



THE EUROPEAN ELT

- **A project lead by ESO on behalf of 14 member states**
 - 42m adaptive telescope with segmented primary based on a 5-mirror design
- **In Phase B since Jan 2007**
 - Goal of Phase B: Proposal for construction by 2010
- **Schedule:**
 - Detailed design phase until end 2010
 - External reviews: Mid-term (May 2009), construction (Sep 2010)
 - Start of construction: 2011
 - First light: 2019
- **Cost**
 - Telescope + 1st gen instruments: ~ 1 Billion Euro
 - Operations (incl new instruments, overheads): ~ 50 M€/year
- **Resources**
 - 2007-2009: 57.2 M€ (including 110 FTEs)
 - Supporting activities from FP6 (28.8 M€, concluded) & FP7 (6.1 M€, ongoing)



THE TASK

ESO's Strategic Principles

ESO Council Resolution, Dec.2004

- **Retention of European astronomical leadership into the era of Extremely Large Telescopes**
- Assure completion of ALMA, and efficiently exploit its superb scientific capabilities
- Maintain VLT in world-leading position for another 10-15 years by continued upgrades
- Exploit *unique* capabilities of the VLT
- **Lead in the construction of an ELT on a competitive timescale**



ELT effort re-oriented at the end of 2005 towards "the best affordable ELT Facility that can be built on a competitive timescale and with acceptable risks"



THE DRIVER

- **Planets in other stellar systems**

- Imaging *and* spectroscopy
- *The quest for Earth-like exo-planets*

- **Stellar populations**

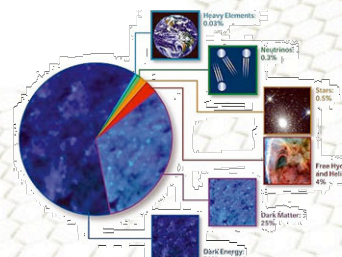
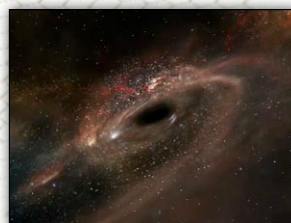
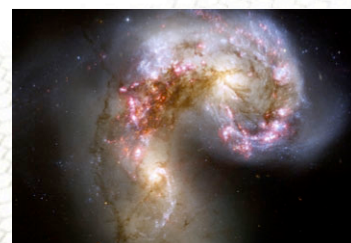
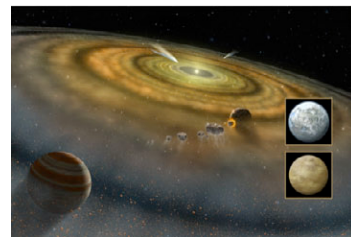
- In galaxies inaccessible today (e.g. ellipticals in Virgo cluster)
- Across the whole history (i.e. extent) of the Universe

- **Cosmology**

- The first stars/galaxies
- Direct measure of deceleration
- Evolution of cosmic parameters
- Dark matter, dark energy
- Tests of GR around black holes

- **The unknown**

- Open new parameter space





ELT SCIENCE CASE DEVELOPMENT IN EUROPE



Florence 2004



Web site



Marseilles 2003

Science case documents

Marseilles 2006



THE SCIENCE CASE: THREE PILLARS

- Contemporary science: *Today's clever ideas* → *the DRM*
- Synergy with other facilities:



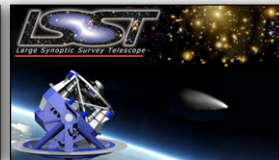
8-10m telescopes



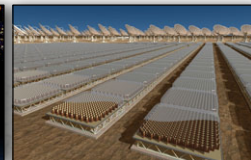
ALMA



JWST



LSST



SKA

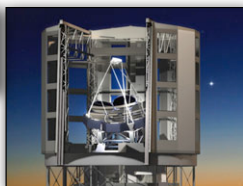
- Discoveries: *Opening parameter space* (*photon sensitivity, spatial resolution*)



VLT

~50 m²

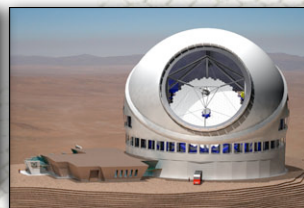
1µm: 25 mas



GMT

~400 m²

9 mas



TMT

~600 m²

7 mas



~1200m²

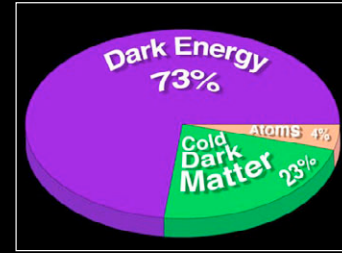
5 mas

(JWST: 25 m²)

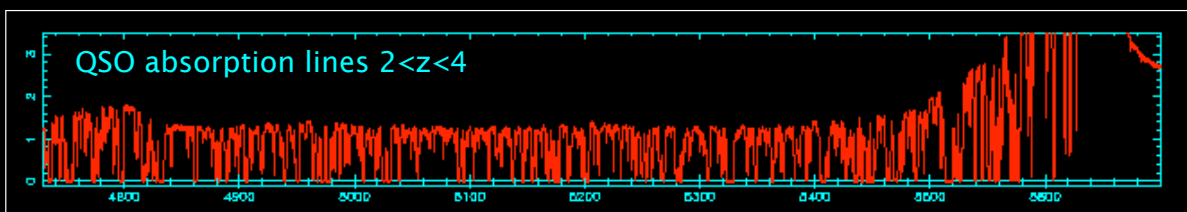
(JWST: 34 mas)

(With thanks to Markus Kissler-Patig and Isobel Hook)

Watching the Universe accelerate in real time



- What is the Dark Energy?
- E-ELT can measure acceleration **directly**, in real time
- Fundamentally different probe (dynamical vs geometrical)
- Weak signal: \sim cm/s/yr. Requires:
 - ELT (collecting area)
 - 20 year monitoring campaign
 - Ultra-high stability, high-resolution spectrograph (CODEX)



J. Liske et al., MNRAS, 2008 and Final DRM report

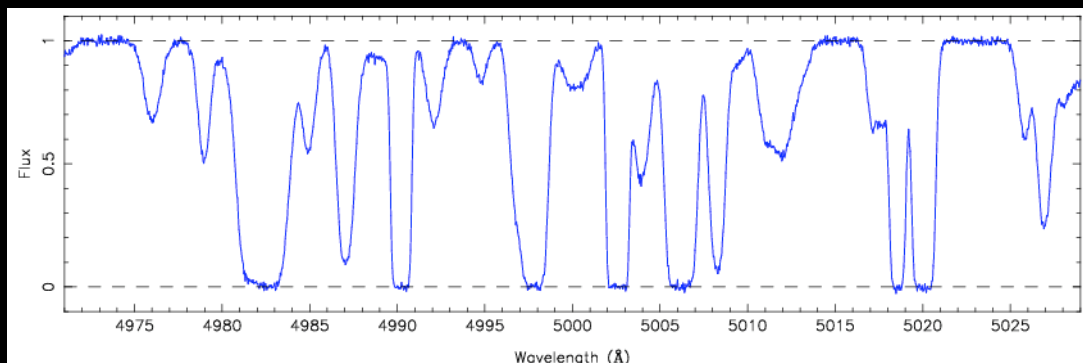
Cosmic Dynamics Experiment

$$\dot{z} = \frac{dz}{dt} = (1+z) H_0 - H(t_e)$$

Measuring the redshift drift requires:

- Many photons, high resolution, extremely stable spectrograph
- \sim 20 yr long spectroscopic monitoring campaign

Best place to observe the redshift drift: the Lyman- α forest.



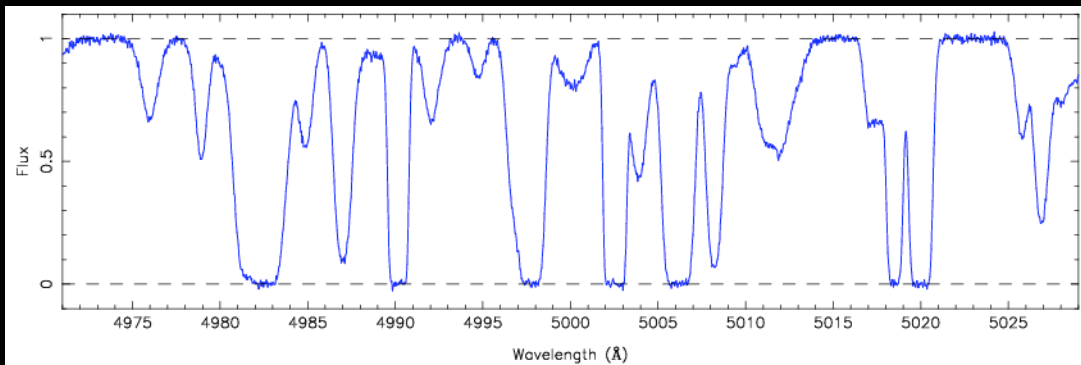
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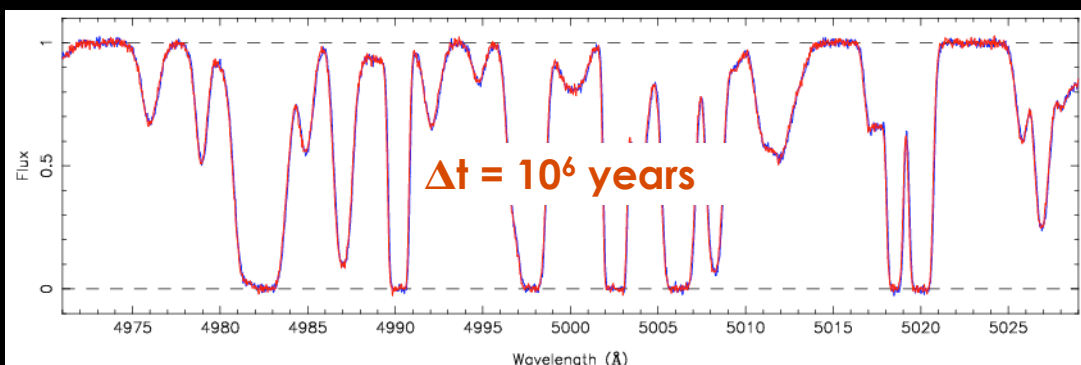
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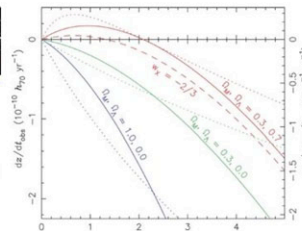
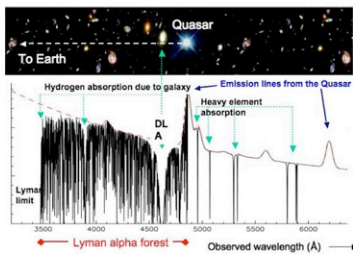
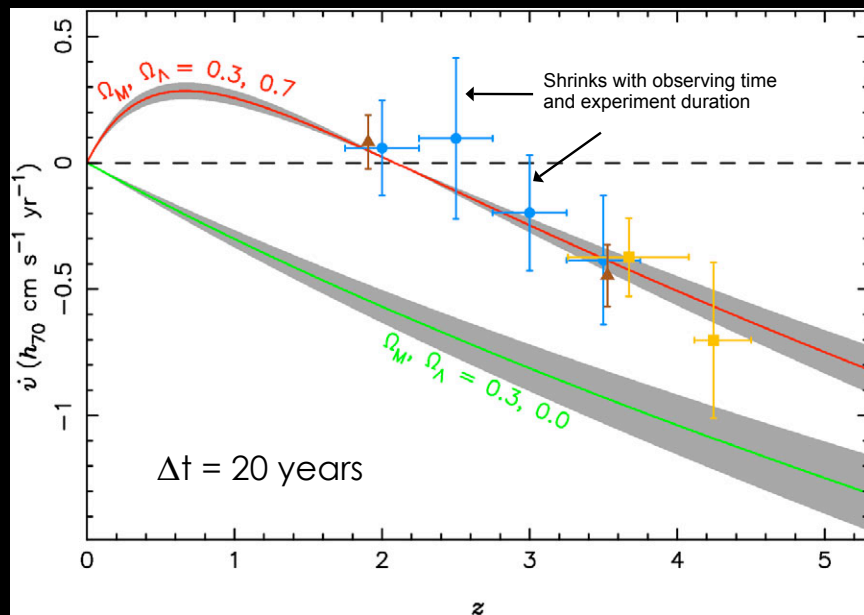


Cosmic Dynamics Experiment

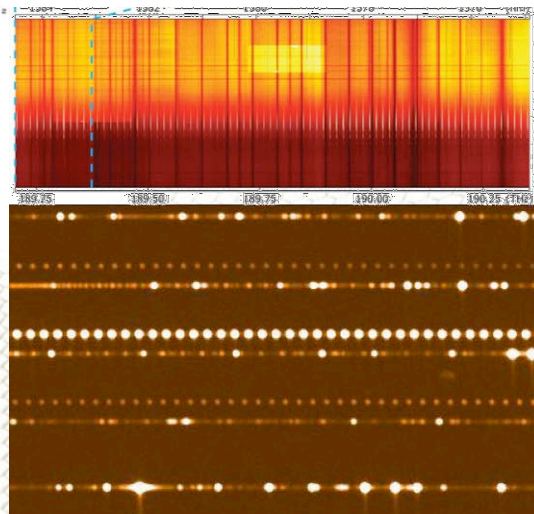
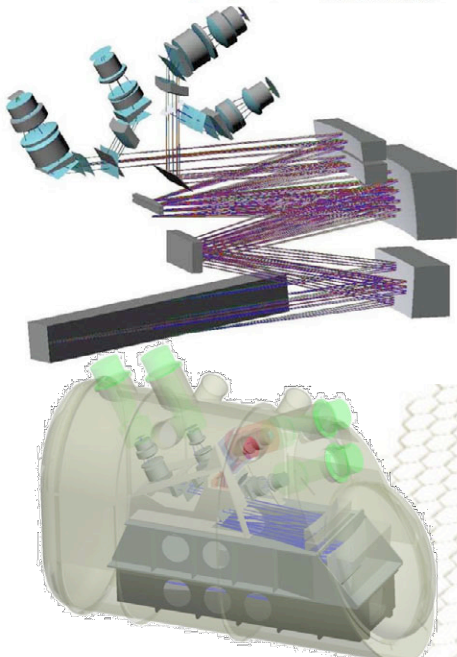
Simulations:

4000 hours over 20 years will deliver any one of these sets of points.

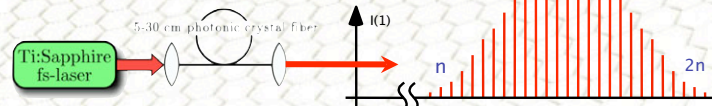
Different sets correspond to different target selection strategies.



CODEx

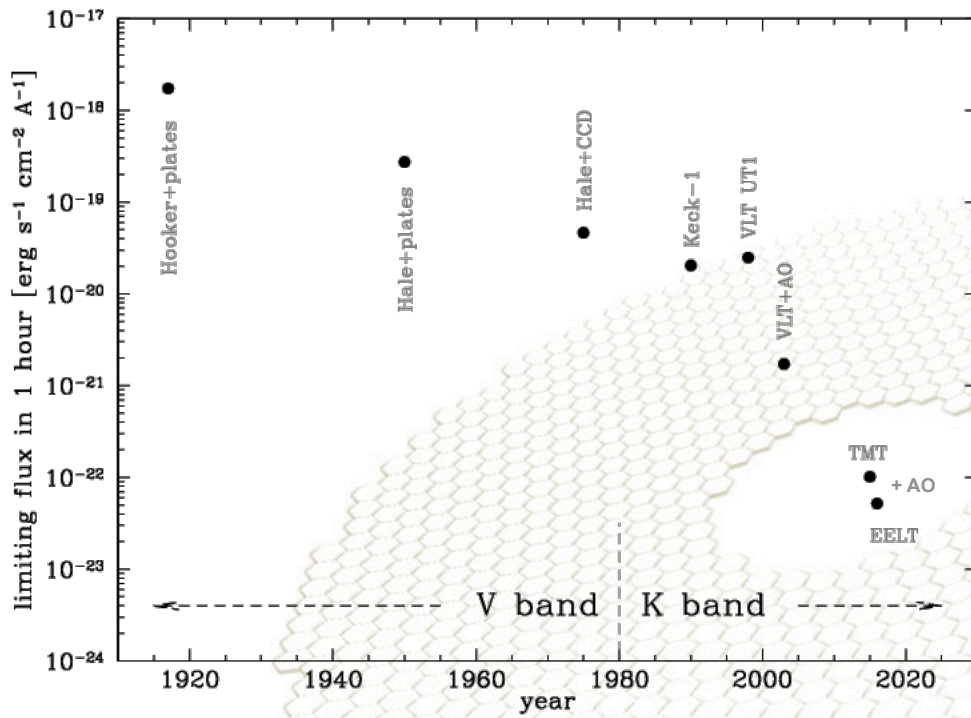


Laser comb calibration

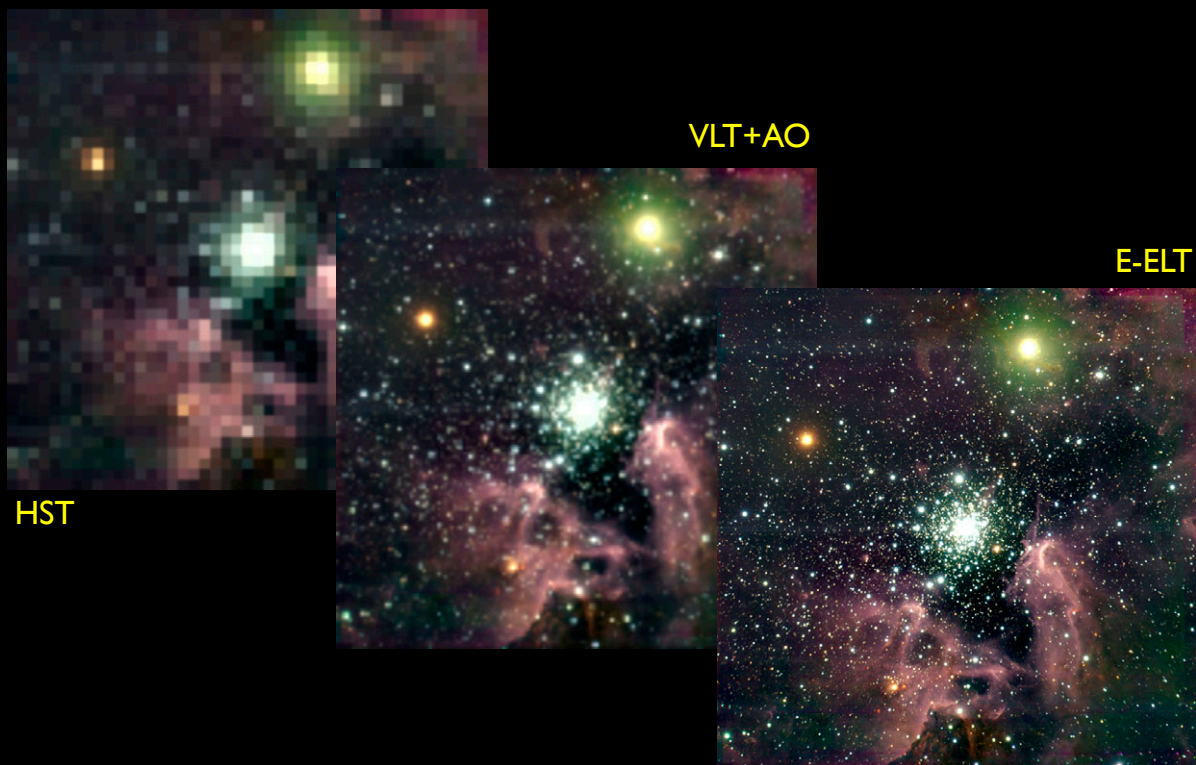




SCIENCE → REQUIREMENTS: 1. SENSITIVITY

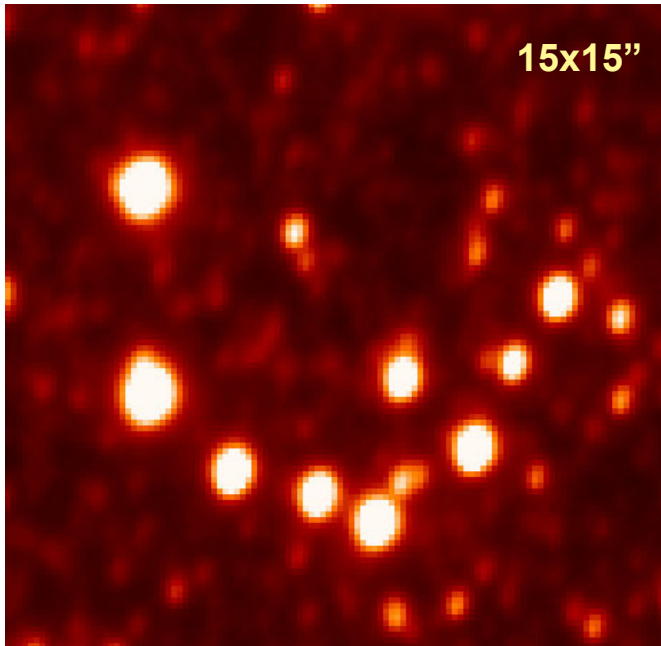


2. HIGH SPATIAL RESOLUTION





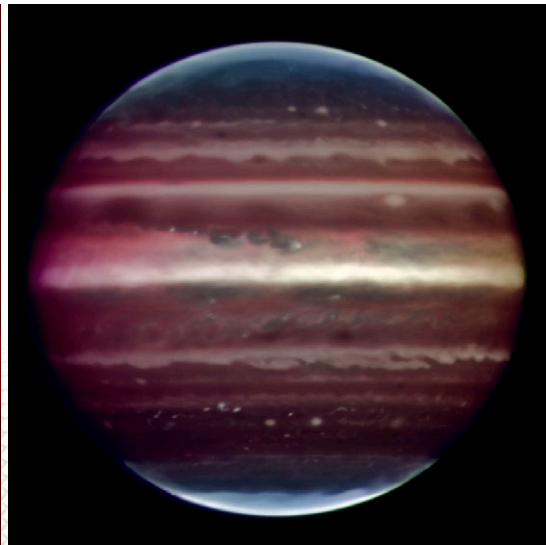
AN AO MILESTONE: MAD



15x15''

MCAO: 3 Guide stars at 2'
K-band, FWHM: 100-120mas, Sr: >20%
0.7'' seeing, Exposure 360 s

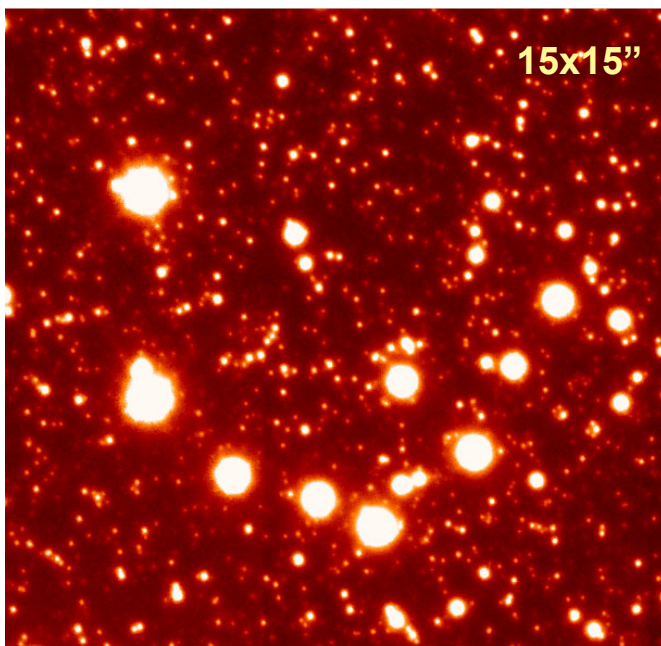
ISAAC seeing: ~ 0.5''



MCAO: 2 Guide "stars" (satellites Europa and Io)
2.14 μ m + 2.16 μ m filters
90 mas resolution (300 km at Jupiter)



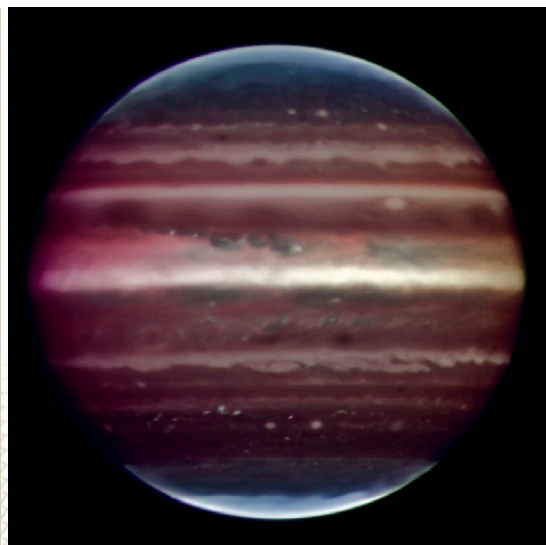
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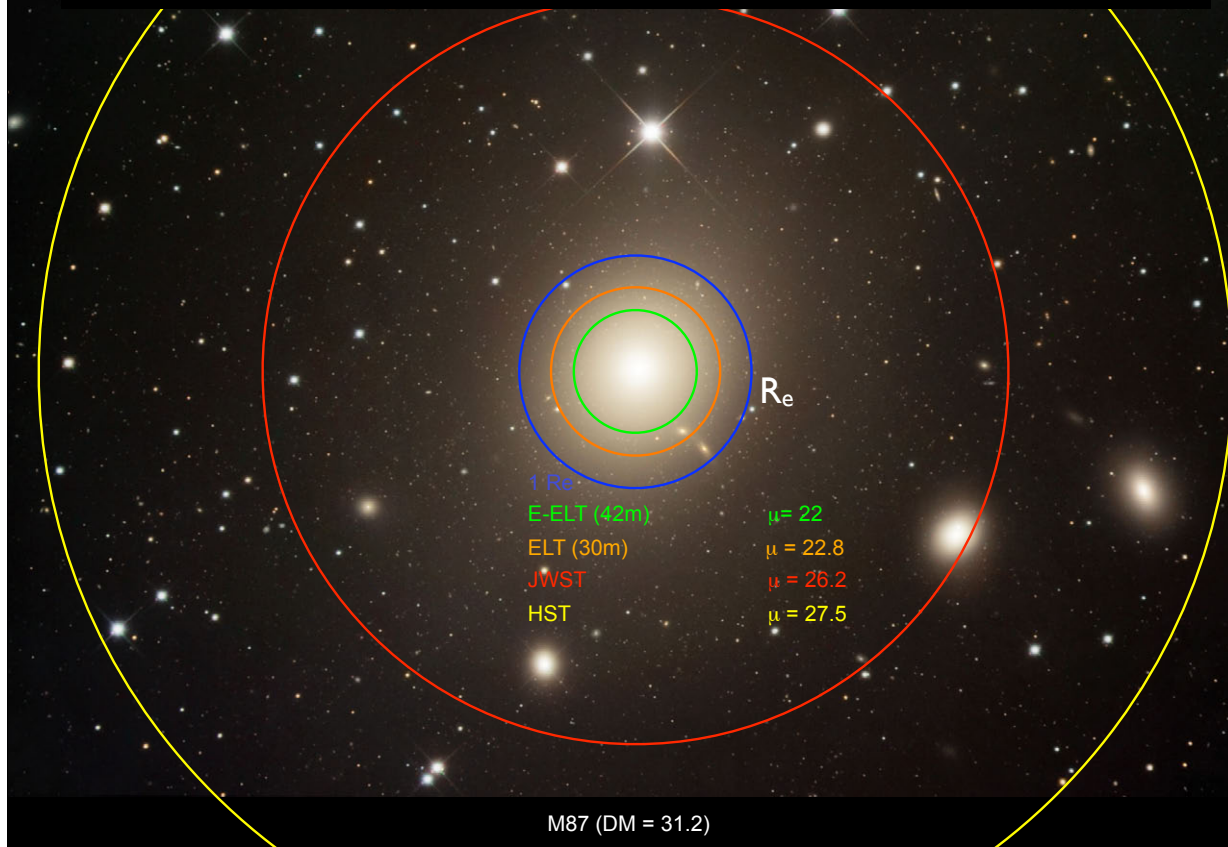
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3. THEIR COMBINATION: DEPTH



E-ELT TOP LEVEL REQUIREMENTS

- **Diameter: $\geq 42\text{m}$ (area $\geq 1200 \text{ m}^2$)**
 - Alt-Az, F/15 to F/18, fully steerable (0-360,0-90). Operational ZD: 0-70
- **Adaptive telescope**
 - GLAO correction ($\geq 5 \text{ arcmin}$, 90% sky, 80% time)
 - better than 2x FWHM improvement for median seeing conditions
 - Post-focal: SCAO, MCAO, LTAO, ExAO, MOAO, ...
- **Science field of view:**
 - 10 arcmin unvignetted. Diffraction limited by design
 - 5 arcmin unobscured by guide probes
- **Wavelength range: 0.3 – 24 μm**
- **Transmission @Nasmyth:**
 - >50% at >0.35 μm , >60 % at >0.4 μm , >70% at 0.7 μm , >80% at > 1 μm
- **Focal stations**
 - Two Nasmyth (multiple instruments, including gravity invariant option)
 - At least one Coudé
 - Fixed instrumentation (fast switching: < 10 min same focus, < 20 otherwise)



PHASE B STATUS

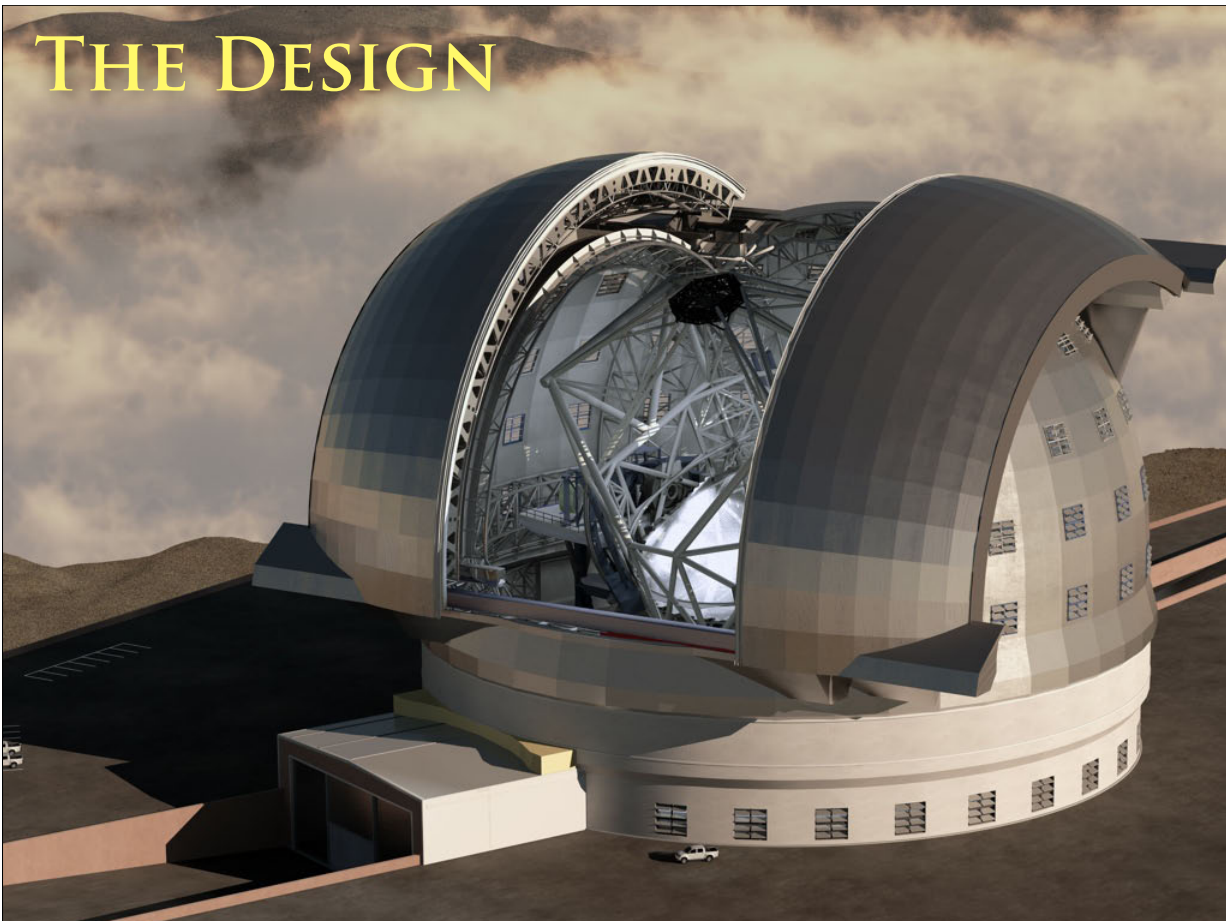
- Site selected: Armazones
 - *VLT and E-ELT as a single observatory*
- Proposal for Construction nearly complete
- Most major contracts (FEEDs) concluded
 - *Prototypes and breadboards being tested*
 - *Industrial reviews contracted*
- Excellent field results at GTC and VLT (control system)
- Instrumentation Phase A studies concluded
 - *Final reviews between Oct 2009 and Mar 2010*
- Science
 - *Design Reference Mission, Design Reference Science Plan*
- Observatory operations plan drafted
 - *Daily activities (maint, calib etc) → FTEs → costs*
 - *Observing modes developed (based on VLT paradigm)*



Armazones and Paranal

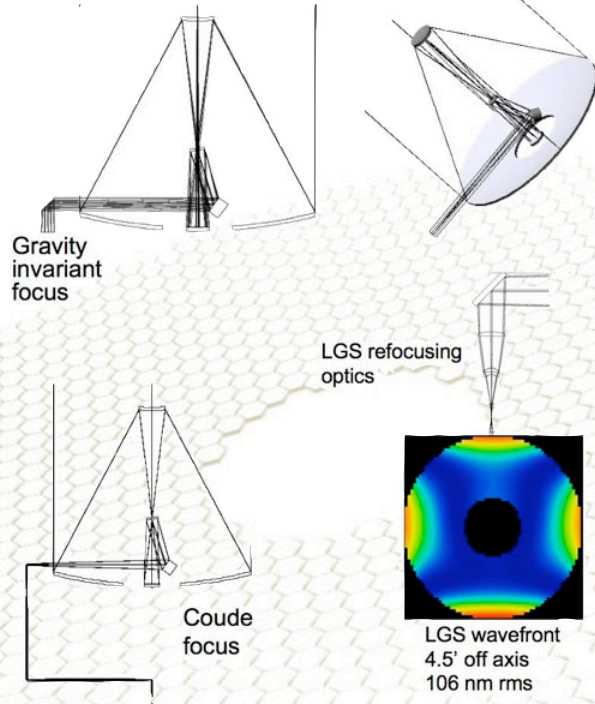
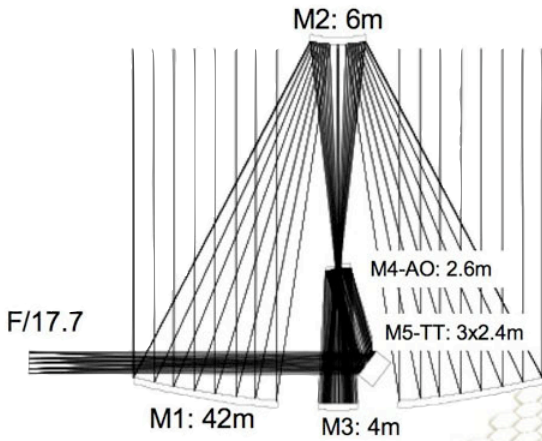
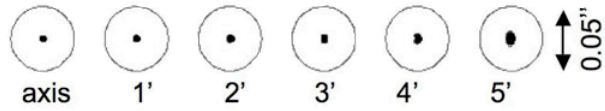


THE DESIGN





NOVEL 5-MIRROR OPTICAL DESIGN

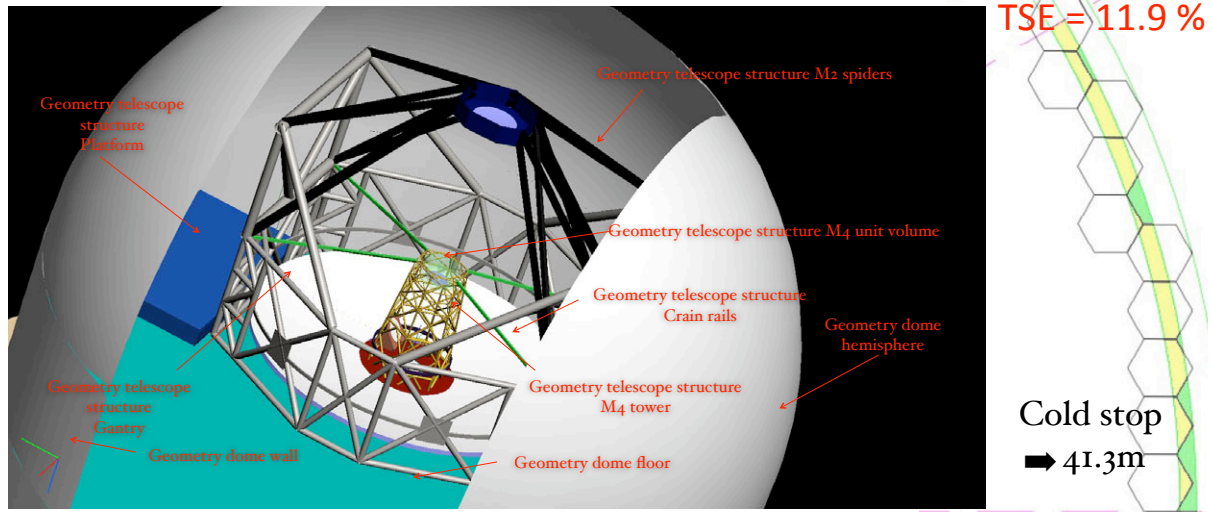


- 5 mirror concept (3 mirror anastigmat + 2 flats)
- diffraction limited over full 10' FoV
- flat, almost telecentric FoV
- "zoom" capability
 - Nasmyth, gravity invariant, coudé foci
- laser "friendly"
 - very low aberrations even at zenith

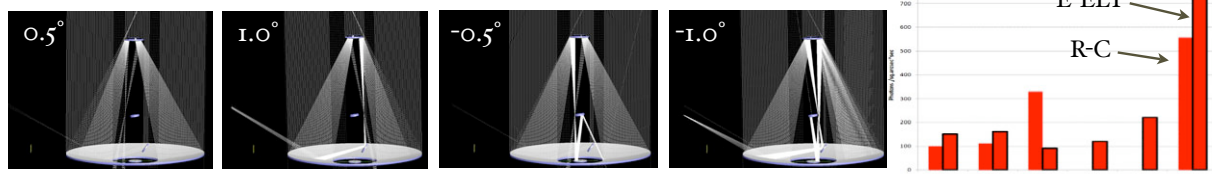


PERFORMANCE ANALYSIS

Thermal

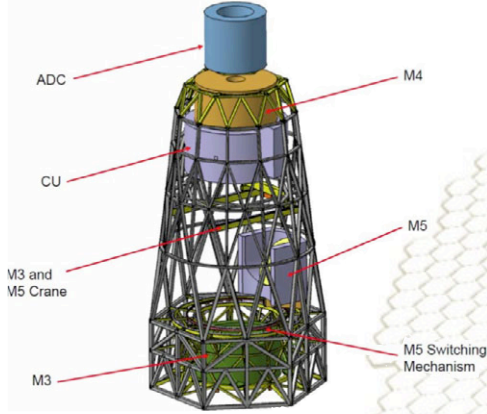
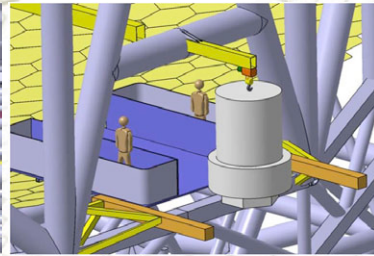
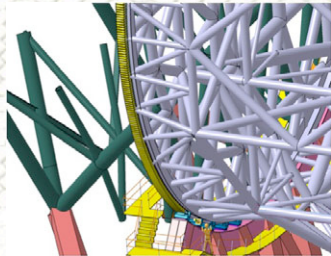
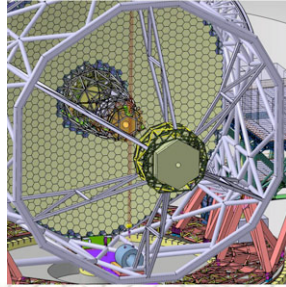
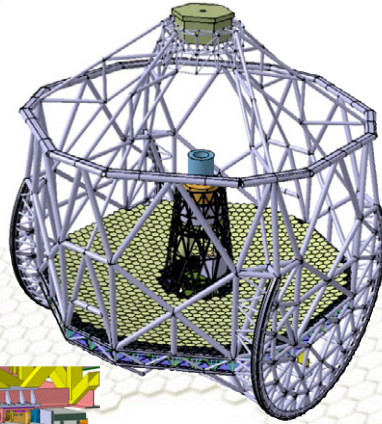
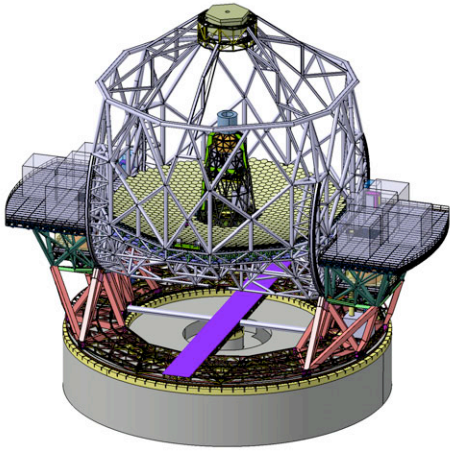


Scattered light

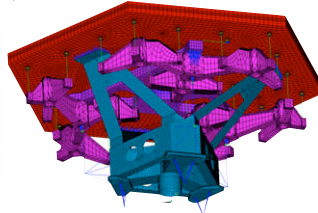
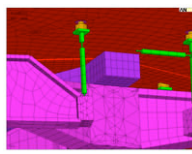
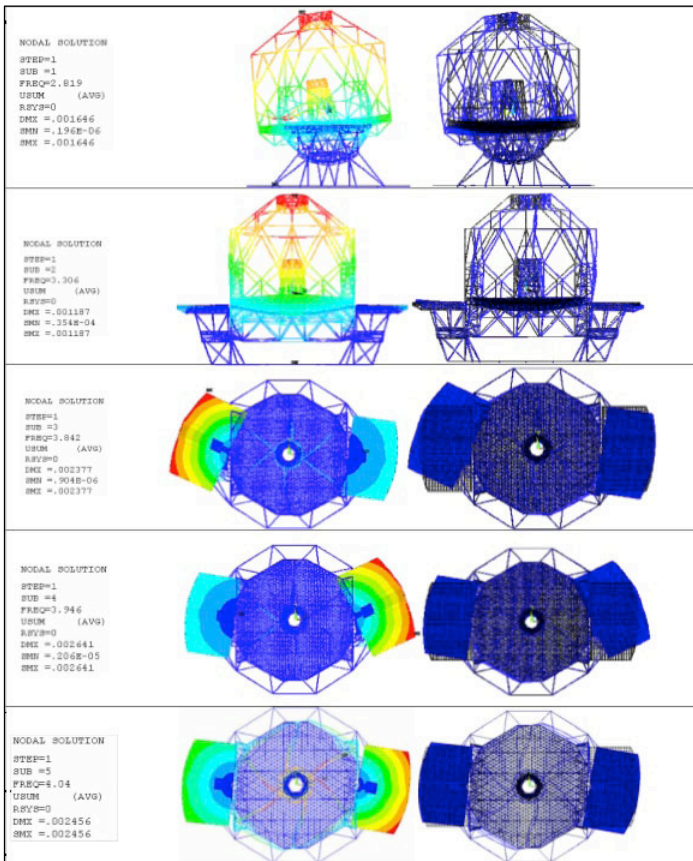


TELESCOPE MOUNT

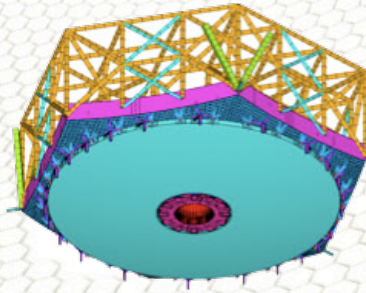
- Two cradle solution
- **Two industrial contracts concluded**
- **FEED concluding**
- Confirm cost and schedule
- Excellent stiffness (~3Hz)



ANALYSIS



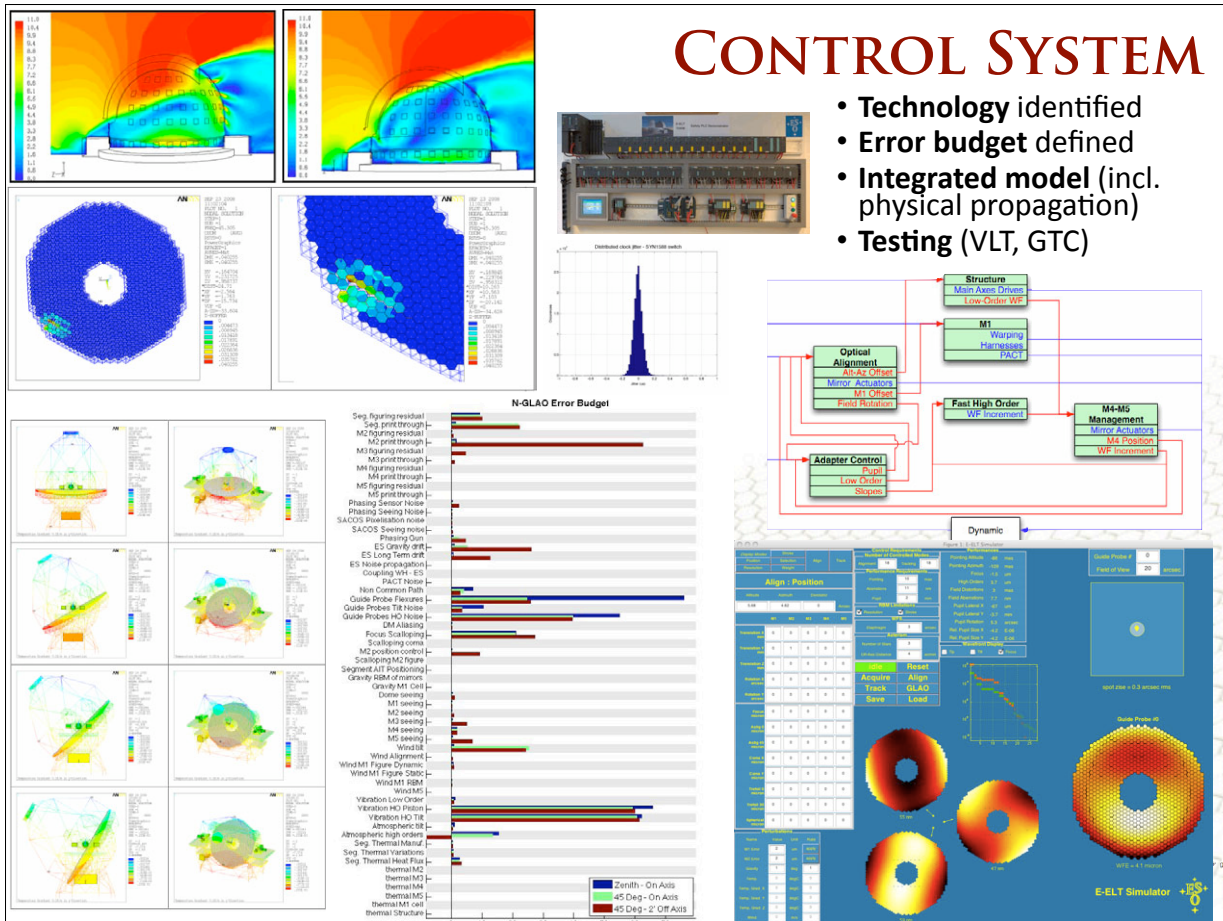
M1 Segment Support
155,000 elements
389,000 nodes



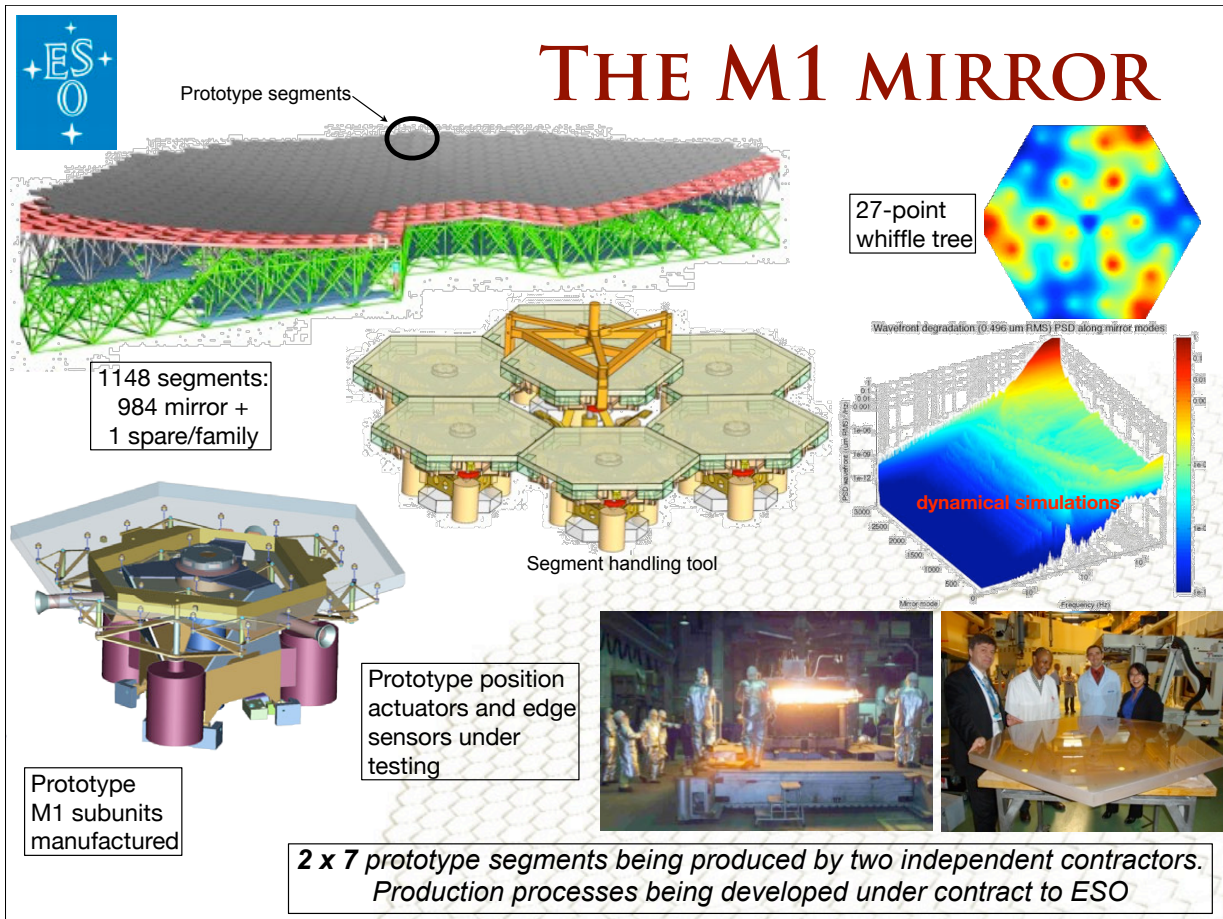
M2 Unit
250,000 elements
240,000 nodes

CONTROL SYSTEM

- Technology identified
- Error budget defined
- Integrated model (incl. physical propagation)
- Testing (VLT, GTC)



THE M1 MIRROR



First Prototype Segments in production

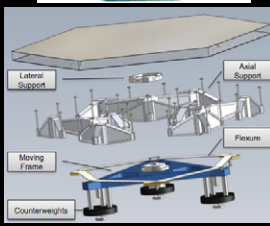
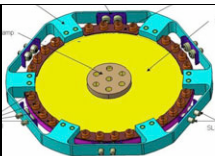
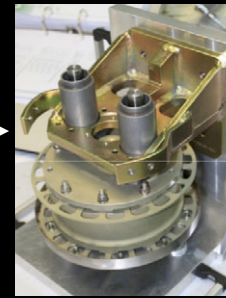


↑ First aspheric segment of an ELT!

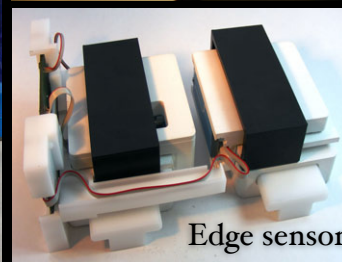
M1 subunit moving to manufacturing



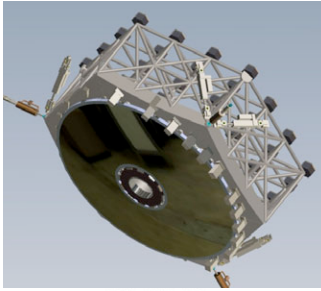
← Position actuators →



Warping harness

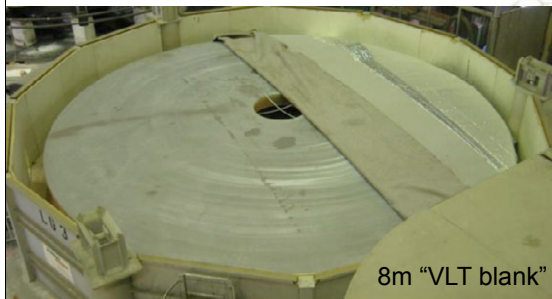
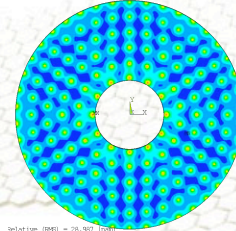
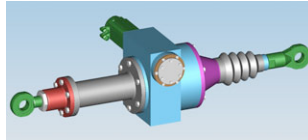
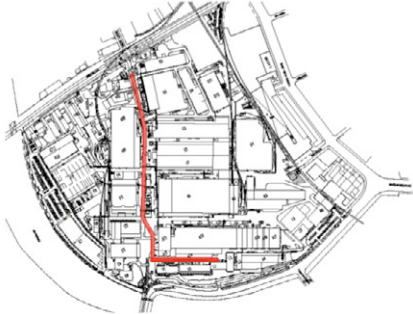
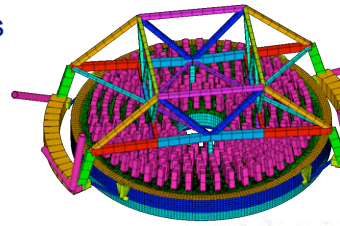


Edge sensor

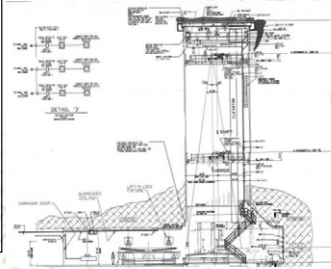
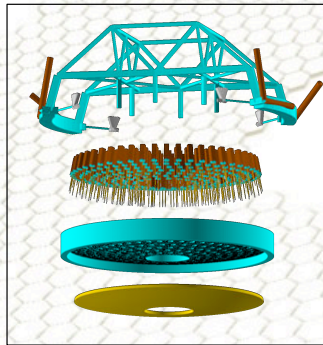


THE M2 UNIT

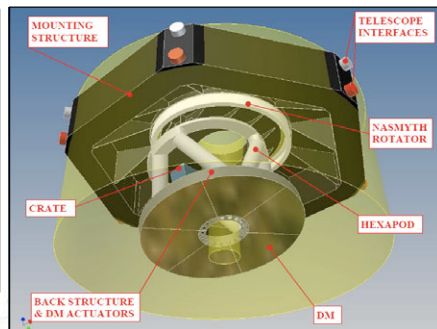
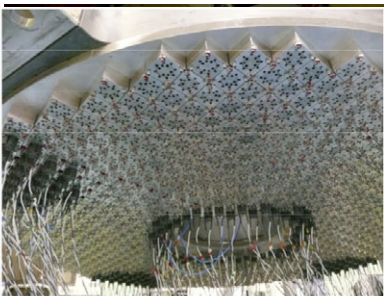
M2 cell contract in final stages
3x blank contracts concluded
Prototype actuators developed
M2 Unit FEED concluding



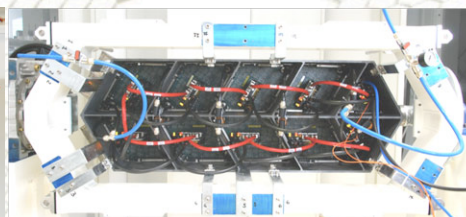
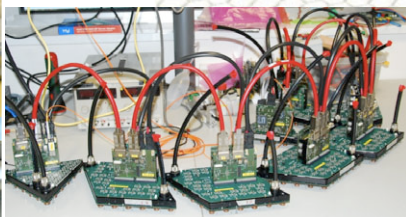
8m "VLT blank"



THE M4 ADAPTIVE MIRROR



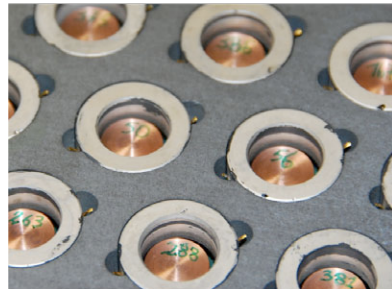
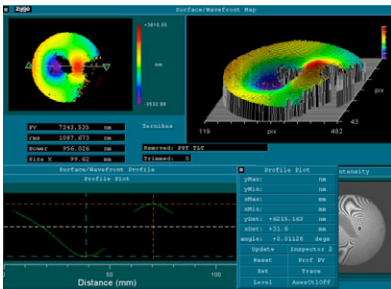
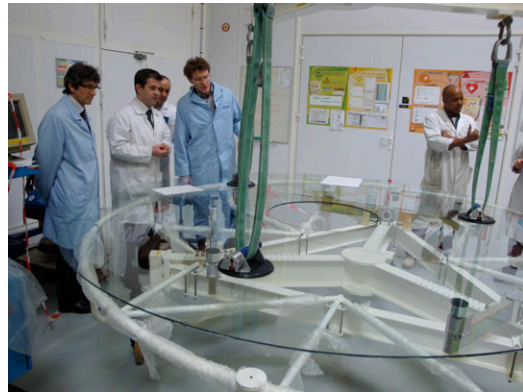
Two 1-m prototypes under testing





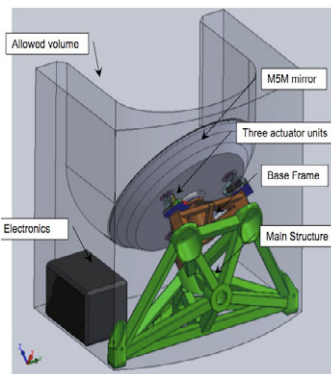
M4: 2 FEED contracts

- 1-m prototype units manufactured
 - #1 integrated and polishing on board
 - #2 integrated with thin shell
- Both suppliers making good progress
 - Within the project schedule
- Inter-actuator stroke measured
- Both suppliers in the final stages of testing

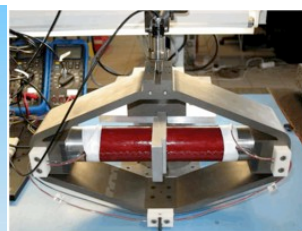
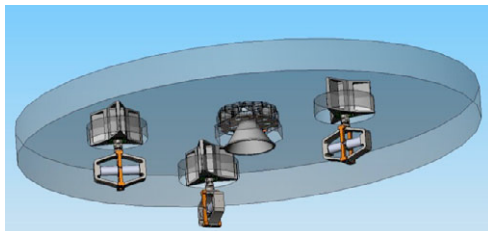


THE M5 FIELD-STABILIZATION MIRROR

Scale 1 prototype electromechanical unit under testing



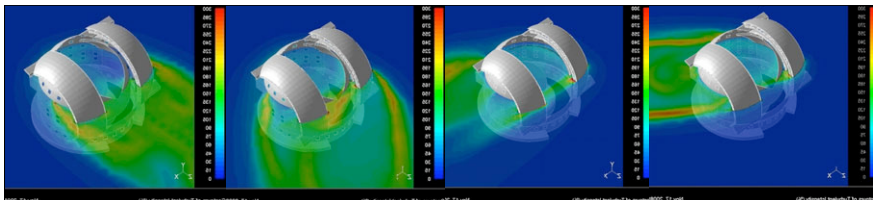
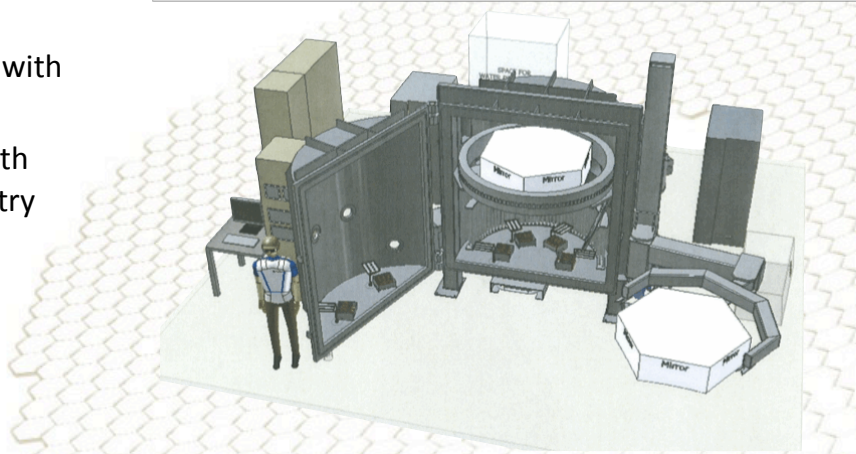
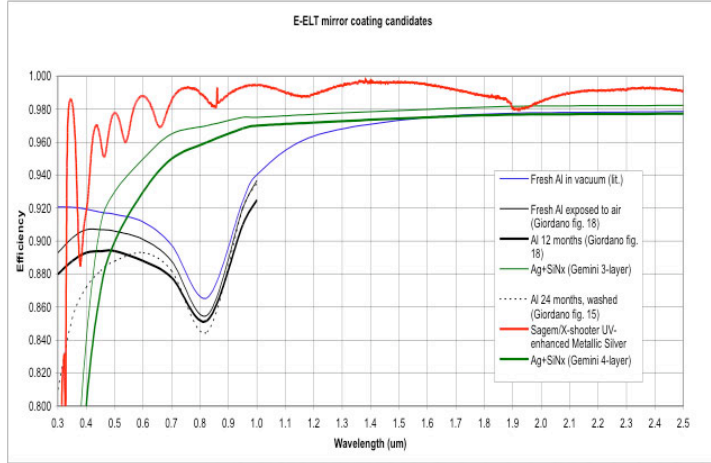
4 mirror studies
"heavy" option considered





Coating and washing

- Need for a 4.2-m and 6-m facility (coating/washing).
- Need for an inline coater for the primary mirror segments
- preliminary enquiry with industry concluded.
- Open discussions with academia and industry



THE DOME

inner and outer arch girders
transversal trusses
tension rods

Integration

Two preliminary designs concluded.
2x FEEDs concluded
Optimization, CFD,
Erection sequence

crane

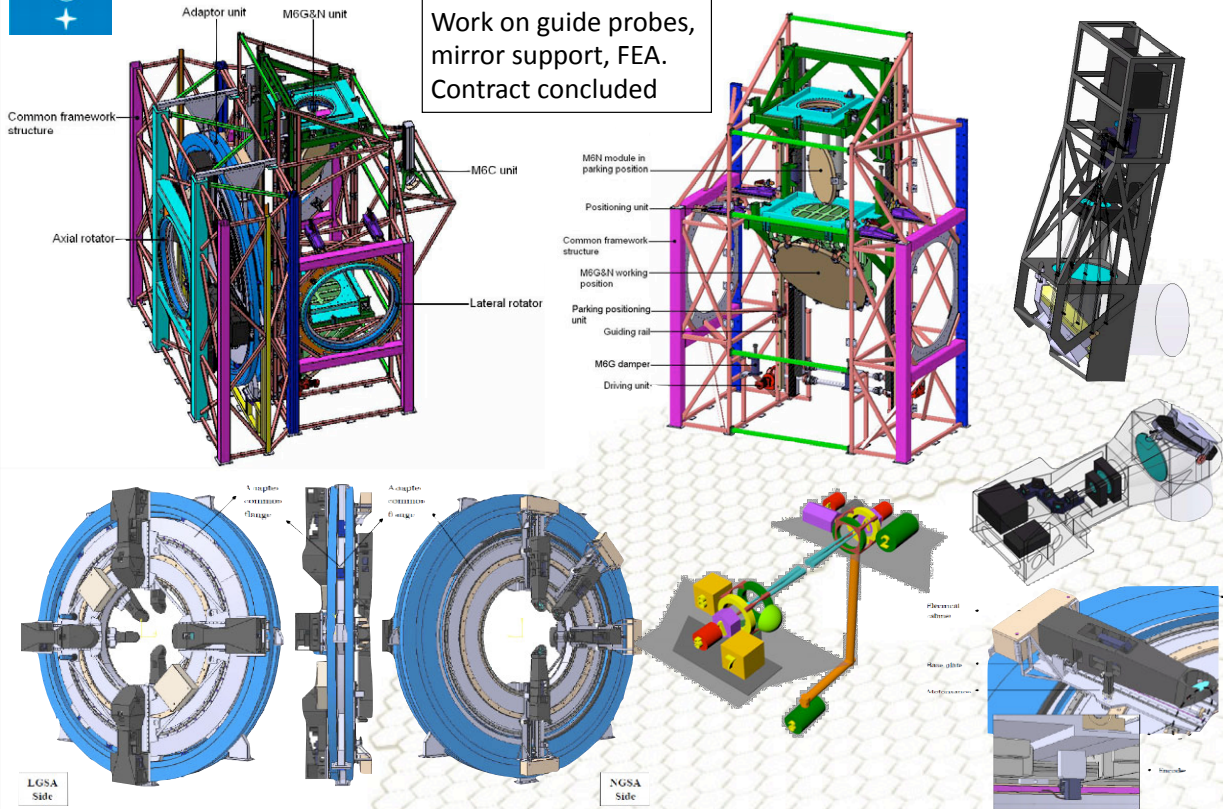
wind screen

wind tunnel tests

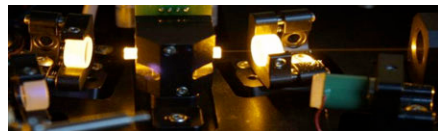


PRE FOCAL STATIONS

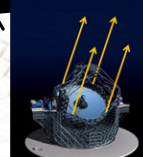
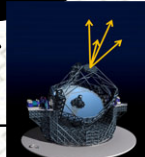
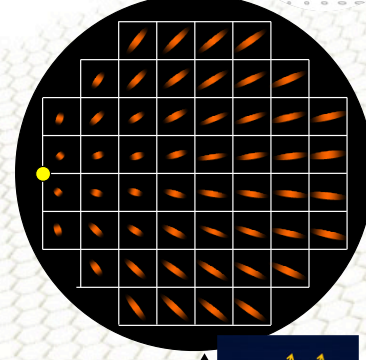
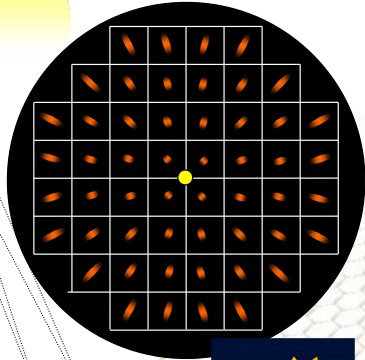
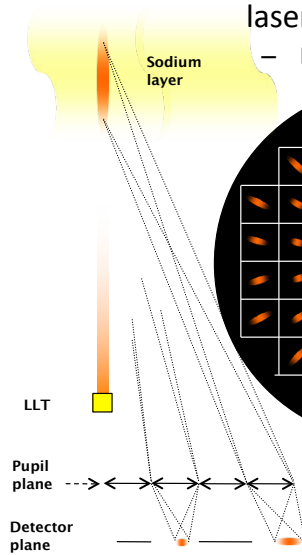
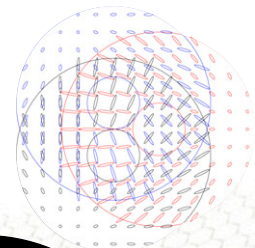
Work on guide probes, mirror support, FEA. Contract concluded



LASERS



- Baseline: in-house fiber laser (>50W CWS)
- Contract awarded for the design of the launch telescopes
- Contract awarded for VECSEL technology lasers (risk mitigation alternative)
 - Including a prototype device

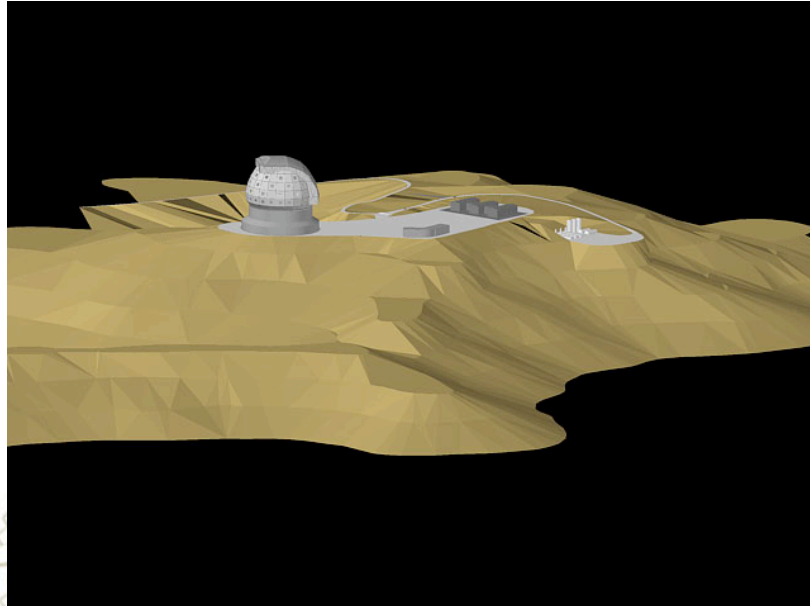




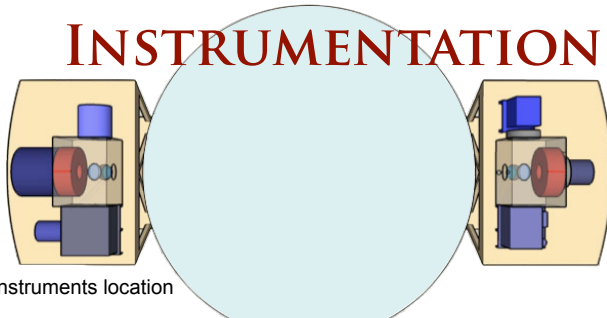
INFRASTRUCTURE

The infrastructure plan includes:

- 10 km of paved road
- 10 MWatts of local generated power
- Wind turbines
- Water capacity of 500 cubic metres
- Telecommunications in and out of the site
- Accommodation for 100 staff
- Control building and laboratories separated from the dome.
- Temporary accommodation during construction.



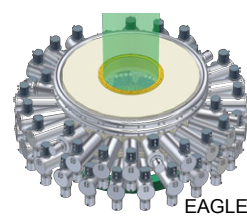
INSTRUMENTATION PHASE A STUDIES



Possible instruments location

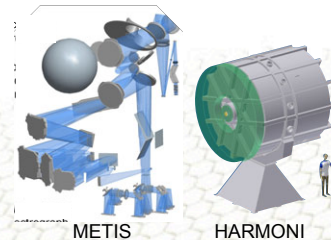


MICADO



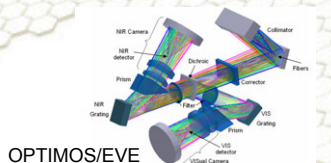
EAGLE

ACRONYM (P.I.)	INSTRUMENT TYPE
EAGLE (J.G. Cuby)	Wide Field, Multi IFU NIR Spectrograph with MOAO
EPICS (M. Kasper)	Planet Imager and Spectrograph with XAO
MICADO (R. Genzel)	Diffraction-limited NIR Camera- AO assisted
HARMONI (N. Thatte)	Single Field, Wide Band Spectrograph - AO assisted
CODEX (L.Pasquini)	High Spectral Resolution, High Stability Visual Spectrograph
METIS (B. Brandl)	Mid Infrared Imager & Spectrograph –AO assisted
OPTIMOS (F.Hammer, O.LeFevre)	Wide Field , Visual, MOS (fibre or slit-based)- AO assisted?
SIMPLE (L. Origlia)	High Spectral Resolution NIR Spectrograph –AO assisted
	POST-FOCAL AO MODULES
MAORY (E. Diolaiti)	Multi Conjugate AO module (high Strehl, field up to 2')
ATLAS (T. Fusco)	Laser Tomography AO Module (high Strehl, narrow field)

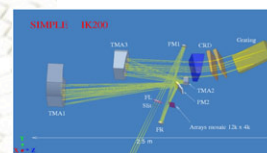


METIS

HARMONI



OPTIMOS/EVE



SIMPLE

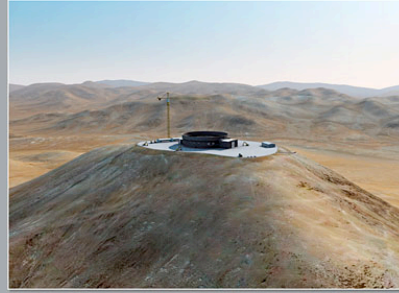
Conclusions: First light possible in 2019



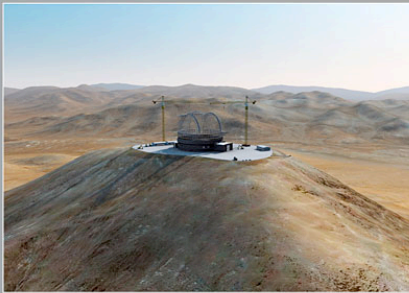
2010



2011



2012



2013



2014

(Dome erection sequence at Armazones)