link between EE and σ^2

NGS very LO :
 \Rightarrow TT < 20mas rms (17rd²) & Focus < 1rd²

NGS / LGS LO – small phase regime
 \Rightarrow < 1rd² (255nm)



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- | | | |
|--|---|--|
| <ol style="list-style-type: none"> 1. NGS very Low Order 2. NGS/LGS Low Order 3. NGS/LGS high Order | } | <p>Very little impact on EE</p> <p>Huge Impact on EE</p> |
|--|---|--|



EAGLE AOS with LGS and NGS

EE versus number of actuators (= number of LGS subap.)

H band, Seeing 0.87", XMM Sub-fields: #1, worst case

6 LGS on 7.2' ring, ~ 400ph per subap.

4 NGS ($m_R < 17$) in 7.3' patrol field (64 subap. WFS)

Telescope Diameter = 42 m, seeing = 0.8 arcsec @ 0.5 mic.

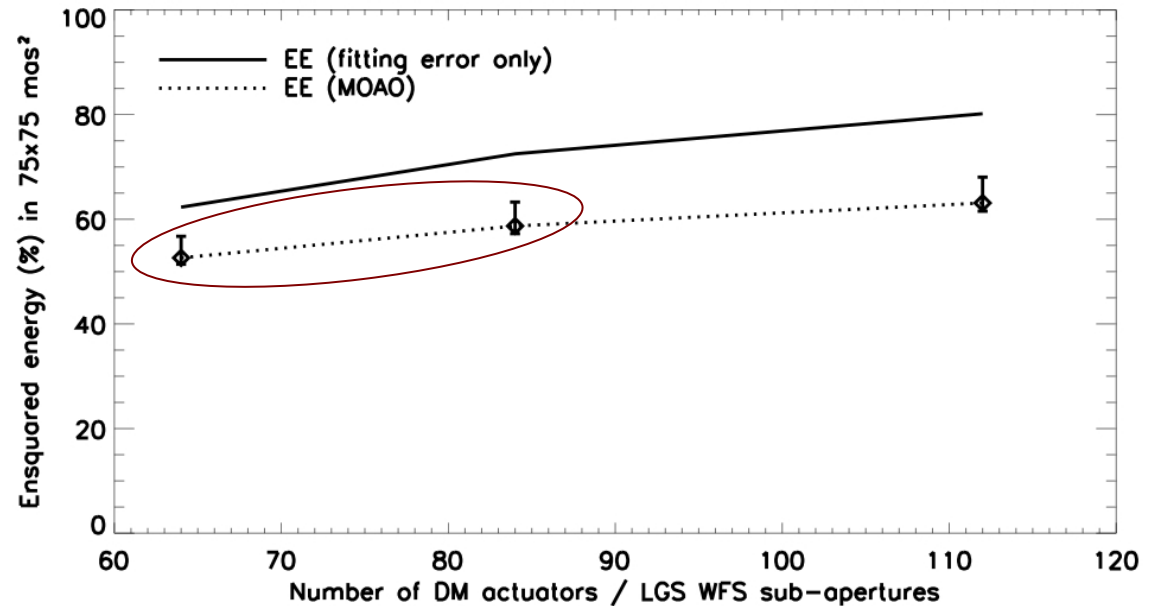
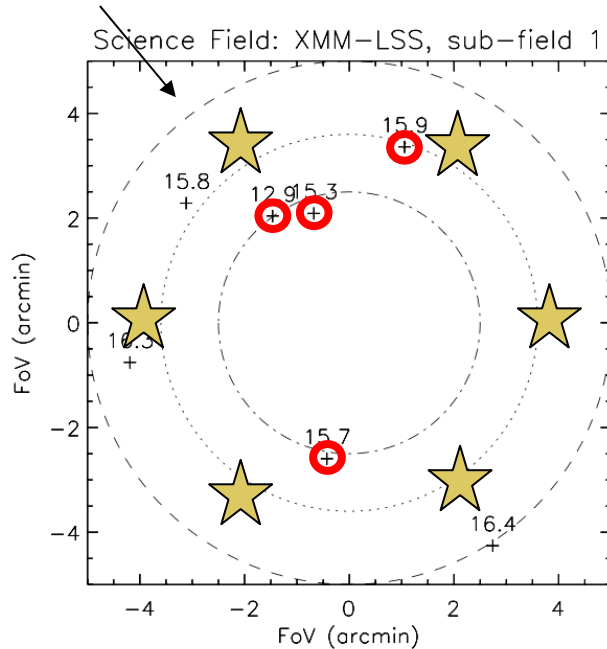
6 LGS, noise variance = 1 rad² @ 0.589 mic.

NGS Pick-Up FoV: 7.3 arcmin, $R_{lim} = 17$, N_{max} NGS WFS = 5

NGS WFS: 64 x 64 sub-apertures

Science Field: XMM-LSS, sub-field 1, FoV diameter = 5 arcmin, H bar

10' FoV





Sky coverage

Three separate analyses of NGS availability (7 arcmin field):

- EAGLE study of randomly-selected fields at $50^\circ < |b| < 90^\circ$
- Besançon sky model for fields at $|b| = 60^\circ$ & 90°
- ESO sky coverage analysis (Calamida, 2009, E-TRE-ESO-080-0588)

Mean densities ($R < 17$) from SuperCOSMOS archive

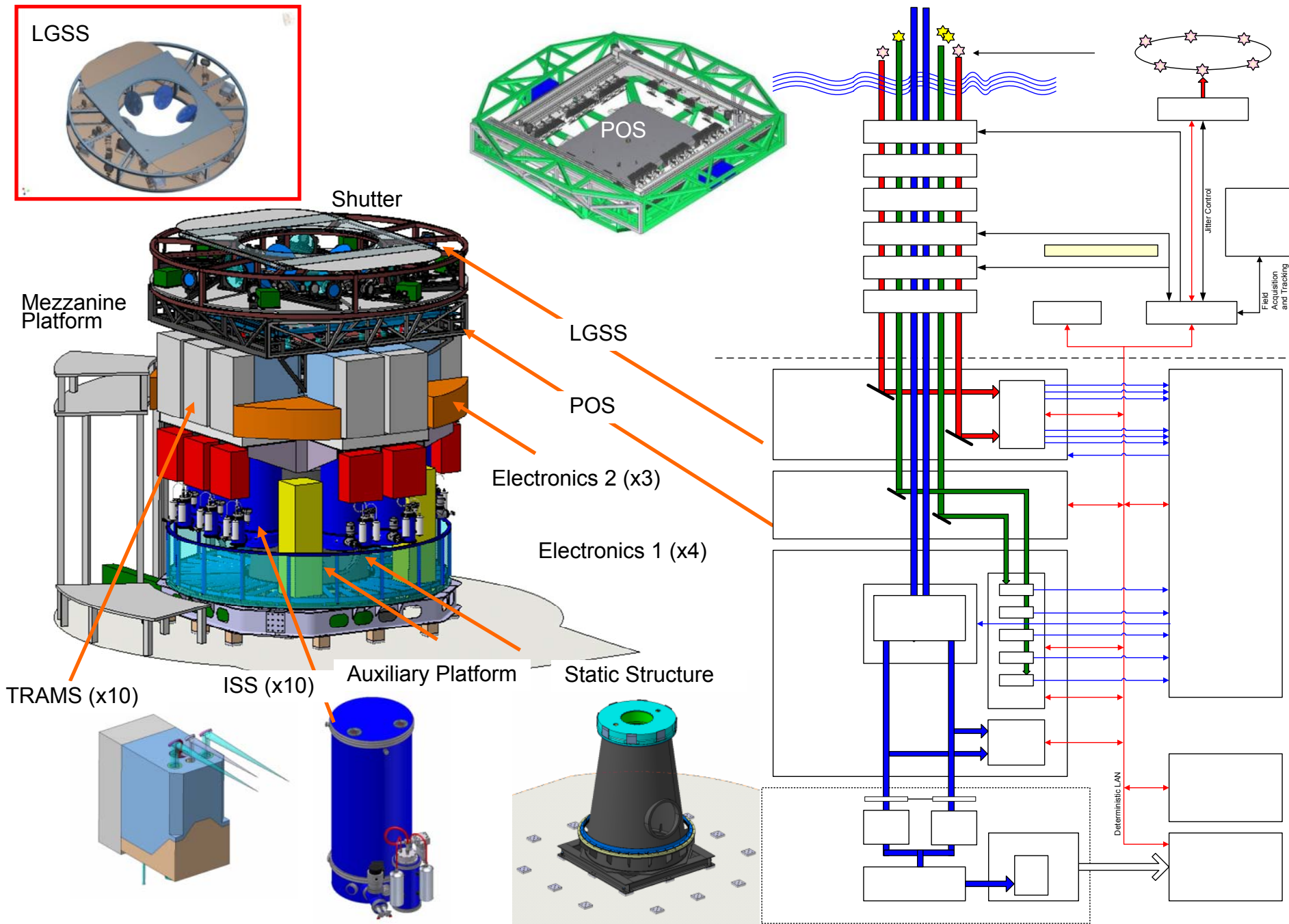
6.2 stars at $|b| = 60^\circ$

4.6 stars at $|b| = 90^\circ$

(cf. "poor" NGS configuration in simulations - only 4 NGS with $R < 17$)

In all three, the large EAGLE patrol field provides excellent sky coverage for AO, while maximising the science targets available

EAGLE Overall Architecture



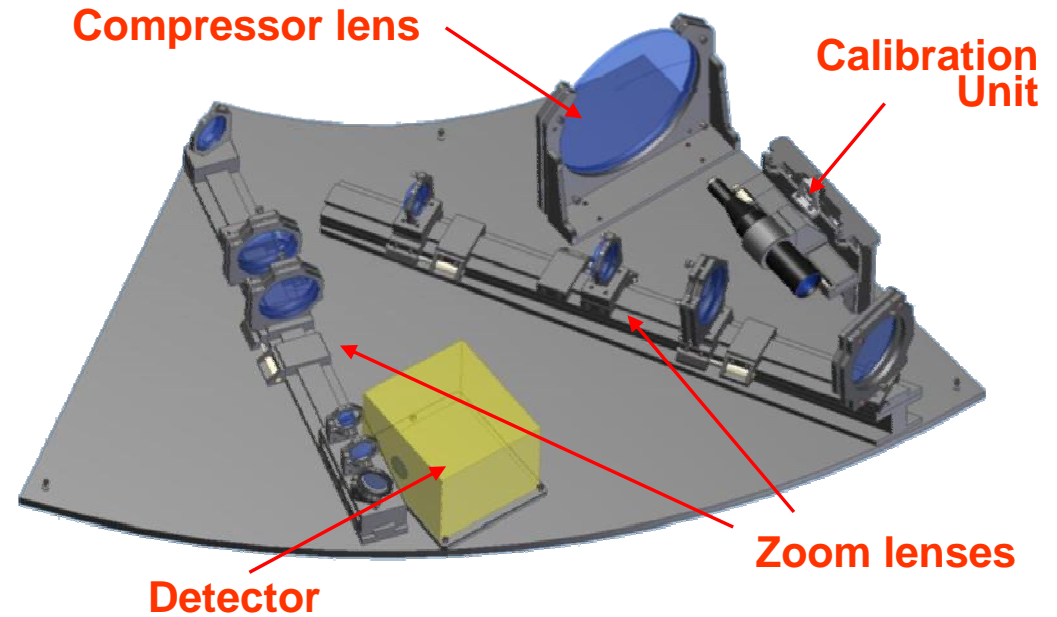
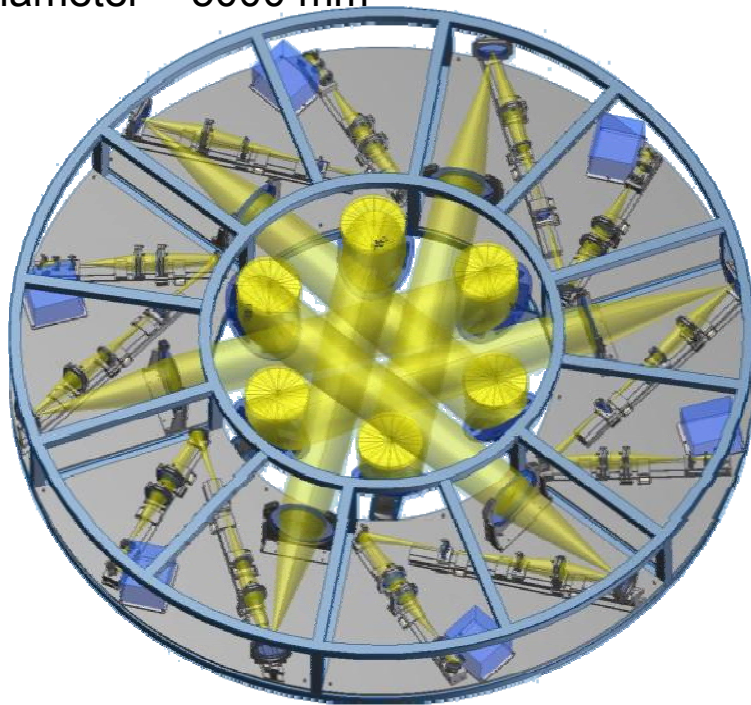


Laser Guide Star Sensing System (LGSS)

Performs LGS wavefront sensing on a 6 LGS asterism with an on-sky diameter of 7.5 arcmin

Corrects for the ~5m path length change due to the varying distance to sodium layer

Diameter = 5000 mm



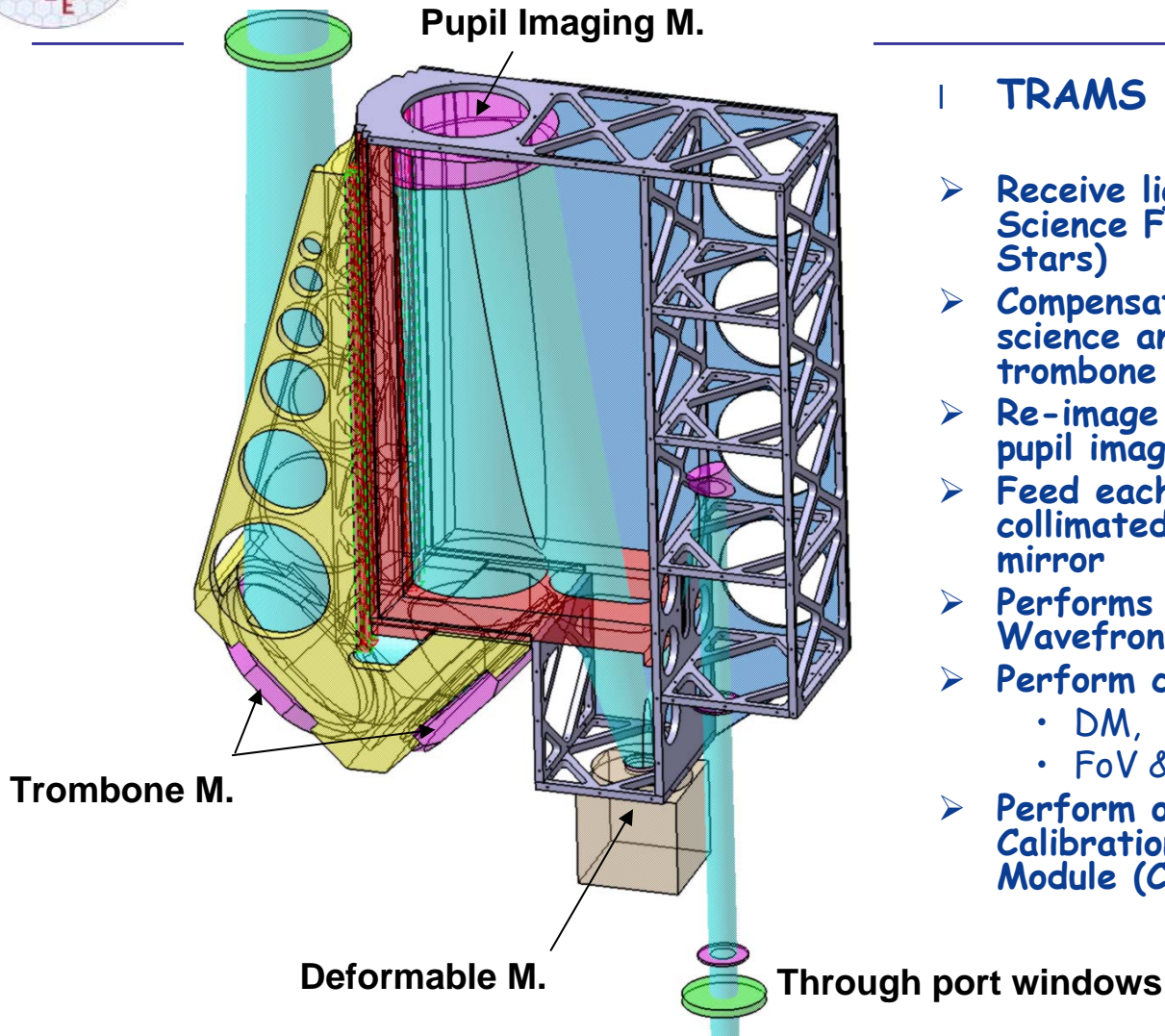
Six identical LGS WFS modules are mounted on a support structure

4 lens zoom-based focus compensation system – VCM an alternative

Less than 1/1000th pupil diameter change over full range of compensation



Target Re-Imaging and Magnification System (TRAMS)



TRAMS Main Functions:

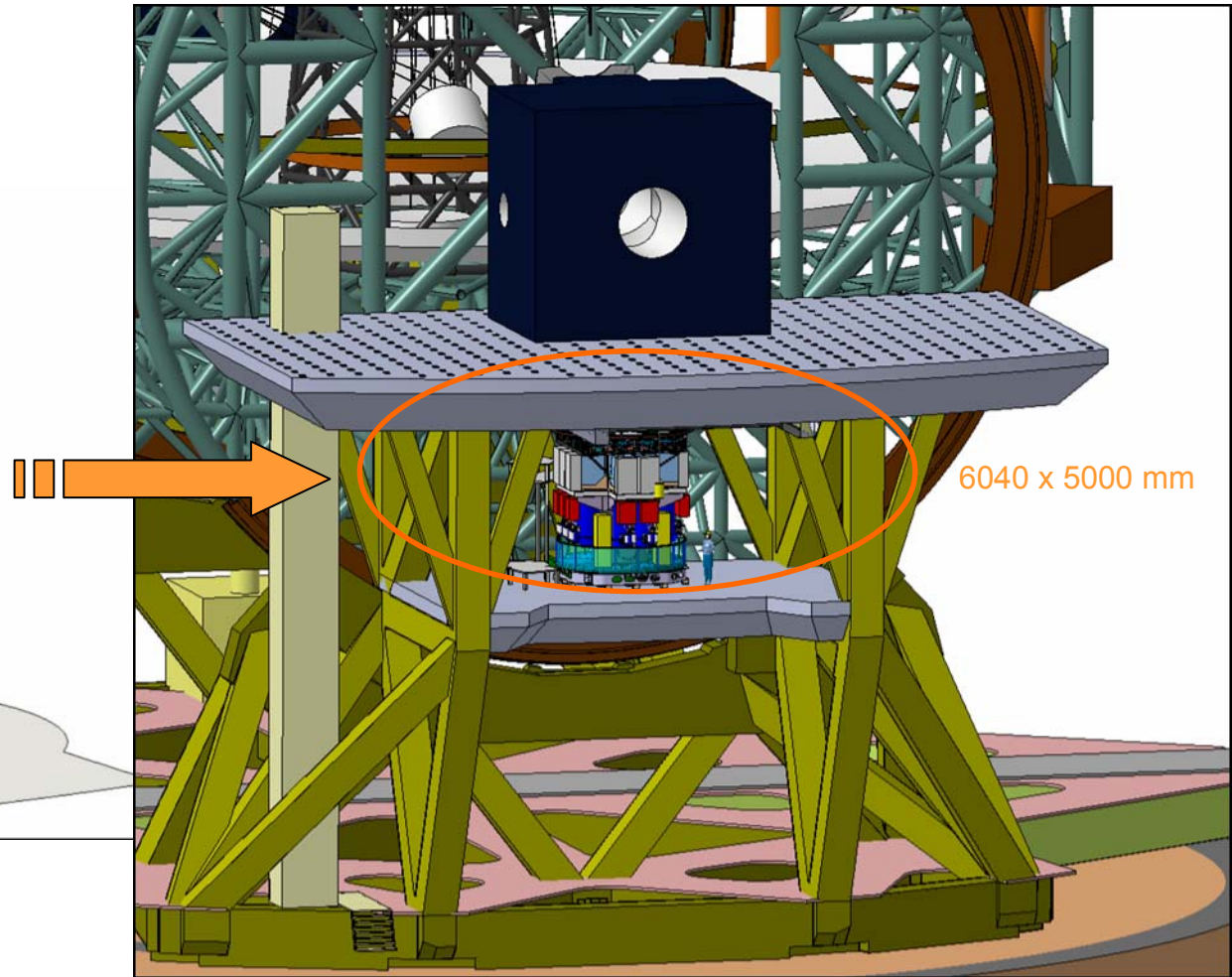
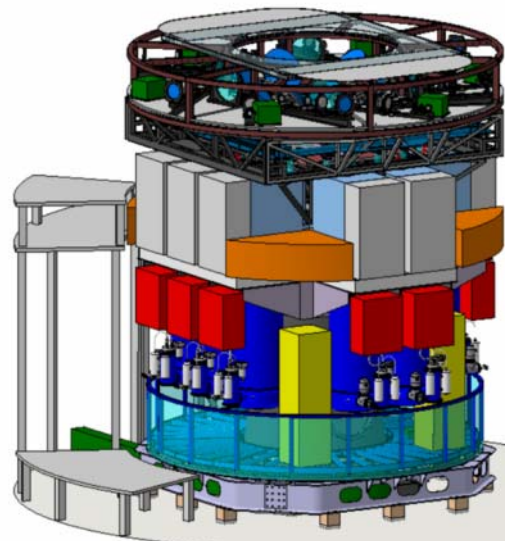
- Receive light from POS BSM (20 Science Fields and 6 Natural Guide Stars)
- Compensates path length of each science and NGS channel by using a trombone
- Re-image pupil on the DM using a pupil imaging mirror (PIM)
- Feed each ISS channel with a 30mm collimated beam using a collimating mirror
- Performs Natural Guide Star Wavefront Sensing (NGSS)
- Perform calibrations:
 - DM,
 - FoV & Pupil
- Perform optical alignment using the Calibration and Alignment Sensor Module (CASM).

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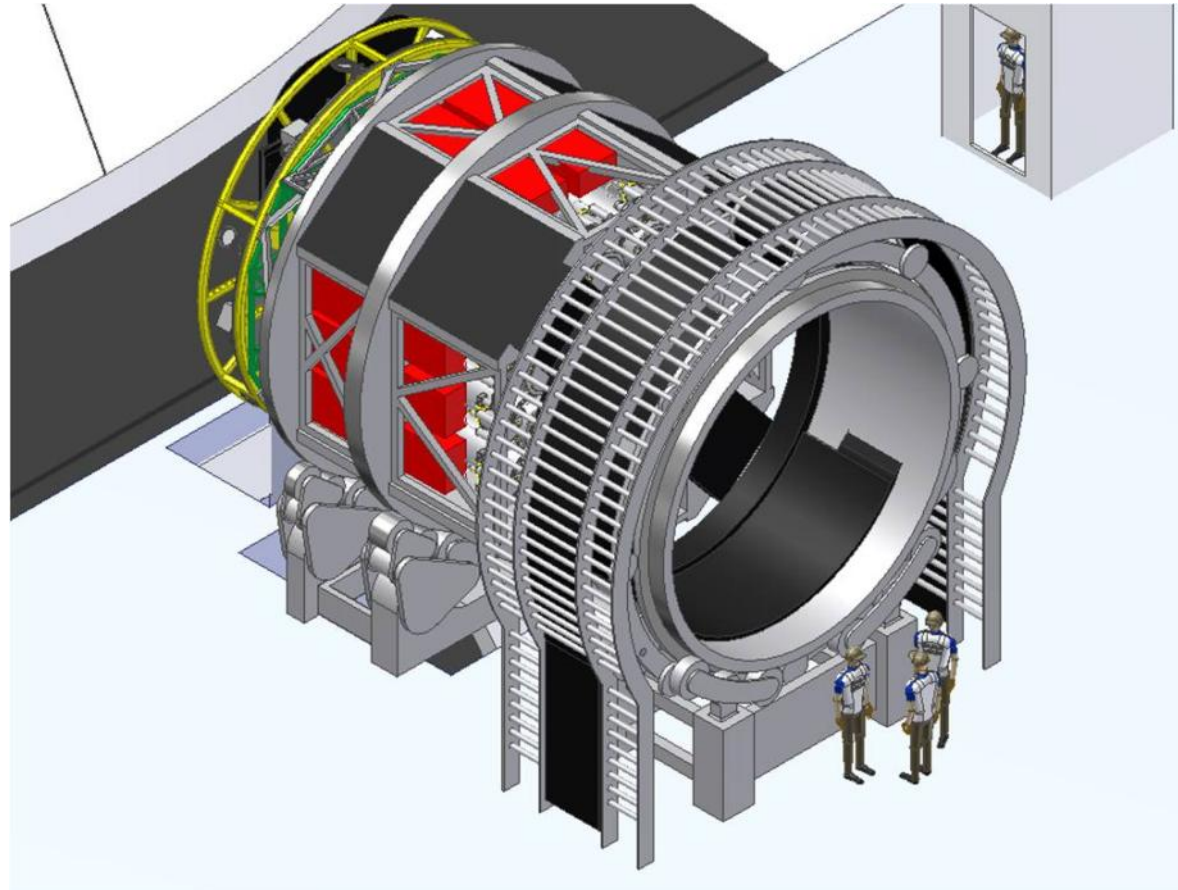
EAGLE installed in the GIFS

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EAGLE at the straight through Nasmyth Platform



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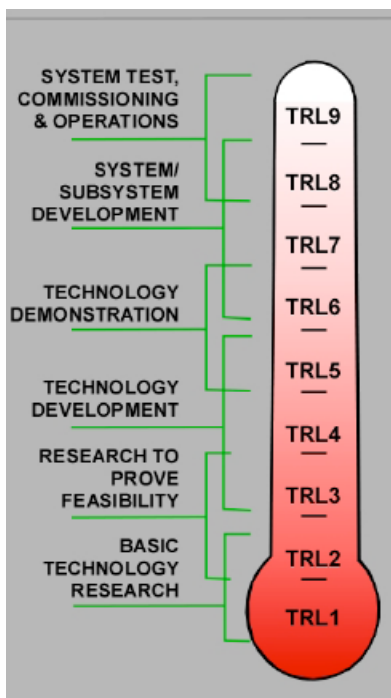


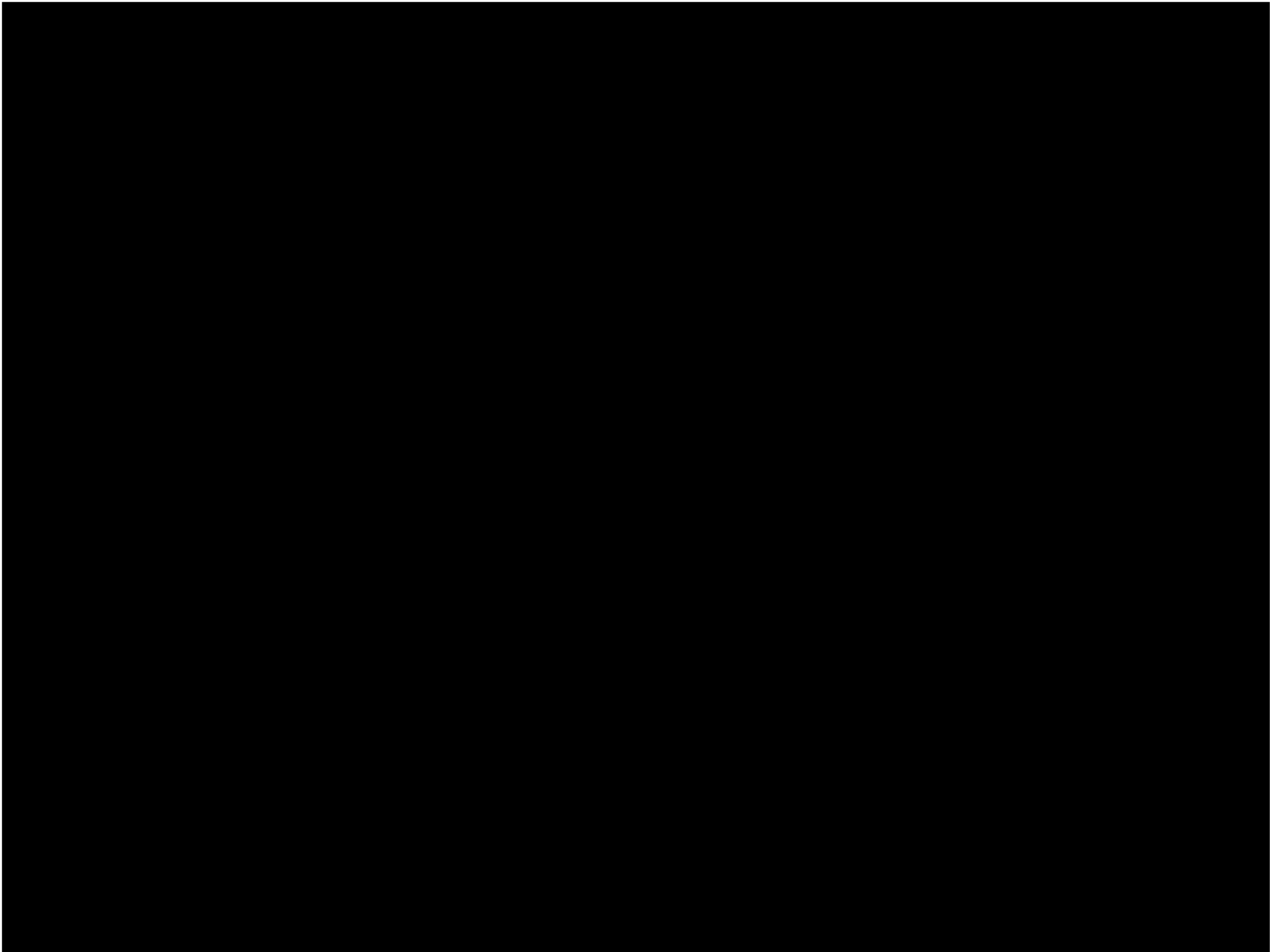


Conclusion

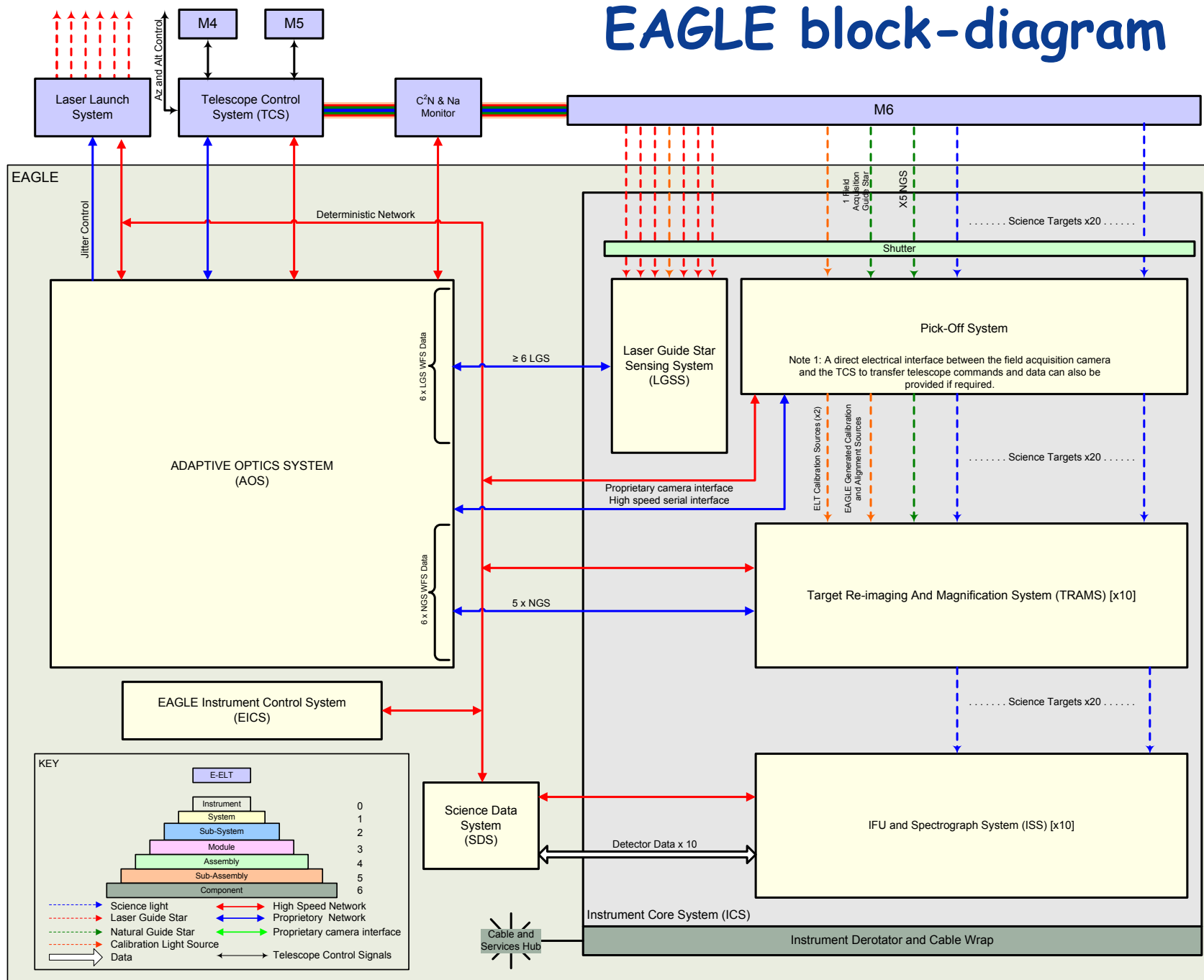
- Multi-IFU near IR - AO assisted - spectroscopy is a key scientific requirement for ELTs
 - The EAGLE design for the E-ELT achieves this requirement at an affordable cost and without technical showstoppers
 - The Technological Readiness Level (TLR) of all components is high
 - **TLR 7 to 9** for all components but for the 6k actuators DMs
 - Back-up is a 4k DMs
 - MOAO has recently achieved a **TLR 6-7** with the CANARY demonstration (see E. Gendron Talk)
 - Laser / Natural Guide star MOAO operation will be demonstrated (lab and on-sky) in the coming months
- ➔ **EAGLE concept is mature and the instrument ready to be built**

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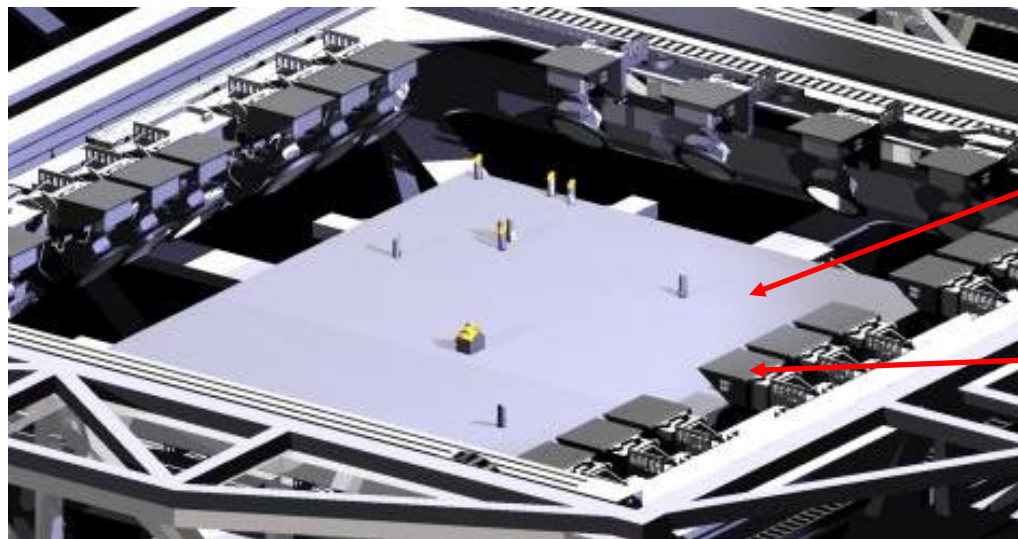


EAGLE block-diagram

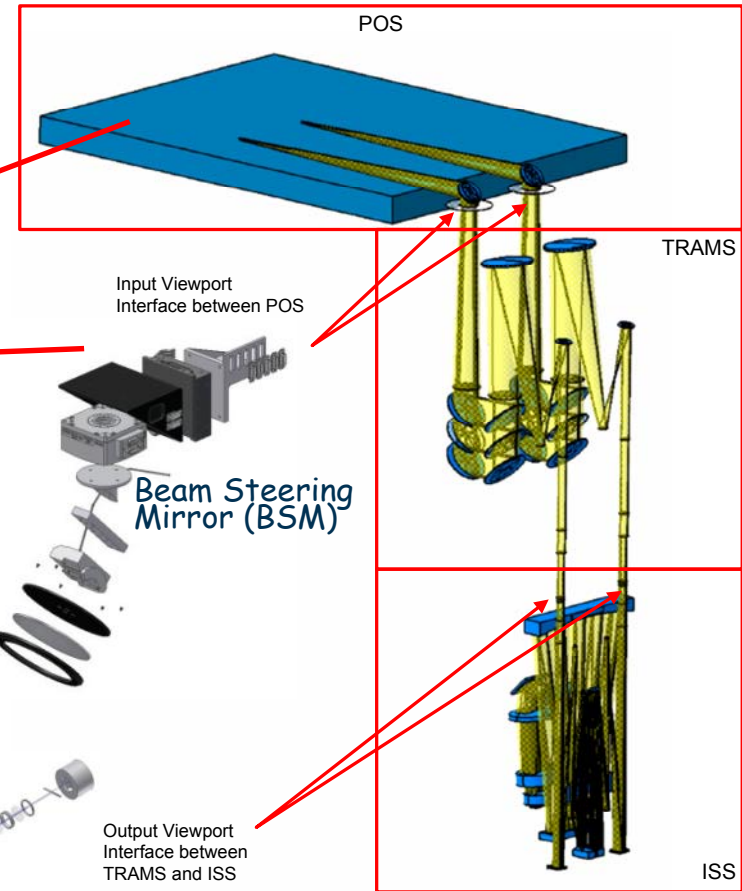




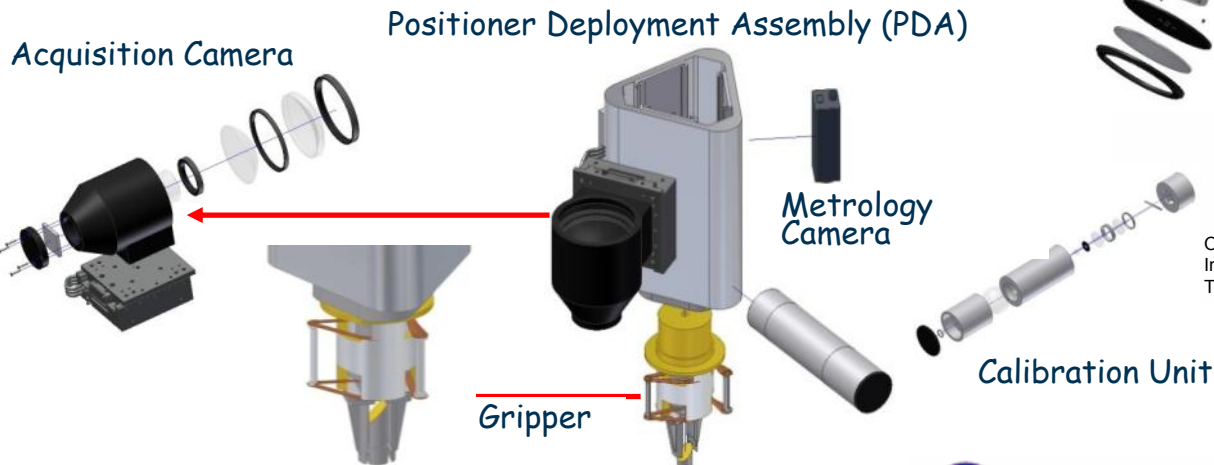
Pick-Off System (POS)



5000 mm x 5000 mm



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LESIA



Galaxies Étoiles Physique et Instrumentation



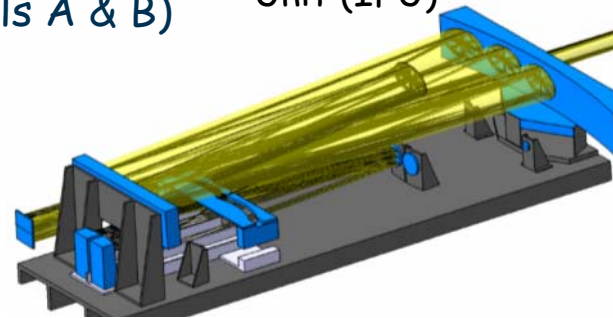
UK Astronomy Technology Centre



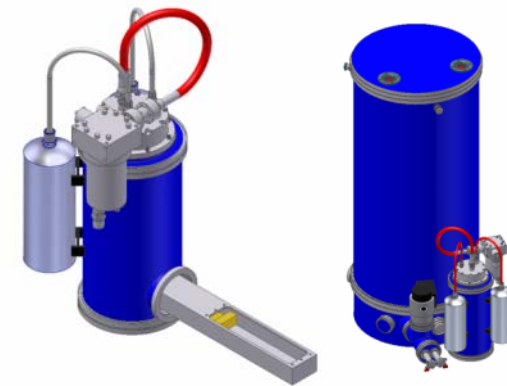
IFU Spectrograph System (ISS) (x10)

ISS consists of:
 2 IFU (science channels A & B)
 1 Spectrograph with
 • 4 K x 4 K detector

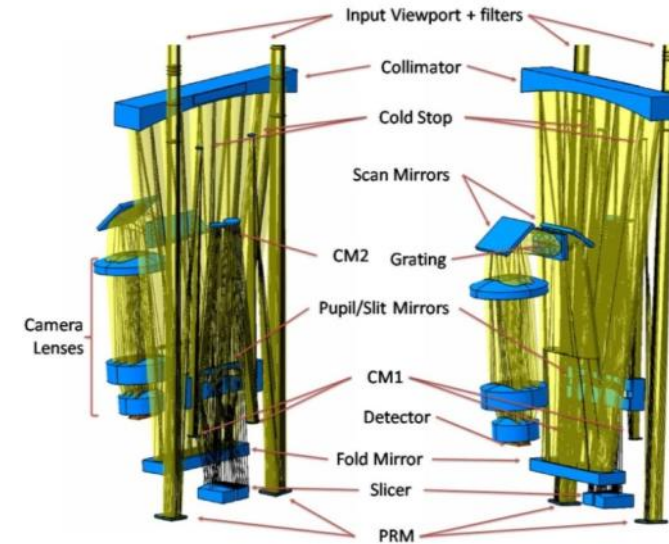
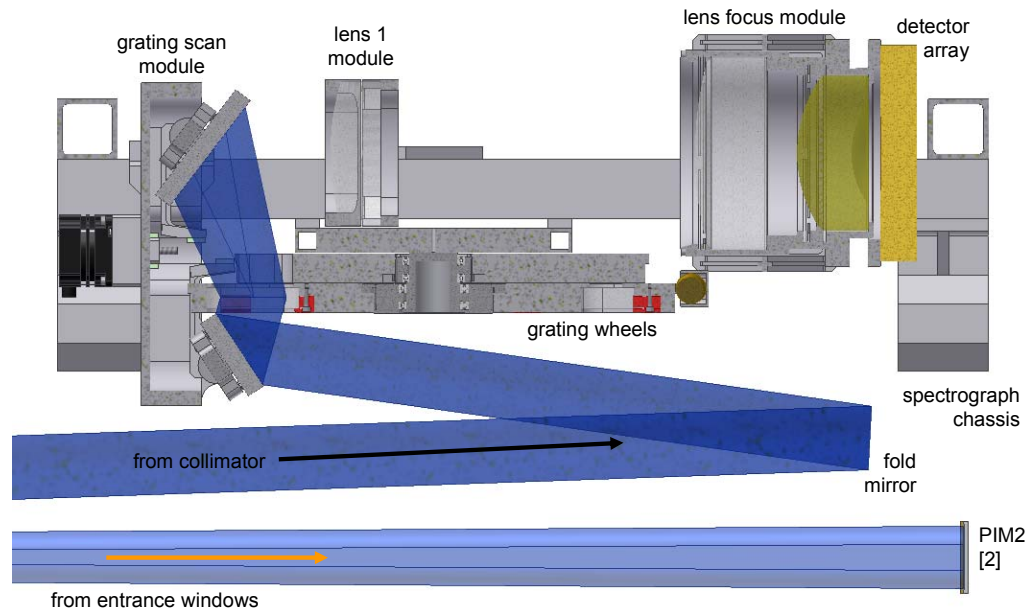
Integral Field Unit (IFU)



Cryostat sub-system



cross-section of spectrograph



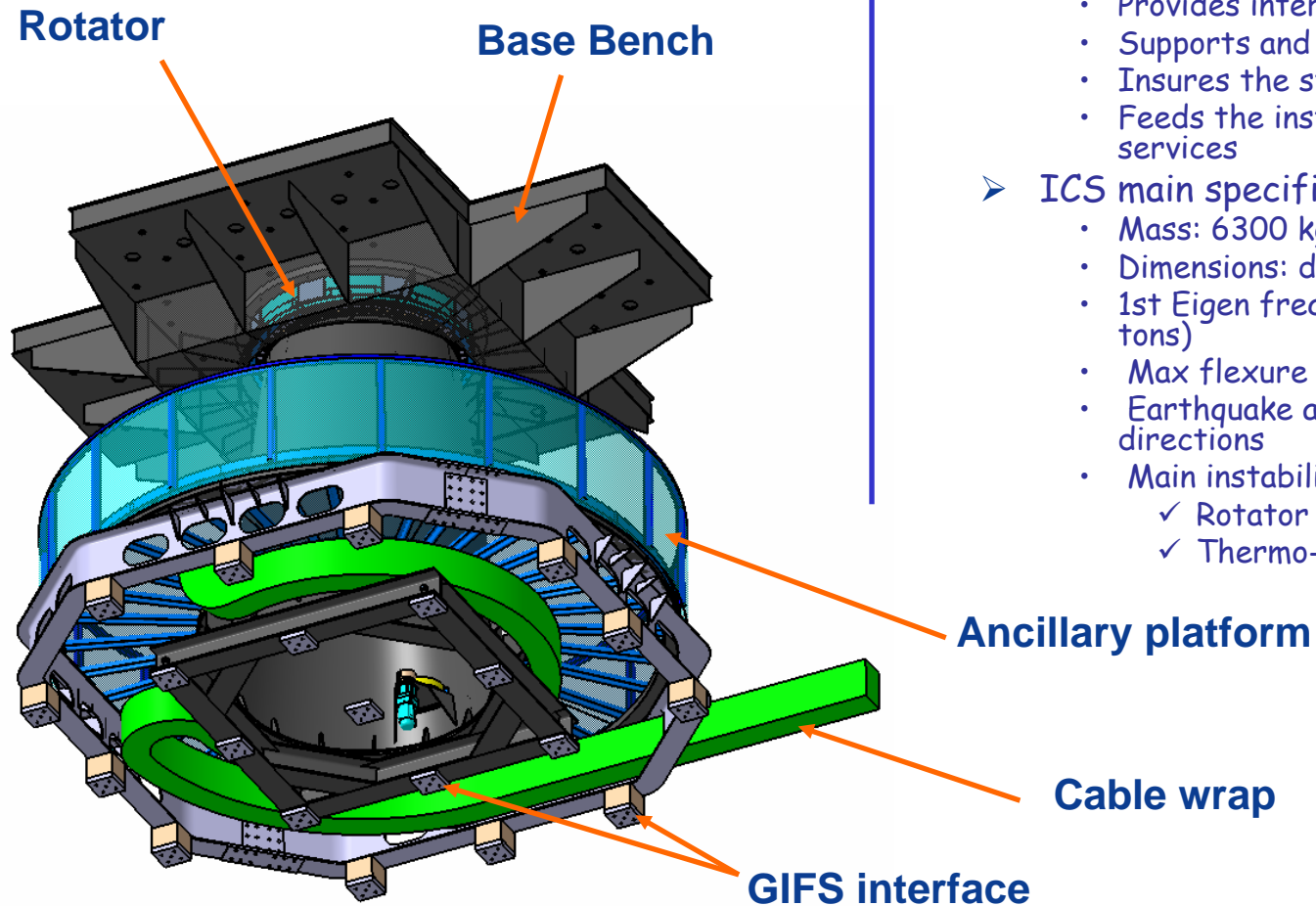
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Instrument Core System (ICS)

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- ICS functions:
 - Provides interface with GIFS
 - Supports and rotates optical channels
 - Insures the stability during exposures
 - Feeds the instrument with all needed services
- ICS main specifications:
 - Mass: 6300 kg
 - Dimensions: diameter 5 m, height 3.34 m
 - 1st Eigen freq.: 15 Hz (with payload 16 tons)
 - Max flexure under gravity: 400 μm
 - Earthquake accelerations of 5g all directions
 - Main instabilities (per hour)
 - ✓ Rotator wobble: 40 μrad
 - ✓ Thermo-elastic bending: 11 μrad