

The California Extremely Large Telescope

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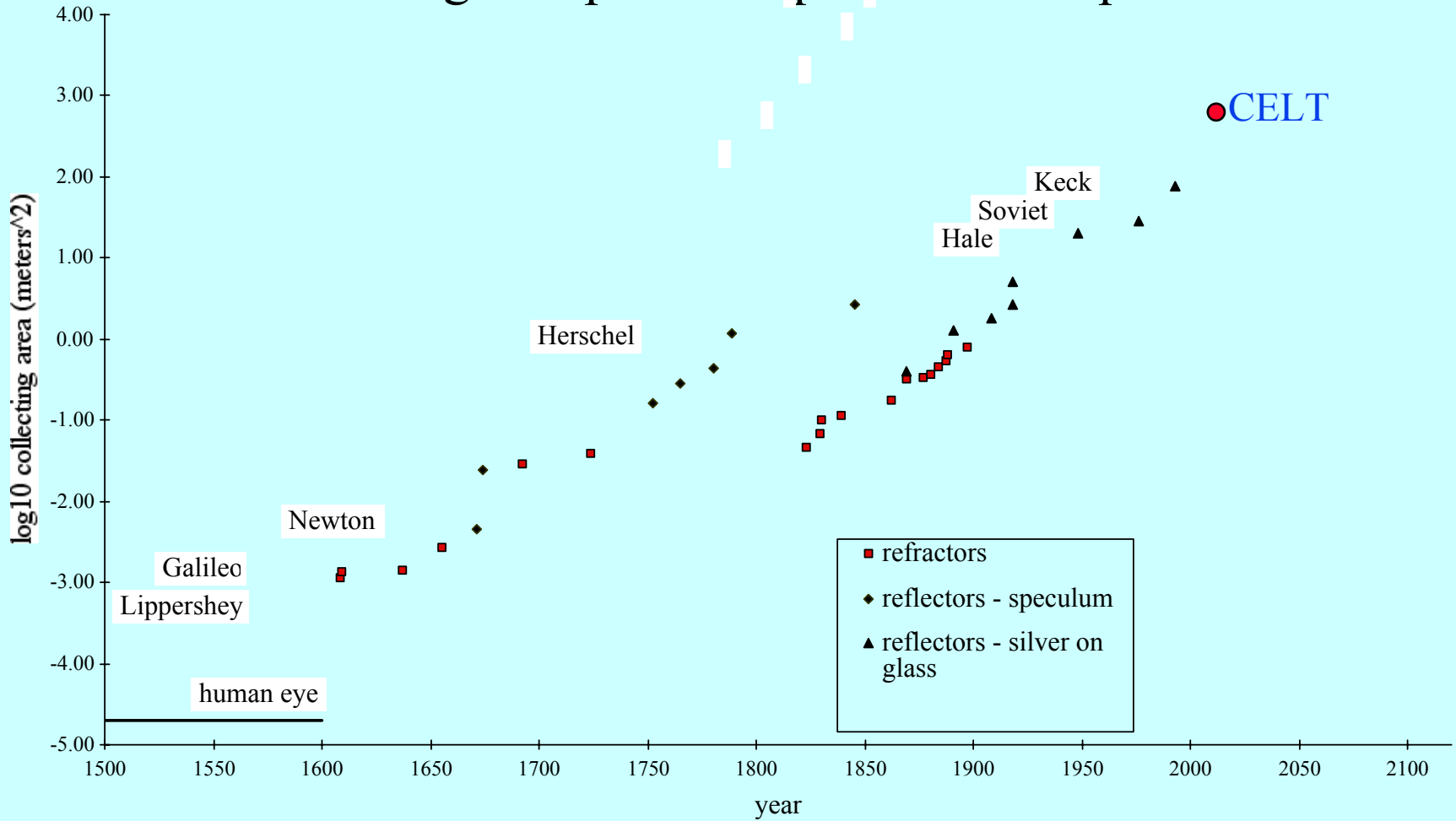
2003 March 17

GSMT Science Working Group

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Largest Aperture Optical Telescopes



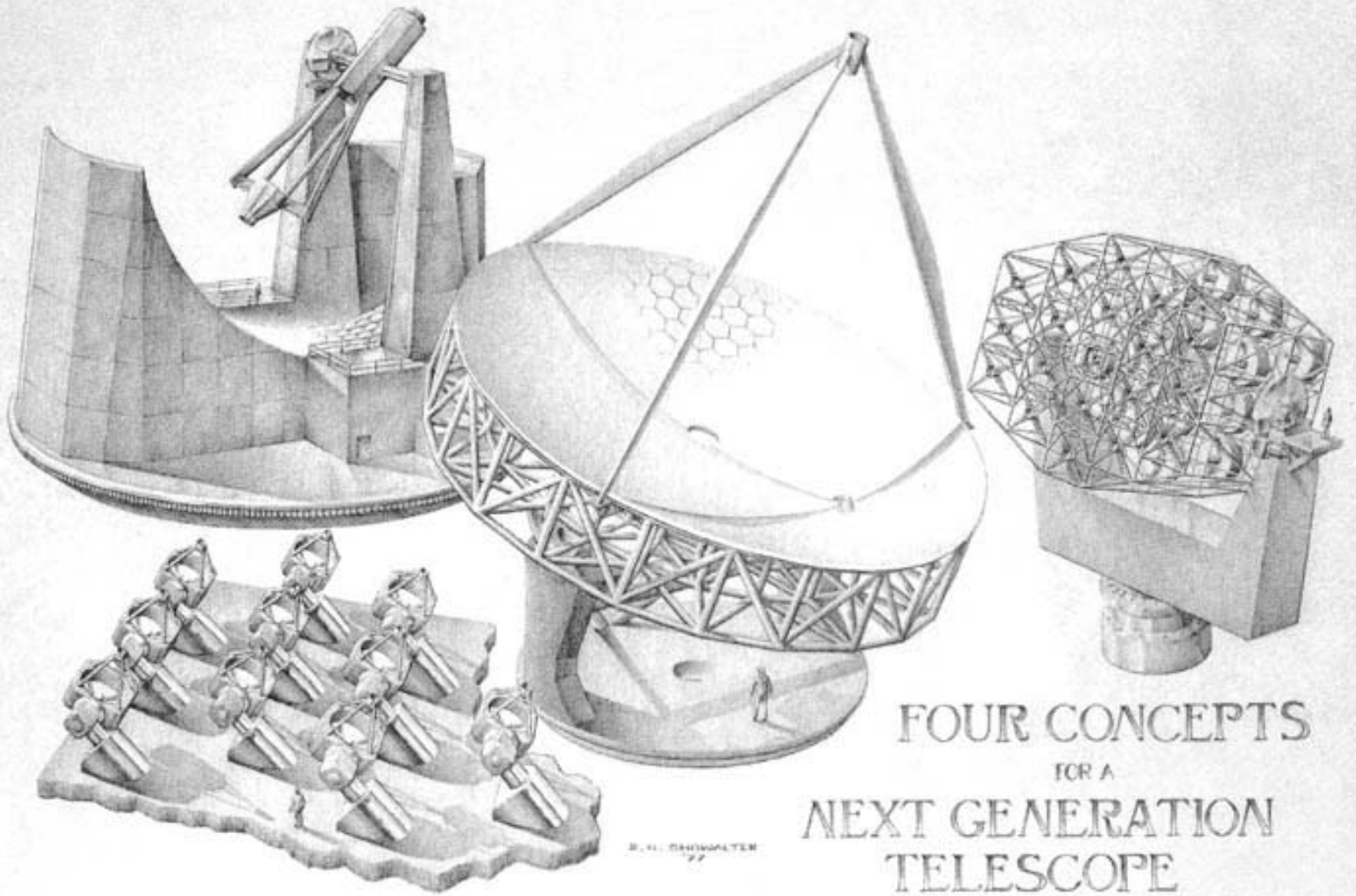
Desire for larger telescopes

- **History shows largest telescope diameter doubles every 31 years**
 - 2.5m 1917 Hooker
 - 5m 1948 Hale
 - 10m 1993 Keck
- **2001 NAS decadal astronomy and astrophysics survey committee (AASC) recommended a 30-m telescope (GSMT) as its highest ground based priority**
- **Other groups in the US and in Europe are thinking and talking about giant telescopes (up to 100-m) on the ground**
- **Advances in adaptive optics makes this particularly exciting**

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

Predicting the Future

- **The KPNO 25 m telescopes studies (~1980)**
 - Steerable Dish
 - Multiple telescope Telescope
 - Shoe
 - Mailbox
 - Singles Array (6 x 10 m, 100 x 2.5 m)
- **NGST (studies now, launch ~ 2010)**
 - 8 m from 2.5 m (descoped to 5.6m) very large increase in size
 - 50° vs 273° cryogenic telescope
 - L2 orbit vs low earth orbit distant, difficult orbit
 - Communications distant, high bandwidth
 - detector arrays very ambitious detectors



FOUR CONCEPTS
FOR A
NEXT GENERATION
TELESCOPE

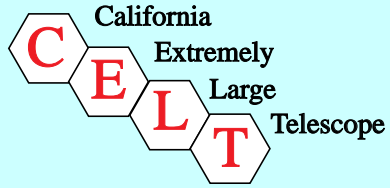
Predicting the future

- **Proposed Future Ground Based Telescopes**

- California Extremely Large Telescope (CELT) 30 m
- 20/20 (University of Arizona study) 30 m equivalent
- Euro 50 (Lund University study) 50m
- OWL (ESO study) 100m

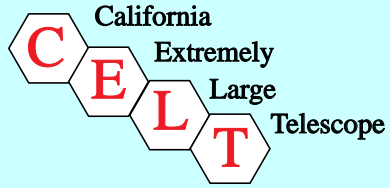
- **Major Issues (mainly cost)**

- mass production of optics
- active control
- adaptive optics
- science instruments
- structural issues
- enclosure/ weather protection



California Extremely Large Telescope

- **CELT is a study to build a 30-m telescope**
- **UC and Caltech are partners**
- **Funding is not yet in hand**
 - Proposal for phase 2 (technology development and preliminary design) being written
- **Site is unknown (several candidates)**



Brief History of CELT

- **Feb 1999** Nelson describes possibilities of an extremely large telescope to Canadian survey committee
- **June 1999** Nelson describes technical issues and ideas for making a 25-m telescope at the Backaskag meeting in Sweden
- **June 1999** UC and Caltech strongly support a joint effort to design and build an ELT
- **2000** AASC decides to recommend a 30-m ground based telescope (GSMT)
- **Sept 2000** Official start of CELT conceptual design effort
- **April 2002** Completion of CELT conceptual design (publish “Greenbook”)

Brief History of CELT-2

- **May 2002 External Review Committee for CELT (Moses committee)**
 - Recommended to UC and Caltech that design was sound and they should support the next phase of development
- **Fall 2002 political difficulties between UC and Caltech**
 - UC and Caltech submit independent proposals to Moore Foundation for Phase 2 support
- **Mar 2003 UC and Caltech agree to partner and form CELT corporation**
- **Mar 2003 CELT interested in partnering with AURA to develop a 30-m telescope**

Key Assumptions for CELT Design

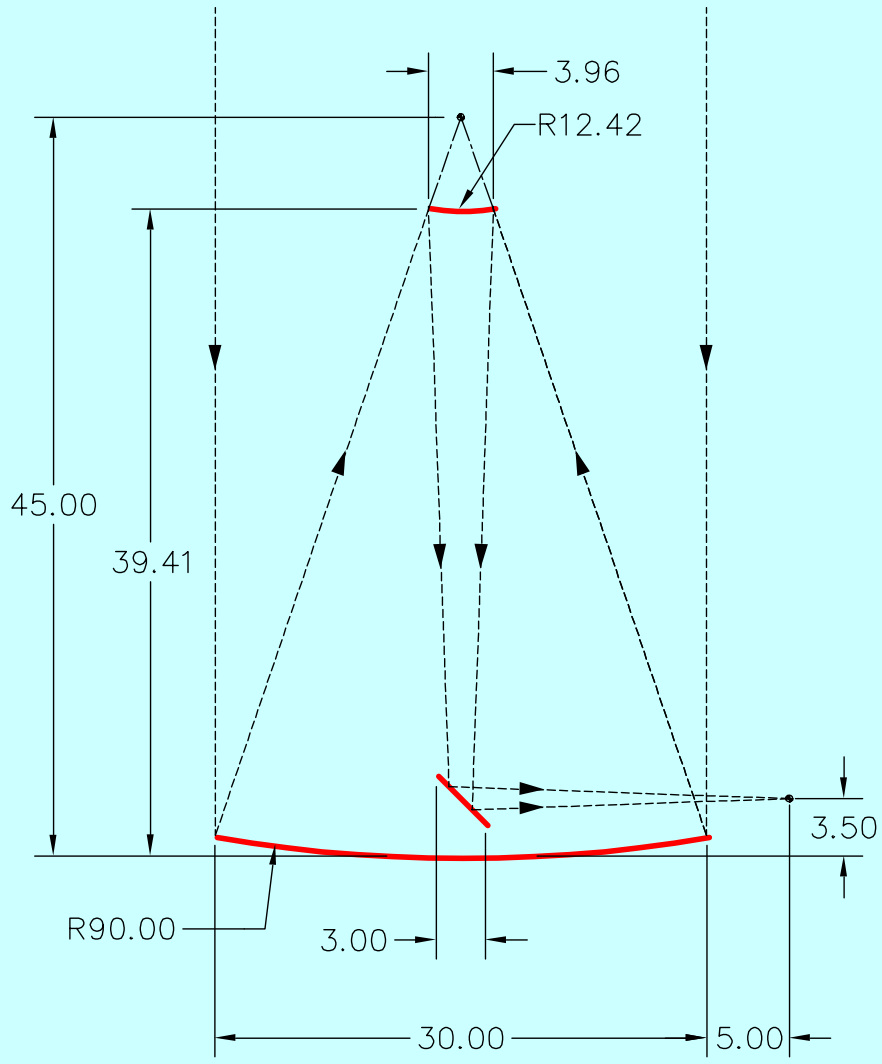
- **Historical experience (Keck +...)**
 - Prime focus in low demand
 - Cassegrain focus a servicing and maintenance complexity
 - Instruments prefer a large working area (also allows for future uncertainties)
 - Instrument exchanges are difficult and a maintenance issue
 - Demand for thermal IR science is modest
 - Interferometry is complex and demand is modest
 - Diffraction limited capability strongly desired
- **Simplifying assumptions for CELT**
 - Single aperture
 - No prime focus (reduces size, simplifies servicing)
 - No cassegrain focus (simplifies instrument exchanges, servicing)
 - Large Nasmyth platforms (carry multiple instruments, all accessible)
 - Thermal IR (emissivity) will be secondary design driver
 - AO system is important

CELT and Stonehenge



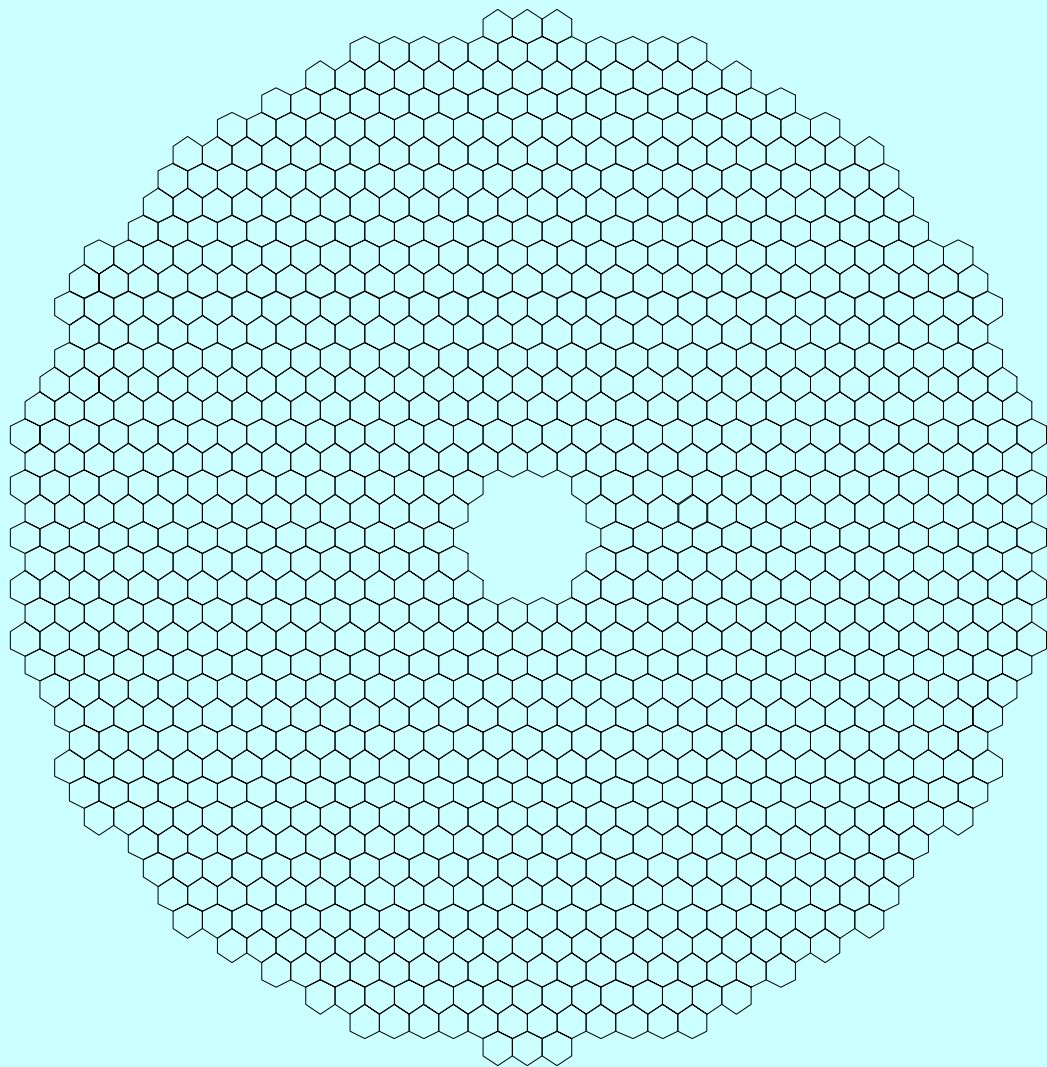
CELT Optical Design

- **Primary is 30m in diameter**
 - 1080 segments, 1m dia each
 - Shape actively controlled (segment piston, tip, tilt)
 - f/1.5 hyperbola
- **Final: f/15 Ritchey-Chretien**
 - Secondary 3.9m in diameter
 - 20 arc minute field of view with 0.5 arc second images
 - 1 arc minute FOV with 0.001 arc second images (design)
- **Instruments at Nasmyth platforms**
 - Articulated tertiary allows direct feed to multiple instruments with no additional optics (3 mirrors total)
 - 2 platforms: 15x30 m
 - Possible lower or upper platforms

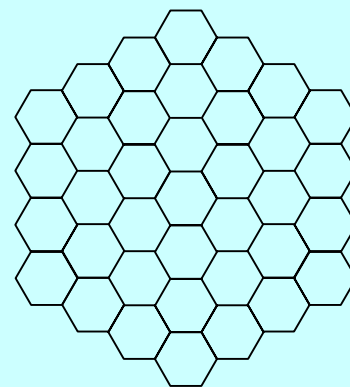


----- light path
 units = meters

CELT

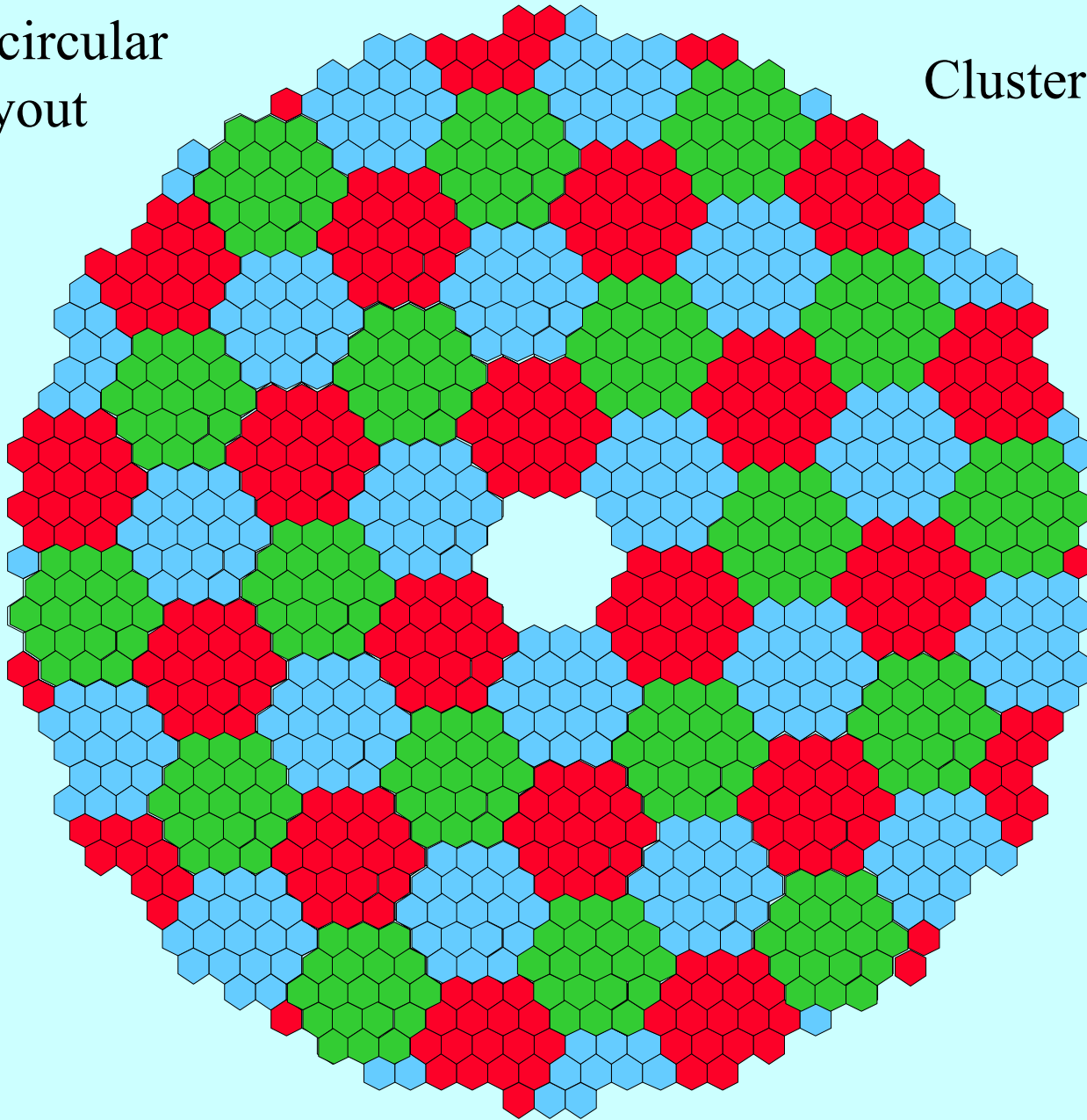


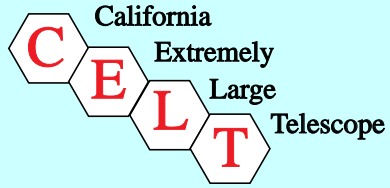
Keck



Most circular
layout

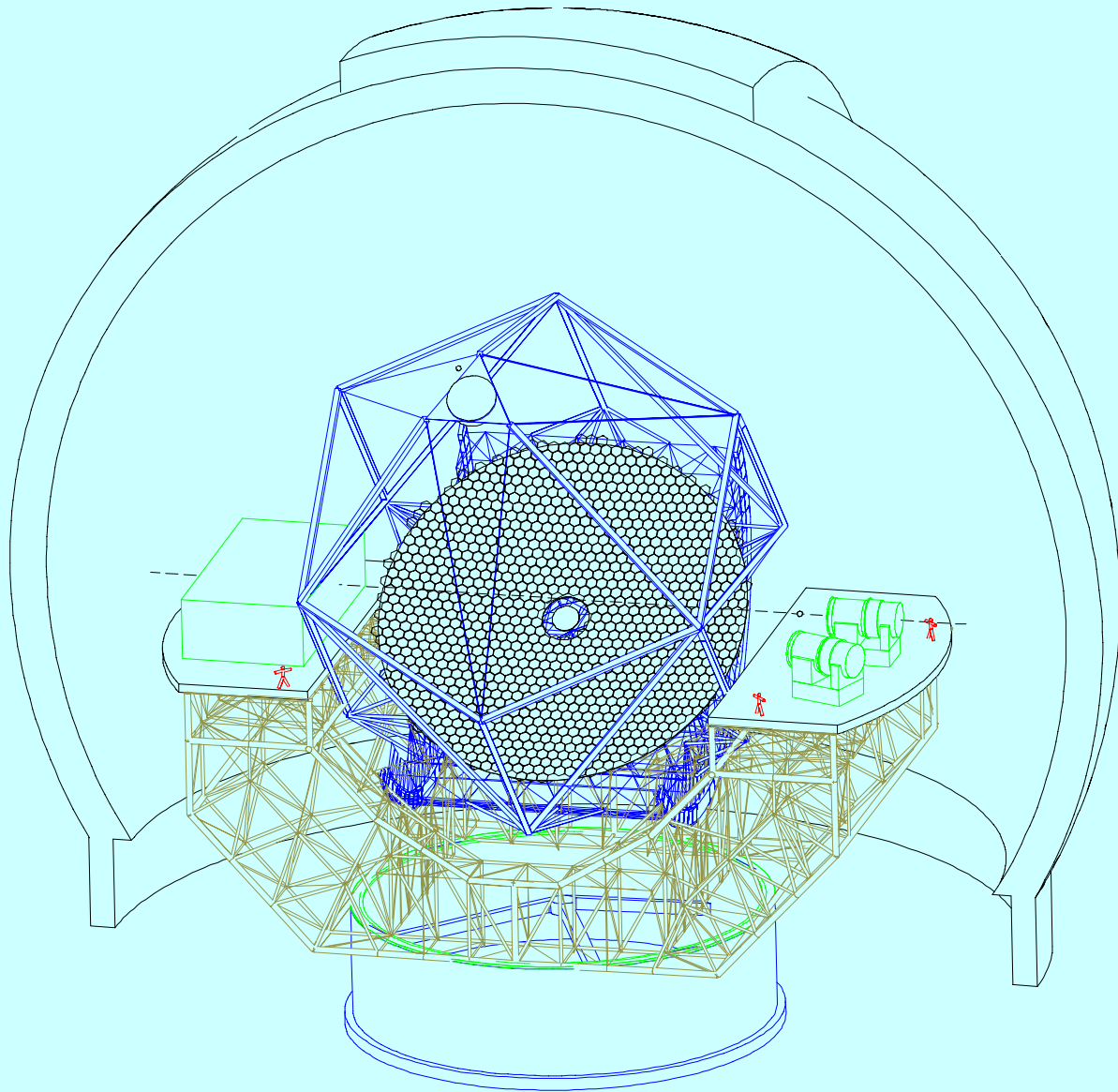
Cluster geometry

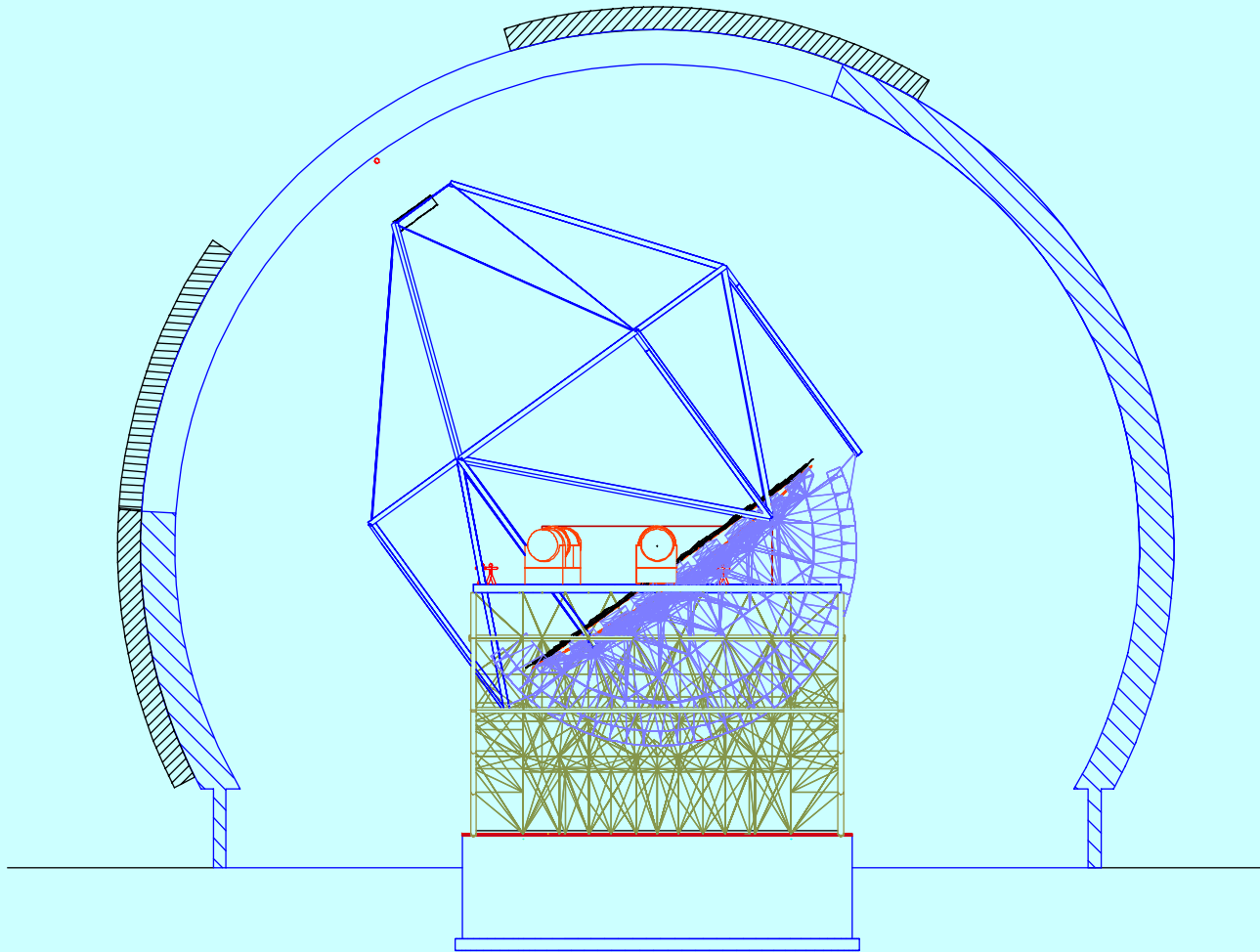




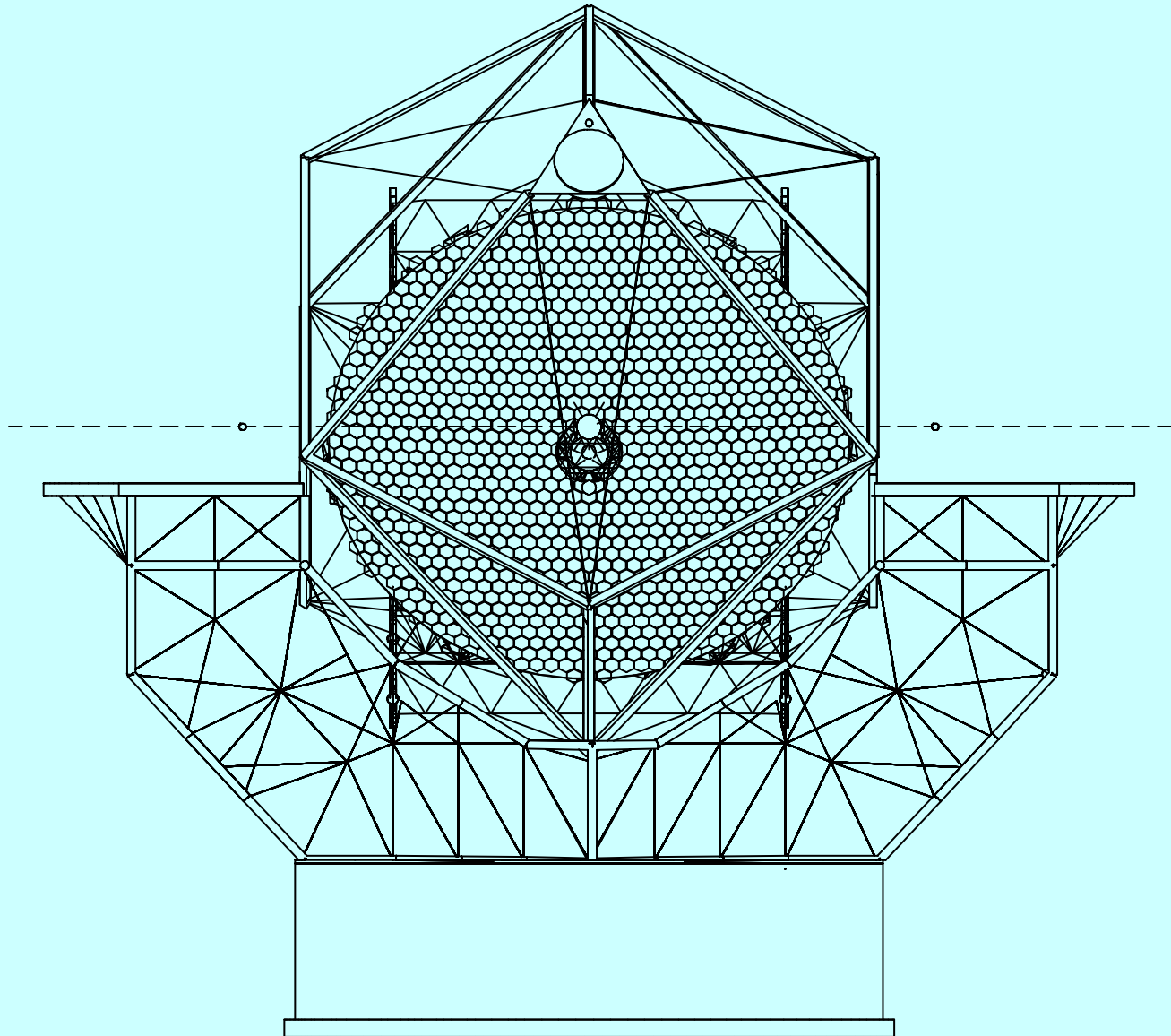
CELT structural design

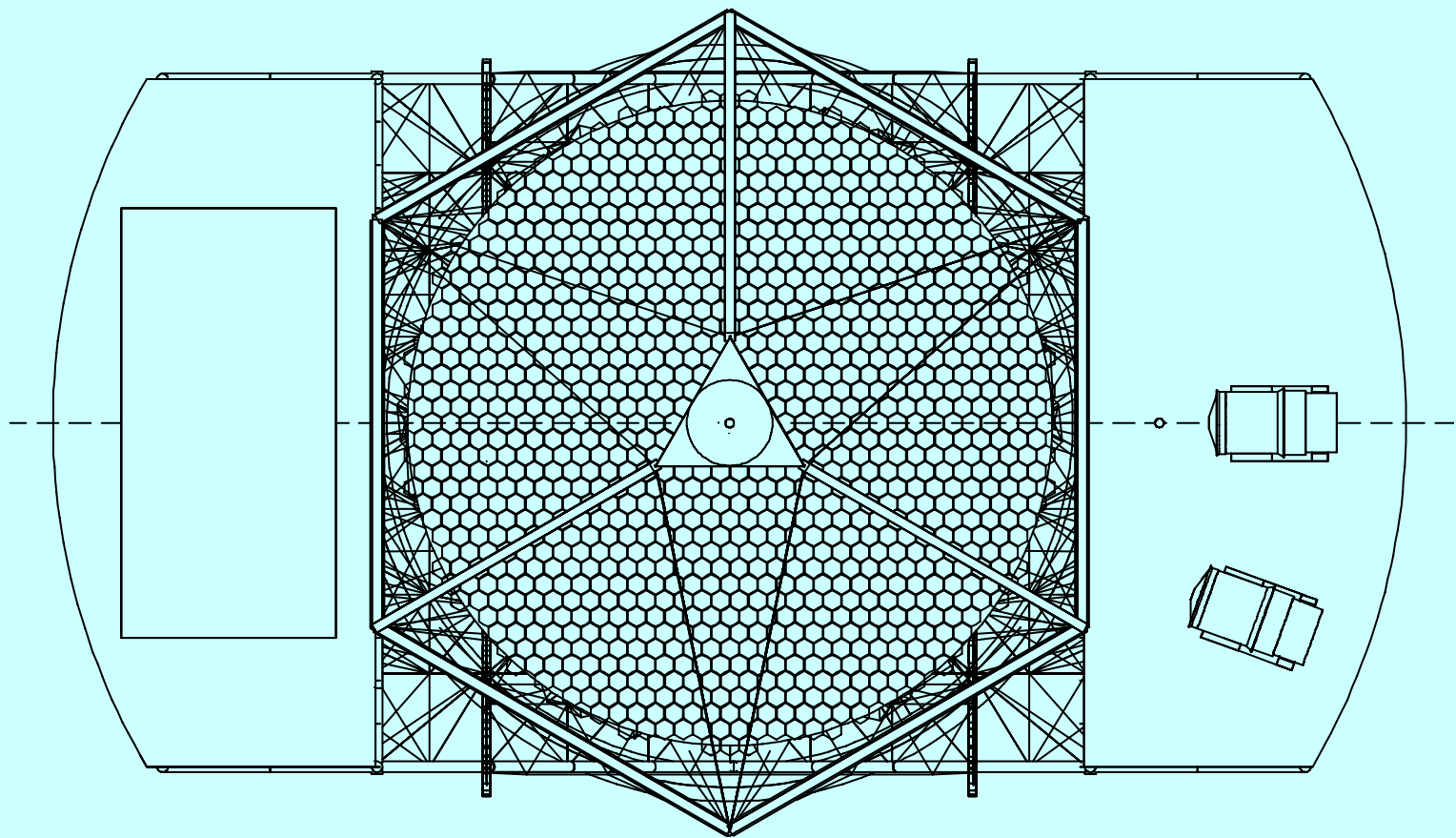
- **main structural design by S. Medwadowski**
- **Space frame concept**
- **Upper truss uses tension and compression members**
- **Hydrostatic bearings**
- **Lowest natural frequency ~ 2Hz (hoping to improve)**





Observing at 54° Elevation





Segment Fabrication

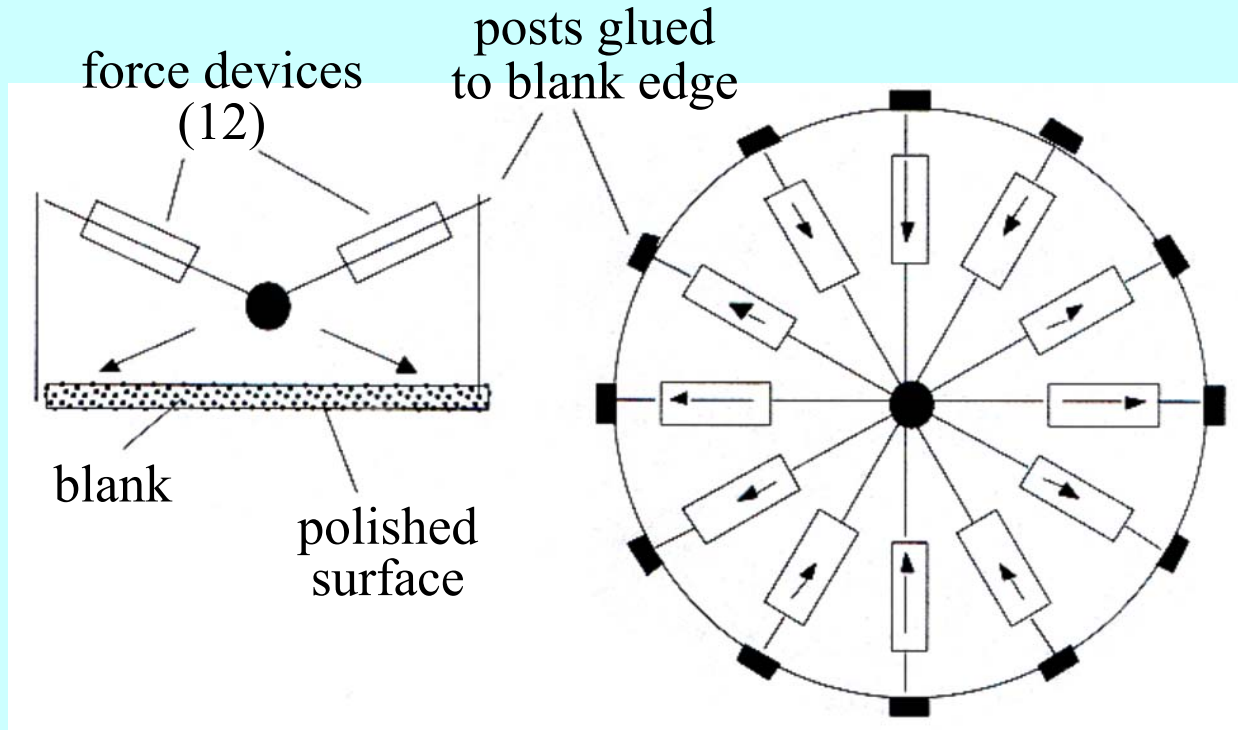
- **Segments are off axis sections of hyperbola**
 - Requirements: ~ 20 nm rms surface (better than Keck)
 - ~ 20 μm deviation from sphere (Keck was $\sim 100\mu\text{m}$)
 - Stressed mirror polishing (oap to sphere)
 - Planetary polishing to increase efficiency (simultaneous polishing)
 - Low expansion material
 - Final corrections with ion figuring

 - In telescope warping harnesses (hopefully not)
 - In telescope AO will correct low order errors

Planetary polishing to produce 1000 segments

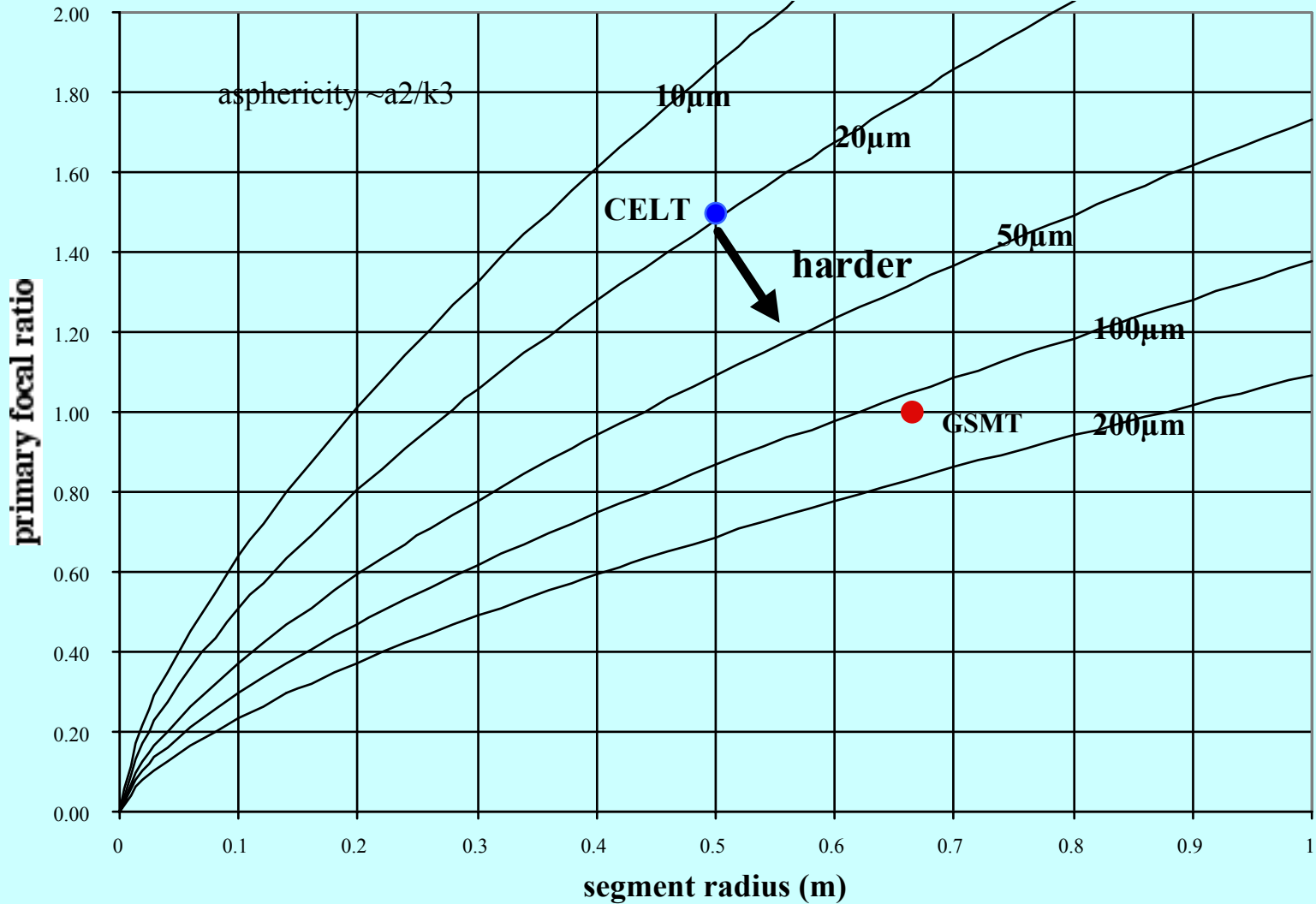


Proposed CELT Stressed Mirror Polishing Set-up



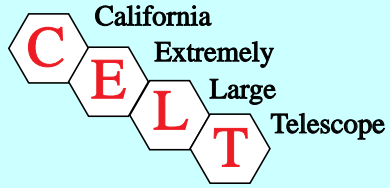
Arrows indicate force direction and magnitude required to create / remove astigmatism

asphericity vs focal length, segment radius



Active Control

- **Active control algorithm (details by G. Chanan)**
 - Same idea as Keck: edge sensors, actuators, least squares fitting
 - Error propagation calculated to be acceptable: $\sim 20x$ sensor noise
- **Edge sensors**
 - Need low cost
 - Need no mechanical interlock
 - Solution is edge sensors on edge faces of segments
 - Much less expensive, also measures edge tilt
- **Actuators**
 - Keck actuators expensive, used roller screw
 - Present CELT idea is voice coil actuator
 - Much less expensive



Active Control Summary

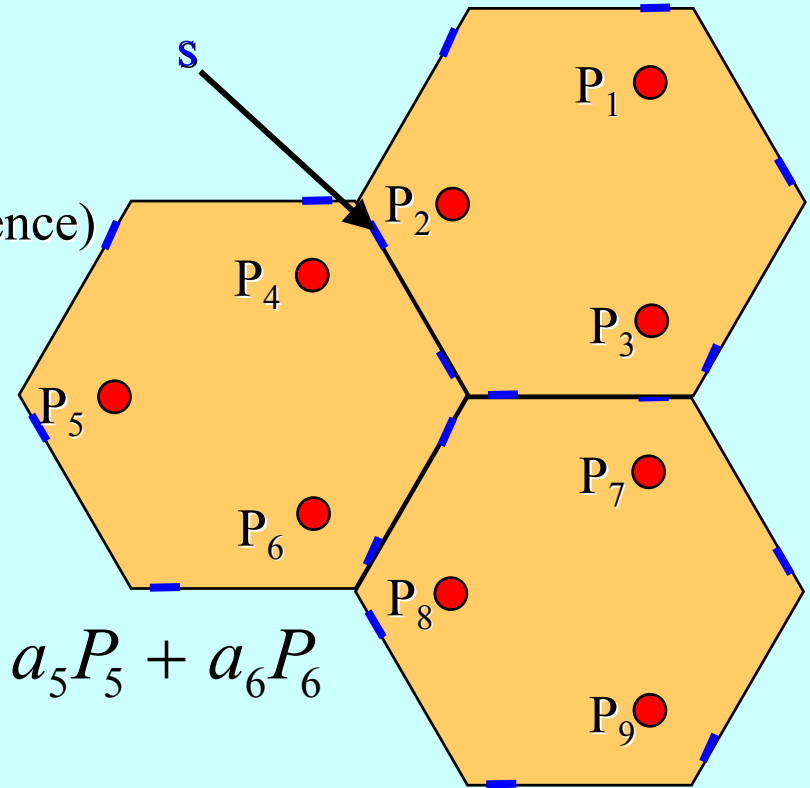
Selected $a = 0.5$ m for segment size

Item	Keck	CELT
segment size	0.9m	0.5m
# segments	36	1080
# edge sensors	168	6204
# actuators	108	3240

Principle of active control with edge sensors

- Actuator (piston)
- Sensor (measures height difference)

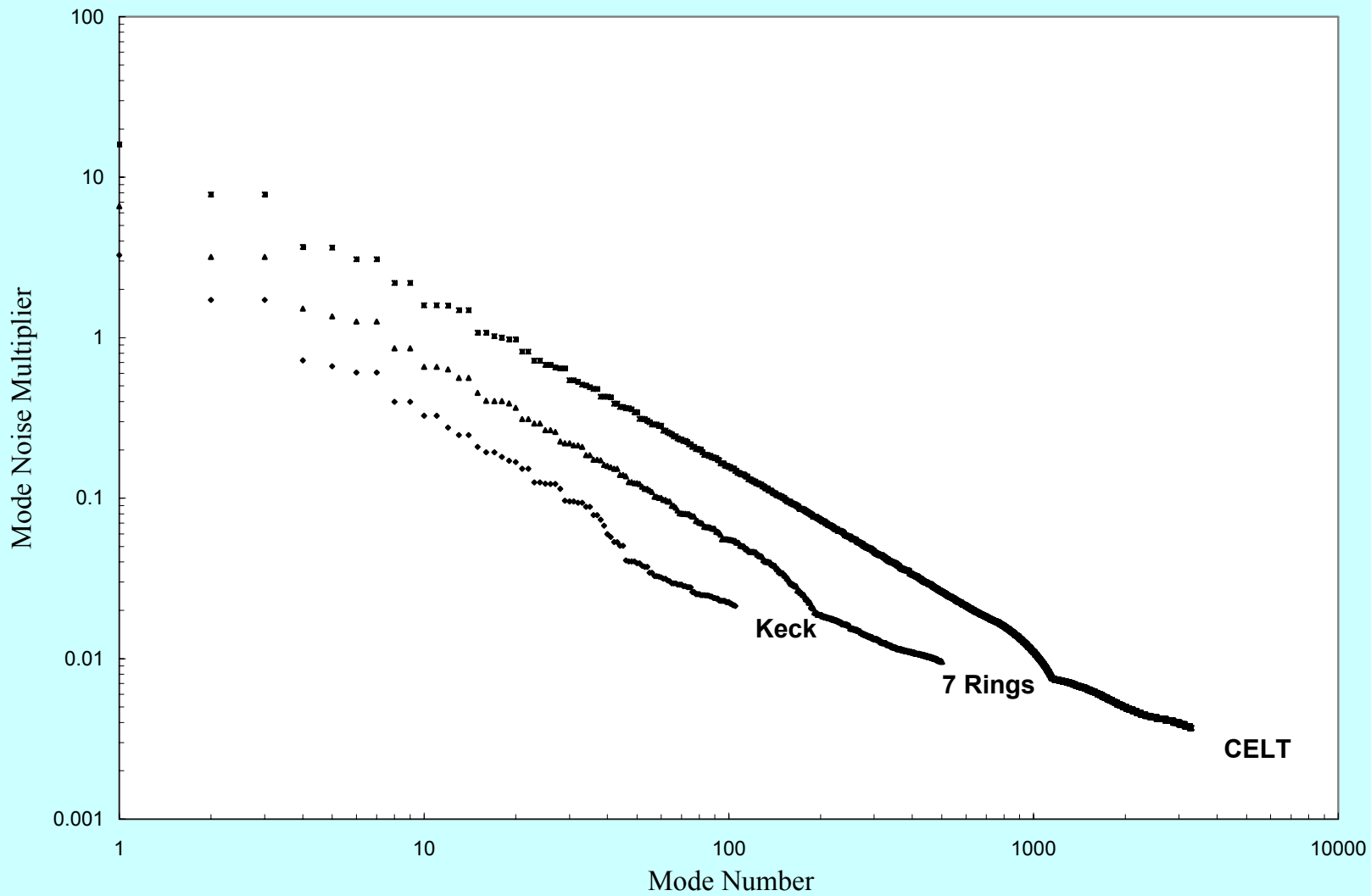
Sensor signal depends only on motion of two **neighbor** segments



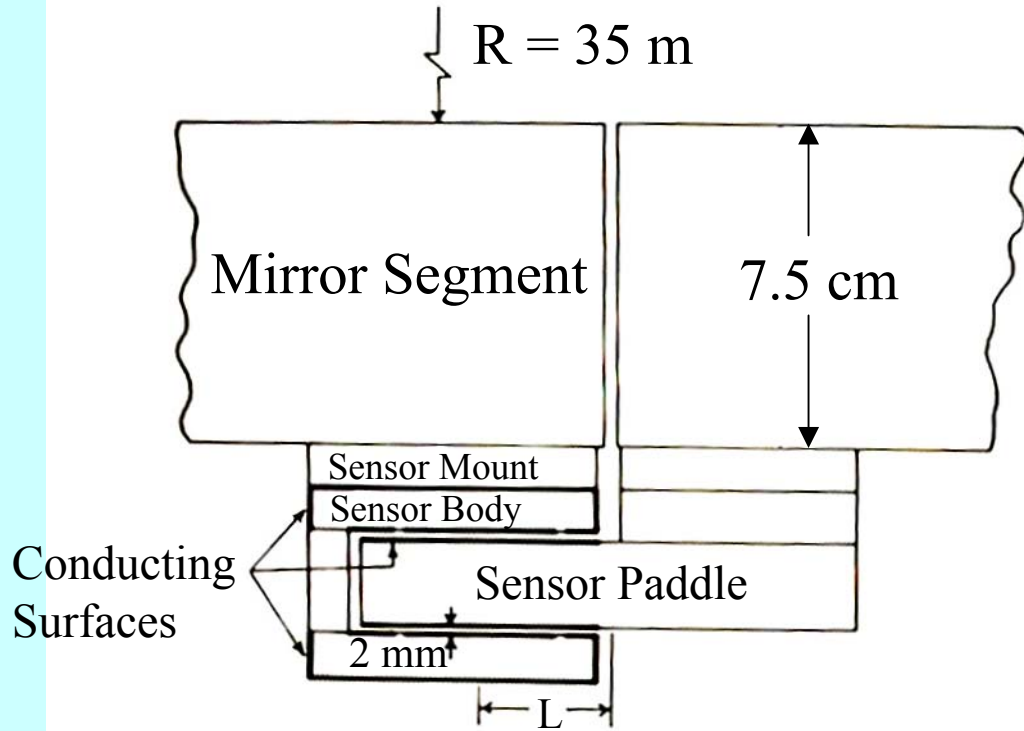
$$s = a_1 P_1 + a_2 P_2 + a_3 P_3 + a_4 P_4 + a_5 P_5 + a_6 P_6$$

a are constant coefficients that depend only on geometry

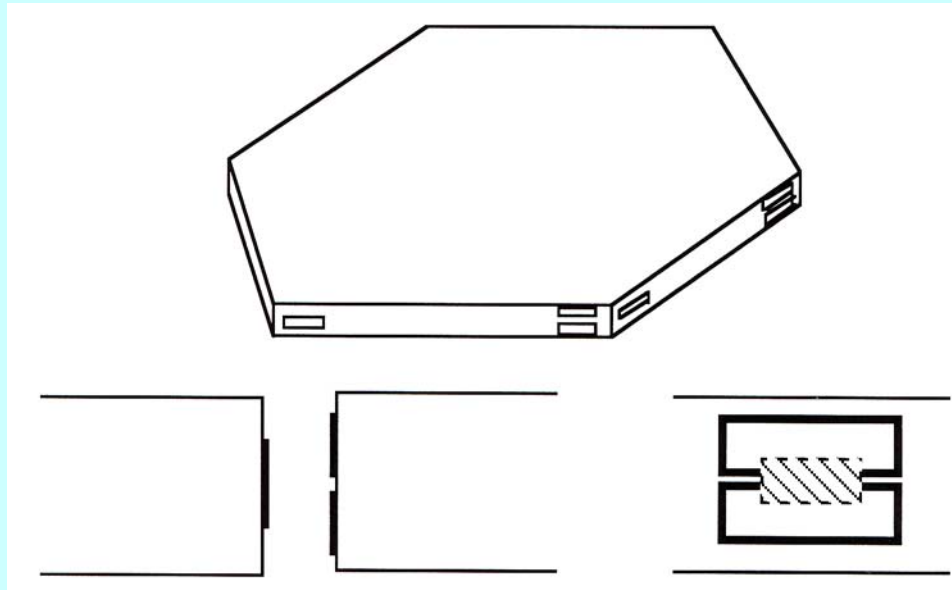
Mode Noise Multipliers for Keck-Like Sensors



Keck Sensor Geometry

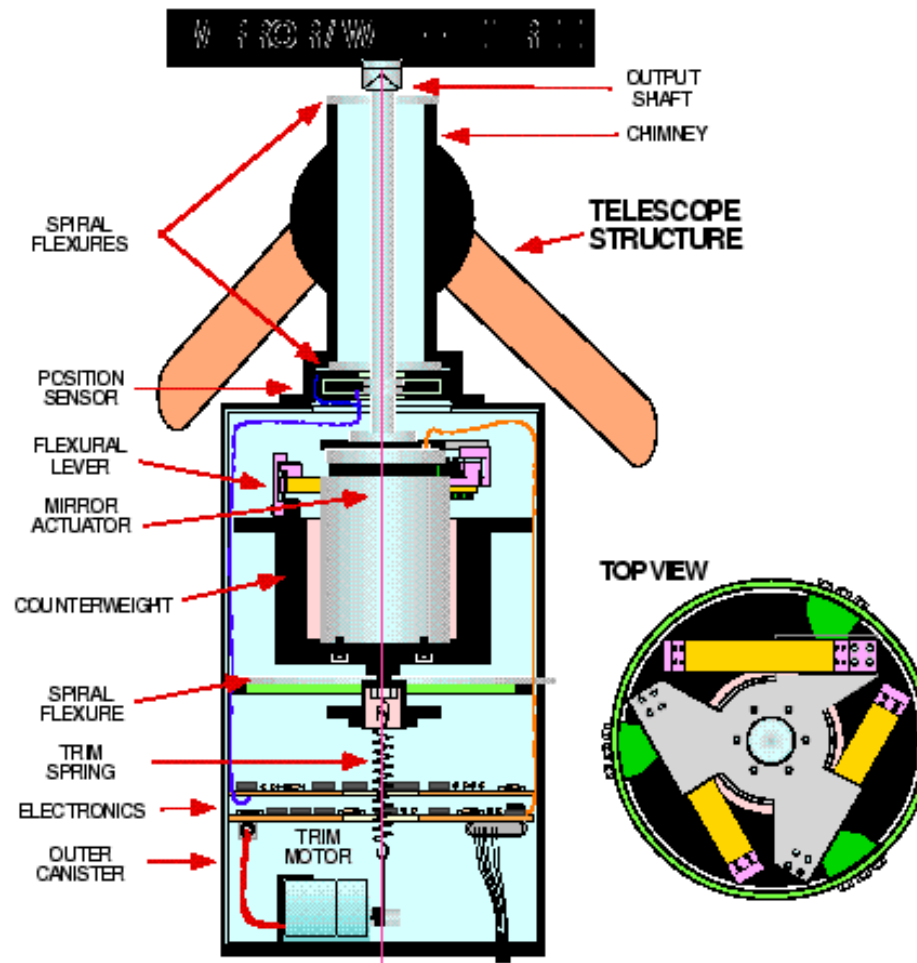


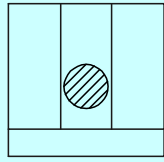
Proposed CELT Sensor Geometry



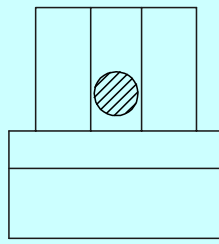
Non-Interlocking Sensors

Voice coil actuator

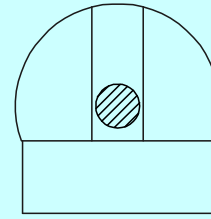




VLT



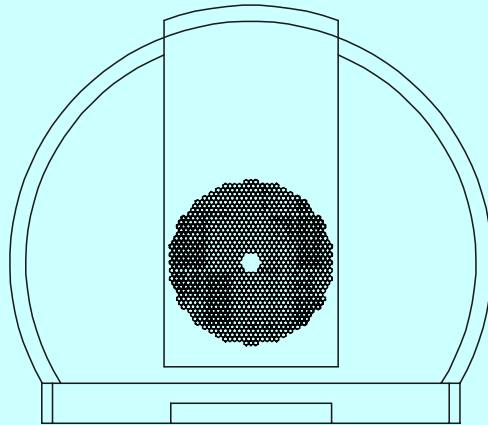
Subaru



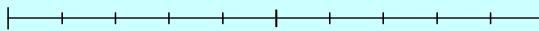
Gemini



Keck

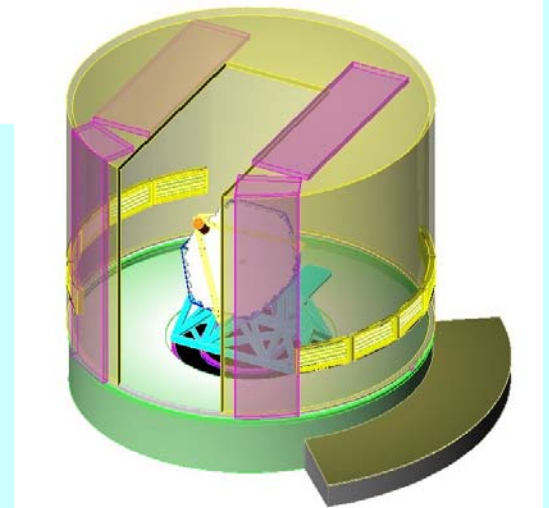
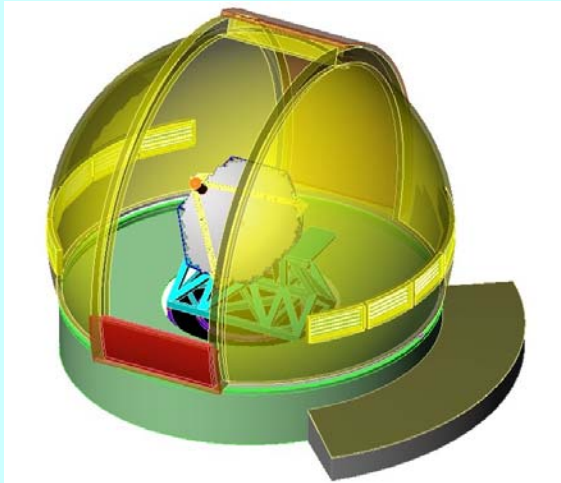
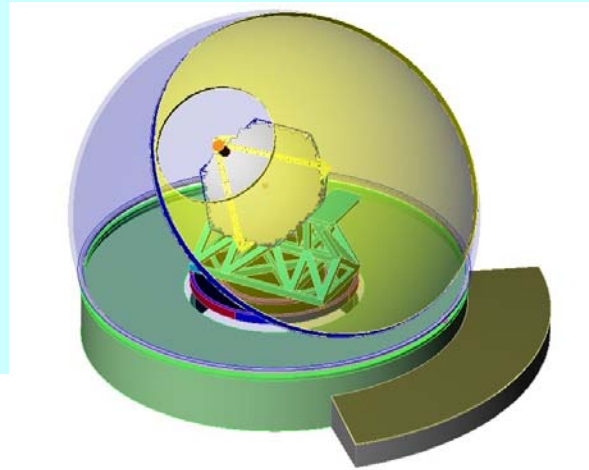


ELT



100 meters

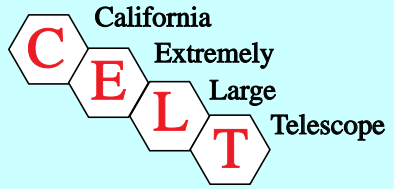
Enclosures



Design options under study (from NIO)

CEL T Issues

- **Want greatest science yield for lowest practical cost**
- **Issues**
 - Review elimination of prime and cassegrain foci
 - Determine optimal location of elevation axis
 - Determine optimal f-ratio of primary
 - Determine optimal segment size
 - **The above depend critically on segment fabrication and active control**
 - Understand impact of wind disturbance on performance
 - Review importance of thermal IR
 - Select site
 - Assess feasibility and costs of science instruments
 - Develop needed AO designs and components



End of Talk

