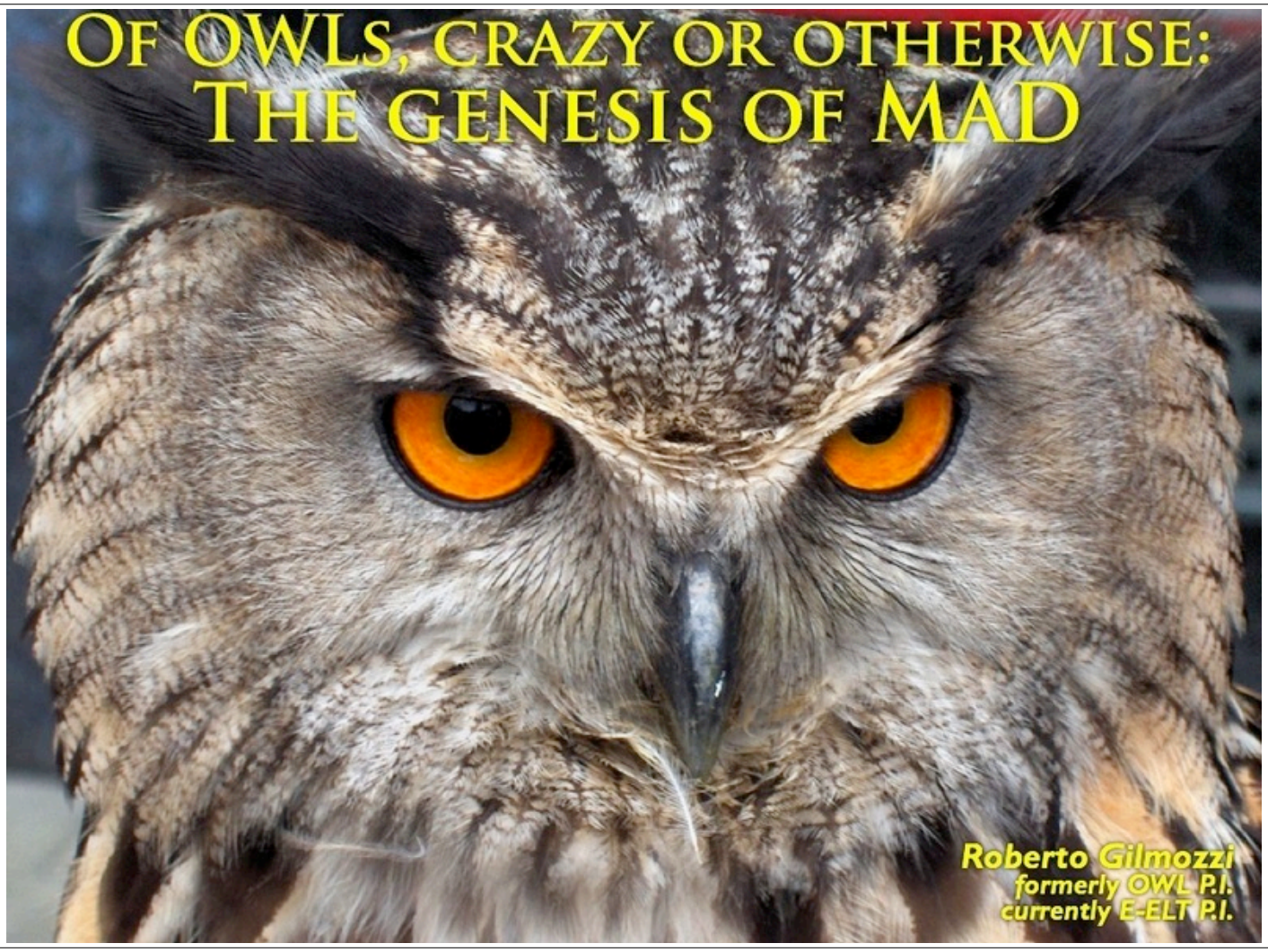
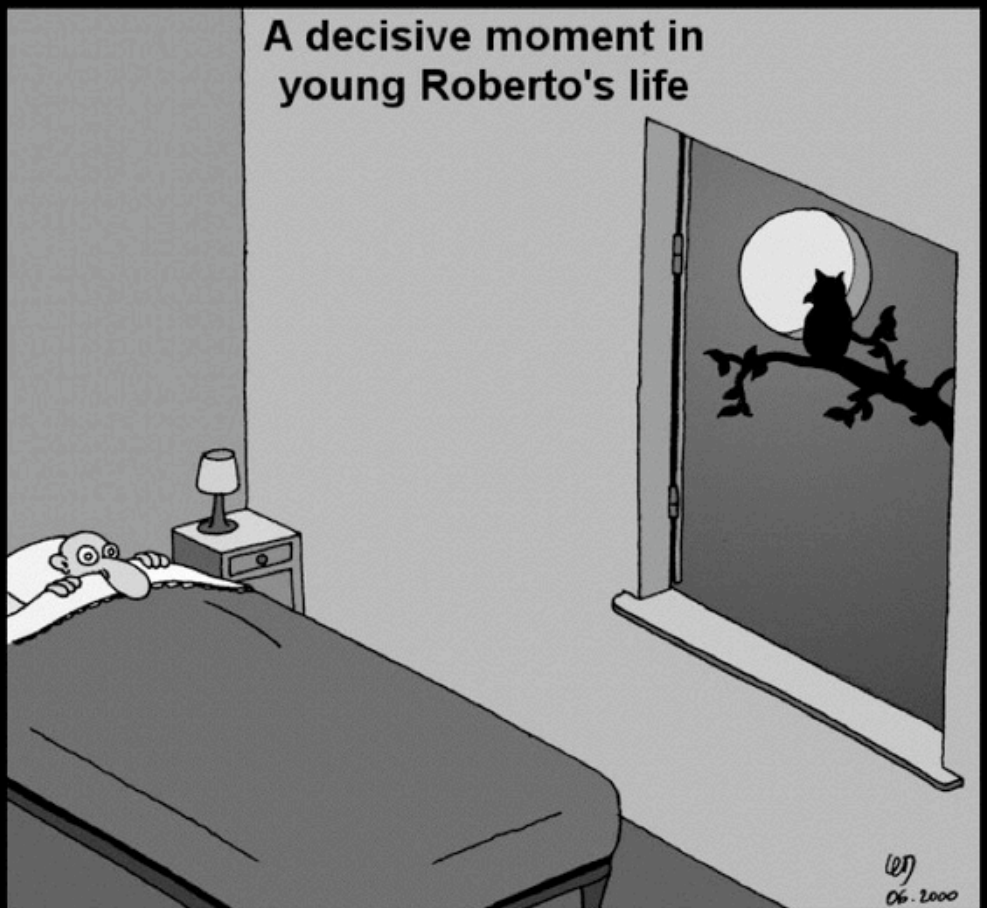
Of OWLs, crazy or otherwise: The genesis of MAD



Roberto Gilmozzi
formerly OWL P.I.
currently E-ELT P.I.

The real reason behind it all



THE CRAZY OWL

- Let's give credit where credit is due, shall we?
  - The 100m concept was named ***OWL*** by Philippe Dierickx, project manager of the design study, after the eponymous bird's keen night vision, and for being ***O**verW**h**elmingly **L**arge*
- Misconceptions... It is ***not*** true that
  - The earliest ***WTT*** (***W**ide **T**errestrial **T**elescope*) was discarded for also meaning ***W**ishful **T**hinking **T**elescope*
  - ***PLATA*** (***P**ossibly the **L**argest **A**stronomical **T**elescope **A**round*) was discarded for the reference to money
  - E-ELT's original name was still ***OWL*** (for ***O**riginally **W**as **L**arger* or alternatively ***O**nce **W**as **L**arge*)
  - ***OWLino*** (***O**verW**h**elmingly **L**arge **i**n **n**ame **o**nly*) was ever an option for the E-ELT

WHAT'S IN A NAME?

Taking The Cosmic View

New Technologies For Peering Into The Heavens Are Pushing Astronomy Into A New Golden Age

By Oliver Morton | NEWSWEEK
From the magazine issue dated Sep 18, 2000

[...] For a long time the largest telescope in the world was the peerless 200-inch (five-meter) reflector at Mount Palomar, California. Now the world has a dozen or more telescopes in the eight- to 10-meter range. There are plans in America to build a giant segmented-mirror telescope that will have a mirror nine times larger still. The European Southern Observatory, which is putting the finishing touches to its prosaically named Very Large Telescope, a composite system with four eight-meter mirrors, has grandiose plans for a later instrument with a mirror 100 meters across. This wonderfully named Overwhelmingly Large Telescope would compare with the Great Pyramid in size, and its ability to gather light would far exceed the sum capabilities of all previous telescopes ever made.

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Suggestions for a name for E-ELT are solicited! Prizes offered!!

THE GENESIS OF MAD (I)

MAD, *adj.* Affected with a high degree of intellectual independence; not conforming to standards of thought, speech and action derived by the conformants from study of themselves; at odds with the majority; in short, unusual. It is noteworthy that persons are pronounced mad by officials destitute of evidence that themselves are sane.

The Devil's Dictionary by Ambrose Bierce (1911)

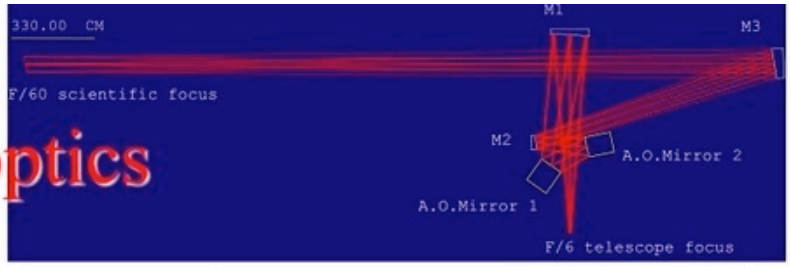
(Doesn't really apply, but I like it anyway...)

The genesis of MAD (II)

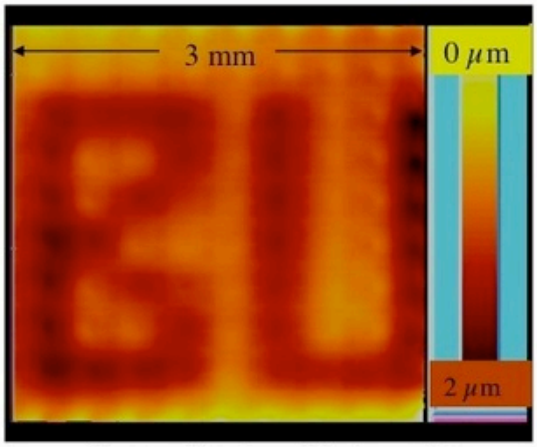
- Recollections
  - The first mention of an MCAO demonstrator in my digital memory (i.e. the laptop) is at the EWR in Apr 2000 and at STC-49 a few weeks later (early May)
  - My carbon memory is less dependable: I vaguely remember that at the time I kept pushing for the idea, but had to resort to the unparalleled historical knowledge of Guy Monnet's for confirmation:

> Guy Monnet wrote:
> What I remember is that around this time you used to point out repeatedly that one mandatory hurdle towards OWL was to prove that MCAO works: first in the Lab to convince ourselves, but then also on-sky to convince the others. You indeed came then with the (bright) demonstrator idea and I immediately jumped on it, pointing out that by building it with as many already in hand spare AO components we would gain in time and cost.

Adaptive optics



- MCAO (tomography), principle demonstrated (Ragazzoni et al)
- 2-3 conjugates probably sufficient (Hubin et al)
- Deformable mirrors - MEMs?
  - IR ~50,000 active elements
  - Vis. ~500,000 active elements
- NGS or LGS?
  - NGS attractive for D>60-80 m
  - telescope designed for NGS, most constraining; backup LGS requires exchange of 2 smallest mirrors



From *Boston University Photonics Center, Precision Engineering Research Laboratory, T. Bifano*

⇒ ***Demonstrator***

STC-50, Oct 2000

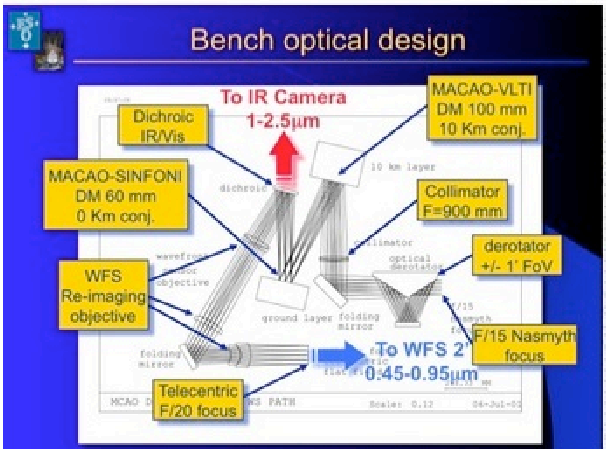
Recommendation on Multi-Conjugate Adaptipve Optics

The STC considers the development of MCAO crucial for the future of Astronomy in Europe. It endorses the conceptual plan proposed by ESO and recommends to work out a detailed fast-track project plan to be presented at the STC-meeting in spring 2001.

Furthermore, the STC encourages ESO to cooperate with the community as much as possible in order to develop a broad level of competence.

The genesis of MAD (III)

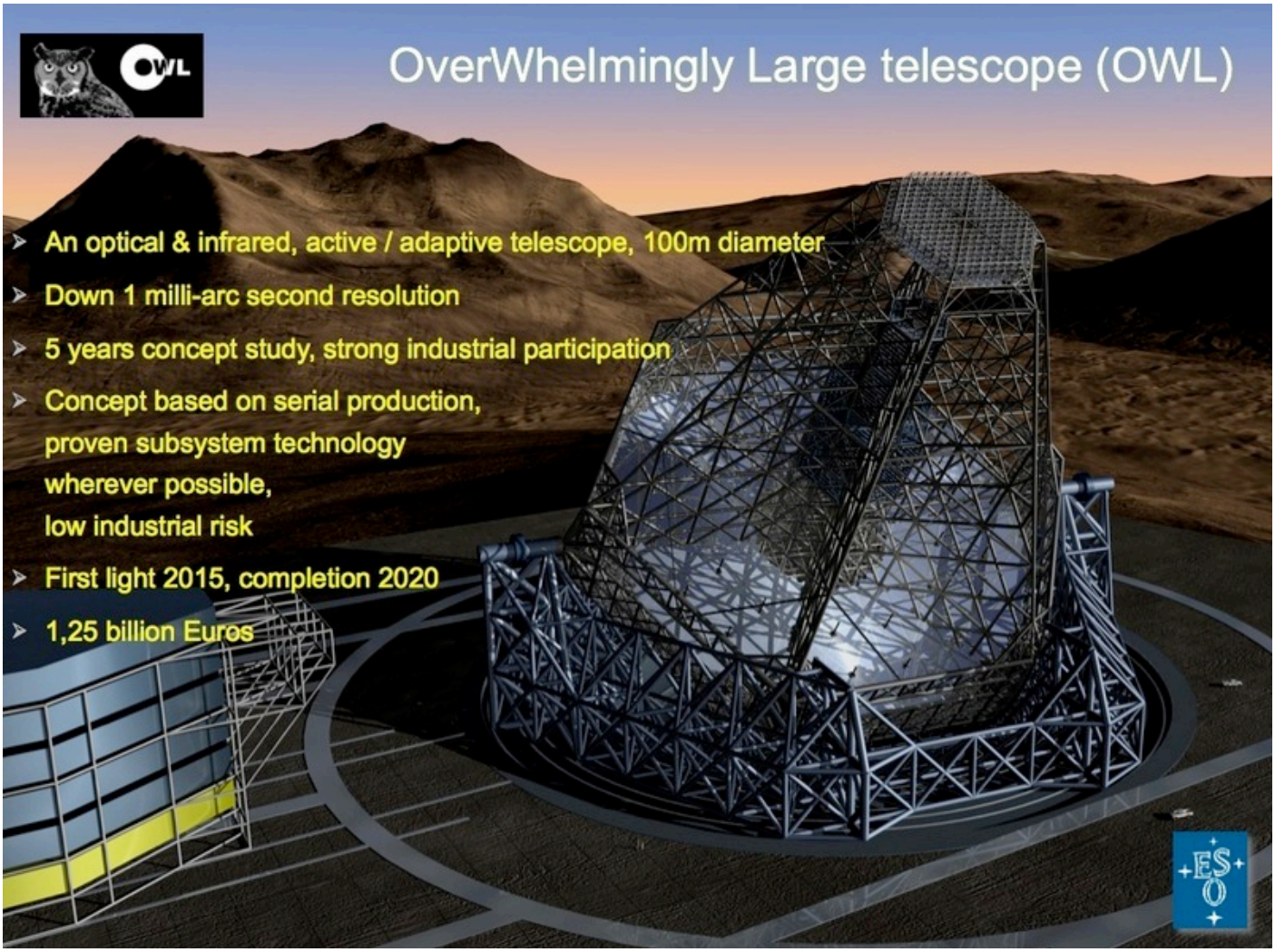
- Recollections, cont'd
  - The name MAD was coined by ***Andrei Tokovinin***, at the time still at ESO
  - Work on MAD started in earnest after we hired ***Enrico Marchetti*** to lead the project (he started in Aug 2001)
  - The official Work Package, **WP373**, was part of the budget submission for 2002 (OWL was WP370...)



Down memory's lane

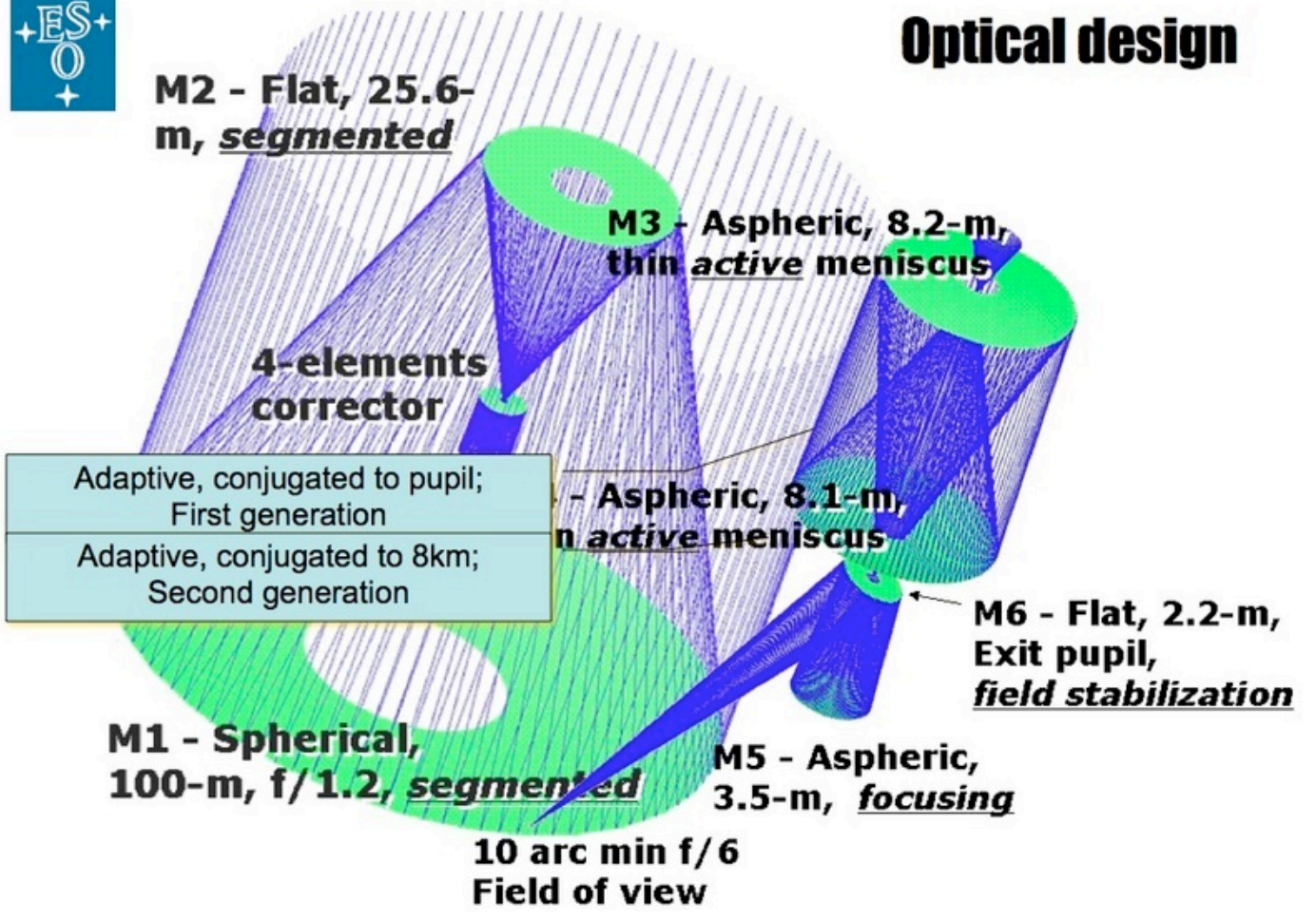
An unlikely precursor

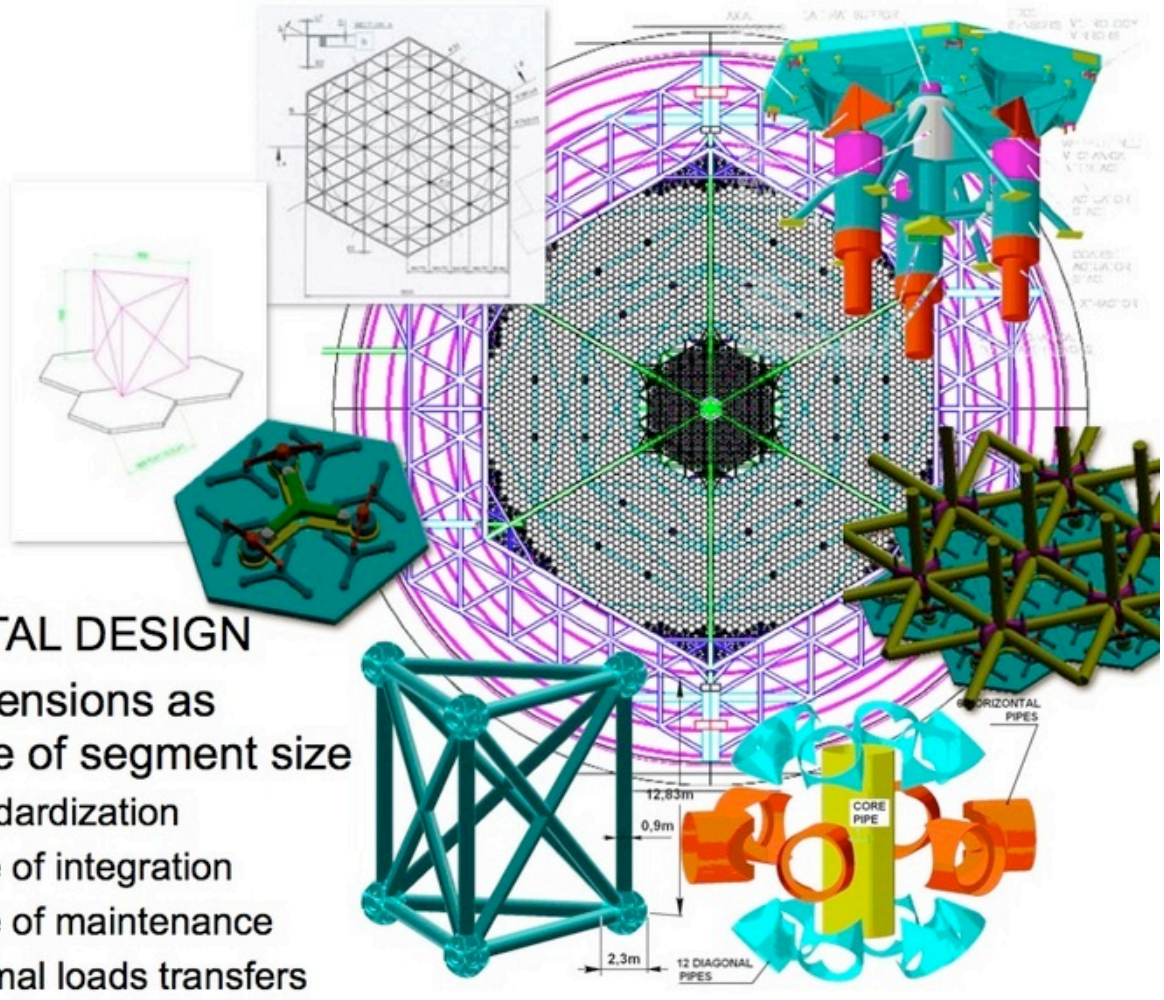
OverWhelmingly Large telescope (OWL)



- An optical & infrared, active / adaptive telescope, 100m diameter
- Down 1 milli-arc second resolution
- 5 years concept study, strong industrial participation
- Concept based on serial production, proven subsystem technology wherever possible, low industrial risk
- First light 2015, completion 2020
- 1,25 billion Euros

Optical design



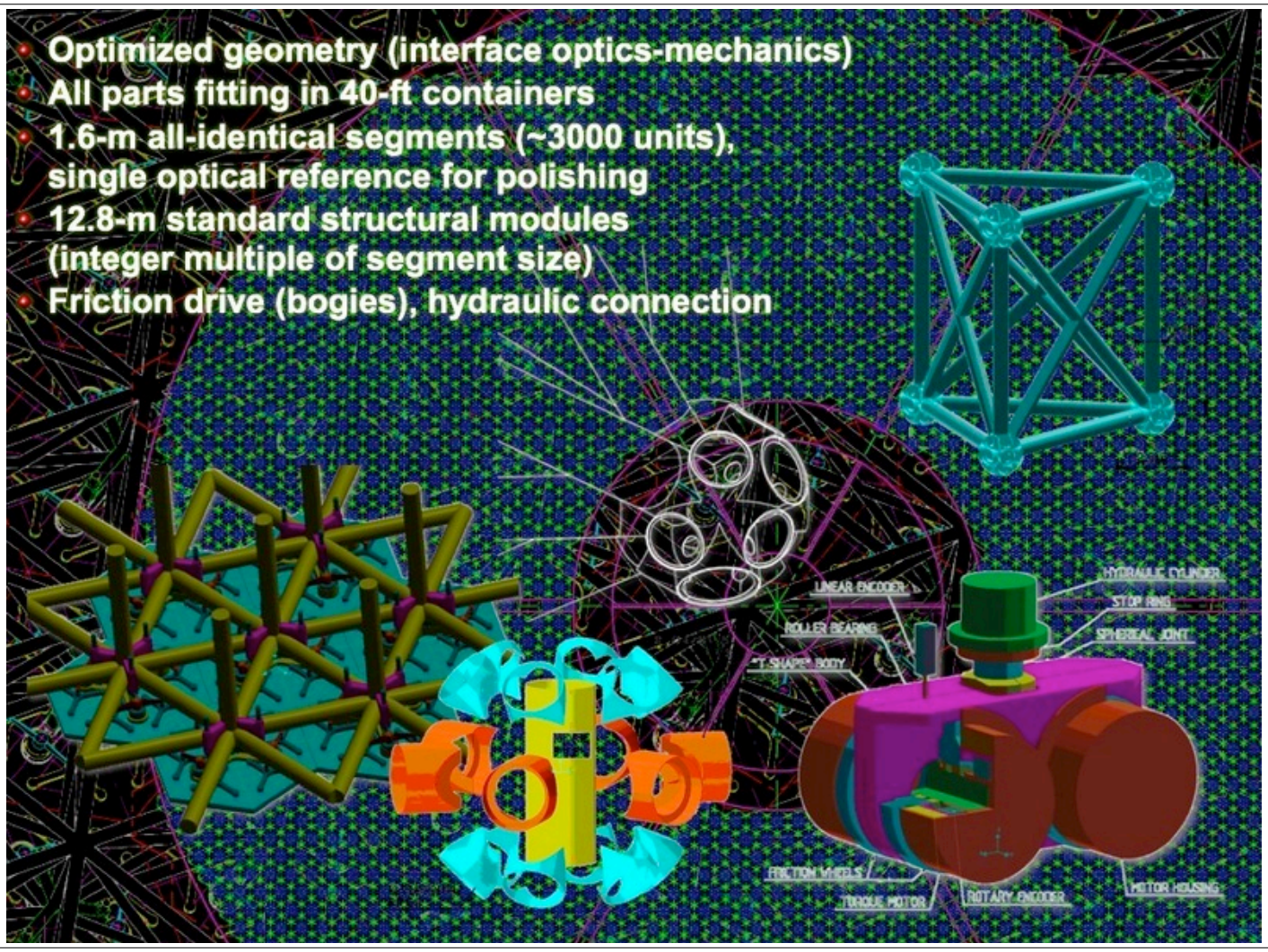


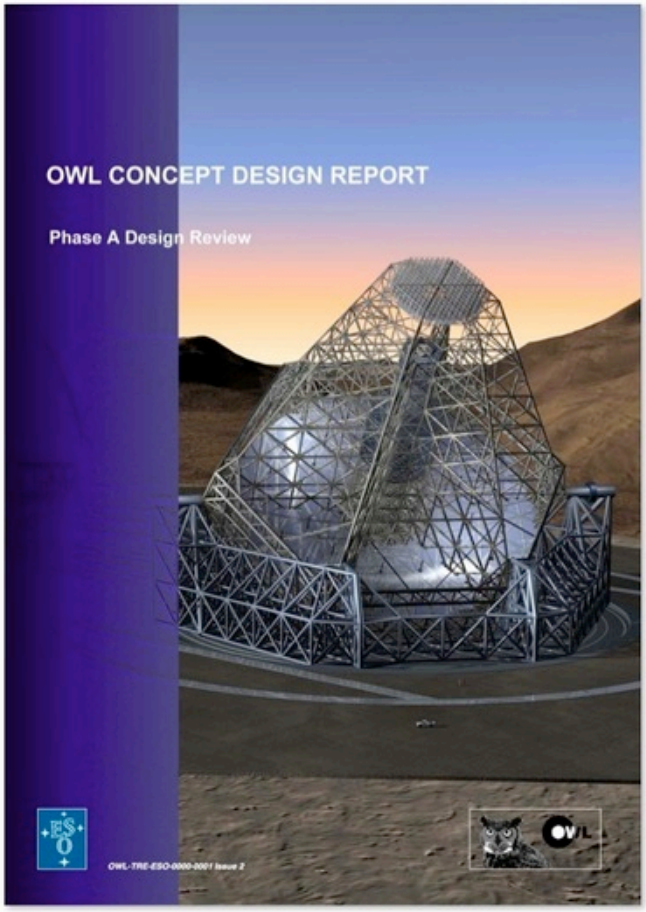
FRACTAL DESIGN

All dimensions as multiple of segment size

- Standardization
- Ease of integration
- Ease of maintenance
- Optimal loads transfers

- Optimized geometry (interface optics-mechanics)
- All parts fitting in 40-ft containers
- 1.6-m all-identical segments (~3000 units), single optical reference for polishing
- 12.8-m standard structural modules (integer multiple of segment size)
- Friction drive (bogies), hydraulic connection





More in …

OWL Blue Book (730 pages)

Public version does not include detailed cost estimates.

www.eso.org/projects/owl

TRANSITION

- **November 2005:** OWL review concluded that although technically feasible the concept was too risky to conclude on a competitive timescale. The review board recommended that the project advance to phase B but to review high risk areas before doing so
- **January 2006 to April 2006:** The ESO DG called upon the community to establish 5 working groups to create a tool box for the EELT evolution.
- **April 2006 to December 2006:** ESO together with industrial and community support established a new baseline reference design for a 42-m European ELT.
- The design was blessed by the ELT Science & Engineering subcommittee of the ESO STC, the STC, the ESRC & the ESO community at the Marseille meeting.
- The ESO Council launched the phase B detailed design phase of the project in **December 2006** with a three year timeline and a budget of 57.2 Million Euro.

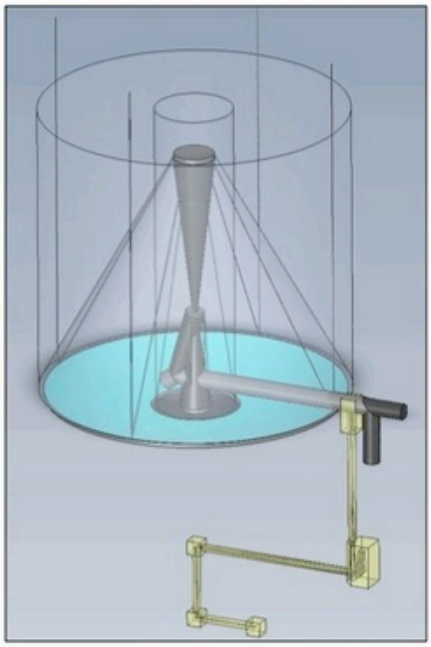
E-ELT Top Level Requirements

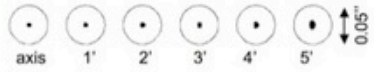
- **Diameter: ≥42m (area ≥ 1200 m²)**
  - Alt-Az, F/15 to F/18, fully steerable (0-360,0-90). Operational ZD: 0-70
- **Adaptive telescope**
  - GLAO correction (≥ 5 arcmin, 90% sky, 80% time)
    - better than 2x FWHM improvement for median seeing conditions
  - Post-focal: SCAO, MCAO, LTAO, ExAO, MOAO, ...
- **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)

Status

- **Phase B extended to December 2010**
- **Mid-term review**
  - Passed 12-13 May 2009
- **All major telescope subsystems undergoing first or second iteration through industrial suppliers**
  - Several reached preliminary design and are moving to next
  - FEED studies ongoing
- **All Phase A instrumentation studies ongoing**
  - 8 instruments, 2 post-focal AO modules
- **Operations scenarios being analyzed**
  - Observing modes
  - Logistics, maintenance, safety
  - Operations costs evaluated
- **Progress of DRM and DRSP**
- **Site Selection Advisory Committee**

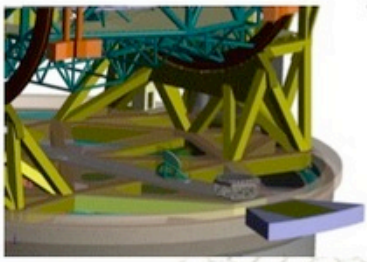
TELESCOPE

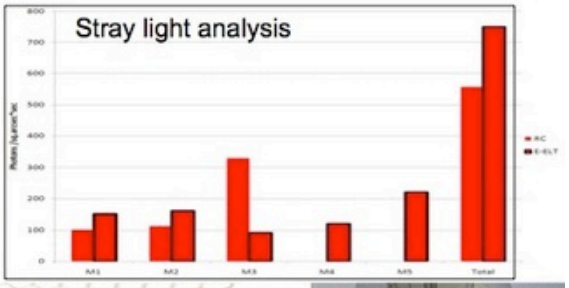


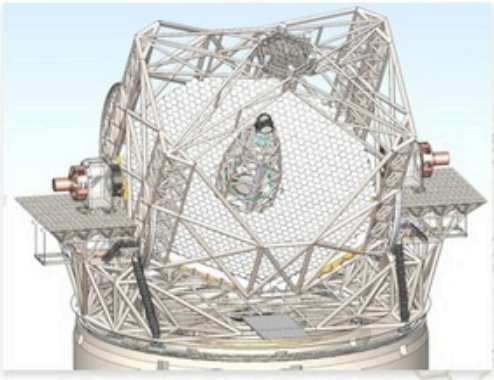


Optical design

- novel 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)

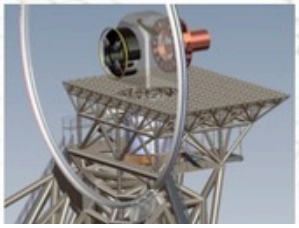




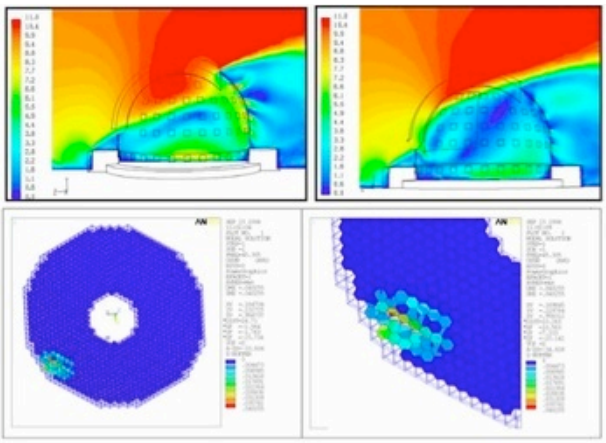


Telescope mount

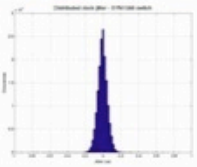
- Two cradle solution
- **Two industrial contracts concluded**
- **FEED ongoing**
- Confirm cost and schedule
- Excellent stiffness (≥3Hz)

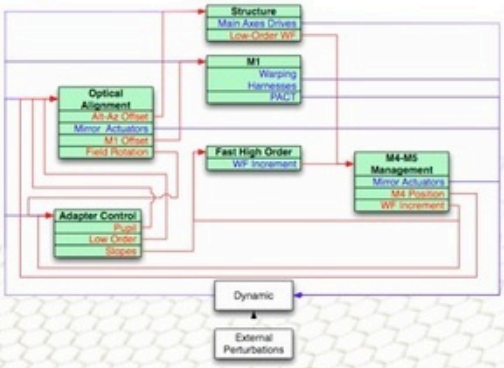


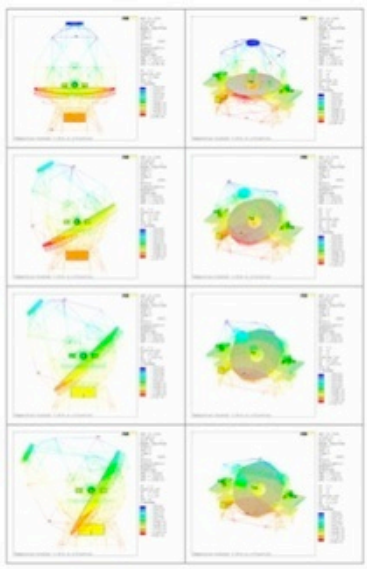
CONTROL SYSTEM

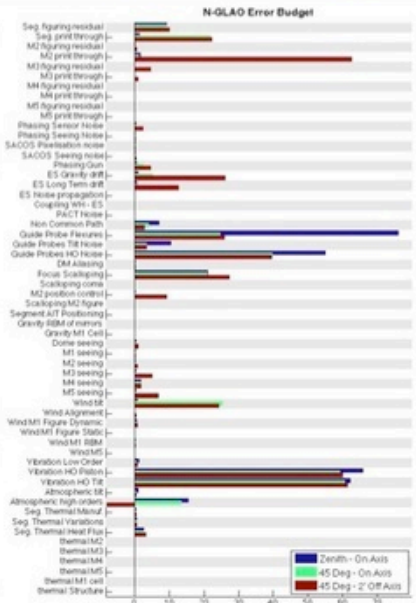


- Substantial progress
- Error budget defined

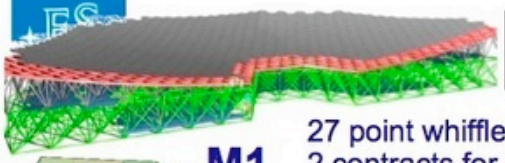








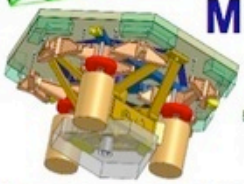
THE MIRRORS

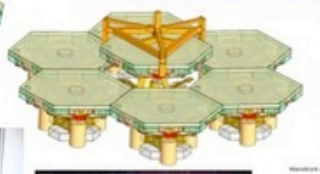


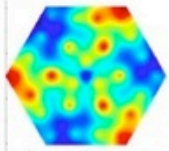
1148 segments:
984 mirror +
1 spare/family

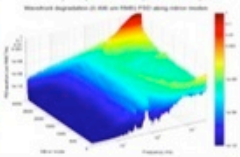
M1

27 point whiffle tree
2 contracts for 7 prototypes +
M1 cell B1 contract ongoing



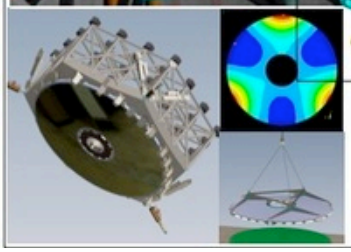




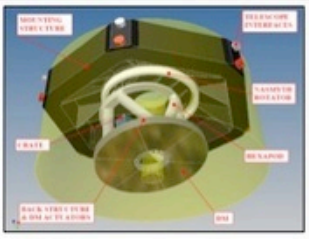


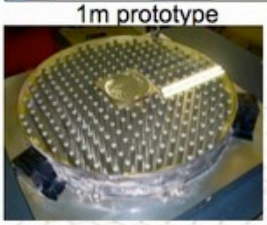
M2

M2 cell contract ongoing
M2 mirror offers received



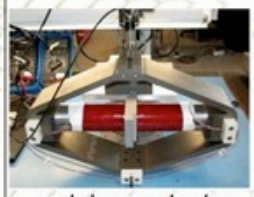
1m prototype





M4

Two industrial studies
will deliver working
prototypes

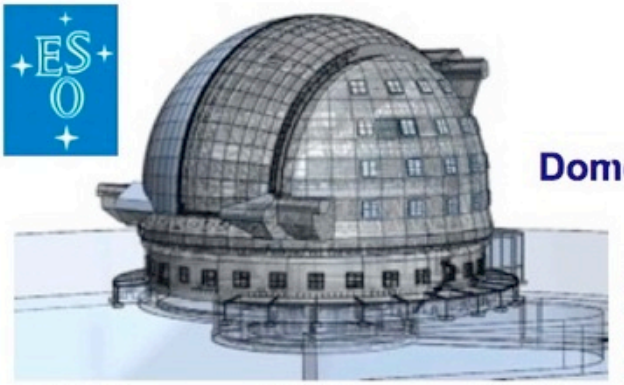


prototype actuator

M5

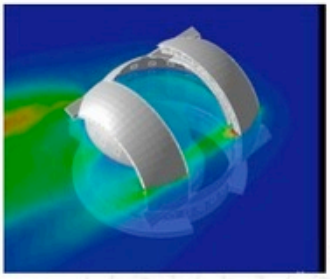
Deliverable of industrial
electromechanical study:
scale 1 prototype

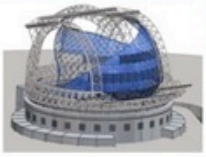
DOME, ADAPTER

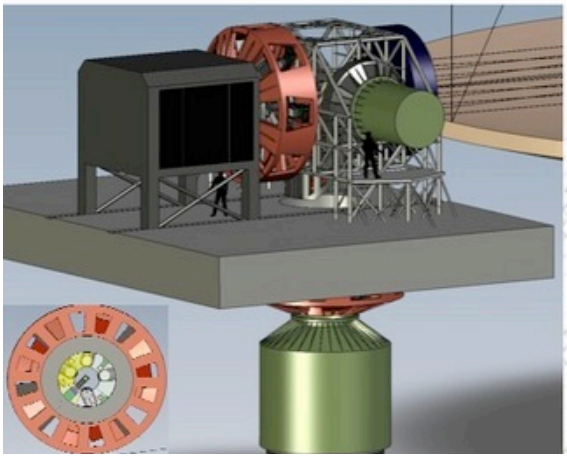


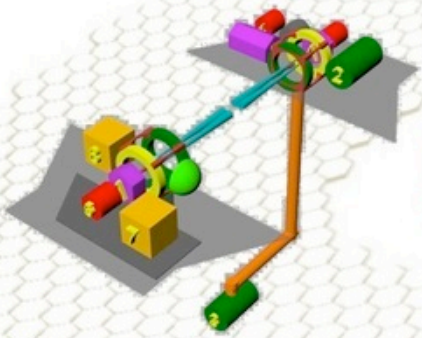
Dome

Two preliminary design
contracts concluded
FEED ongoing



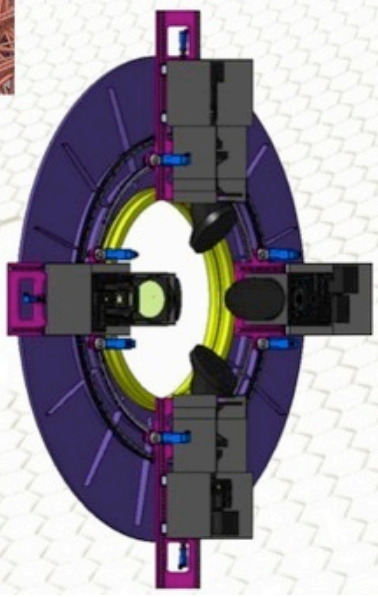




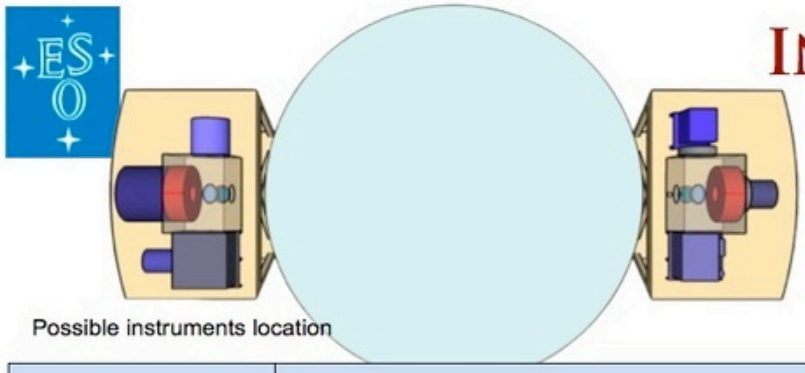


Adapter rotator

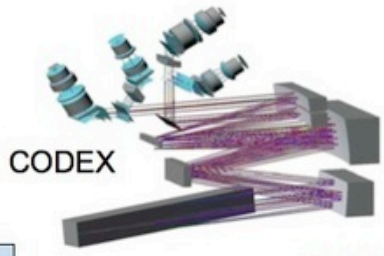
LGSs and NGSs WFSs
in a single unit.



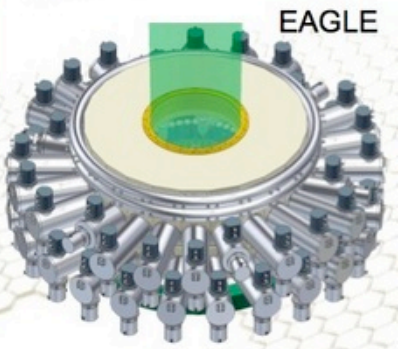
INSTRUMENTATION

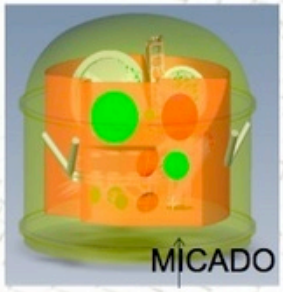


Possible instruments location

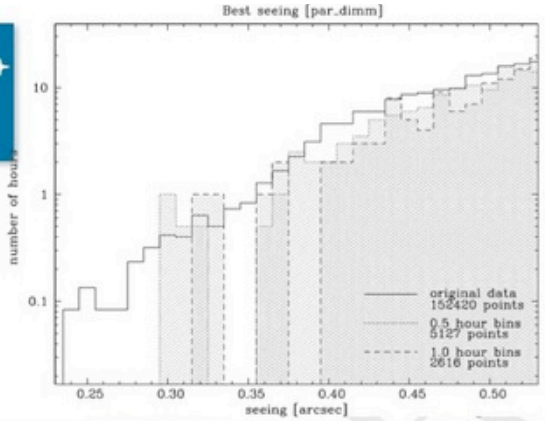


ACRONYM (P.I.)	INSTRUMENT TYPE
EAGLE (J.G. Cuby)	Wide Field, Multi IFU NIR Spectrograph with MOAO
EPICS (M. Kasper)	Planet Imager and Spectrograph with XAO
MICADO (R. Genzel)	Diffraction-limited NIR Camera- AO assisted
HARMONI (N. Thatte)	Single Field, Wide Band Spectrograph - AO assisted
CODEX (L.Pasquini)	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)





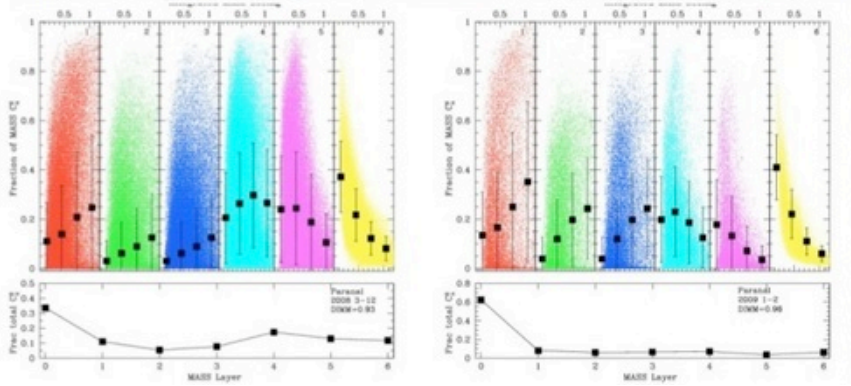
SITE CHARACTERIZATION

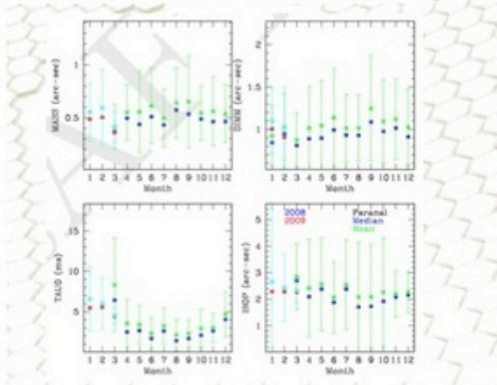


- Data continue to be collected
  - Seeing, C_n^2, PWV, wind, cloudiness etc
- Surface layer physics
  - Correlation with vertical wind and temperature gradients

	Temperature [°C] (median)		Wind Speed [m/s] (median)		Pressure [mb]		Relative Humidity [%] (median)	
	All data	Jan-Feb 2009	All data	Jan-Feb 2009	All data	Jan-Feb 2009	All data	Jan-Feb 2009
Day	12.7 ± 2.4 (12.8)	13.8 ± 1.8 (13.7)	7.0 ± 4.1 (6.2)	6.1 ± 3.1 (5.8)	743.6 ± 1.3	743.7 ± 1.2	20.7 ± 16.1 (15)	29.0 ± 15.1 (28)
Night	11.7 ± 2.6 (11.9)	13.3 ± 1.8 (13.3)	6.4 ± 4.0 (5.8)	5.4 ± 3.1 (4.9)	743.6 ± 1.3	743.6 ± 1.2	17.6 ± 15.7 (11)	26.2 ± 15.7 (25)

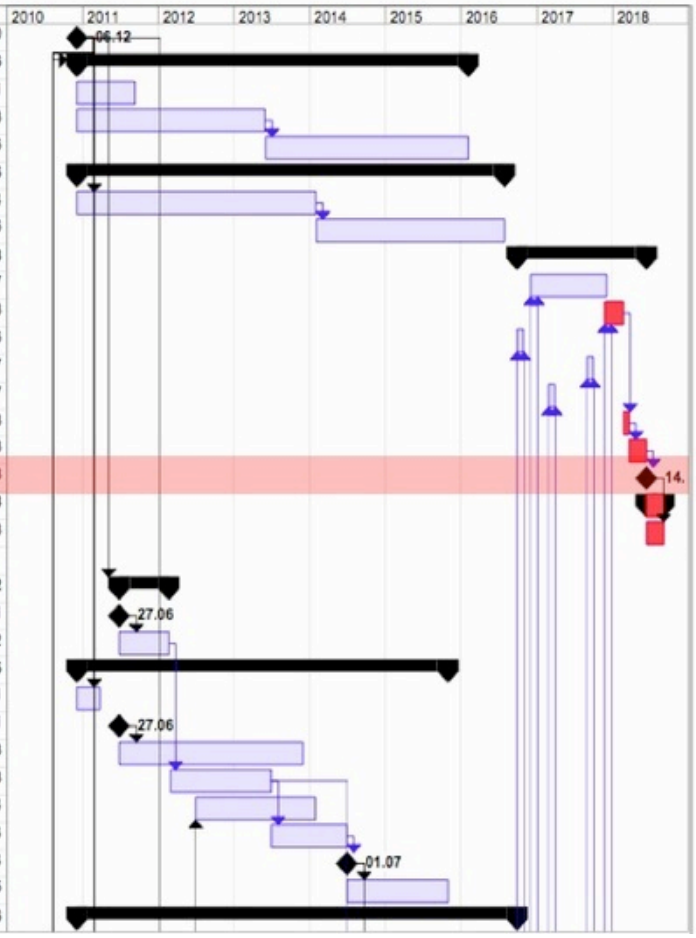
	DIMM seeing [']		MASS seeing [']		τ_0 [ms]		θ_0 [']	
	All data	Jan-Feb 2009	All data	Jan-Feb 2009	All data	Jan-Feb 2009	All data	Jan-Feb 2009
Mean	1.05 ± 0.47	1.06 ± 0.44	0.56 ± 0.32	0.57 ± 0.32	4.00 ± 3.46	6.32 ± 3.64	2.39 ± 1.81	2.55 ± 2.34
Median	0.93	0.96	0.48	0.49	2.89	5.52	2.16	2.29





Technical schedule

ID	Task Name	Duration	Start	Finish
1	December 2010 council meeting	0 days	Mon 06.12.10	Mon 06.12.10
2	**Accomodation and Ofiices**	**1350 days**	**Mon 06.12.10**	**Fri 05.02.16**
3	Temporary camp	200 days	Mon 06.12.10	Fri 09.09.11
4	EU activities	650 days	Mon 06.12.10	Fri 31.05.13
5	Construction	700 days	Mon 03.06.13	Fri 05.02.16
6	**Technical Buildings**	**1475 days**	**Mon 06.12.10**	**Fri 29.07.16**
7	EU activities	825 days	Mon 06.12.10	Fri 31.01.14
8	Construction	650 days	Mon 03.02.14	Fri 29.07.16
9	**AIV**	**446 days**	**Thu 29.09.16**	**Thu 14.06.18**
10	m1 integration into telescope	365 edays	Sun 04.12.16	Mon 04.12.17
11	m2 installation on telescope	90 edays	Sat 25.11.17	Fri 23.02.18
12	m3 installation into telescope	30 edays	Thu 29.09.16	Sat 29.10.16
13	m4 installation in telescope	30 edays	Fri 01.09.17	Sun 01.10.17
14	m5 intallation into telescope	30 edays	Tue 28.02.17	Thu 30.03.17
15	test instrument installation	20 days	Fri 23.02.18	Thu 22.03.18
16	system tests	60 days	Fri 23.03.18	Thu 14.06.18
17	First light	0 days	Thu 14.06.18	Thu 14.06.18
18	**Commissioning**	**60 days**	**Fri 15.06.18**	**Thu 06.09.18**
19	commissioning telescope	60 days	Fri 15.06.18	Thu 06.09.18
20				
21	**Site preparation**	**172 days**	**Mon 27.06.11**	**Wed 22.02.12**
22	contract signature	0 days	Mon 27.06.11	Mon 27.06.11
23	ground preparation	240 edays	Mon 27.06.11	Wed 22.02.12
24	**dome procurement**	**1280 days**	**Mon 06.12.10**	**Sun 01.11.15**
25	dome CfT for construction	80 days	Mon 06.12.10	Fri 25.03.11
26	dome contract signature	0 days	Mon 27.06.11	Mon 27.06.11
27	dome final design	888 edays	Mon 27.06.11	Sun 01.12.13
28	dome and MS foundations	487 edays	Thu 01.03.12	Mon 01.07.13
29	dome European manufacturing	577 edays	Sun 01.07.12	Wed 29.01.14
30	dome erection	365 edays	Mon 01.07.13	Tue 01.07.14
31	ready for parallel telescope	0 days	Tue 01.07.14	Tue 01.07.14
32	dome erection part II	488 edays	Tue 01.07.14	Sun 01.11.15
33	**MS procurement**	**1518 days**	**Mon 06.12.10**	**Thu 29.09.16**



Conclusions

Many thanks to the original OWLers, and particularly to Philippe Dierickx