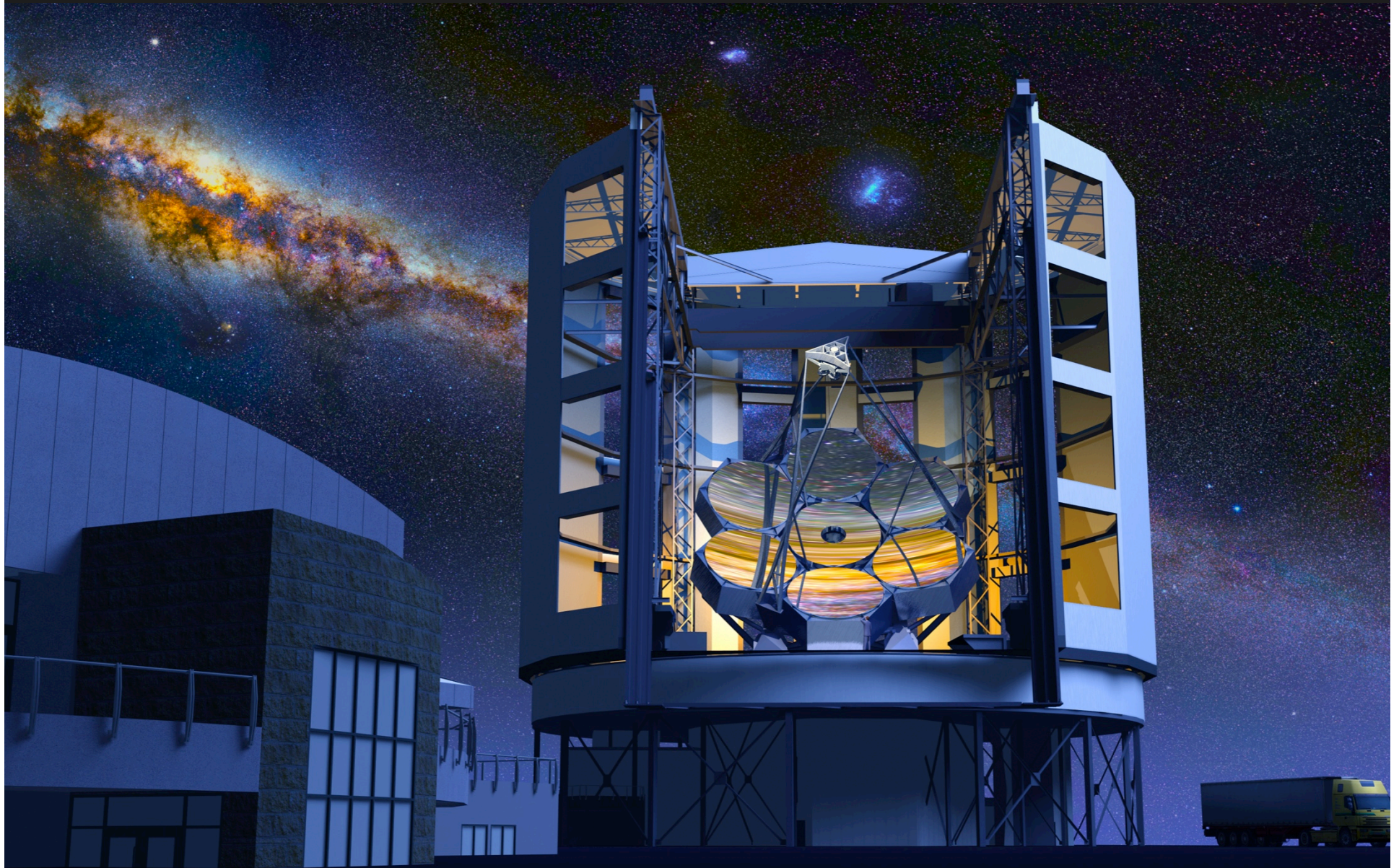


The Giant Magellan Telescope AO Program



AO for ELT 2– Victoria, 26 Sep. 2011

Antonin H. Bouchez



The GMT AO Team

Project Office

Antonin Bouchez, Gelys Trancho

University of Arizona

NGSAO & GLAO WFS

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Australian National University

LTAO, RTC

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Harvard-Smithsonian CfA

Phasing Camera

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U. Chicago

Ed Kibblewhite

Secret Weapon

Marcos van Dam (Flat Wavefronts, NZ)

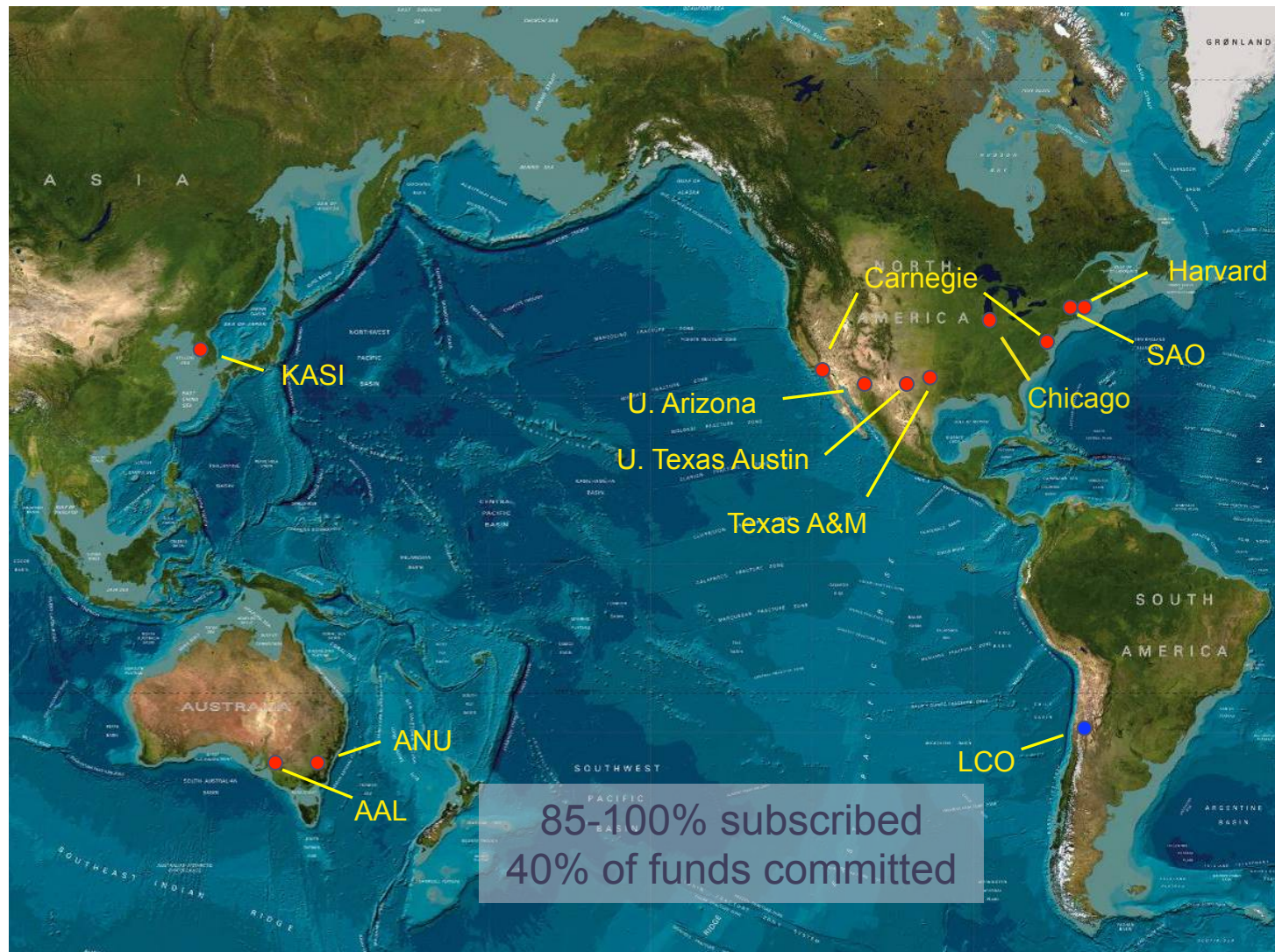


Talk Outline

1. GMT Overview
2. AO Requirements
3. AO System Overview
4. Adaptive Secondary Mirror
5. AO System Design
6. Segment Phasing
7. Integration & Schedule



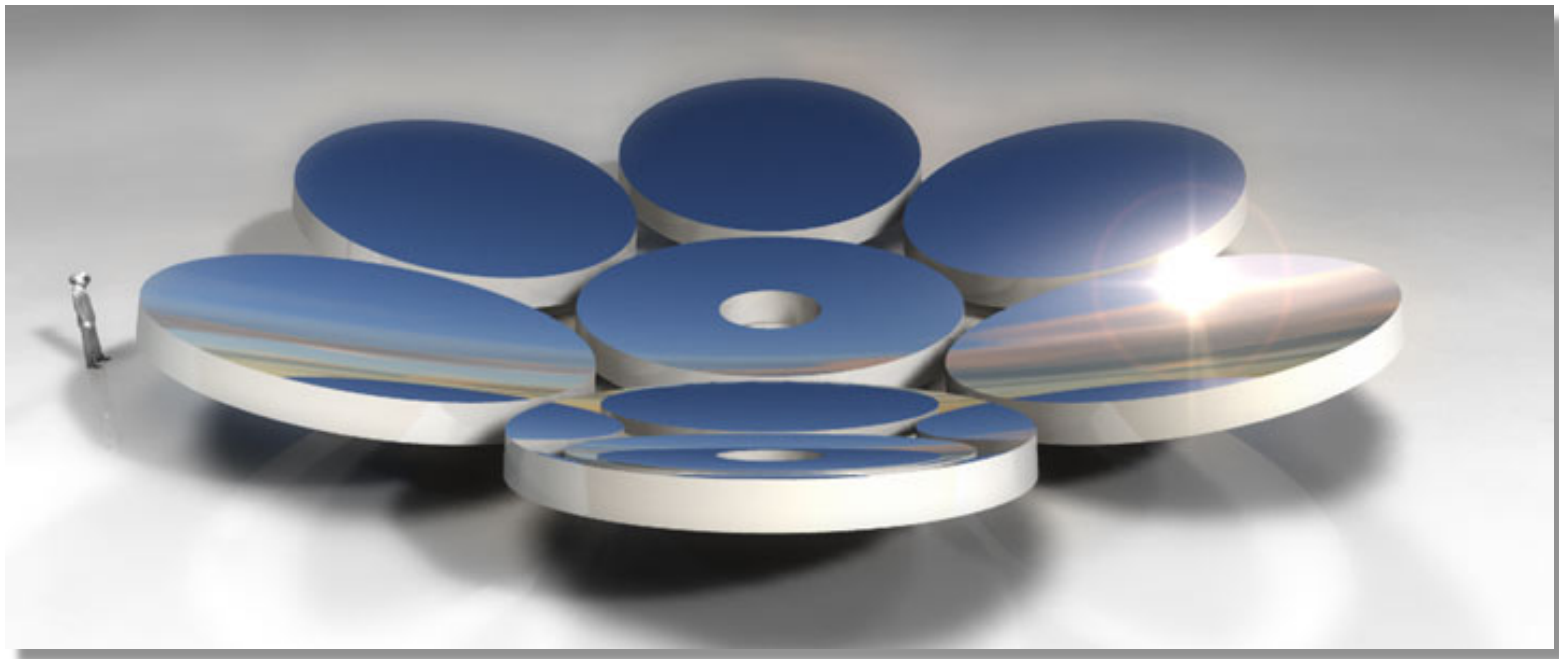
The GMT Partnership





The GMT Concept

A Giant-Segmented Mirror Telescope



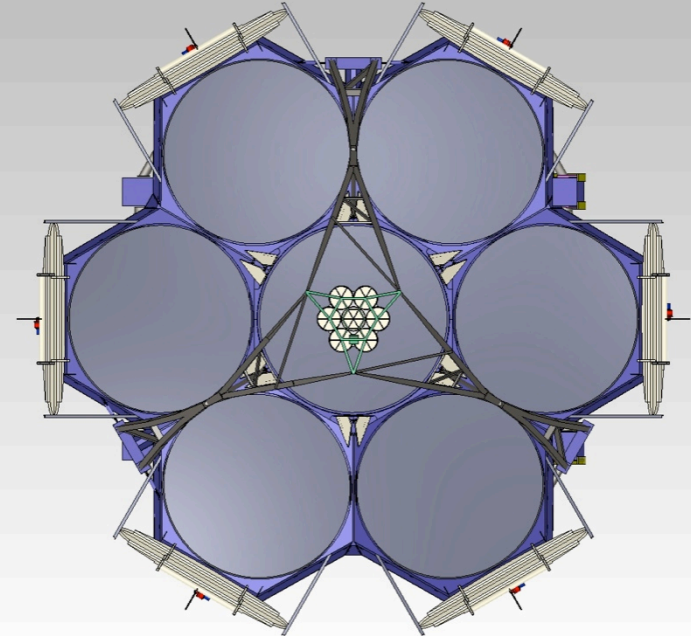
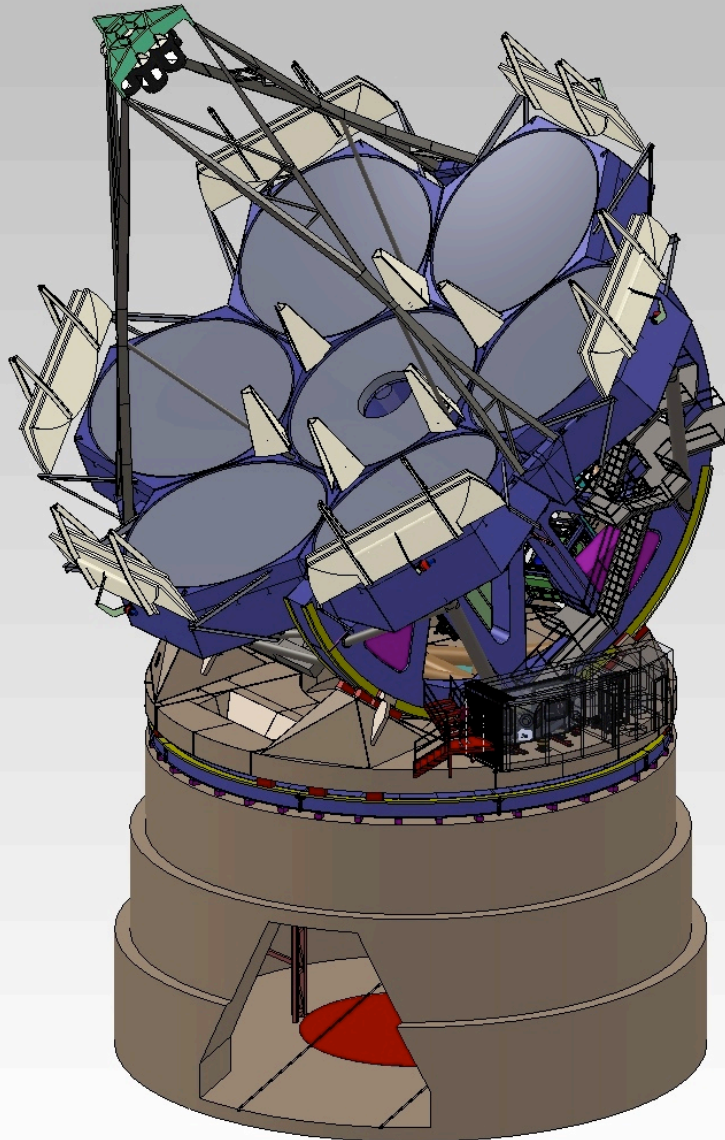
Gregorian optical configuration

Seven 8.4 m primary mirror segments (*2 optical prescriptions*)

Seven 1.05 m secondary mirror segments (*2 optical prescriptions*)

25.4 m edge-to-edge; area equivalent to 21.9 m diameter circular aperture

Telescope Design



Height: 38.7 meters

Mass: 1,125 metric tons

Lowest Mode: 4.5 Hz



Primary Mirror Segment Fabrication

- GMT1 Completion 11/11

Currently 26 nm RMS WFE. Final figuring & acceptance testing.

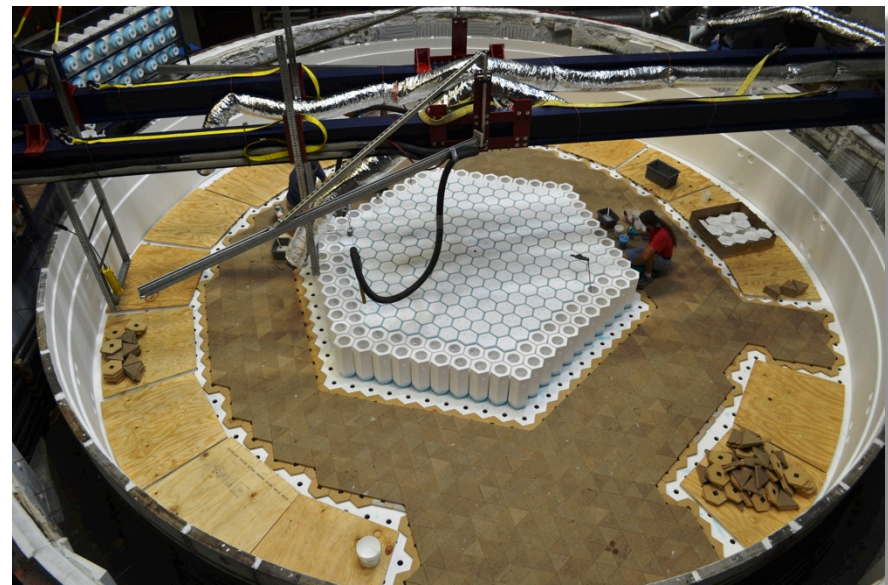
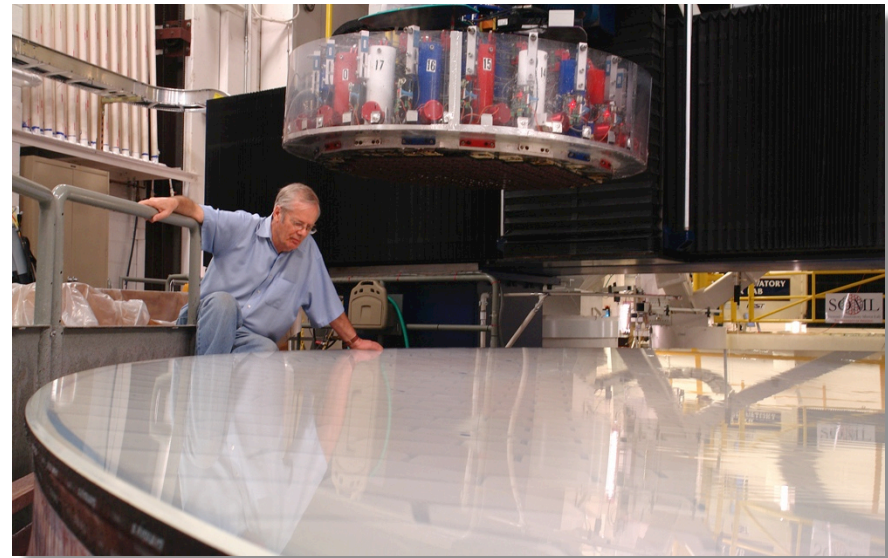
- GMT2 Casting 01/12

Mold assembly

- GMT3 Casting 02/13

Material deliveries

Segments 4-8 at ~ 12 month intervals





Wide-field Instruments

Gregorian Instrument
Rotator: 9 m diam. x 6.5 m

NIRMOS

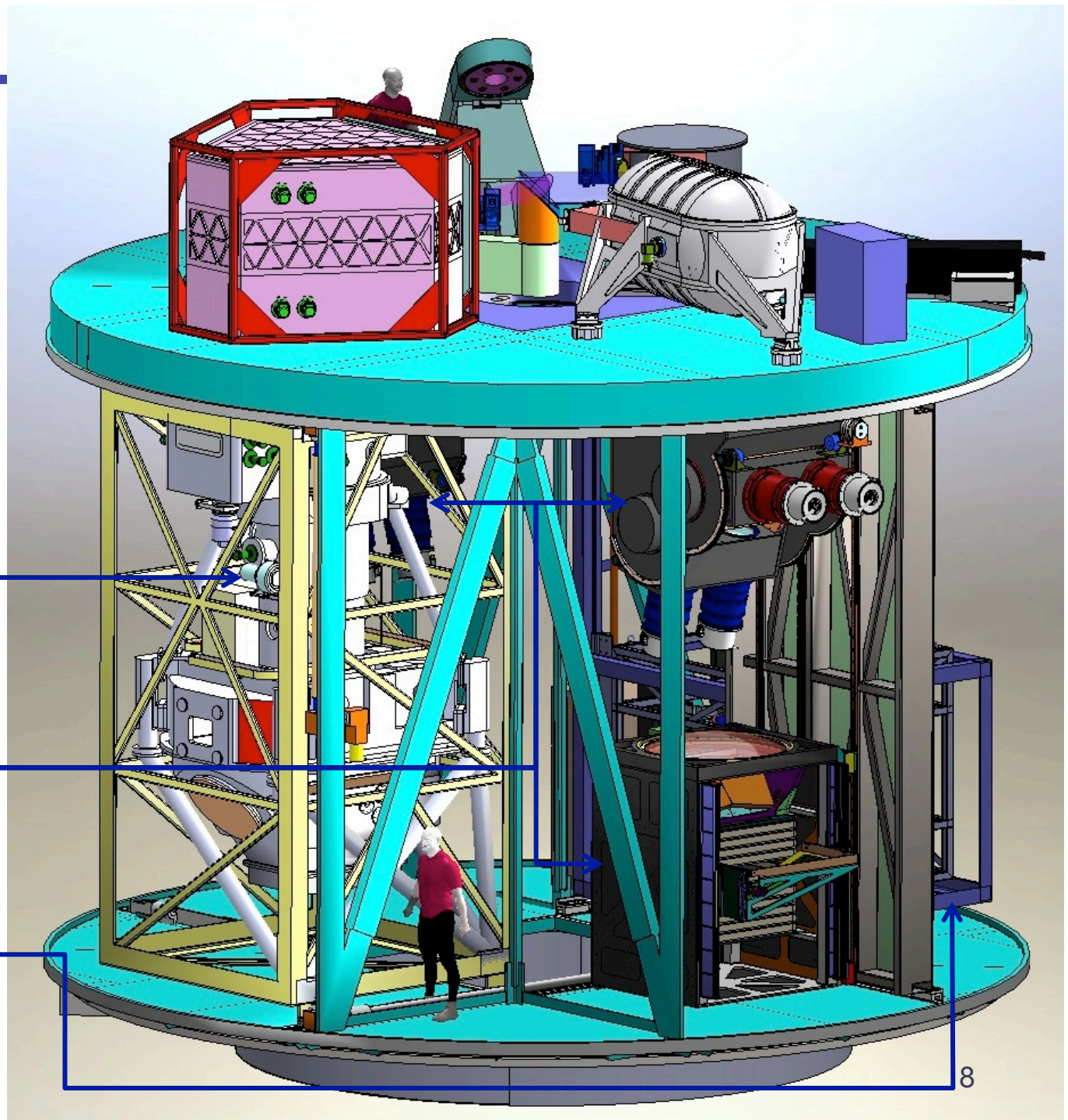
1-2.5 μm , 6.5x6.5 arcmin.
multi-object spectrograph
(GLAO)

GMACS

0.4-0.95 μm , 9x18 arcmin.
multi-object spectrograph
(natural seeing)

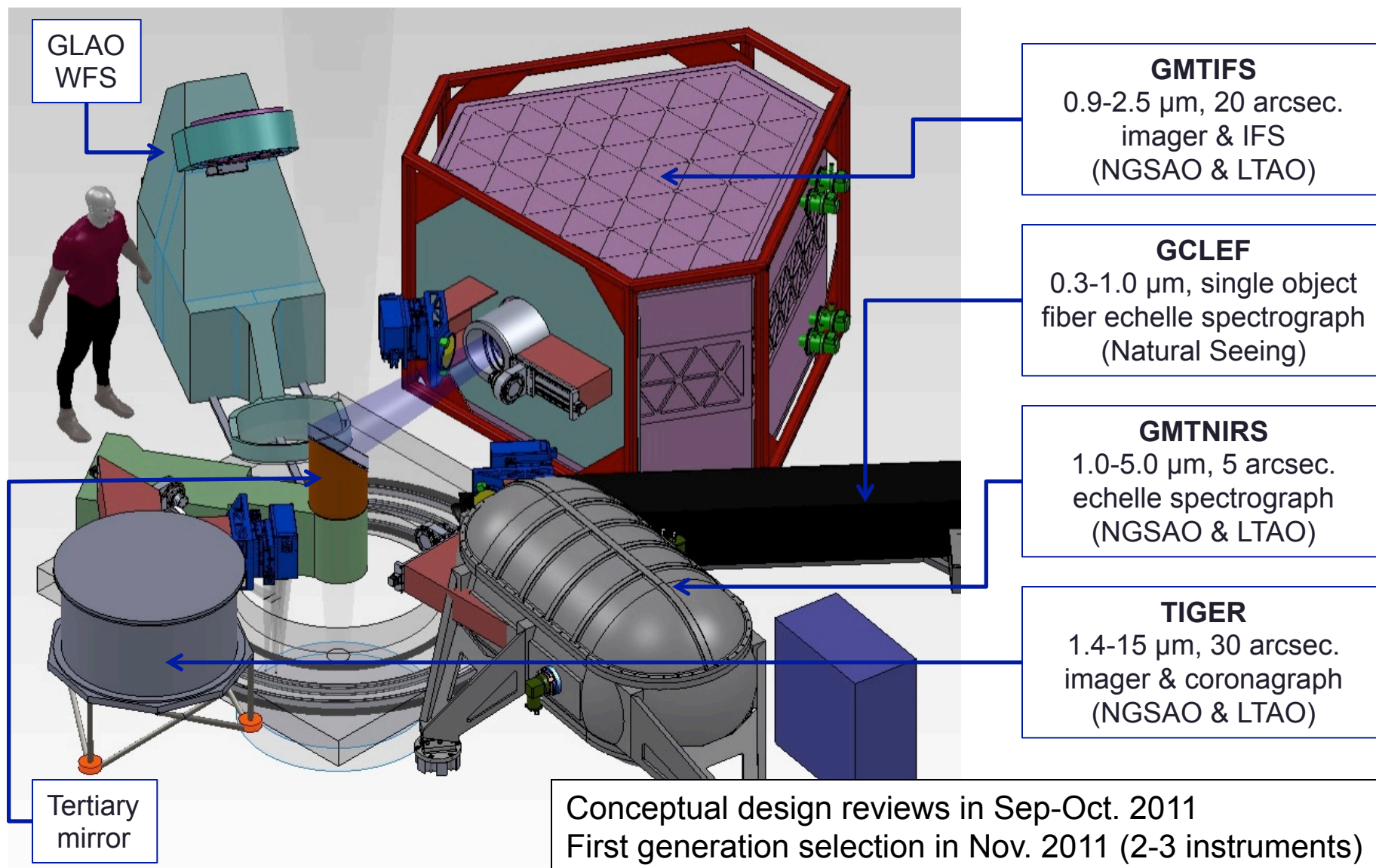
MANIFEST

20 arcmin. field
fiber feed
(limited GLAO)





Narrow-Field Instruments





Site: Cerro Las Campanas, Chile

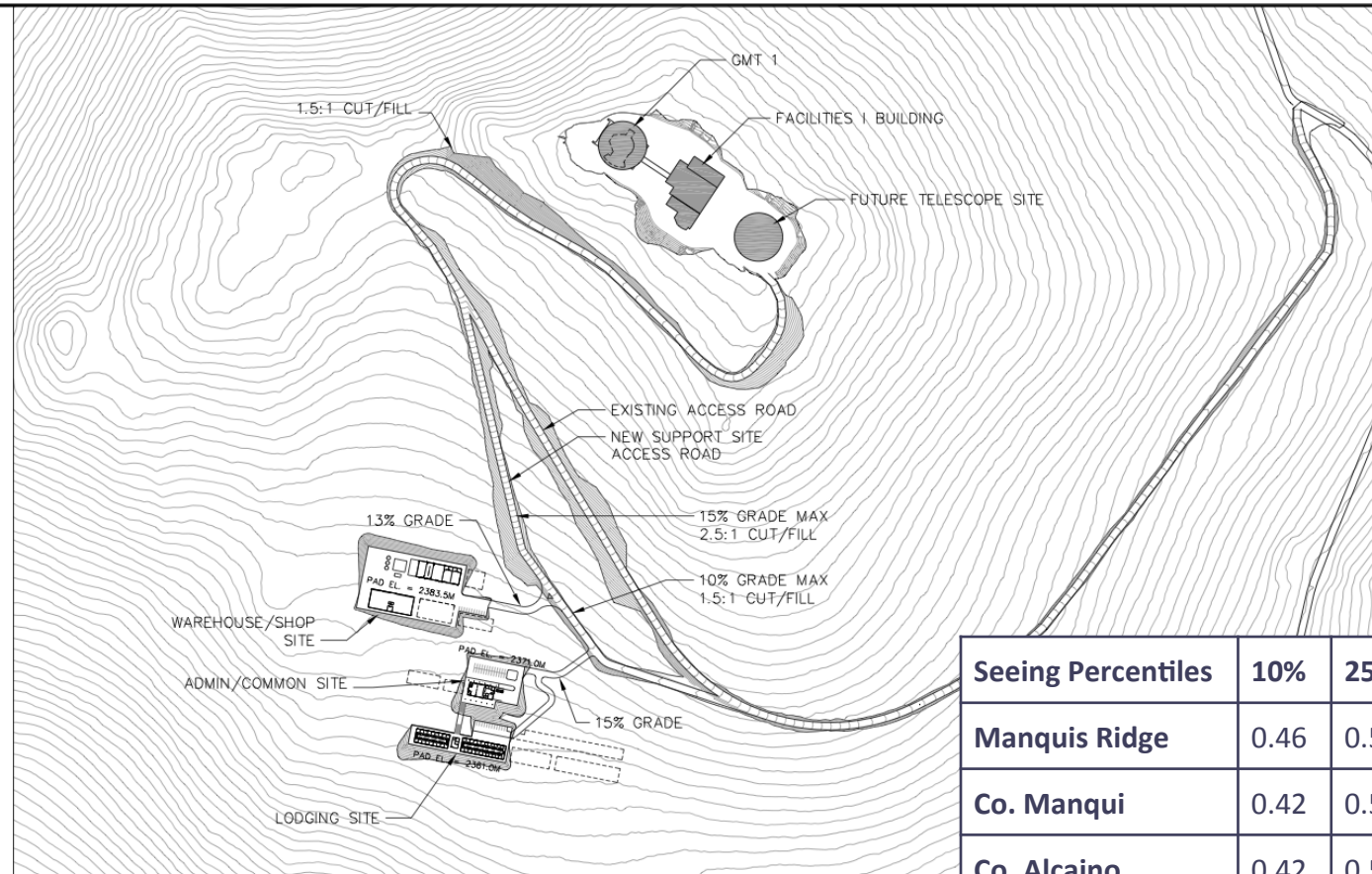


Grading to begin in Nov. 2011

Project No. 100160
Project Giant Magellan Telescope
Sheet No. 1 OF 1 BY D.S.A.
Drawing No. CG-302

SUBJECT: GMT SITE ACCESS ROAD & SUPPORT SITE

DATE: 07/27/2011



General Notes:

Max. Grade: 10% U.N.O.
Road Width: 8.5M
Min. Turning Radius: 25M
Surface: Paved
Cut/Fill Grading: 2.5:1 U.N.O.

Roadwork

Existing access road expansion:
Final width: 8.5M
Length: 2.6Km
Max slope: up to 10%
Min. radius: 25M
Cut: 27,515M³
Fill: 14,868M³
Net: 12,647M³ Cut

Bypass road addition:
Final width: 8.5M
Length: 0.69Km
Max slope: up to 15%
Cut: 7,623M³
Fill: 13,973M³
Net: 6,359M³ Fill

Overall Net: 6,288M³ Cut

Support Site Grading

Warehouse Site:
Cut: 466M³
Fill: 20,435M³

Seeing Percentiles	10%	25%	50%	75%	90%
Manquis Ridge	0.46	0.55	0.67	0.85	1.07
Co. Manqui	0.42	0.51	0.62	0.79	0.99
Co. Alcaino	0.42	0.50	0.62	0.79	1.01
Co. Las Campanas	0.42	0.50	0.63	0.79	0.99

GMT ACCESS ROAD + SUPPORT SITE

1:5000

CONTOUR INTERVALS AT 5 METERS





AO Science Requirements

Mode	Description, Science Cases, Performance Requirements
Natural Guide Star AO (NGSAO)	<u>High Strehl over a narrow field of view using bright guide stars.</u> Science Cases: Extrasolar planets, star formation SCI1883: >75% K Strehl for R<8 stars. SCI1882: >10⁵ contrast at 4λ/D in L' band (goal: 10⁶ at 2λ/D)
Laser Tomography AO (LTAO)	<u>Moderate Strehl over narrow field of view with high sky coverage</u> Science Cases: Galaxy assembly, black holes, star formation SCI1884: >30% H Strehl over 20% of sky at pole. SCI1885: >40% K EE in 50x50 mas over 50% of sky at pole. SCI1886: >50% K EE in 85x85 mas with K=15 on-axis NGS.
Ground Layer AO (GLAO)	<u>Seeing improvement over a large field of view</u> Science Cases: First light, galaxy assembly SCI1887: 25%-50% image size reduction in near-IR over 6.5 arcmin



Performance Requirements & Simulations

Science requirement flow down to:

- NGSAO : <170 nm RMS WFE.
- LTAO : <260 nm RMS high-order WFE and...
 - <2 mas RMS tip-tilt over 20% of sky at the galactic pole
 - <10 mas RMS tip-tilt over 50% of sky at the galactic pole

Modeling approach: Analytic error budgets guide design; wave-optics simulations with random star fields to verify requirements compliance.

- Simulation Tools:
 - YAO – Yorick AO simulation tool (F. Rigaut)
Fast. Used for Monte-Carlo simulations of tip-tilt error
 - OOMAO – Object-oriented Matlab AO tools (R. Conan)
Comprehensive. Includes outer loops (focus, dynamic calibration)
 - AOSim2 – (J. Codona)
High-contrast NGSAO simulations with coronagraphs



AO System Design Features

AO correction built into telescope with an adaptive secondary mirror

Facilitates low background observations at $> 2 \mu\text{m}$

Enables GLAO correction for all wide-field instruments

NGSAO/LTAO wavefront sensors replicated for each instrument

Eliminates all warm optics between telescope & narrow-field AO instruments

A single deployable GLAO wavefront sensing facility

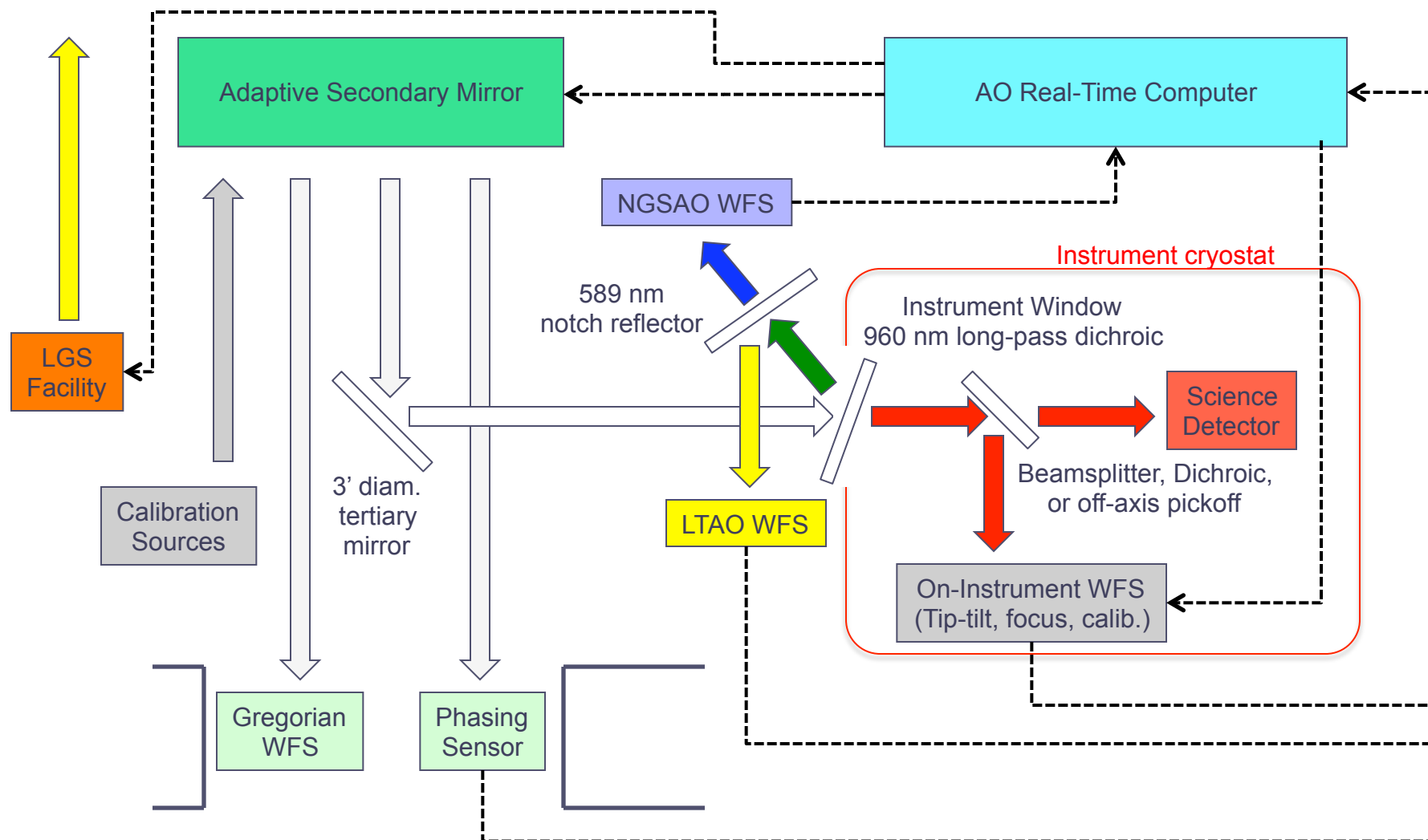
Available to all *Direct Gregorian* instruments

6 x 20 W sodium lasers launch from periphery of primary

Greatly simplifies beam transfer system



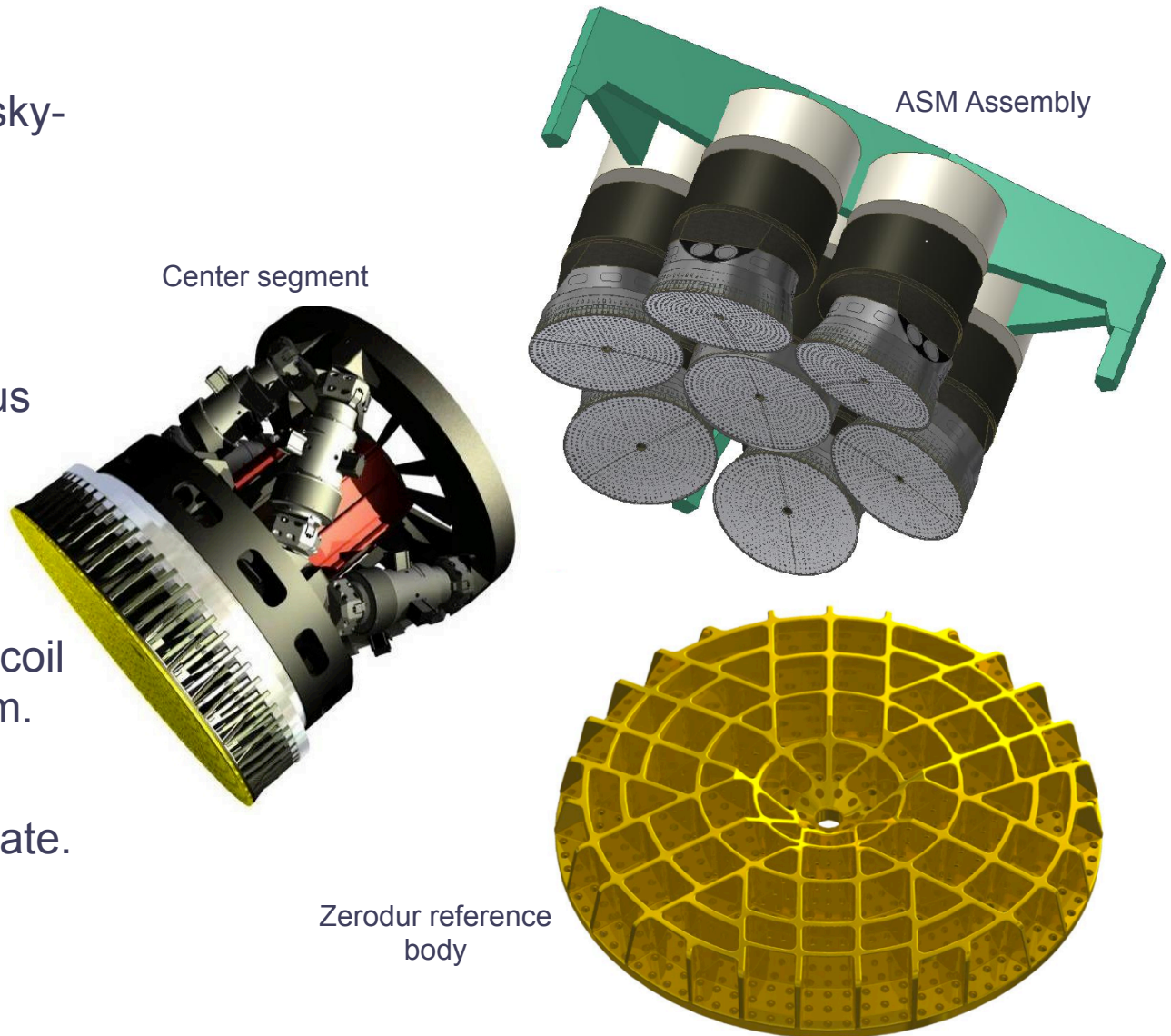
NGSAO/LTAO System Design





Adaptive Secondary Mirror

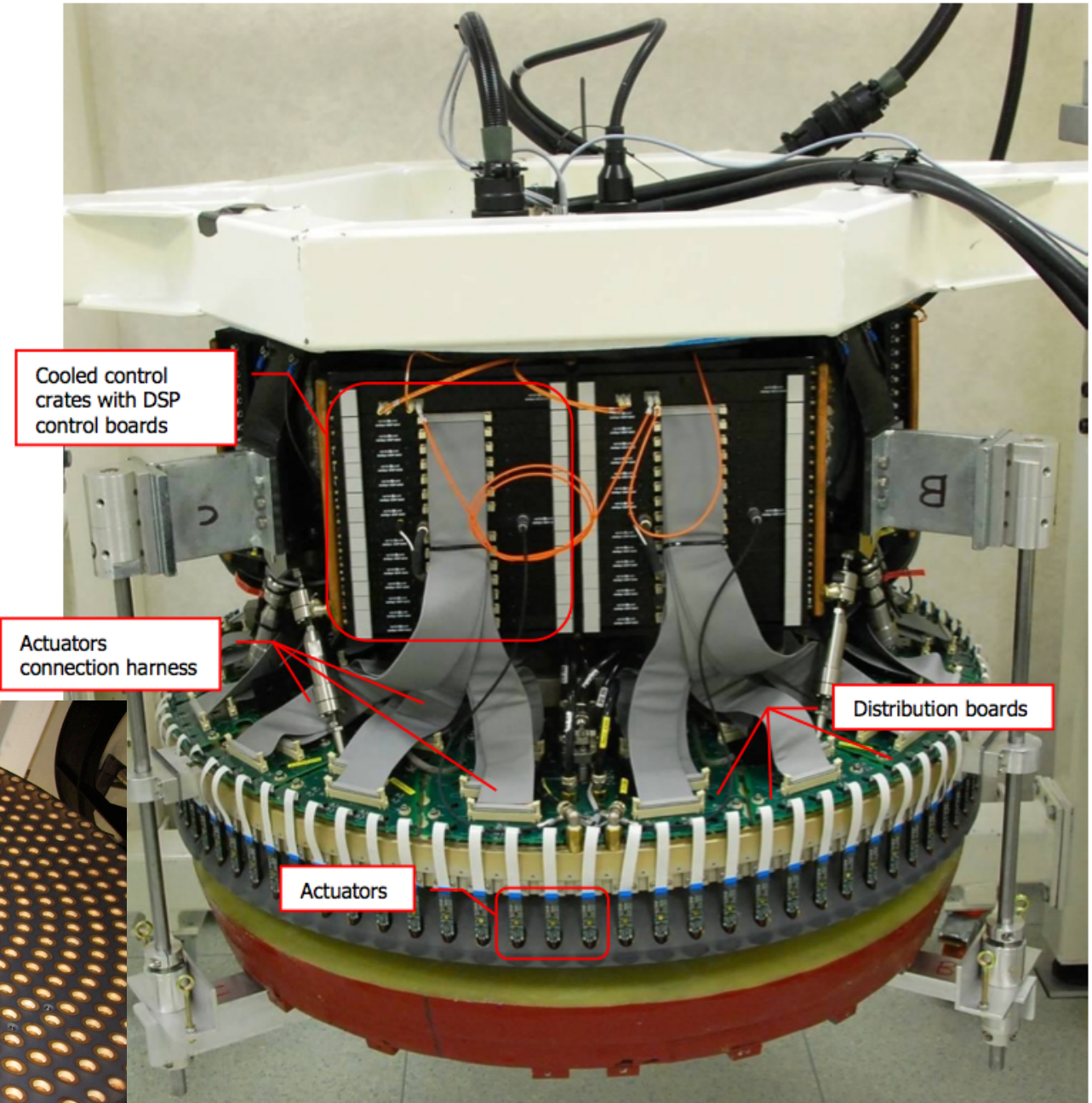
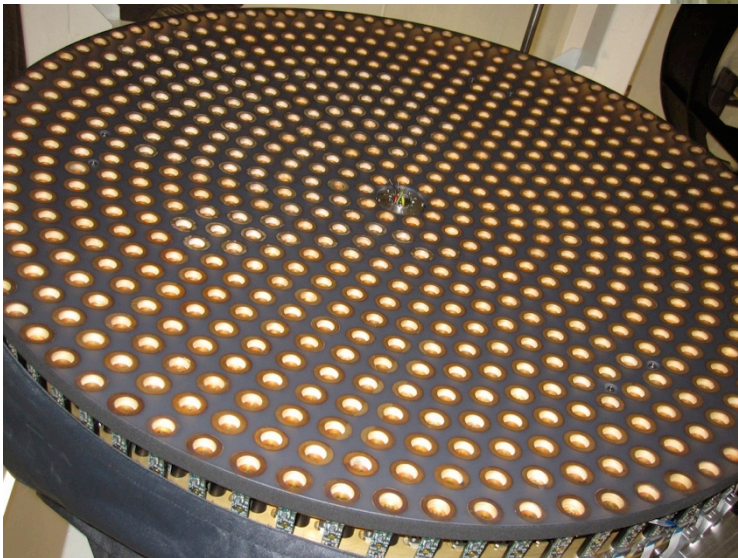
- Secondary assembly is sky-baffled for low thermal background.
- Each segment has 672 actuators, similar size and actuator density to previous ASMs
- 4704 actuators total
- High control bandwidth using a closed-loop voice coil – capacitive sensor system.
- Preliminary Design to be performed by ADS/Microgate.





The Large Binocular Telescope ASM

Viewed from below, face sheet removed



Viewed from above

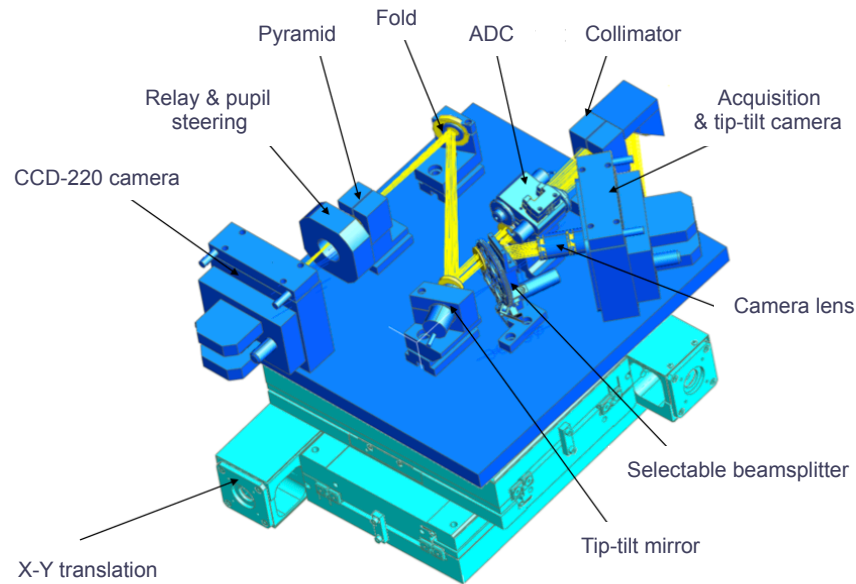


The Present State of Adaptive Secondaries

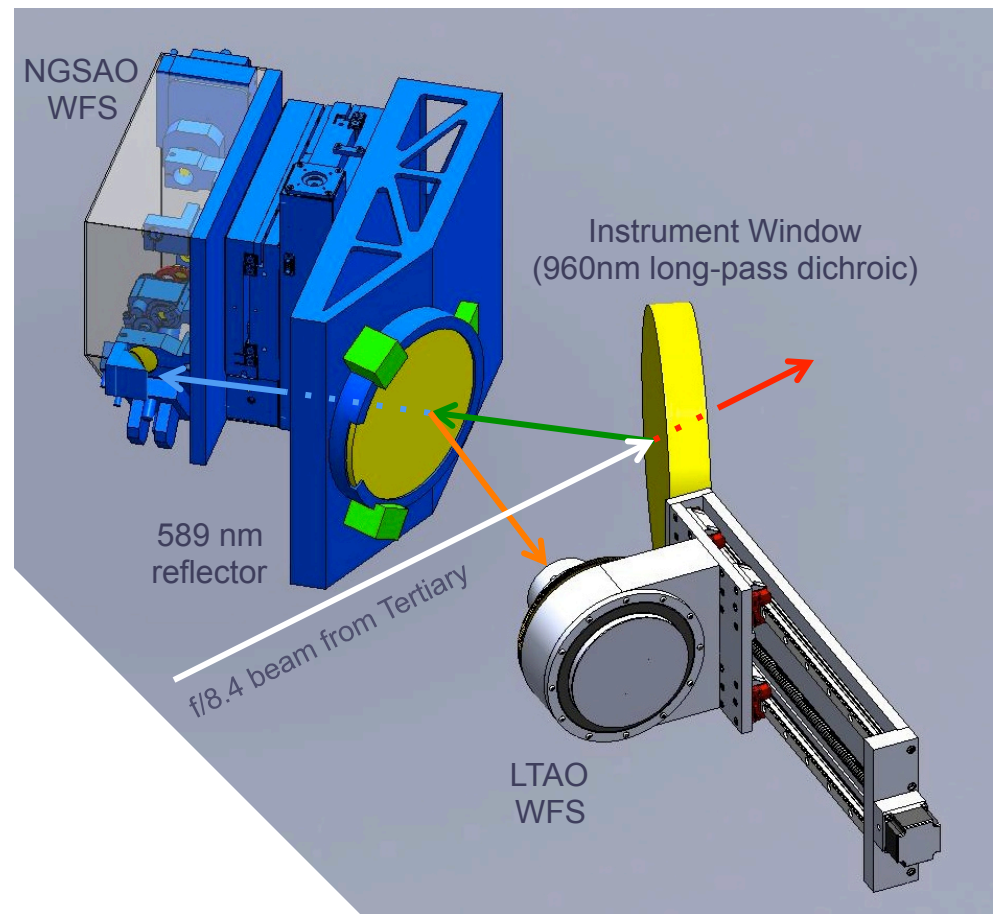
Telescope	Diameter (m)	Actuators	Status
MMT	0.64	336	Operational (22% of scheduled observing time since Jan 2010)
LBT 1	0.91	672	Operational since May 2010
LBT 2	0.91	672	Commissioning in Oct. 2011
Magellan	0.85	585	Completed optical testing
VLT	1.16	1170	Under construction
GMT	7 x 1.06	7 x 672	PDR in Aug. 2012



Visible Wavefront Sensor Assembly

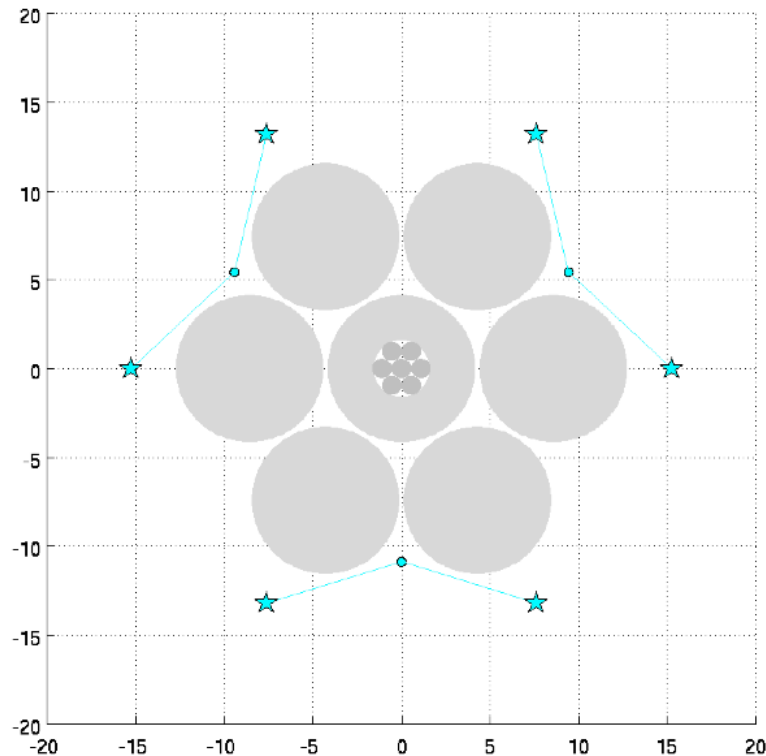


- 90x90 Pyramid WFS
 - Visible acquisition & tip-tilt camera
 - 6 50x50 Shack-Hartmann LGS WFS.
- NGSAO
- LTAO





Laser Tomography AO



On-axis guidestar implementation

- Narrow field passed to instrument (TIGER, GMTNIRS)
- Dichroic or beamsplitter directs on-axis guidestar to OIWFS.

High sky coverage implementation

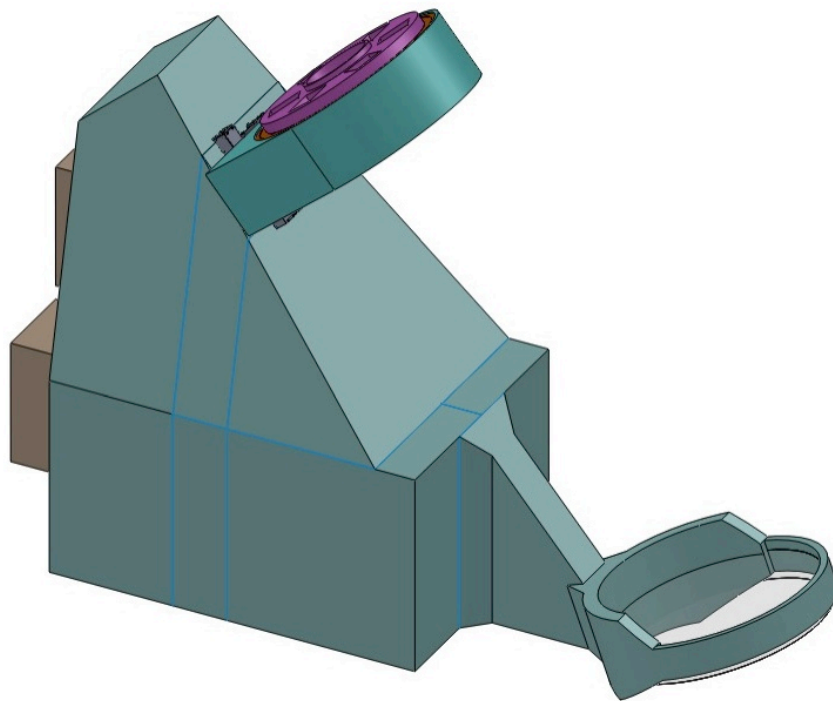
- 3 arcminute diam. field passed to instrument
- Steering mirror in pupil plane directs off-axis guidestar to OIWFS.
- Open-loop correction with MEMS DM to provide diffraction-limited tip-tilt and focus sensing in H/K.

Laser Guidestar Facility

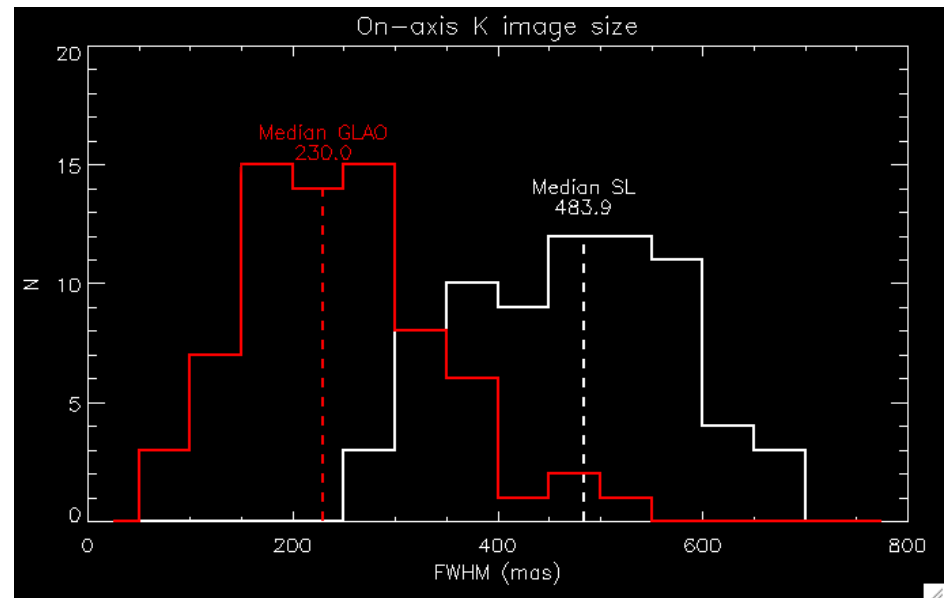
- Baselineing 6 x 20 W Toptica Raman fiber amplifier lasers
- Off-axis laser launch from 3 locations

LTAO system design, performance simulations, and algorithms will be presented by Rodolphe Conan (Tue.) and Marcos van Dam (Fri.)

Ground Layer AO



- 6 LGS constellation, on 3.0' radius
- Tip-tilt, focus, and low-bandwidth NGS correction provided by 3 peripheral Gregorian WFS
- Expect ~50% FWHM improvement at K band, over 6.5' diameter field
- Requires 700 mm diam. long-pass dichroic, R=5230 mm cylinder on back.





Phasing the GMT mirror segments

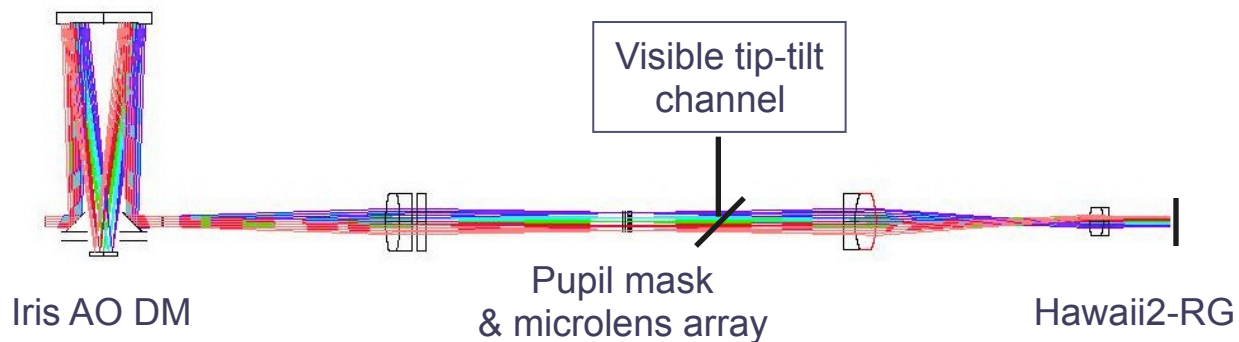
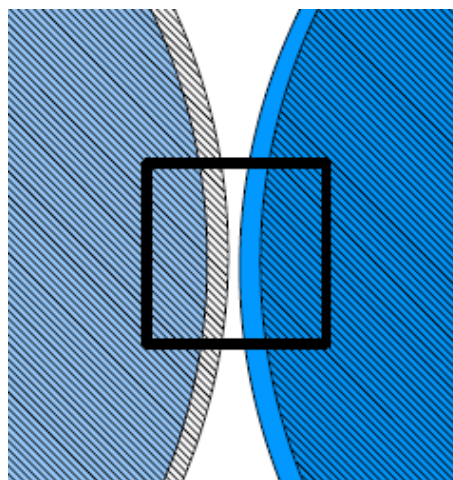
- To achieve diffraction-limited images (NGSAO & LTAO), the GMT segments must be phased to ~ 50 nm RMS.
- Primary segments are borosilicate, 40 cm separation. Edge sensors are unlikely to remain stable at this level over long periods.

Strategy

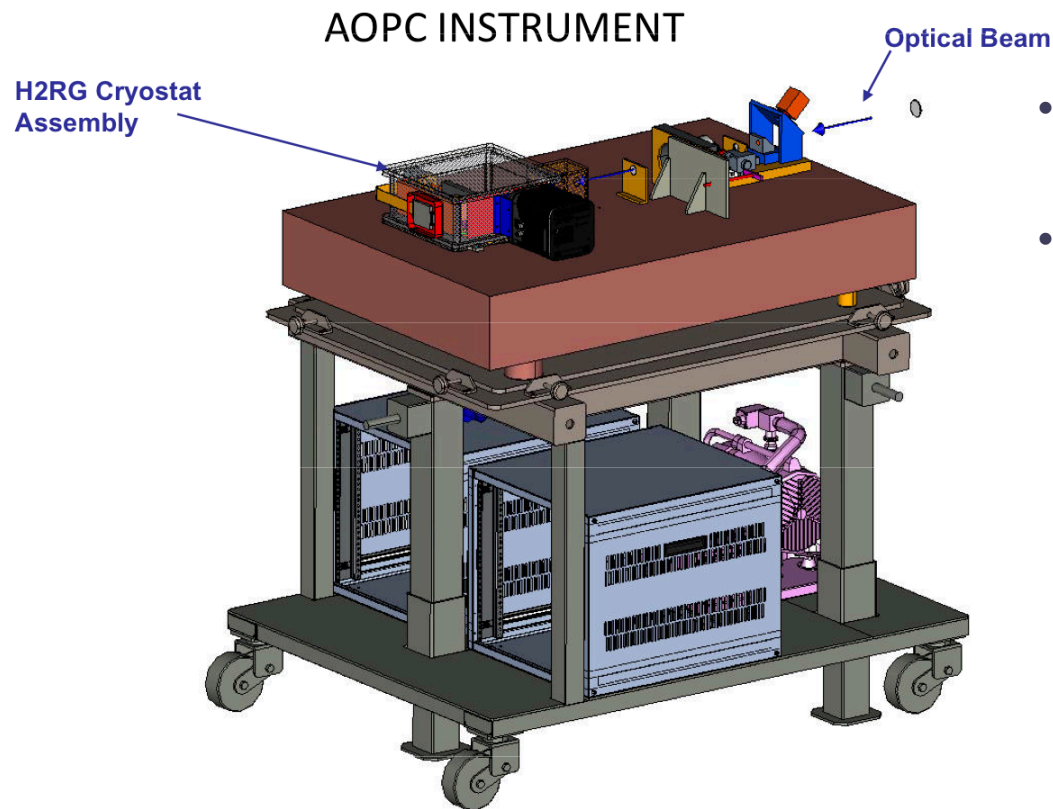
- NGSAO – Use a Pyramid WFS to measure and correct both telescope & atmosphere.
- LTAO – No sufficiently bright star within the isoplanatic region to measure optical path difference. Proposed solution:
 - Fast (100+ Hz): Edge sensors, likely using off-the-shelf laser interferometers between adjacent segment.
 - Slow (0.03 Hz): Off-axis optical phasing sensor continuously updating the edge sensor zeropoint.
 - Atmospheric piston: Ignore and accept 120 nm RMS WFE

Optical Phasing Sensor

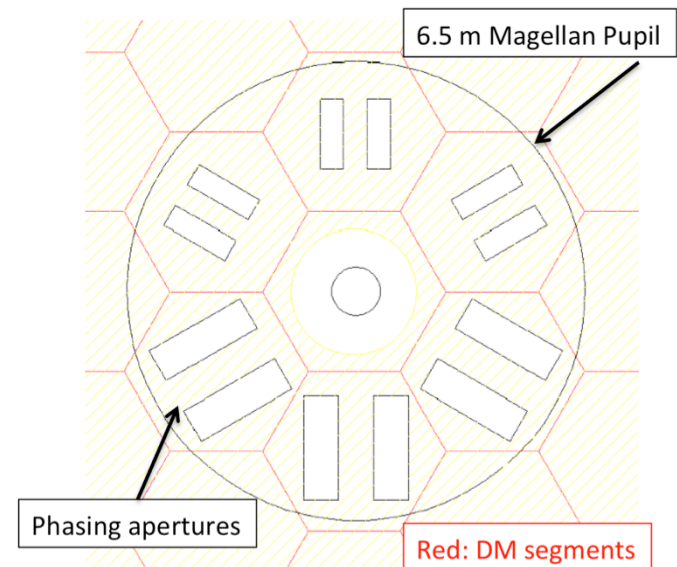
- Hartmann type sensor
- 1.6 m subapertures spanning segment gaps
- Independent tip-tilt on each aperture using segmented DM
- Image fringes in K band
- Expect to use $R < 15$ stars



Prototype Optical Phasing Sensor

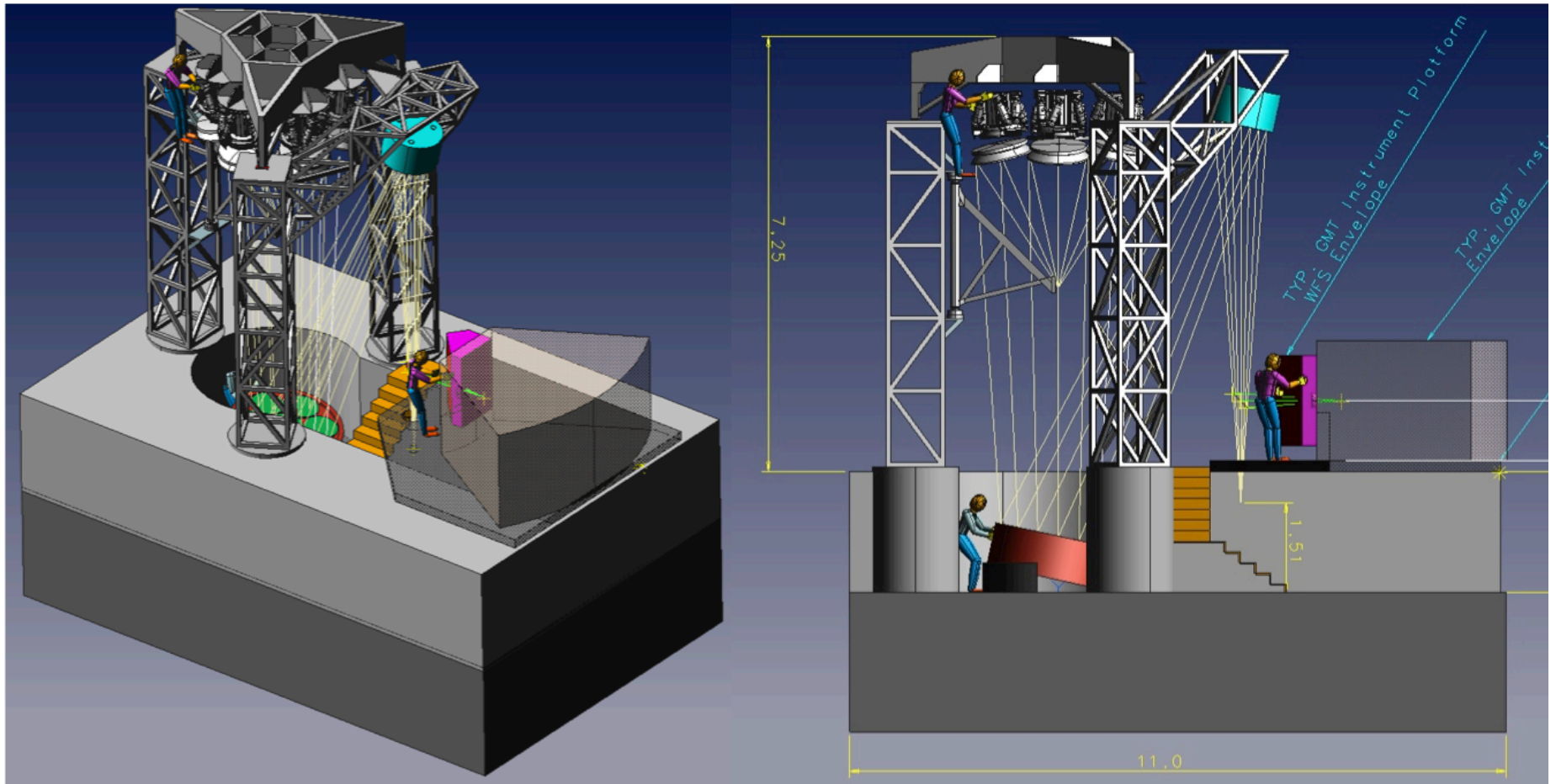


- Built by Smithsonian Astrophysical Observatory (B. McLeod PI)
- Replicates apertures of OPS, on Magellan Clay 6.5 m telescope
- Initial on-sky tests in April 2012





AO System Integration & Testing



ASM calibration facility also used for AO integration and AO-Instrument integrated testing



Project Critical Paths and Milestones

