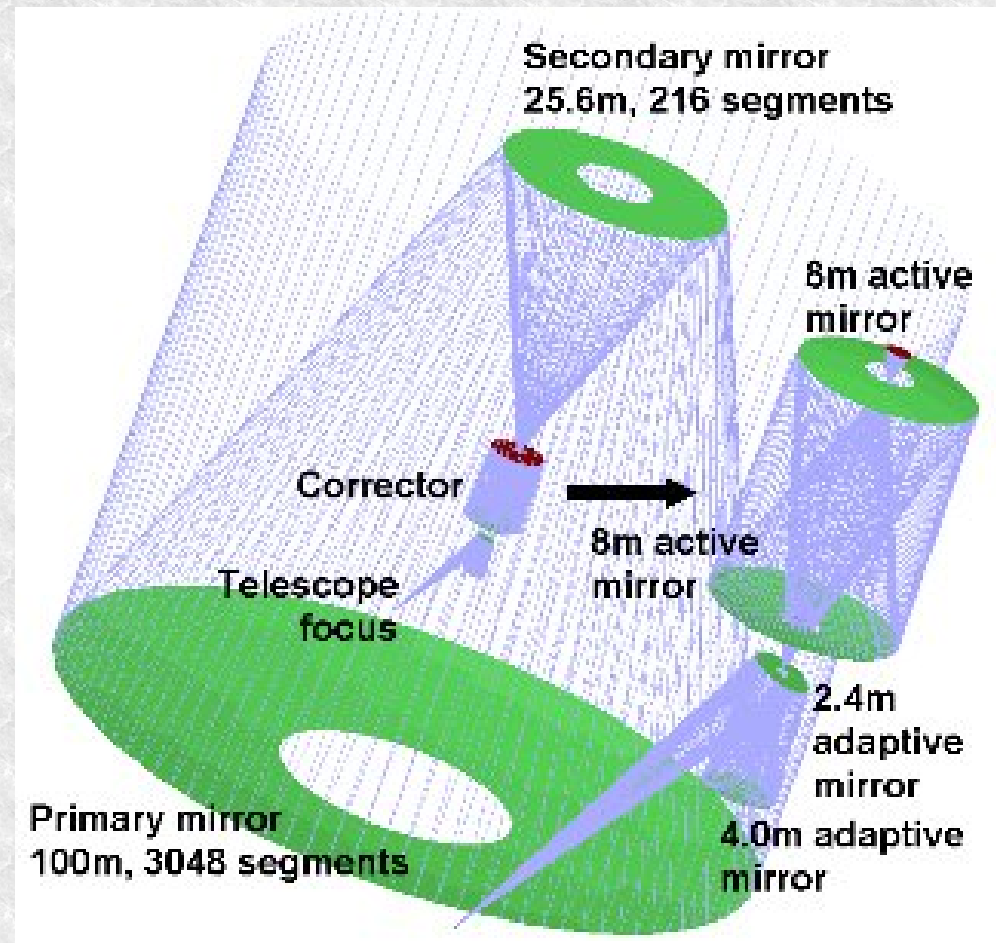


# Óriástávcsövek

Ph.D. szeminárium

*Székely Péter*

*2004. november 29.*



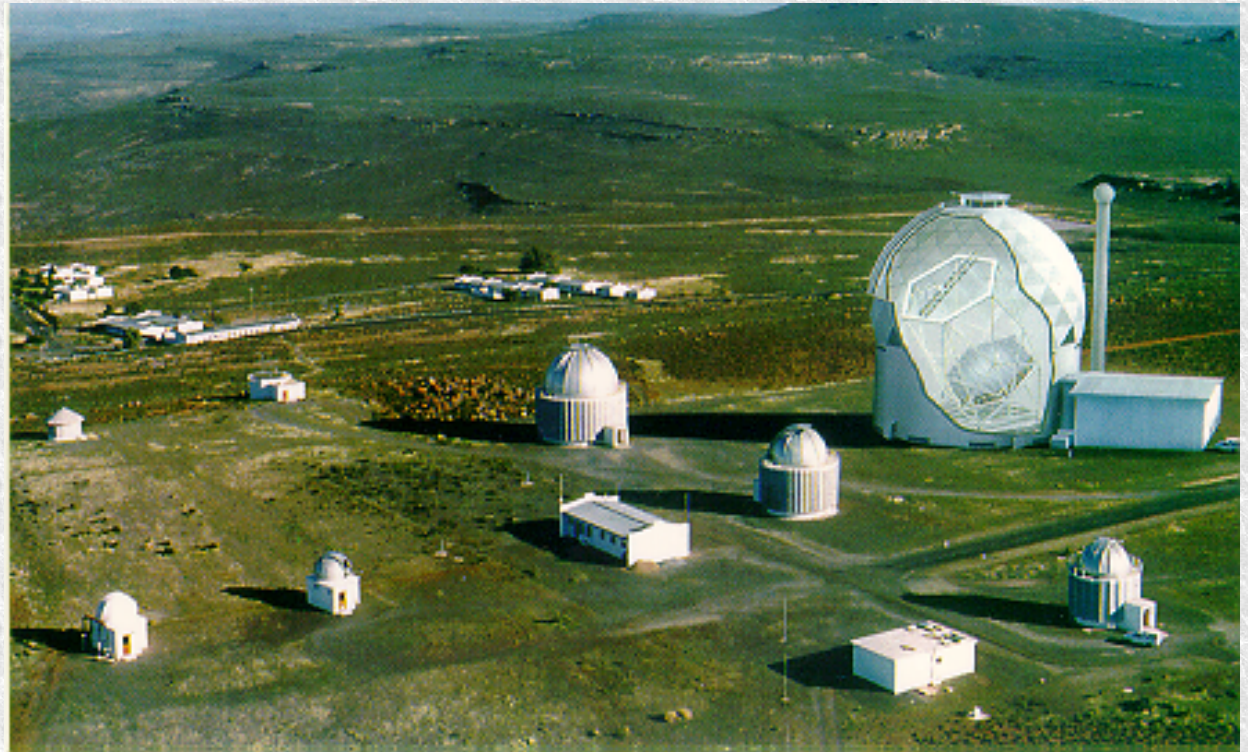
# *HET & SALT*



# Bevezetés

## **Általában:**

- A SALT egy építés alatt álló 10 méteres teleszkóp Dél-Afrikában.
- A déli félteke legnagyobb eszköze lesz
- **Partnerek:**



- South Africa (host institution: the South African Astronomical Observatory).
- Poland (through the Nicholas Copernicus Astronomical Centre, Warsaw).
- Rutgers University, New Jersey, USA.
- Göttingen University, Germany.
- The Hobby-Eberly Telescope Board (consisting of partners in the USA & Germany).
- Carnegie Mellon University, Pittsburgh, Pennsylvania, USA.
- University of Wisconsin, Madison, Wisconsin, USA.
- New Zealand (founding institution: the University of Canterbury).

# A Hobby-Eberly Telescope

(HET)

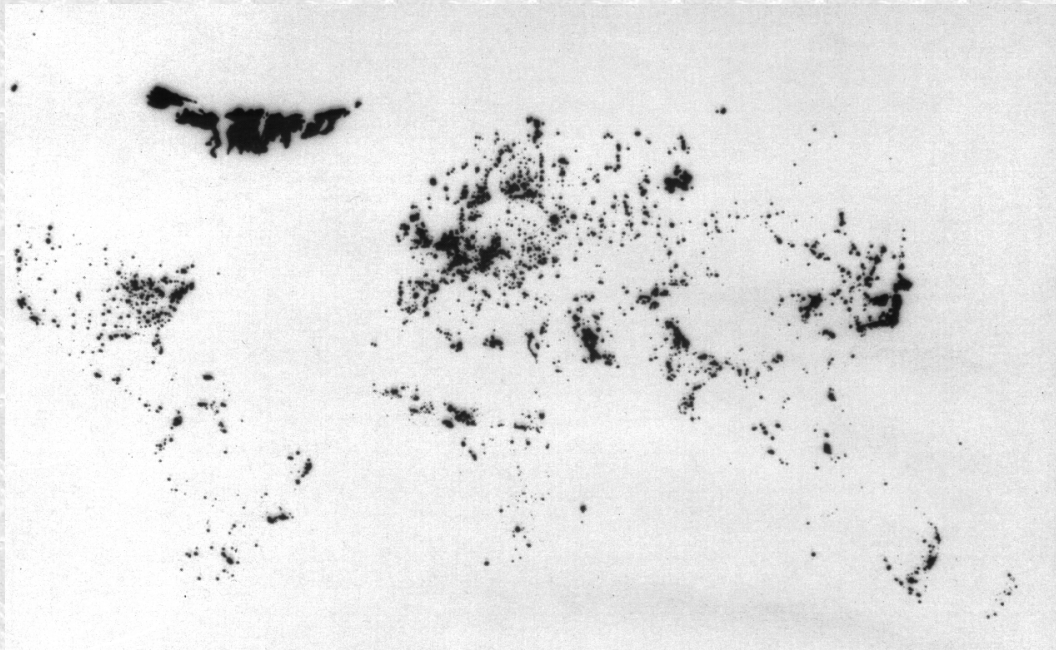


**A HET helye: McDonald  
Observatory, Fort Davis, Texas**

- A SALT a déli “ikertestvére” lesz a HET-nek.
- A HET egyetemek konzorciuma: USA (Texas, Penn State & Stanford) és Németország (Göttingen & München).
- A HET építésének vége: 1997, teljes tudományos üzem: 1999.
- A SALT nagyon hasonló a HET-hez, de tanulva a hibákból + felhasználva az új fejlesztéseket.

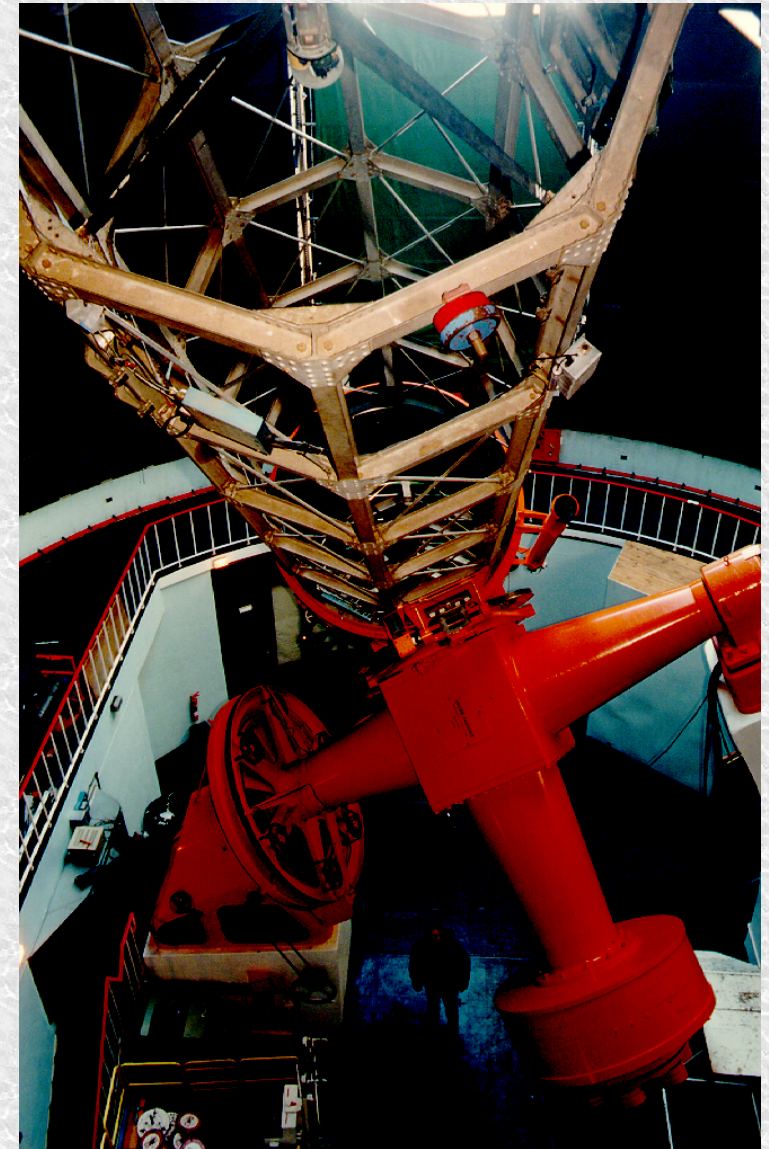
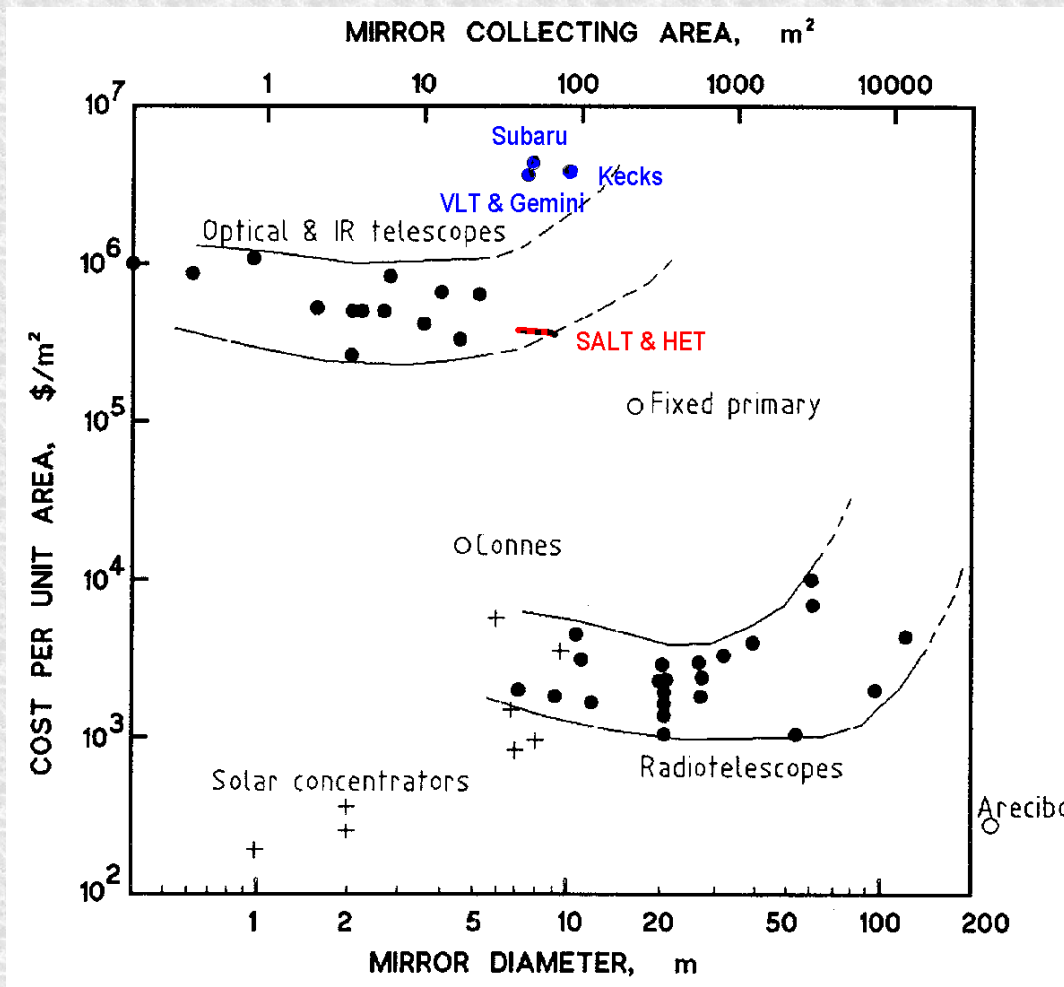
# SALT motivációk

- Déli félteke legnagyobb távcsöve.
- Dél-Afrika-i csillagászat (élettartam > 30 years).
- Kedvező körülmények (seeing, időjárás stb.).



## További motivációk...

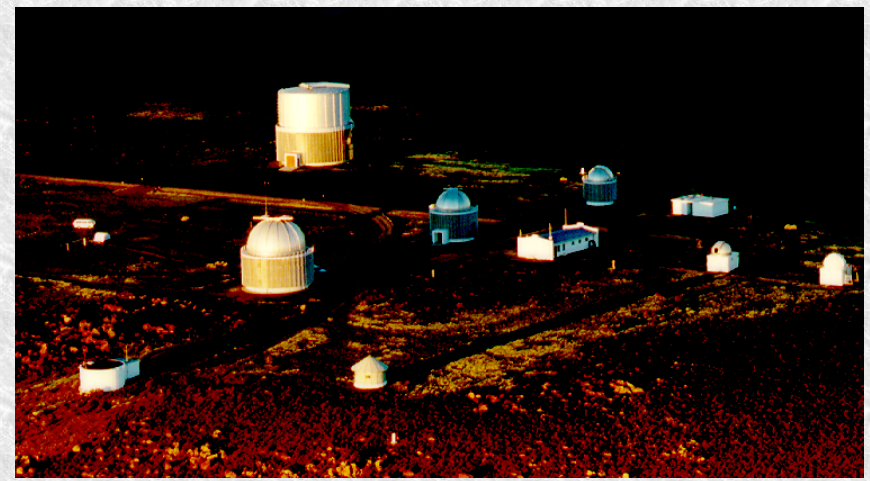
- Jelenlegi eszközök idejétmúltak
- Az ég 70 %-a hozzáférhető egy “hagyományos” berendezés árának ~ 20%-ért.



The 1.9-m (74 inch) telescope at Sutherland, currently the largest in Africa.

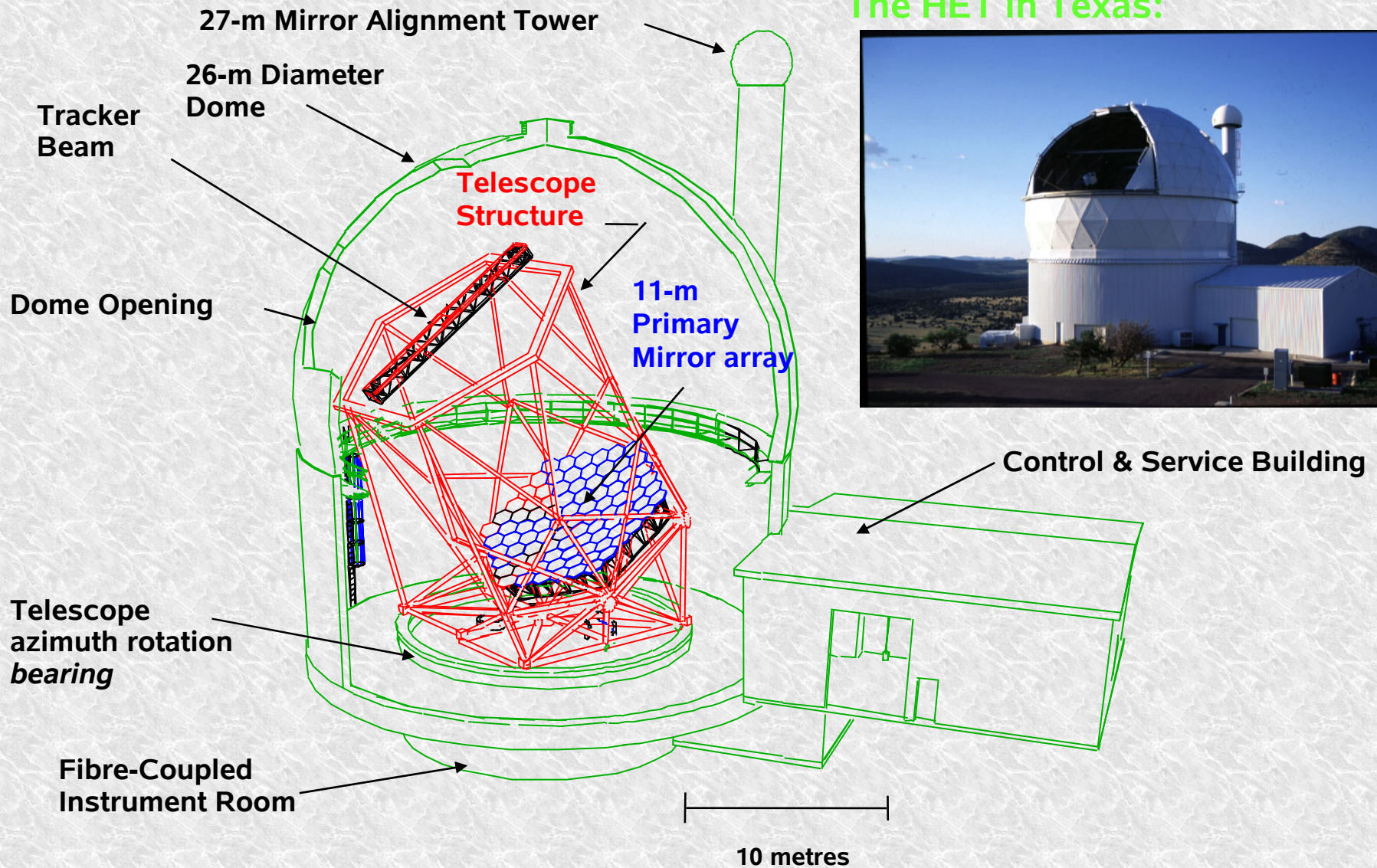
# Hol van a SALT?

## Sutherland, Great Karoo plató



# Korai koncepció diagramja a SALT-nak:

The HET in Texas:





# Az Arecibo koncepció:

Fixált magasságú főtükör a fókuszfelület "követésével".

(Arecibo volt az első ilyen elvű eszköz).

Szférikus fókuszfelület a főtükör sugarának felénél

A kép mozgása a fókusz felületén:  
Ny-K

Csillag mozgása: K-Ny

Főtükör sugaránál a görbület közepe

A tracker a detektorokkal követi a fókuszt.



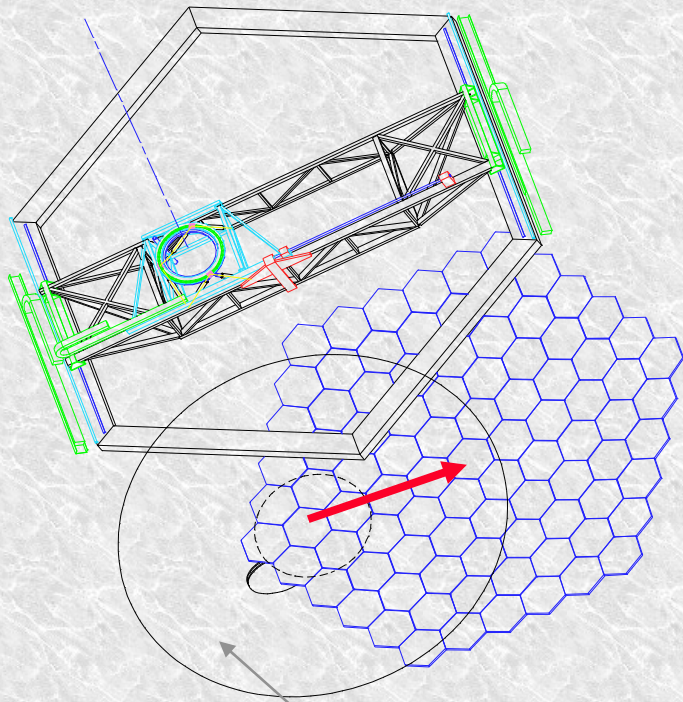
A SALT be van döntve 37°-ra a zenittől.

Szférikus főtükör

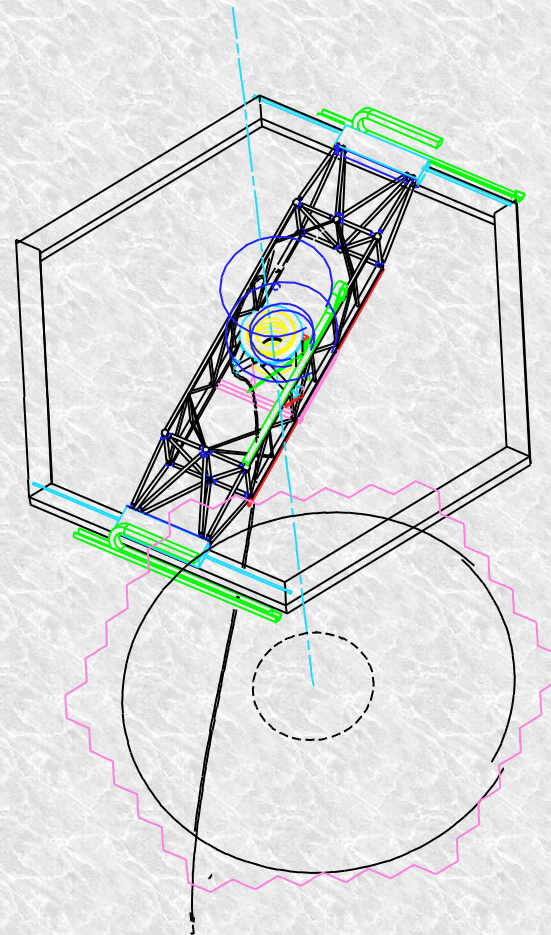
# Hogyan működik a távcső?

**A tracker off-centre és a kilépő pupilla részlegesen a főtükörön, legrosszabb esetben még mindig egy 7 méteres teleszkóp!**

**A tracker és a nyaláb centrálva a főtükörön. Teljes 9.2 méteres fénygyűjtő terület.**



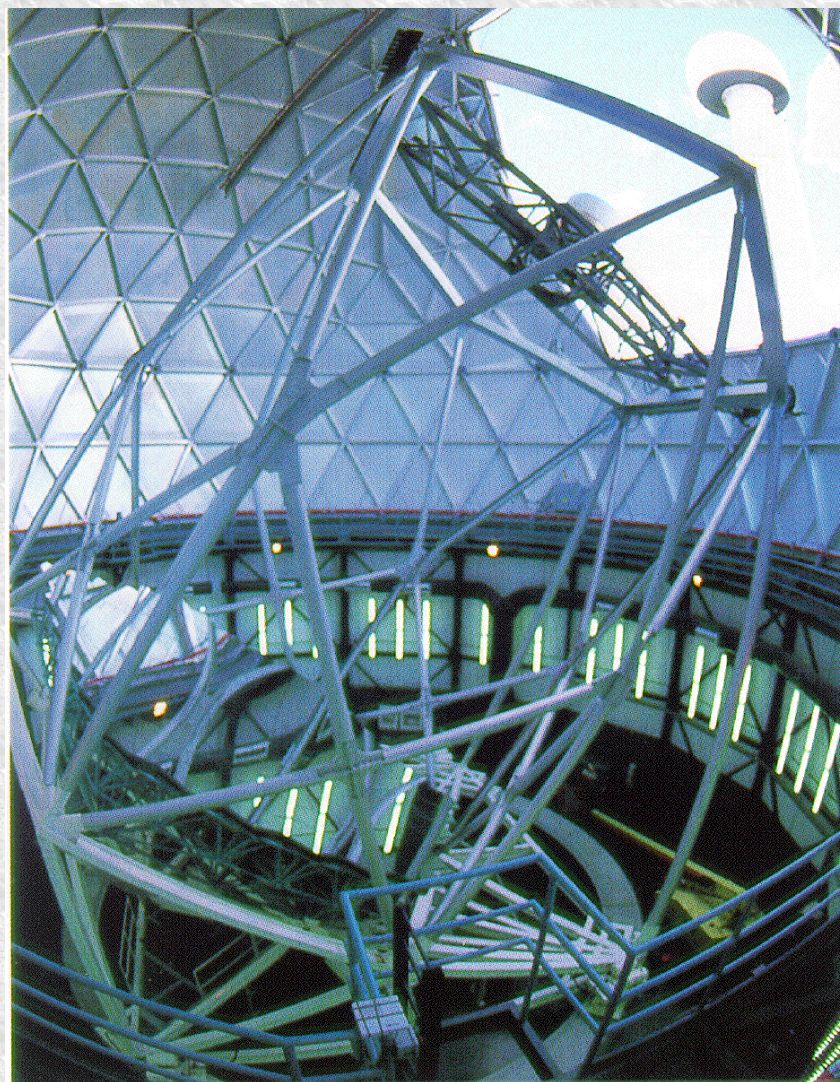
**A nyaláb egy része leárnyékolt**



# SALT: bedöntött Arecibo-szerű optikai-IR teleszkóp

## Alapvető tulajdonságok

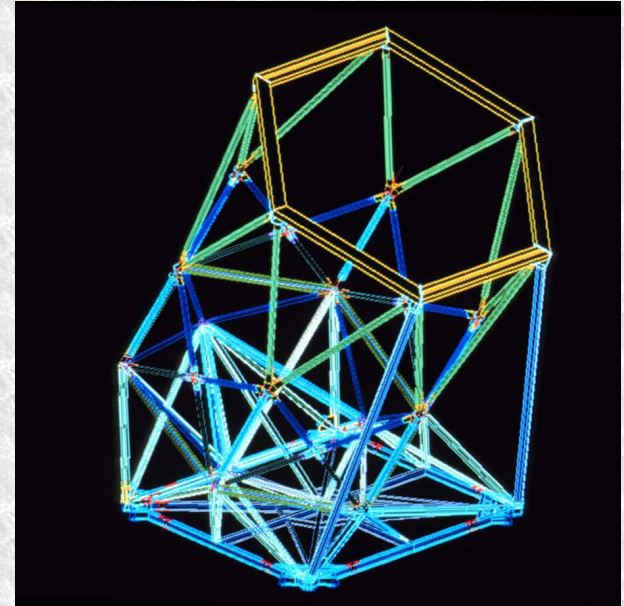
- Főtükör elrendezése
  - szférikus
  - 91 azonos hexagonális szegmens
  - unphased (azaz nem diffrakció limitált)
  - a tükrök acél vázon vannak
- A távcső be van döntve:  $37^\circ$ 
  - deklináció:  $+10^\circ < \delta < -75^\circ$
  - azimut forgatás csak kezdeti pozicionáláshoz
- Objektumok követése  $12^\circ$ -on át a fókuszfelületen
  - a racker végez minden precíziós mozgást
  - a tracker tartalmaz egy Spherical Aberration Corrector (SAC) eszközt: 8 ívperces látómező (primér fókuszbán)
  - nagy spektrográfok optikailag csatoltak
- Képminőség
  - távcső “error budget”: 0.5” FWHM



## Adatok:

### *Távcső*

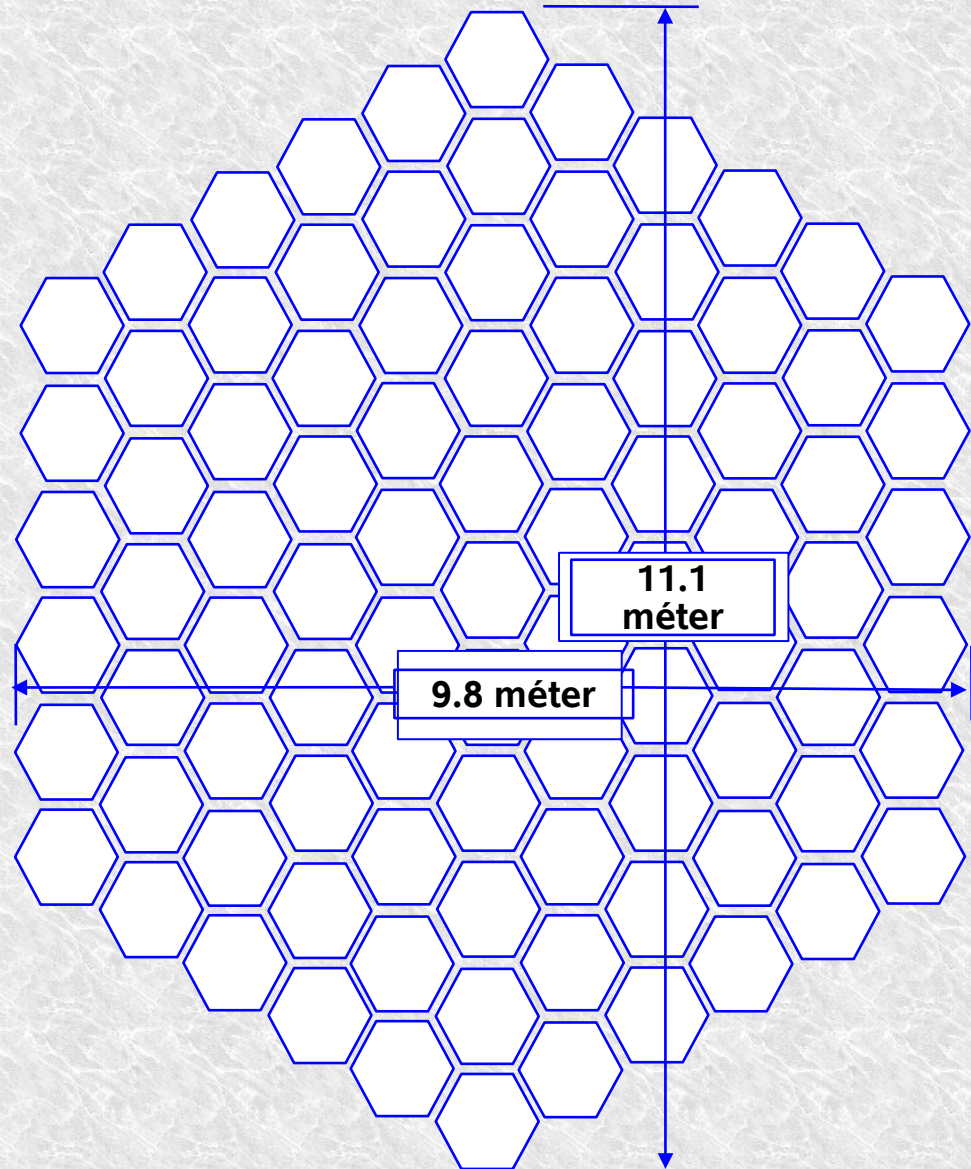
- A Hobby-Eberly Telescope módosított verziója .
- Méretek: hossz 13 méter, tükör tömb  $11 \times 10$  méter.
- Tömeg: 82 tonna.
- Fénygyűjtő terület: 77.6 négyzetméter
- Hullámhossz tartomány: 340 nm - 2500 nm (UV – közeli IR).
- Távcső forgása azimutban: 8 légcsapágyon, pontosság 3 mikron. A tracker cél követése 10 fokos szabadsággal ~2.5 óráig.
- Objektumok közti átállási idő < 5 min.
- Száloptikák néhány objektum (10-20) fényét az alagsori berendezésekbe vezetik.
- A tracker része a Prime Focus Instrument Platform, ami tartalmaz egy leképező spektrográfot. Ez több objektumot képes egyszerre mérni.



# Főtükör elrendezése

## Tulajdonságok:

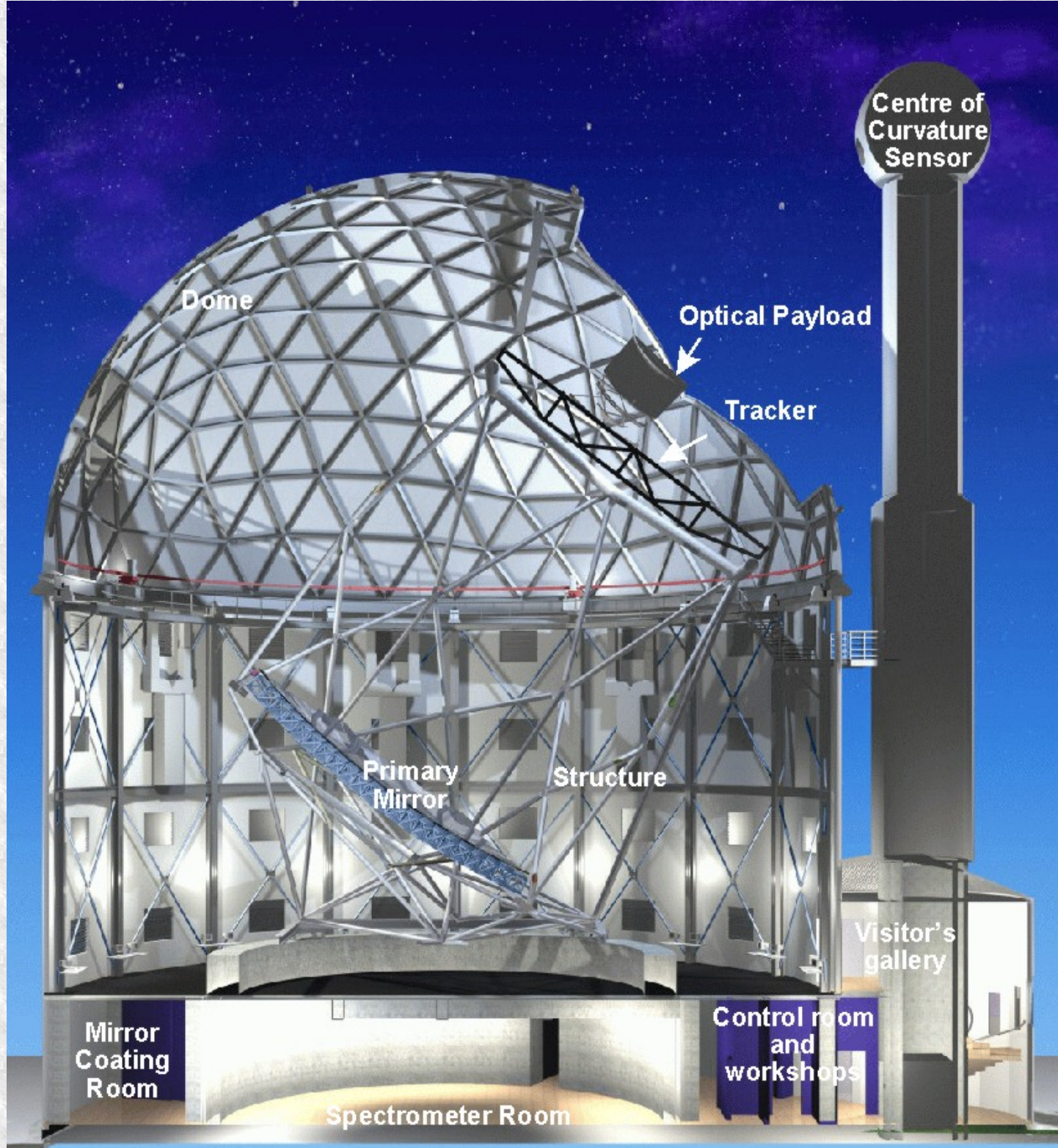
- szegmentált hexagonok tömbje, mindegyik 1 méter széles és 50 mm vastag
- maximális tükör átmérő:  
**11 m**
- tükör felület pontossága:  
**0.052 mikron (1/10 hullámhossz)**  
(simaság a mm 5/100,000 része)
- látómező:  
**8 ívperc (~1/4 Hold)**
- felbontás:  
**0.25 – 0.5"**  
(10 km-ről egy érme)
- Tükörtömb tartóelemei:  
• 'space frame' 1747 gerenda, 383 csomópont, 4 mm pontosság.



# A HET képgalériája

*A SALT nagyon hasonló lesz.*





Centre of Curvature Sensor

Dome

Optical Payload

Tracker

Primary Mirror

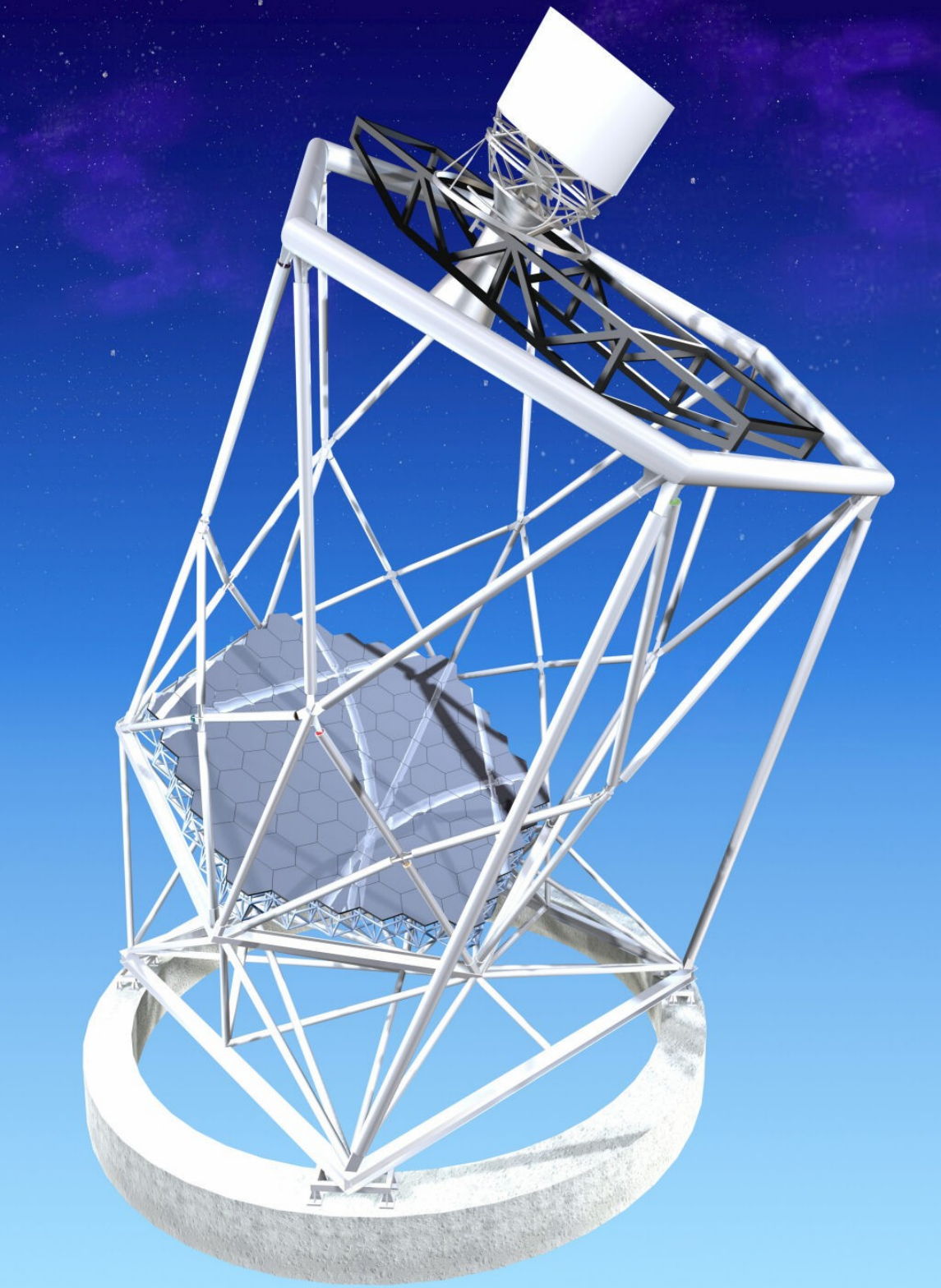
Structure

Visitor's gallery

Mirror Coating Room

Control room and workshops

Spectrometer Room

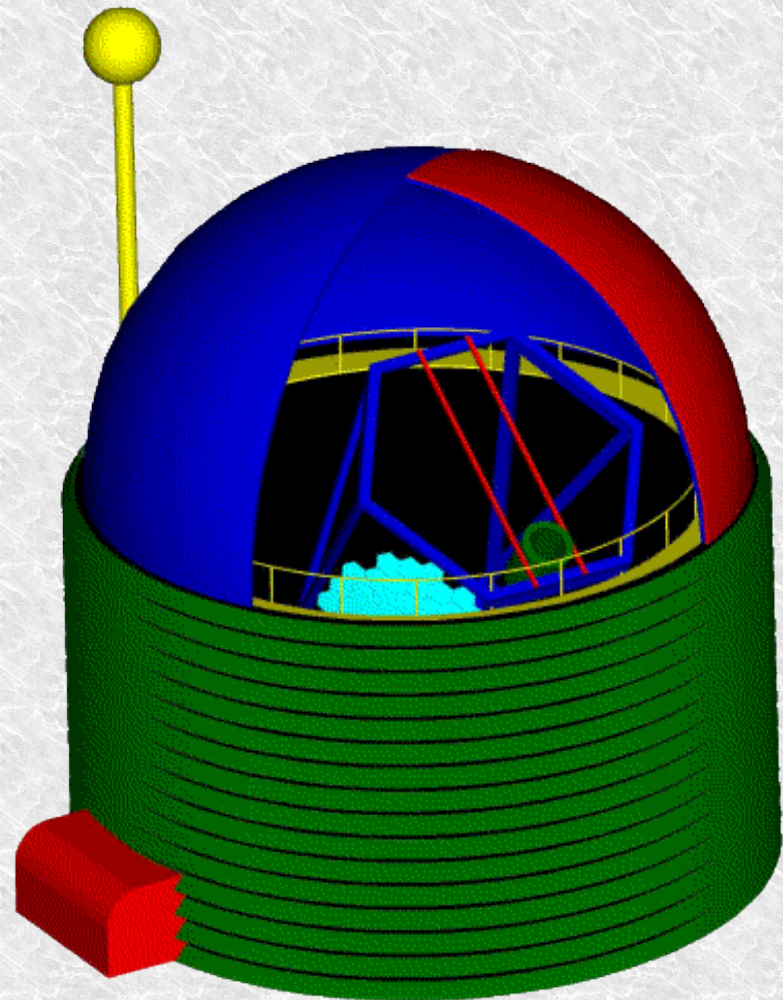




## Épület és a dóm

### *Korai koncepciók:*

- Geodézikus dóm, félgömb alkú.
- Légkondicionálás éjjel-nappal.
- A 28 méter magas torony tartalmazza a görbület beállításához szükséges berendezéseket (91 tükör szegmens).
- Vezérlőterem, munkaszobák, laboratóriumok termálishan elszigeteltek a távcsőtől.



## SALT, ahogy ki fog nézni Sutherland-nál...

### Néhány tény ismét:

- déli félteke legnagyobb magában álló távcsöve
  - 23X fénygyűjtő terület 1.9 m teleszkópnak
  - 11 m főtükör
  - 13 m főtükör paraxiális fókuszhossz
- belépő nyaláb átmérő = 10.5 vagy 11m
- f/arány = 4.2, effektív fókuszhossz = 44.1 vagy 46.2m
- “tudományos” látómező = 8 ívperc
- távcső tömege = 80 tonna
- tracker tömege = 4.5 tonna
- hullámhossz tartomány:  
~340-2500 nm





## A HET főbb paramétereit

### *Primary Mirror Array*

*Maximum Diameter* 11 meters

*Area* 77.6 sq. meters

*Focal Length* 13.08 meters

*Filling Factor* ~96.6%

### *Tracker Optical Package*

*Maximum Diameter* 490 nm

*Type* Four Element Gregorian

*Effective F. Ratio (output)* 4.7

*Focal Plane FoV* 3.5 arc minutes diameter

*Final Image Scale* 5 arc-sec./mm

*Entrance Pupil Diameter (on primary)* 9.21 meters

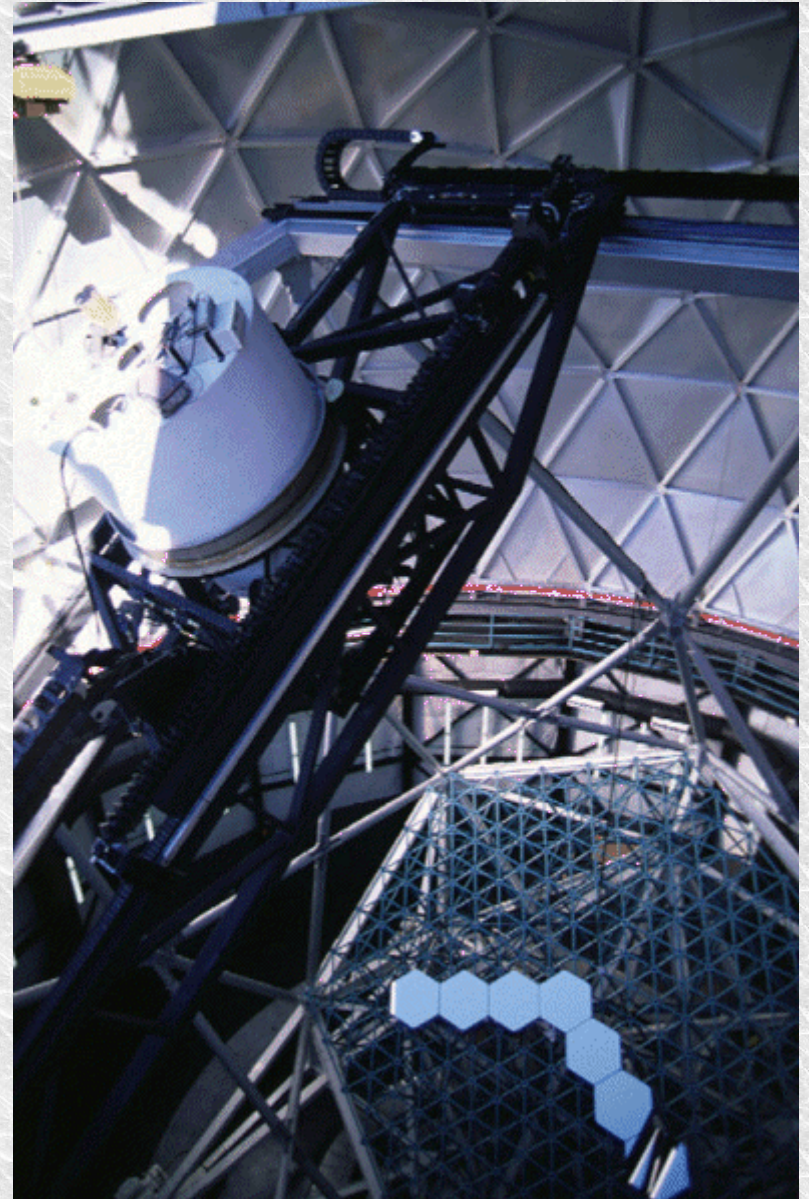
### *Telescope Parameters*

*Telescope Tilt Angle (Z)Azimuth* 35°

*Angular Range (FoV tracker)* 12°

*Declination Range* -10°20' to 71°40'

*Site Altitude* ~2 km (6640 ft.)



## HET detektorok

**LRS:** low resolution spectrograph, primer fókuszban

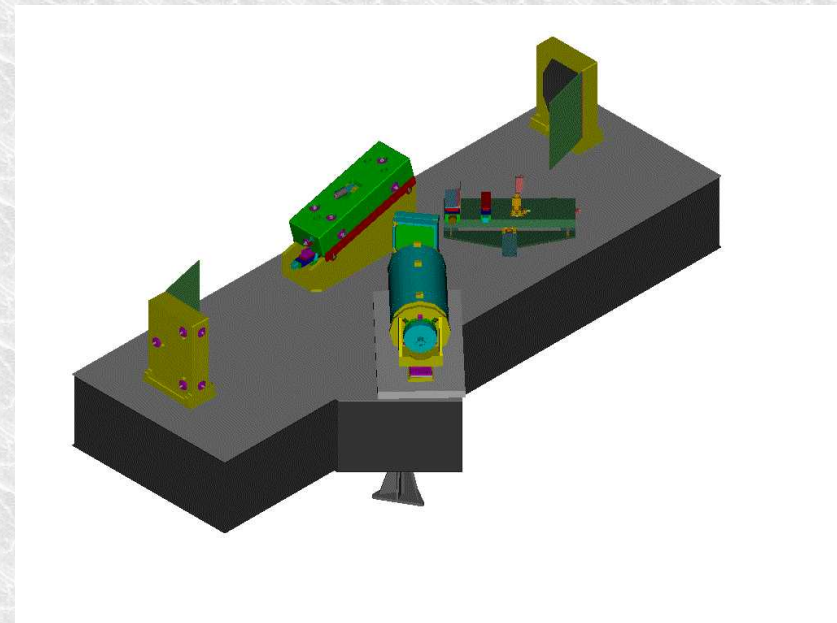
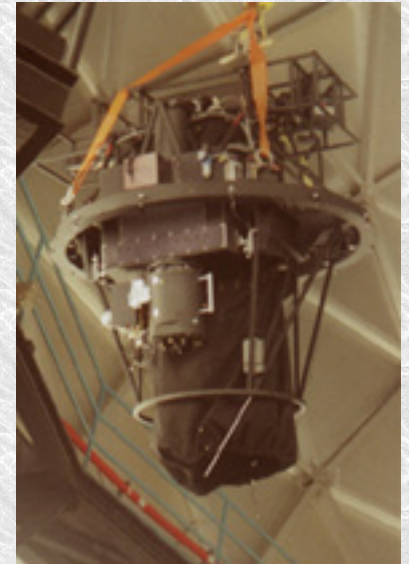
R = 600 (4150 - 10100 Å), 1300 (4300 - 7300 Å) and 1900(6250 - 9100 Å)

**MRS:** medium resolution spectrograph

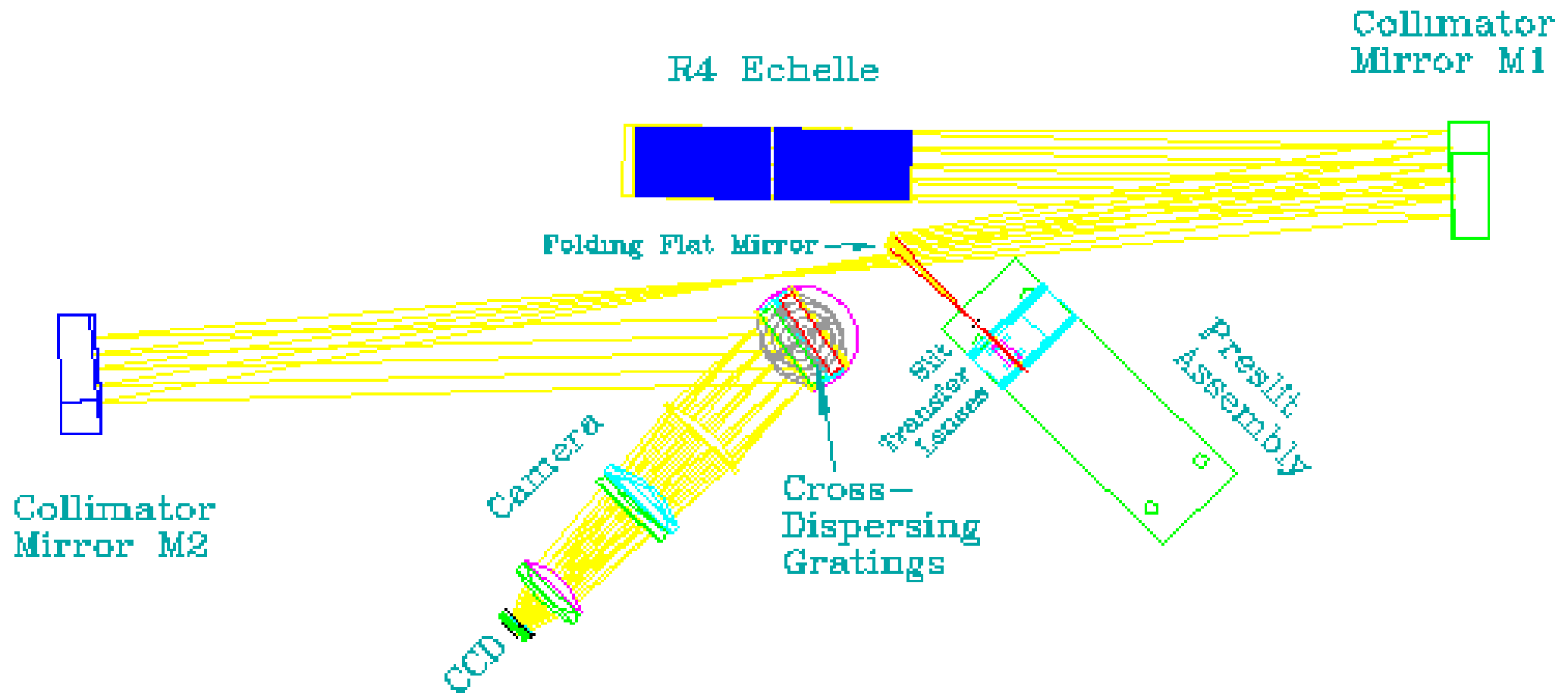
R = 35000 to 21000

**HRS:** high resolution spectrograph

Resolution	Fiber	mag	Time(s)	S/N	Wavelength (Å)
15,000	3"		14.0	1800	5800
15,000	2"		13.6	1800	5800
30,000	3"		12.5	1800	5800
30,000	2"		12.1	1800	5800
60,000	3"		10.5	1800	5800
60,000	2"		10.1	1800	5800
120,000	2"	7.6	1800	100	5800
120,000	2"	7.2	1800	100	5800



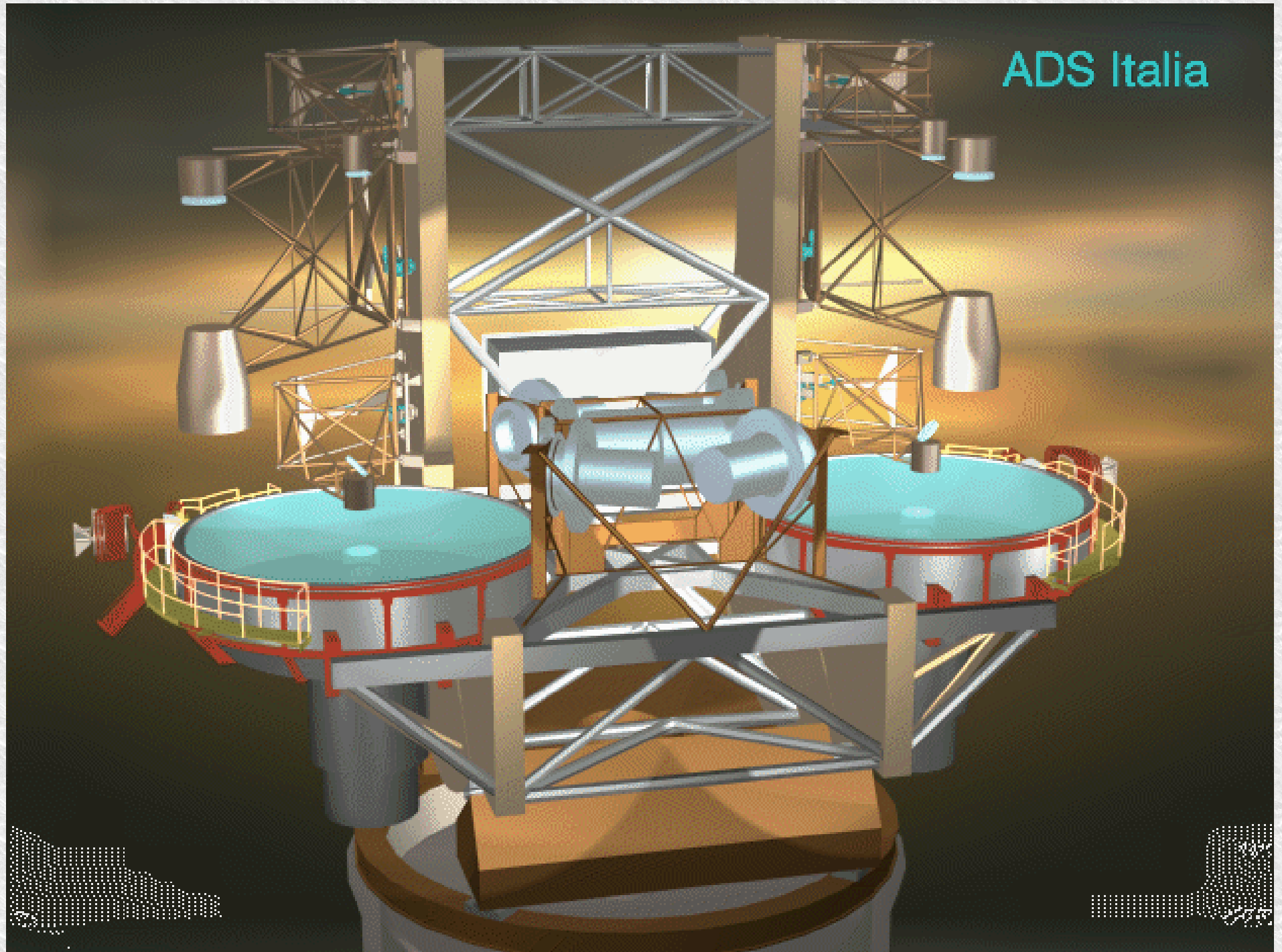
# A HRS elrendezése



HRS Optical Layout

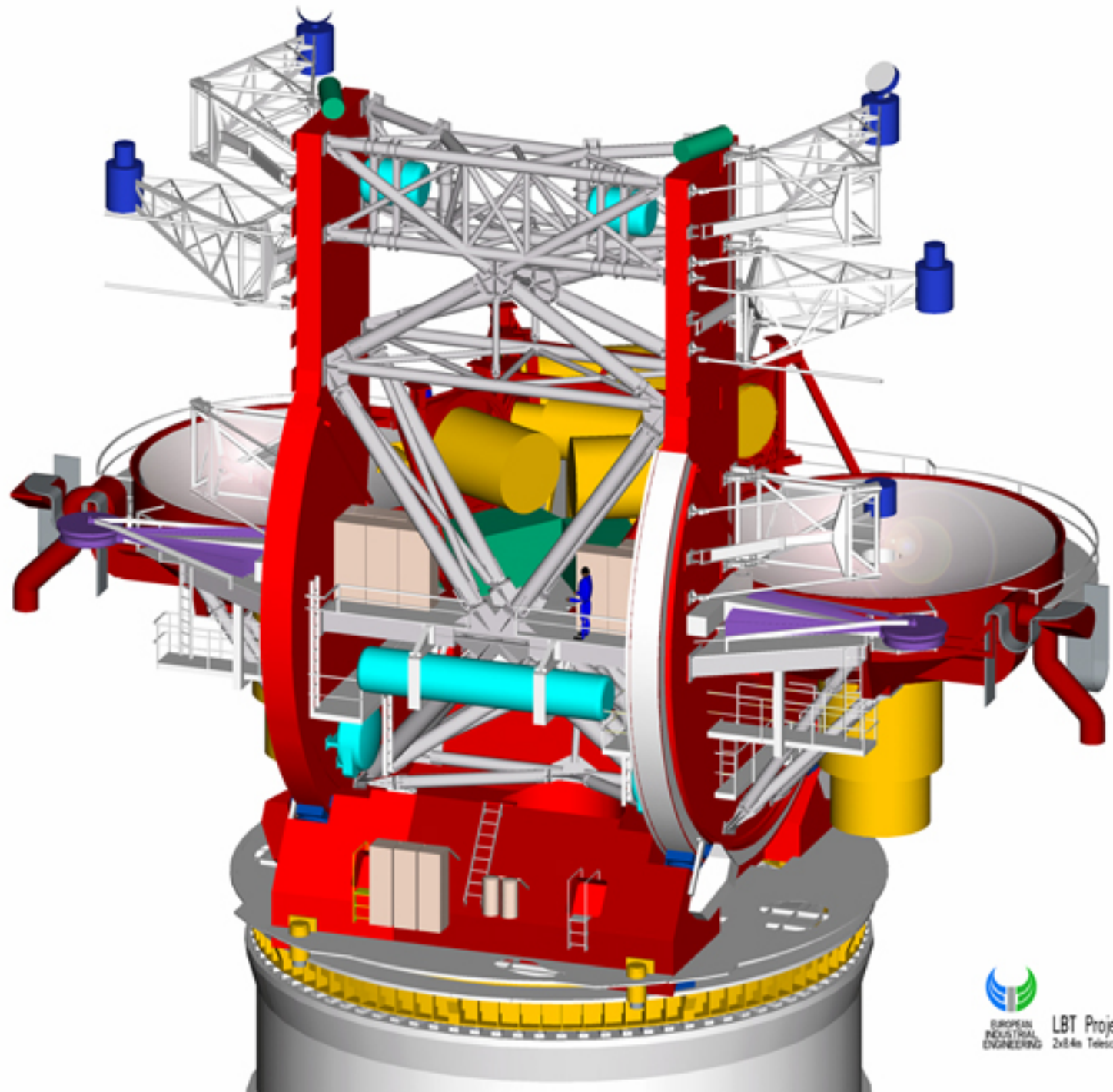


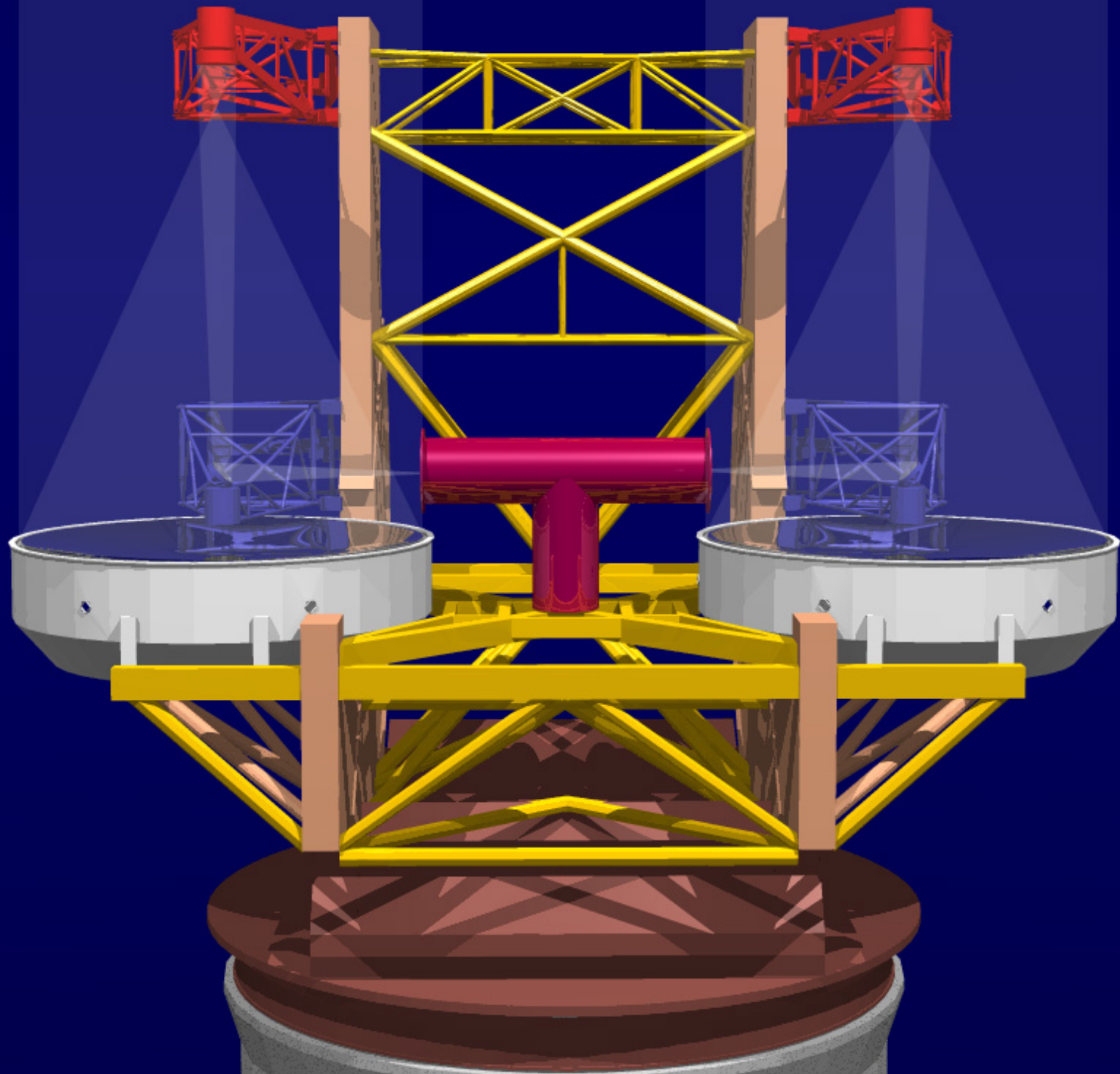
# Large Binocular Telescope (LBT)









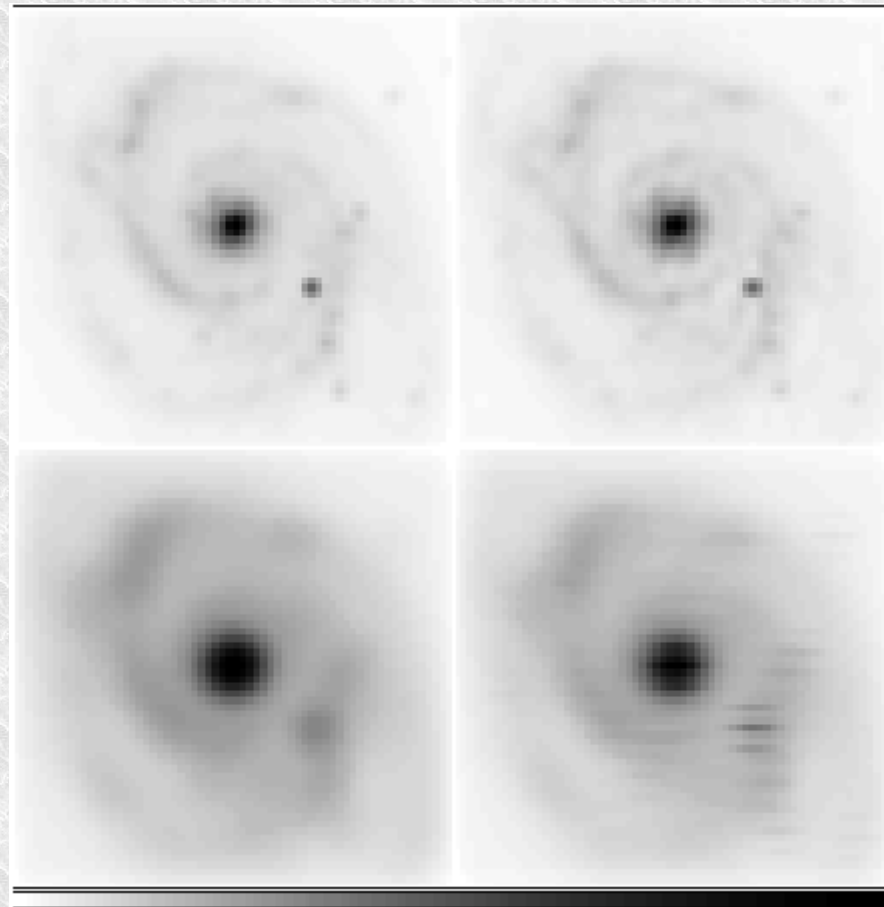


The elevation optical support structure moves on two large C-shaped rings and the compact azimuth platform transmits the loads directly down to the pier. The two 8.4 meter (331 inch) diameter primary mirrors are mounted with a 14.4 meter center-center separation. By using swing arms to rotate the secondary mirrors and their supports, it is possible to switch the telescope from one mode of observation to another very quickly.

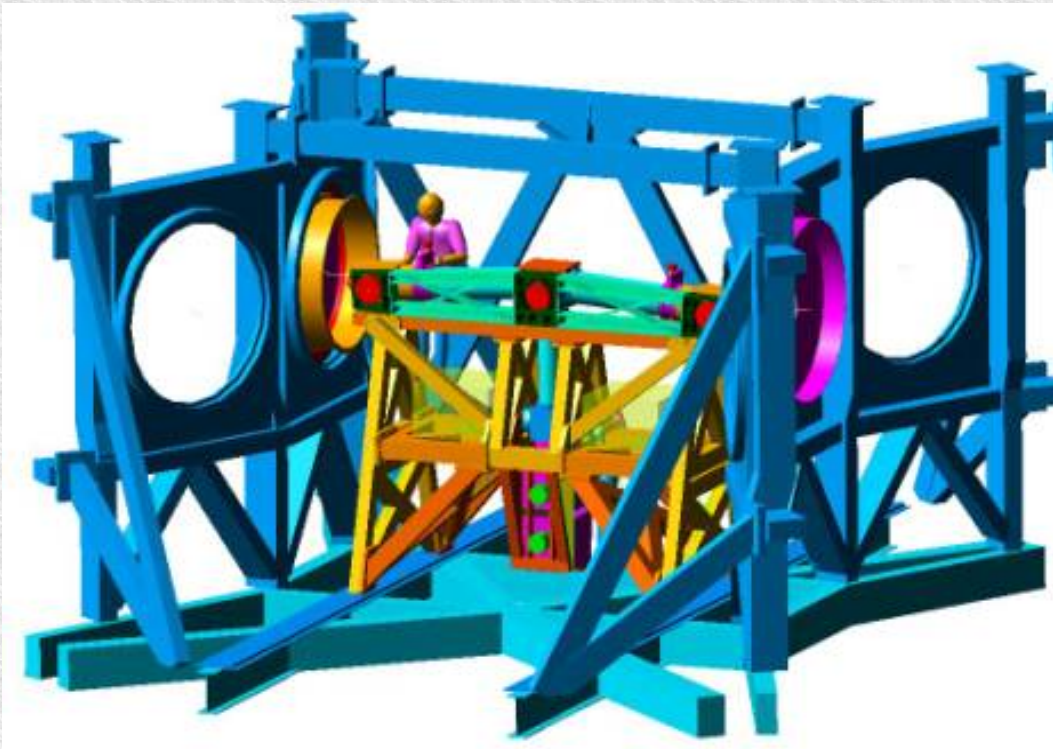
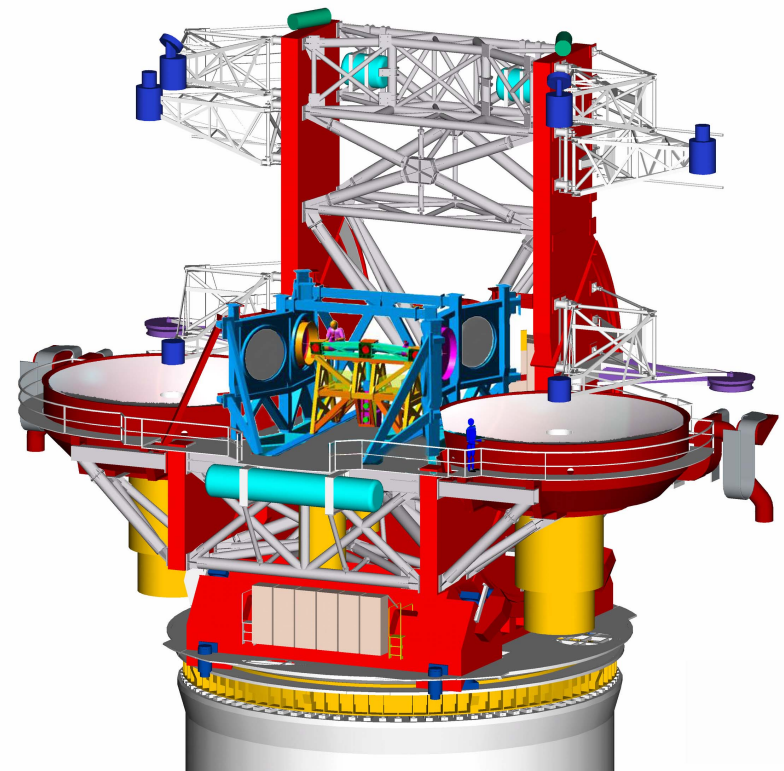
The short focal length of the primary mirrors (F/1.142) permits a compact, and therefore quite stiff telescope structure.

- \* Telescope Structure: model A', platform design
- \* Pier Diameter: 13 meters for azimuth track
- \* Building Height: ~ 40 meters at roofline
- \* Drive Mechanism: gear and pinion
- \* Vibration Specification: < 0.025 m amplitude above 8 Hz
- \* Telescope Moment of Inertia: approximately  $1.0 \cdot 10^7$  Kg m<sup>2</sup> (both axes)
- \* Maximum Angular Speed: 1.5 degrees/second
- \* Error Budget: telescope and optics to match  $r_0 = 45$  cm atmosphere
- \* Implied Image Size from Telescope = 0.22 arcsecond FWHM
- \* Short Term Tracking Specification: 0.03 arcsecond rms motion (5 seconds)
- \* Whole Sky Pointing Specification: 0.3 arcsecond rms
- \* Wind Speed for Pointing and Tracking Specs: 24 km/hr
- \* Maximum Operating Wind Speed: 80 km/hr
- \* Primary Mirror Aluminizing: on-board the telescope
- \* Support Spacing: 2 "C" rings on 10 meter centers
- \* Telescope Height: ~ 25 meters at elevation axis (30 m above bedrock)
- \* Support of Telescope: hydrostatic pads
- \* Telescope and Drive Stiffness Goal: locked rotor frequency > 8 Hz
- \* Encoders: strip type
- \* Telescope Mass: approximately 580 metric tons
- \* Maximum Angular Acceleration: 0.3 degrees/second<sup>2</sup>
- \* Survival Wind Speed (closed): 225 km/hr

The Large Binocular Telescope (LBT) will have two 8.4 m apertures spaced 15m center-to-center. Adaptive optics will be used to recover deep long exposure diffraction limited images in the infrared. The figures show simulated images of a galaxy at 2.2 micron wavelength. A single telescope gives the image in the lower left; when both apertures are combined in phase, higher resolution interference fringes are superimposed (lower right). If three similar images are obtained during the night with parallactic angles -45 degrees, 0 degrees and 45 degrees, a high resolution image can be deconvolved by the blind deconvolution method. The result (upper right) is very similar to the diffraction limited image from a 23.4 m filled circular aperture telescope (upper left.)



# *LBTI*



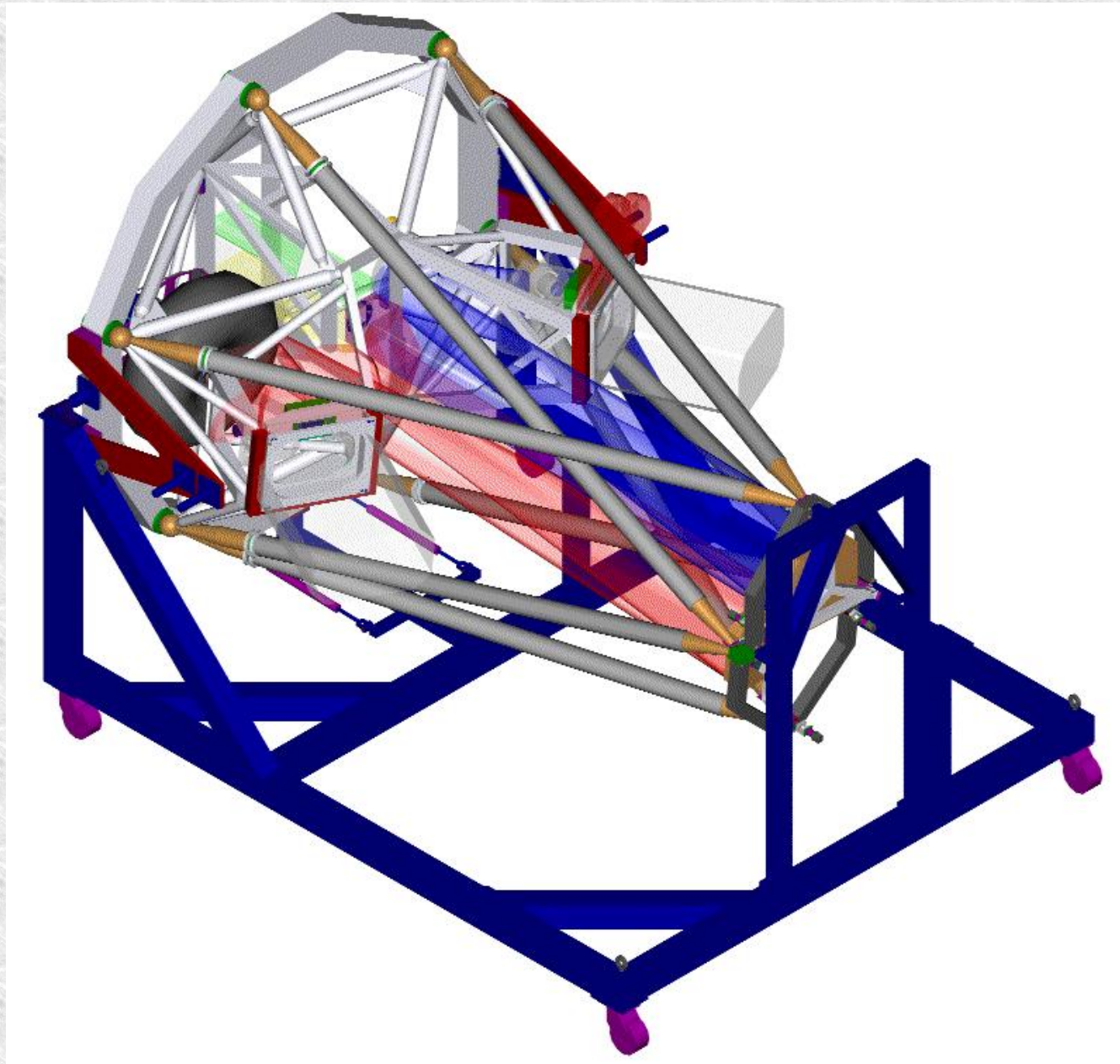
## Az LBT interferométer

- állatövi porkorongok detektálása
- gázóriások más csillagoknál
- planetáris rendszerek észlelése
- null-interferometria
- Föld-szerű bolygók???

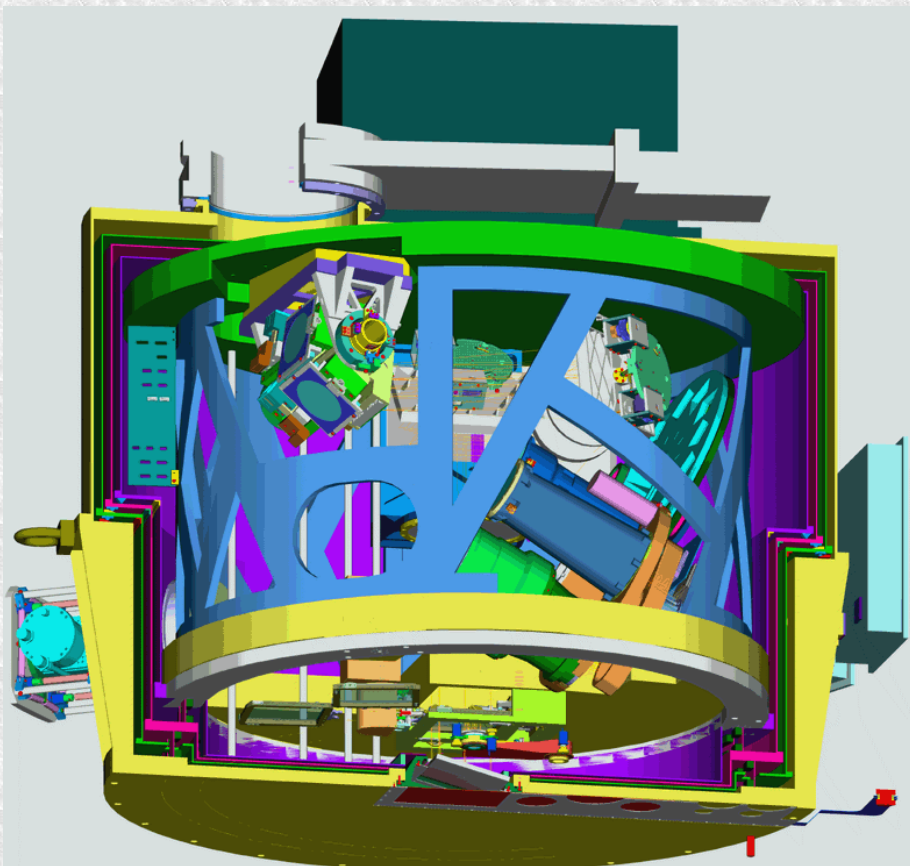
*MODS*

*(Multi-Object Double Spectrograph)*

*R ~2000-8000*



# LUCIFER



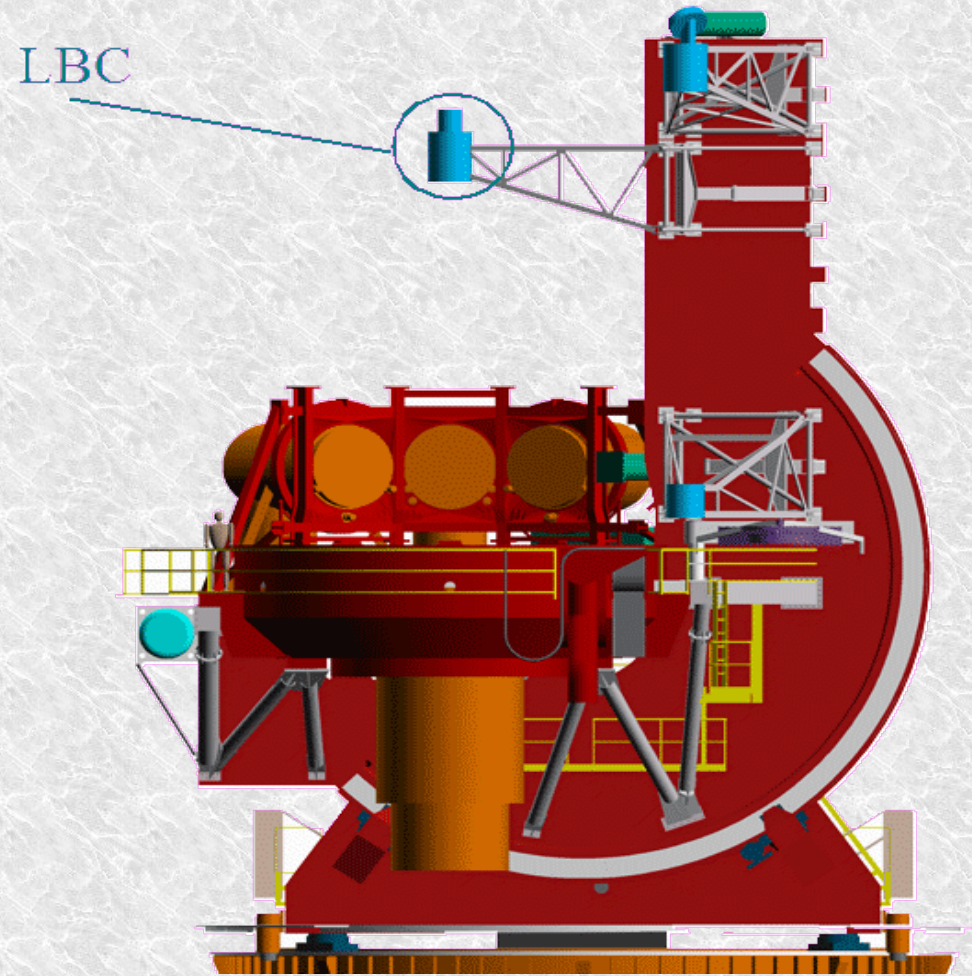
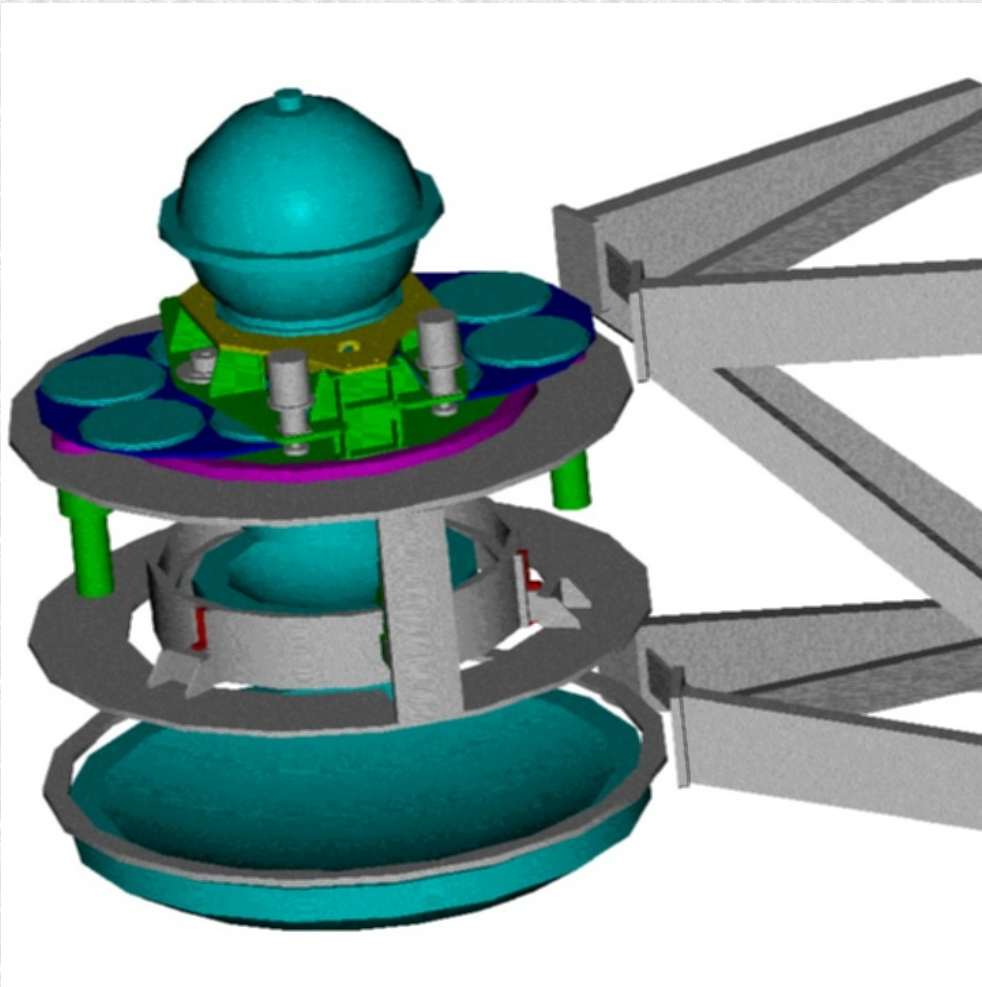
*LBT NIR spectroscopic Utility  
with Camera and Integral- Field Unit for  
Extragalactic Research*



## The Large Binocular Cameras (LBC):

*two wide-field, high-throughput imaging cameras located at the Prime Focus stations.*

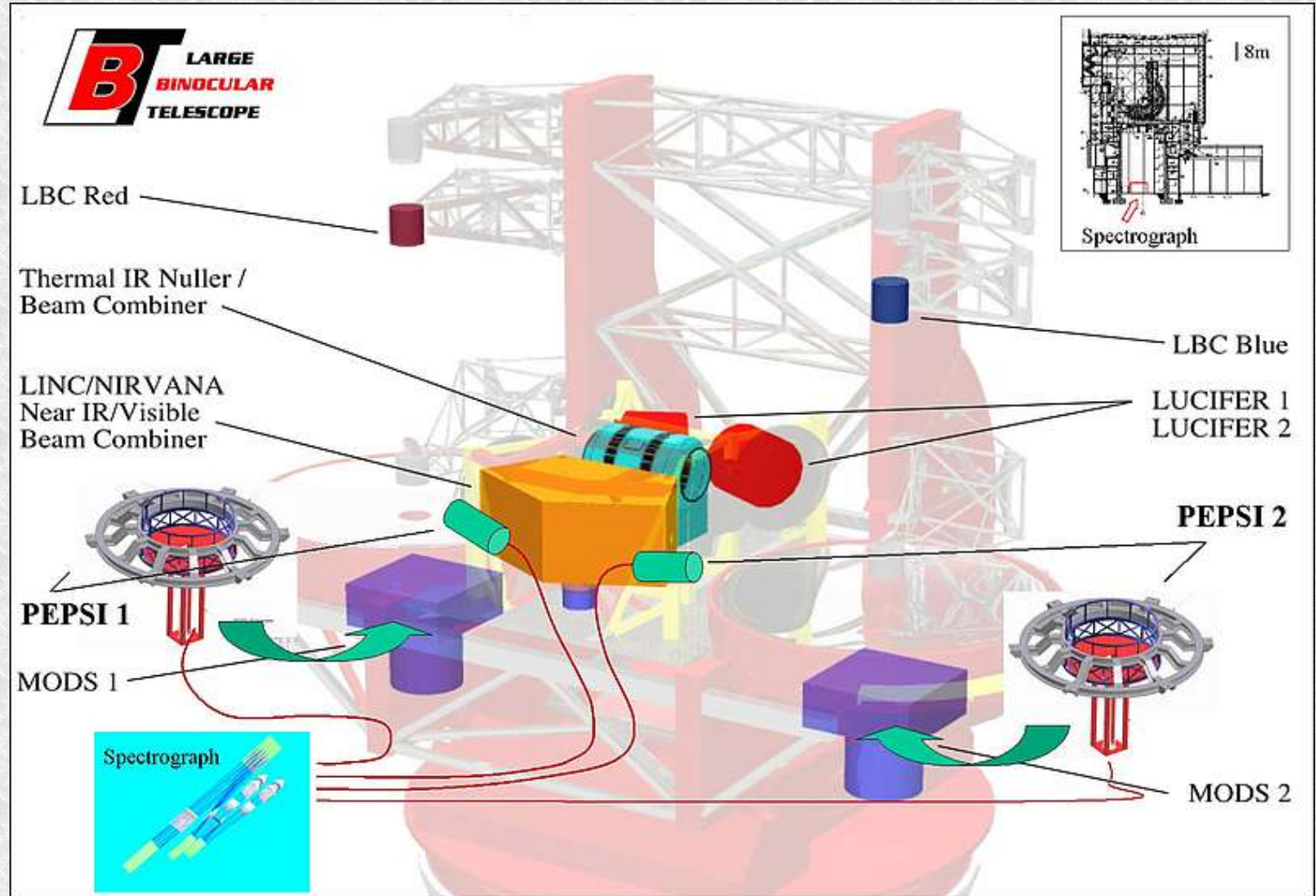
*Each LBC has a wide field of view, equivalent to 23'x23' (i.e. 1/6 of square degree), and provides images with a sampling of 0.23"/pixel, adequate to match the best seeing conditions. The optical design and the detectors are optimized in different wavelength ranges: one for UV-blue wavelengths (from 320 to 500 nm, corresponding to the UVB bands), and one for the red-IR bands (from 500 to 1000 nm, corresponding to the RIz bands). In the full binocular configuration, both channels will be available simultaneously, and will both point in the same direction of the sky, thus doubling the net efficiency of the LBT.*





# Potsdam Echelle Polarimetric and Spectroscopic Instrument

PEPSI FOR THE LBT

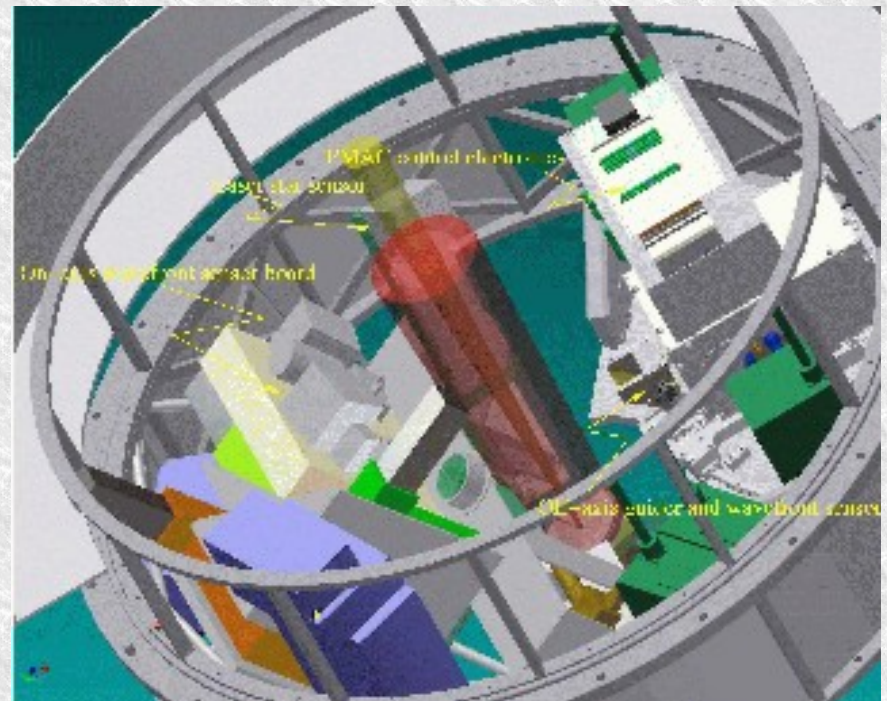
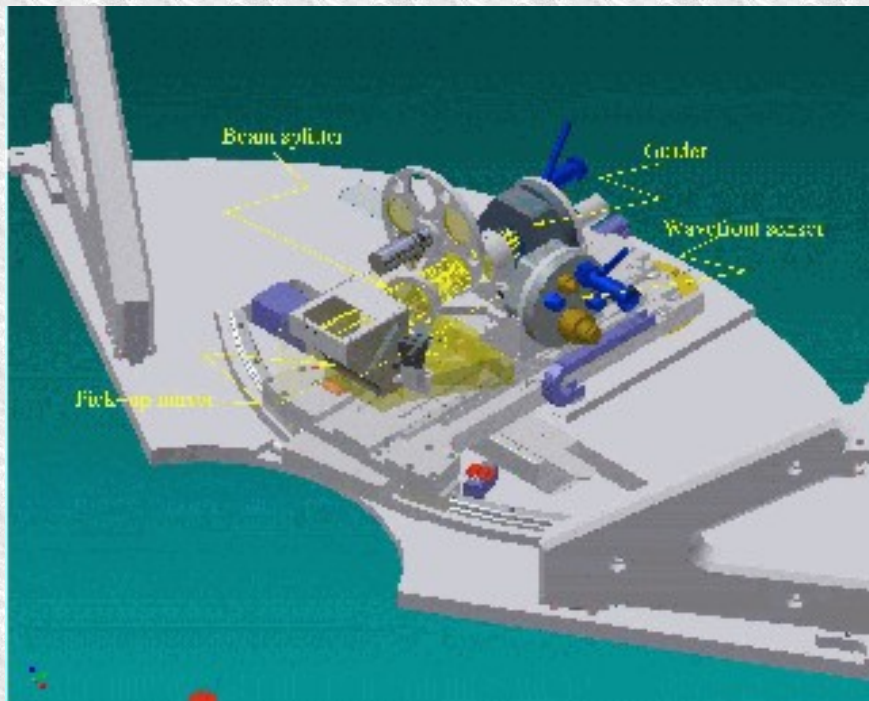


*R akár 300.000 is lehet...*



*Acquisition, Guiding, and Wavefront sensing units (AGW units) for the telescope.*

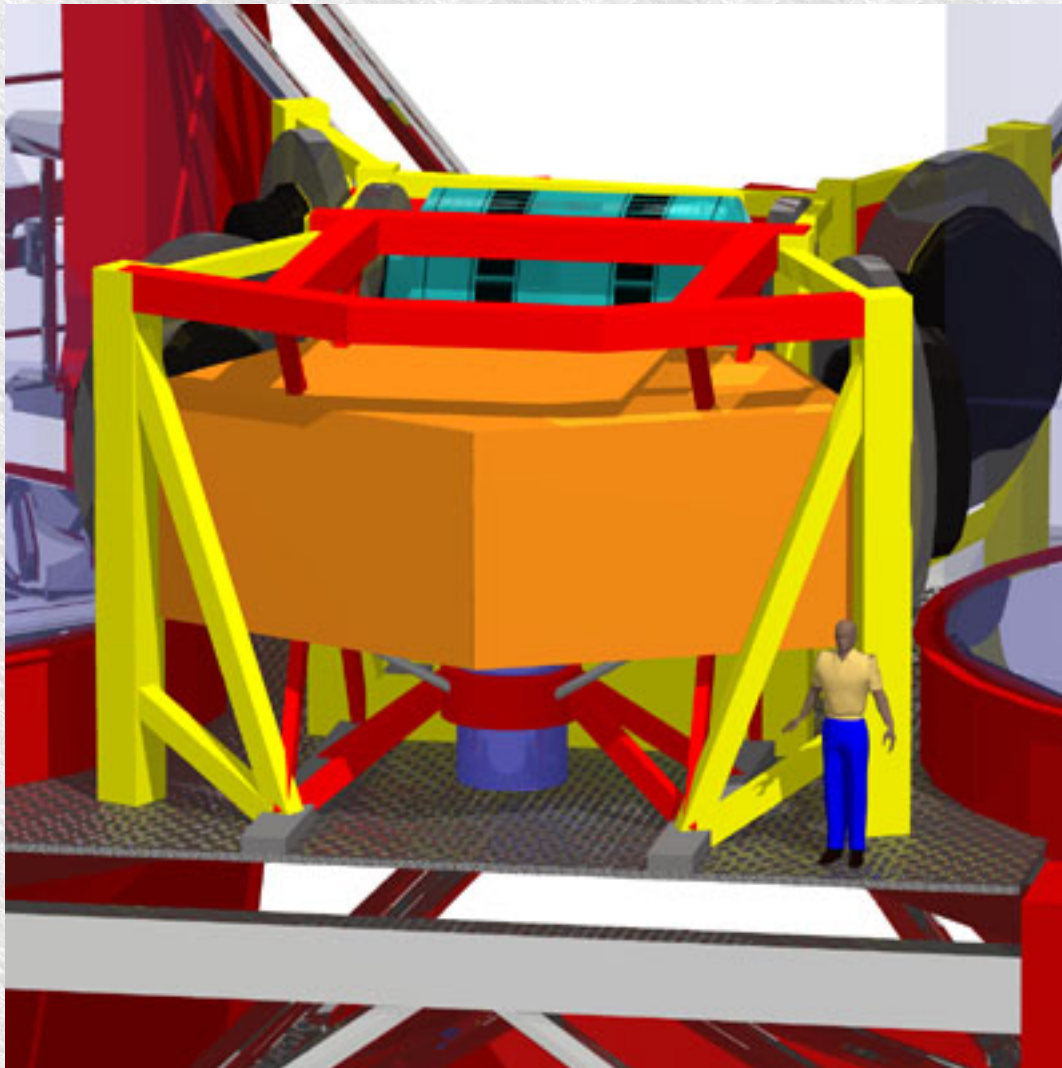
*The AGW units are each divided into two sub-units, the Off-axis and the On-axis units.*





## *LINC-NIRVANA*

### *The German-Italian Beam Combiner for the LBT*



*LINC-NIRVANA is an imaging interferometer for the Large Binocular Telescope (LBT).*

*It will combine the radiation from the two 8.4 m primary mirrors of the LBT in so-called "Fizeau" mode. This configuration preserves phase information, and allows true imagery over a wide field of view.*

*The beam combiner will operate at wavelengths between 1.0 and 2.4 microns, using state-of-the-art detector arrays. When coupled with its advanced multi-conjugated adaptive optics system (MCAO), the LINC-NIRVANA instrument will deliver the sensitivity of a 12 m telescope and the spatial resolution of a 23 m telescope, over a field approximately 10 arcseconds square.*

# AIRY

## *Astronomical Image Restoration in interferometry*

*The following problems are and will be investigated by the group*

- # Deconvolution of multiple images of the same astronomical target,*
- # Denoising of a Point Spread Function (PSF) determined by means of a guide star,*
- # Blind deconvolution,*
- # Deconvolution in the case of space-variant PSFs.*

# Restoration Methods

# Tikhonov Regularization (TR) method

# Projected Landweber (PL) method

# Iterative Space Reconstruction Algorithm (ISRA)

# Lucy-Richardson/Expectation-maximization (LR-EM) method

# Ordered Subsets-EM (OS-EM) method

*és sok minden más...*

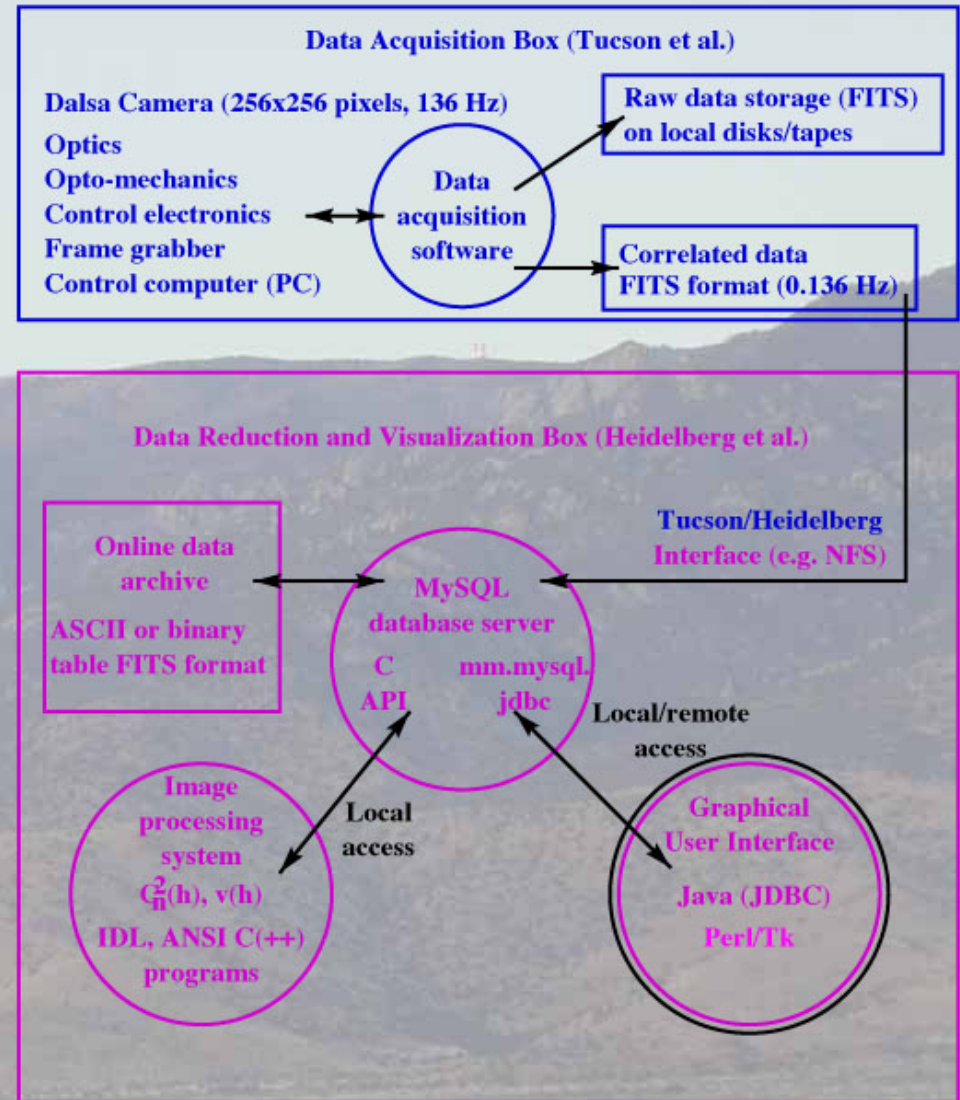
**MAPS**

*Multiple Atmospheric  
Phase screens and Stars*

*TurbuLenZ*

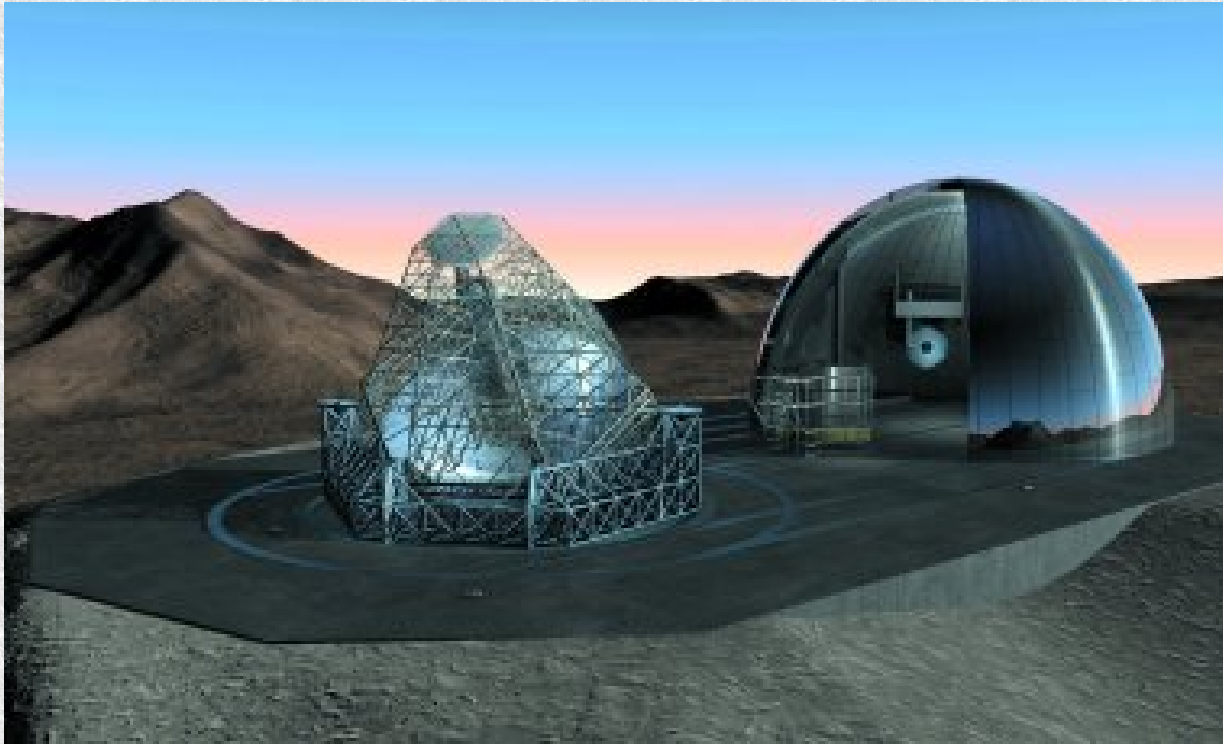
*Software Simulations of Kolmogorov  
Phase Screens  
with Fresnel Diffraction.*

## LBT SCIDAR PROJECT



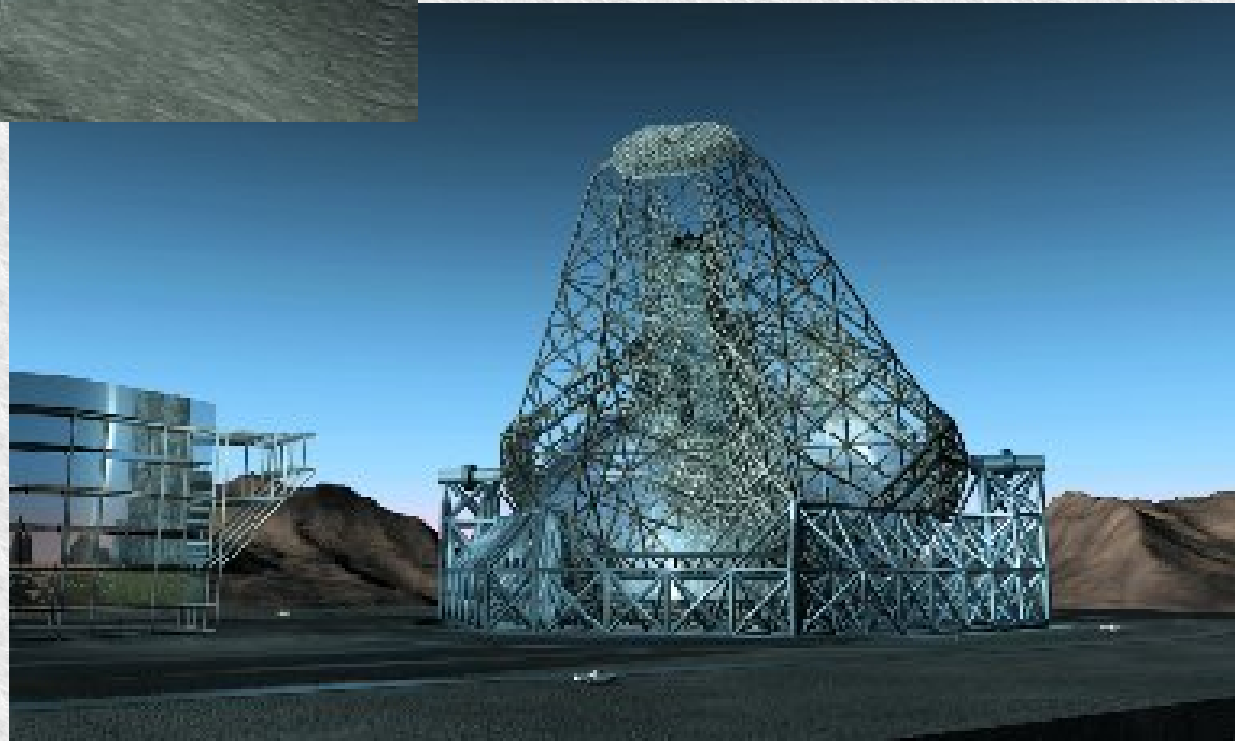
LBT SCIDAR Software Architecture (6 April 2000)

## ...és a valóban óriások...



OWL, ELT és társaik:

10 méternél nagyobb  
tükrökkel



# *OWL: Overwhelmingly large telescope*

pár szóban:

- segmented Ritchey-Chrétien concept: 100 m primary mirror
- angular resolution will be 40 times better than that of the HST
- OWL could start science operation as a 60-m class telescope by 2016-2017
- with full 100-m capability by 2021
- total estimated cost of OWL is about 1,200 millions of Euros

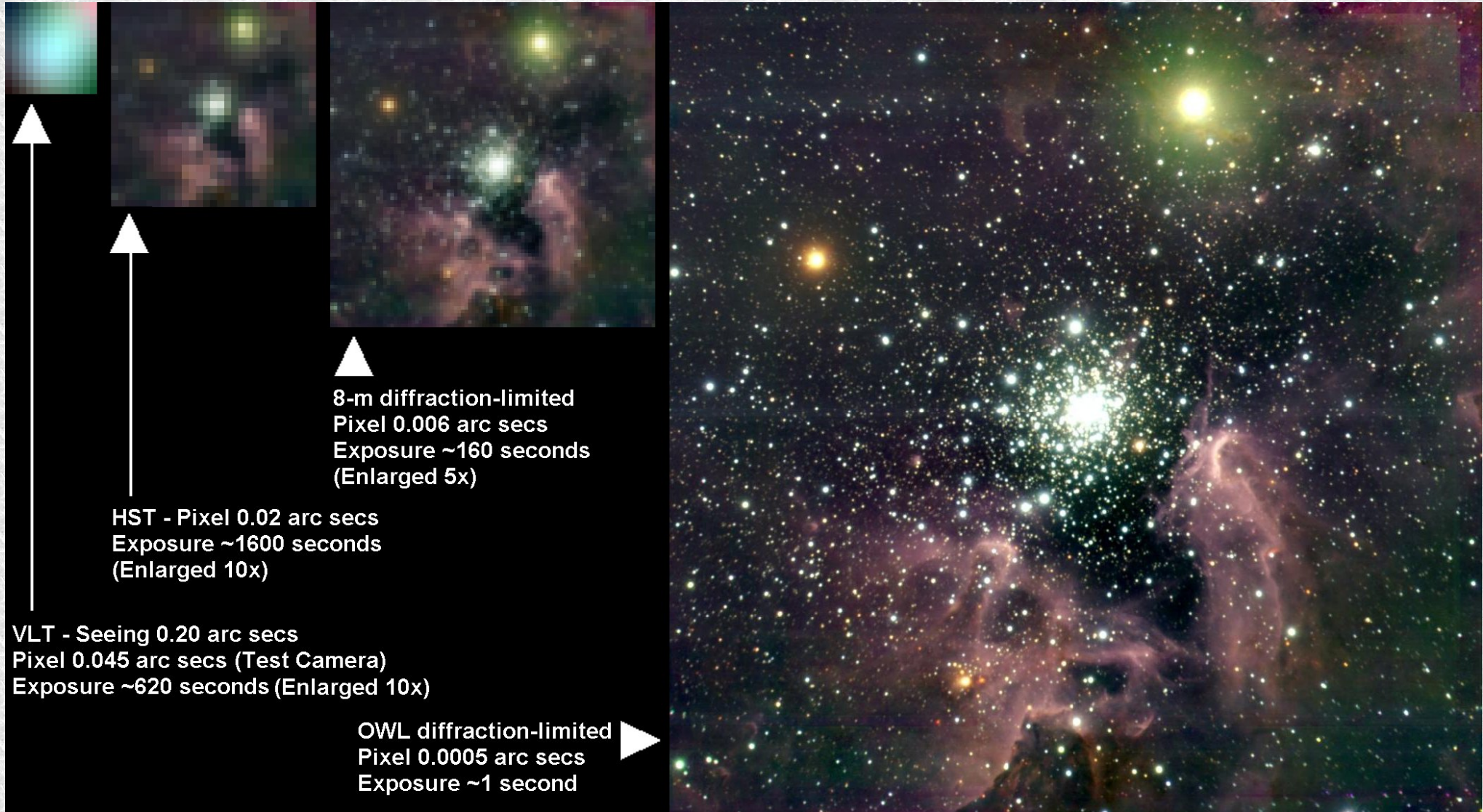
A tudományos célok:

exobolygók légkörének analízisétől, DM & DE felderítésén át naprendszerbeli objektumok űrszondás minőségű kutatásáig...

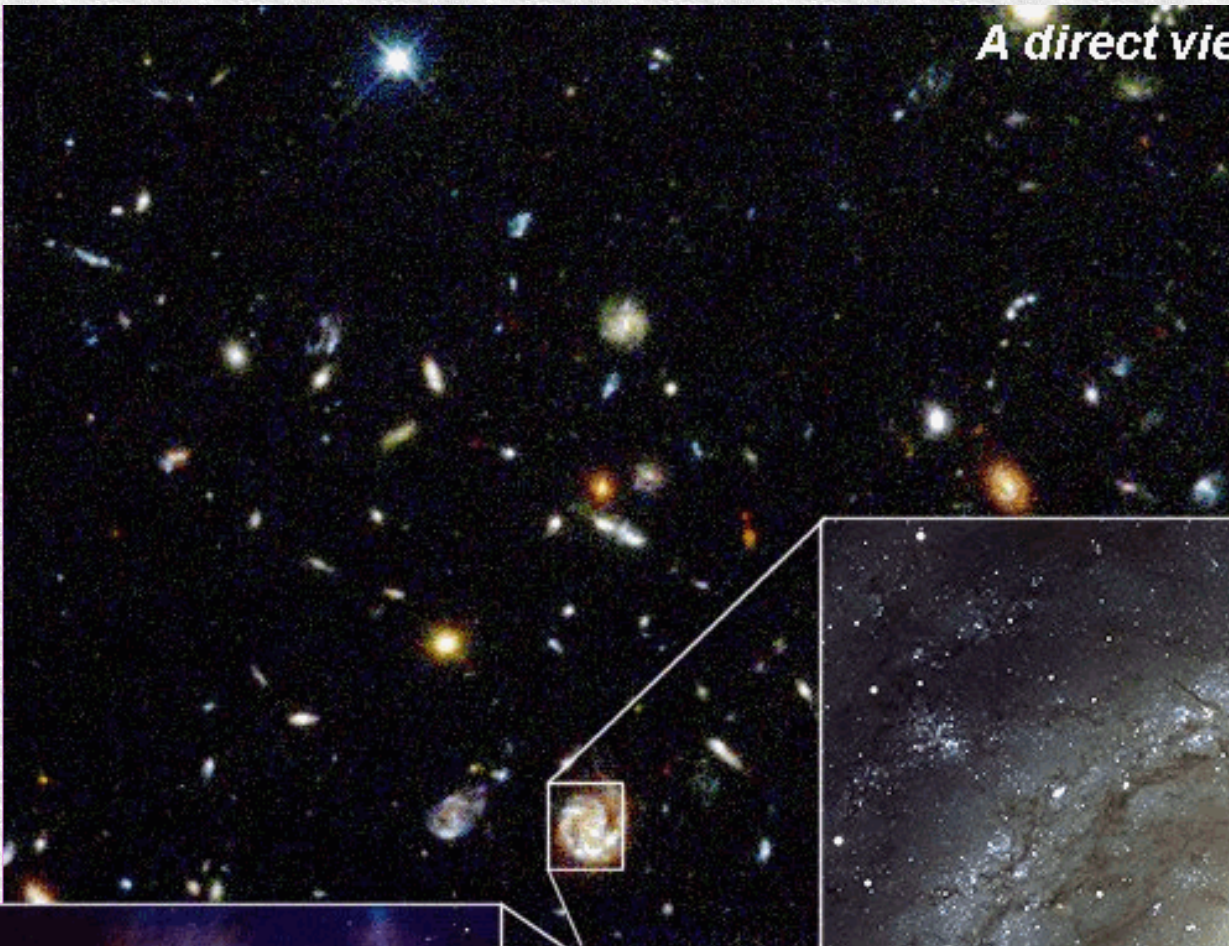
*“Olyan módon fogja forradalmasítani a csillagászatot, mint Galilei távcsöve...”*



## A teljesítményről beszélnek a jól ismert képek...

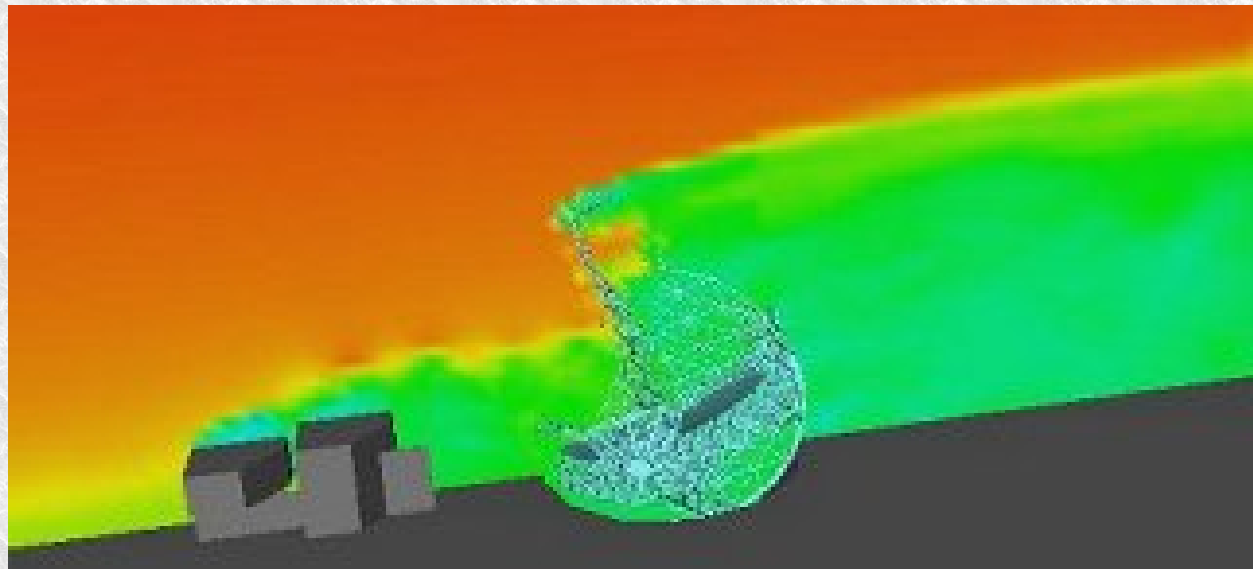
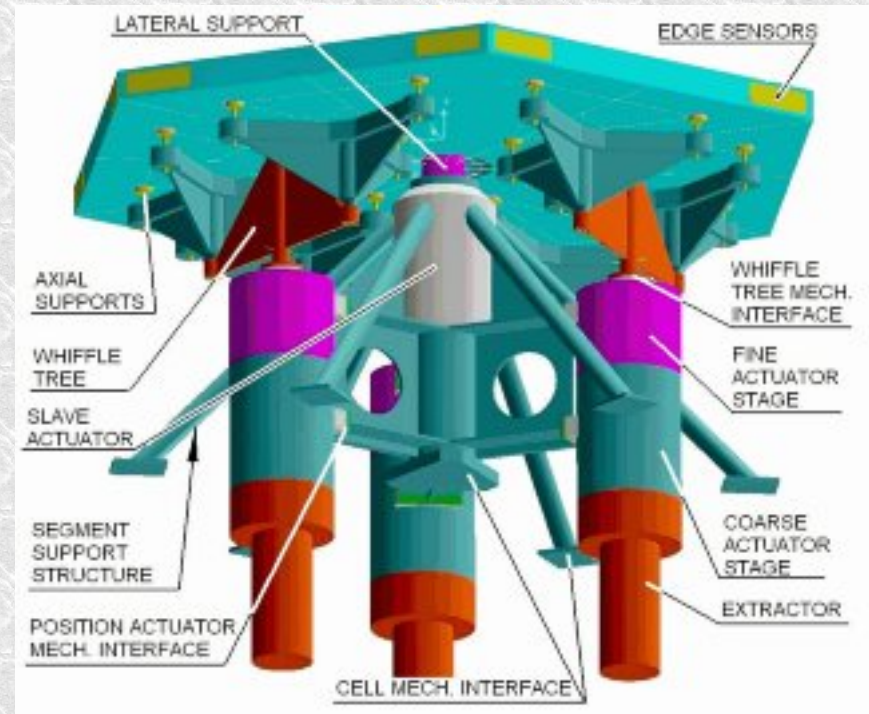


*A direct view of star formation history  
in the universe with OWL*

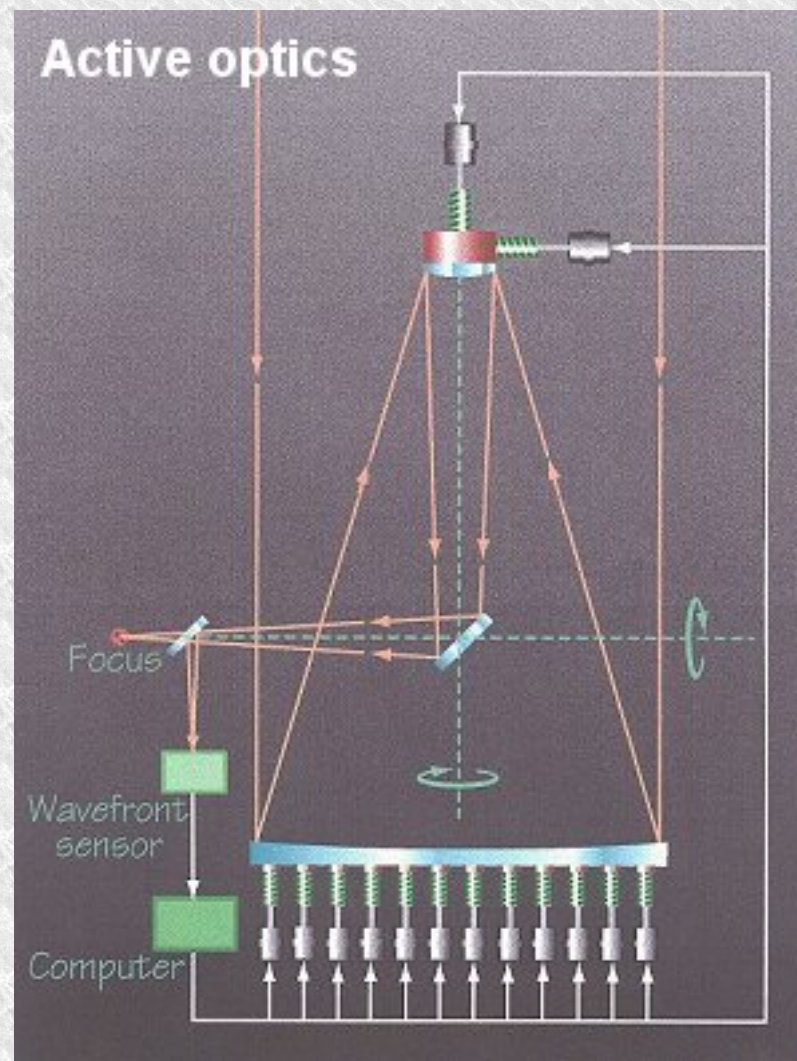
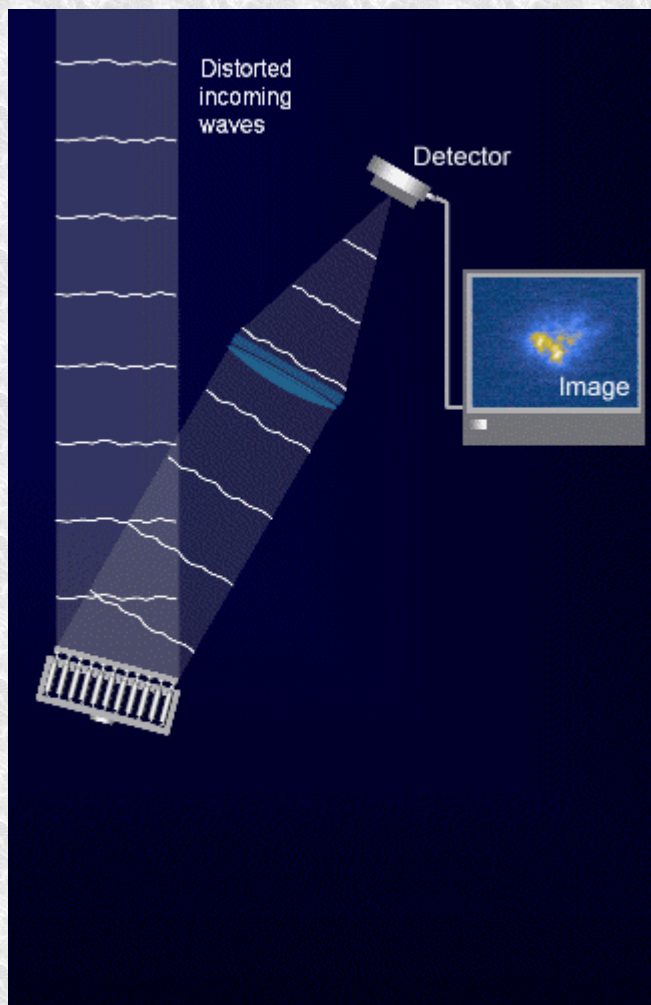


## Száraz számok:

- pupil size (diameter) 100 m
- 3264 segment
- collecting area  $> 6000 \text{ m}^2$
- diffraction-limited resolution over field of view :
  - visible ( $0.5 \text{ } \mu\text{m}$ )  $> 30$  arc sec.
  - infrared ( $2 \text{ } \mu\text{m}$ )  $> 2$  arc min.
- seeing-limited field of view 10 arc min.
- wavelength range  $0.32\text{-}12 \text{ } \mu\text{m}$
- elevation range:
  - operational 30-89 degrees
  - technical 0-90 degrees

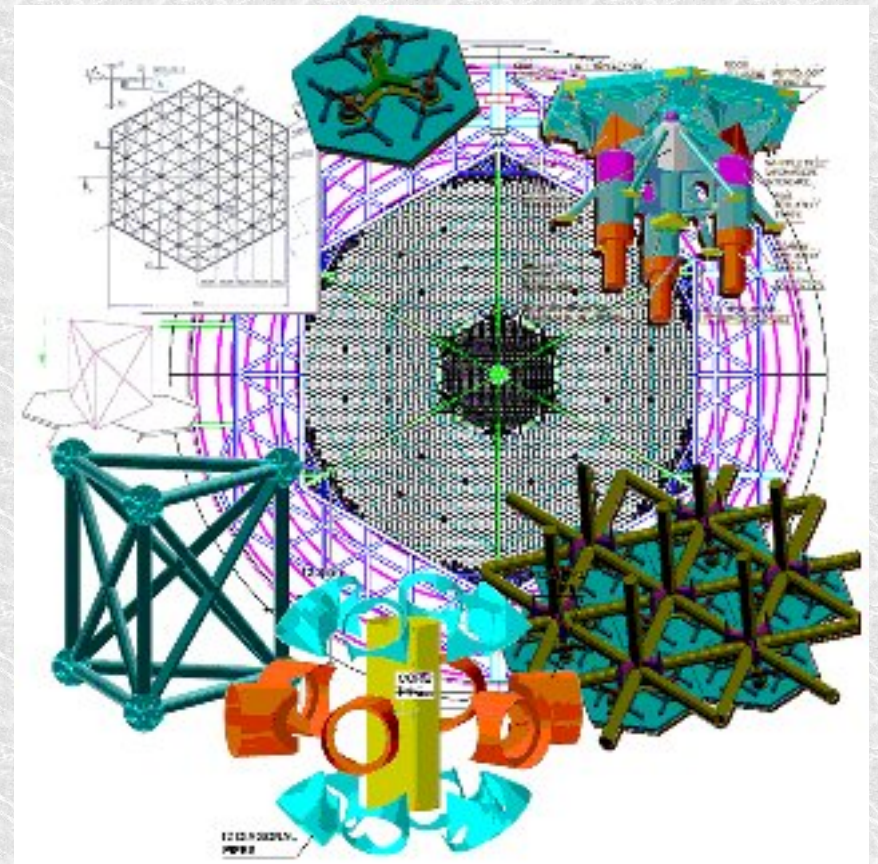
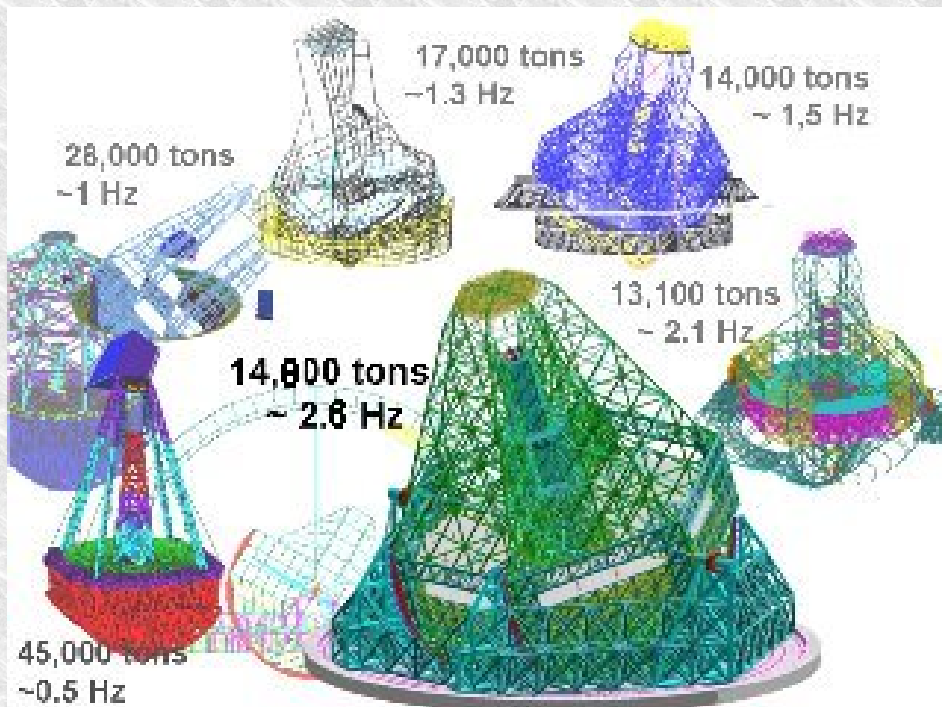


## Az éles látásért...

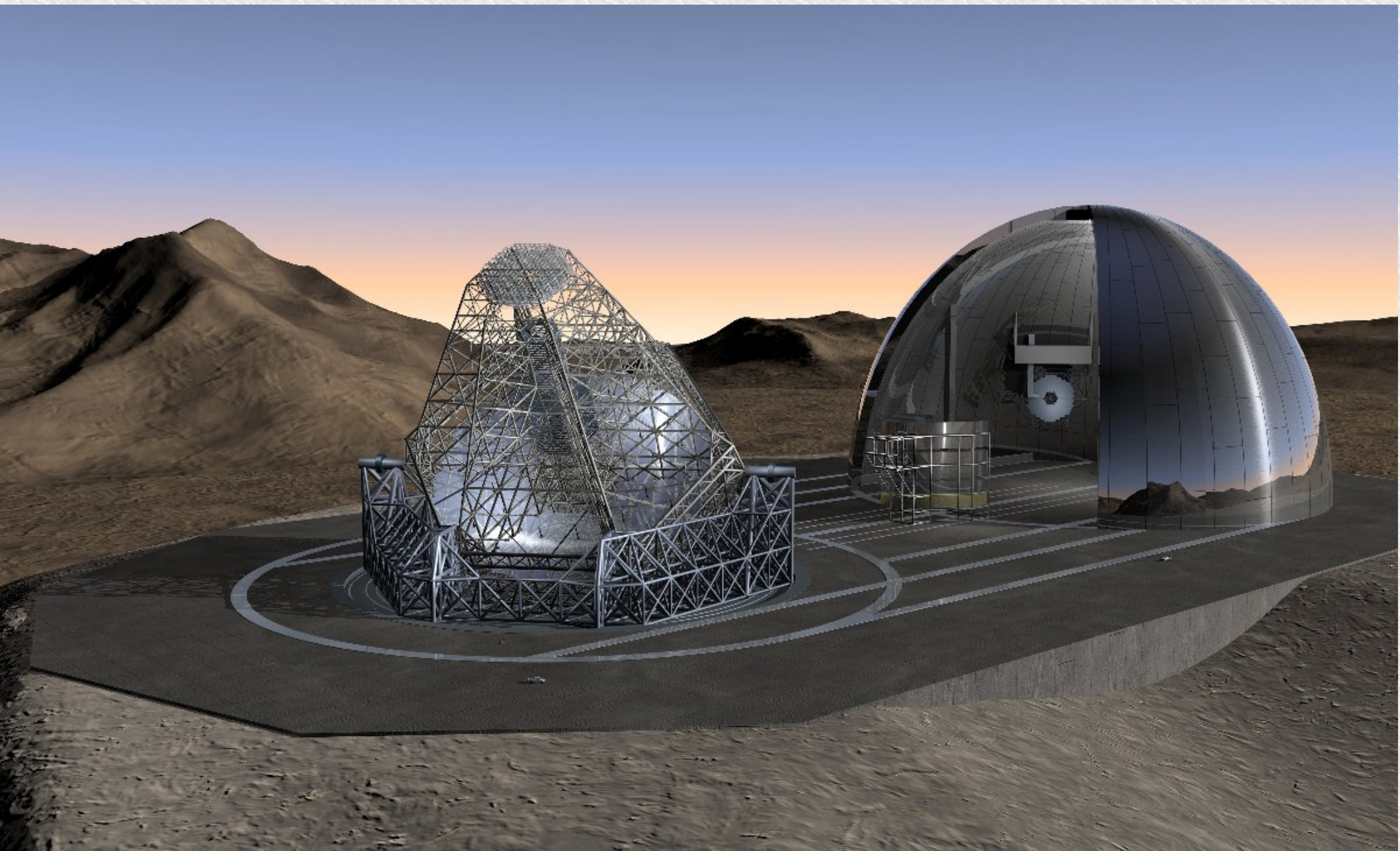




Csúcstechnika, hogy elkerüljük a túlterhelést...



Egyelőre csak fantáziarajz...

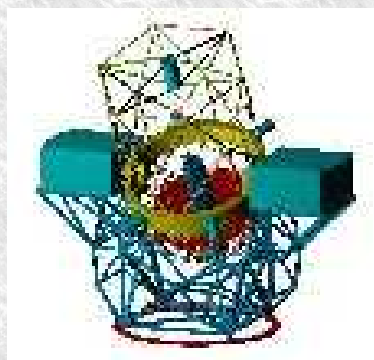


## **EXTREMELY LARGE TELESCOPES:**

Aperture (m)

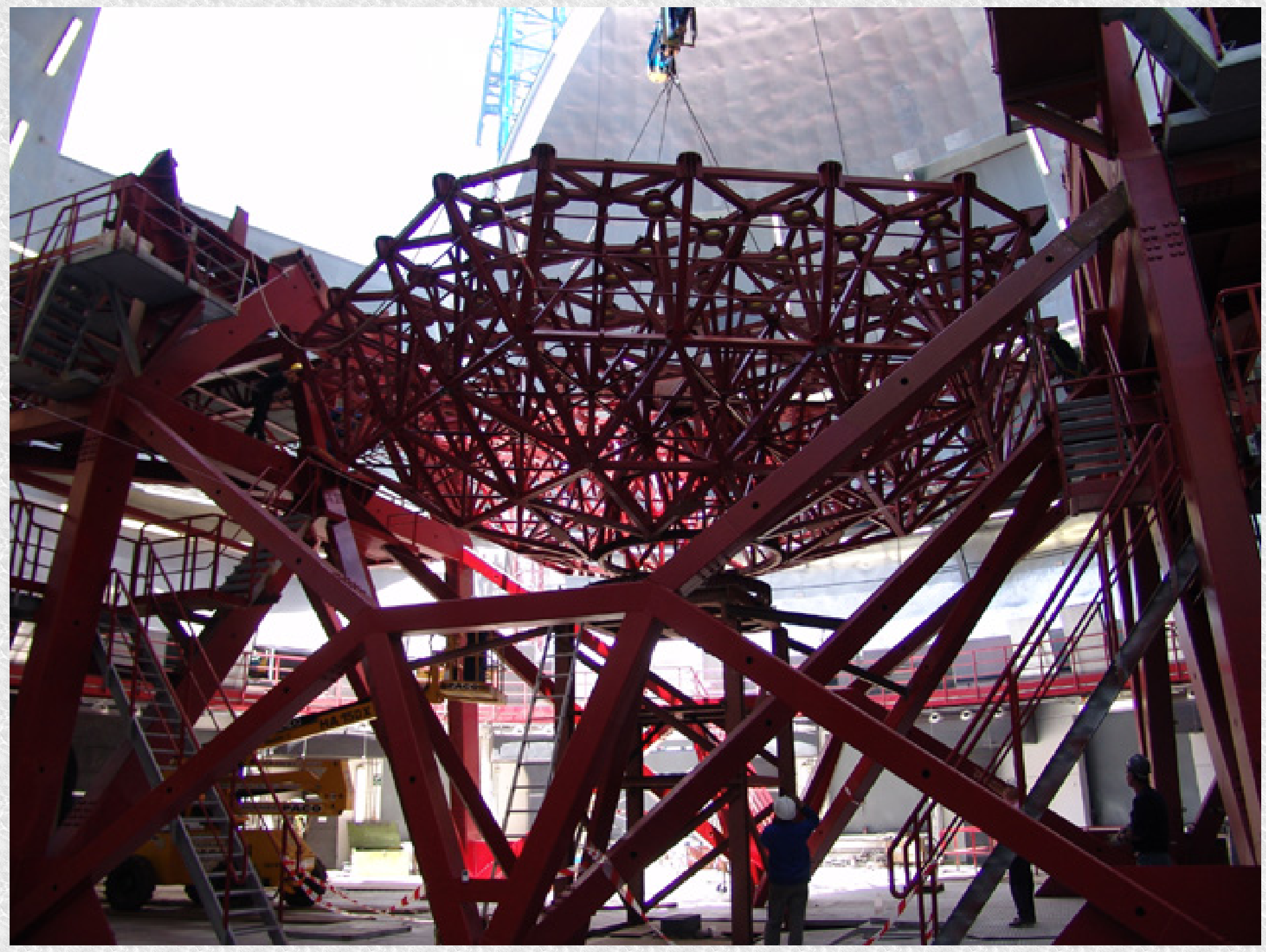
<b>TMT</b>	30	US-Canada: AURA, CALTECH, University of California and ACURA
<b>GMT</b>	25	The Giant Magellan Telescope
<b>EURO50</b>	50	Collaboration between Swedish, Spanish, Finnish and Irish institutes.
<b>LAMA</b>	42	Large Aperture Mirror Array
<b>GTC</b>	10.4	Gran Telescopio Canarias

# GTC Project

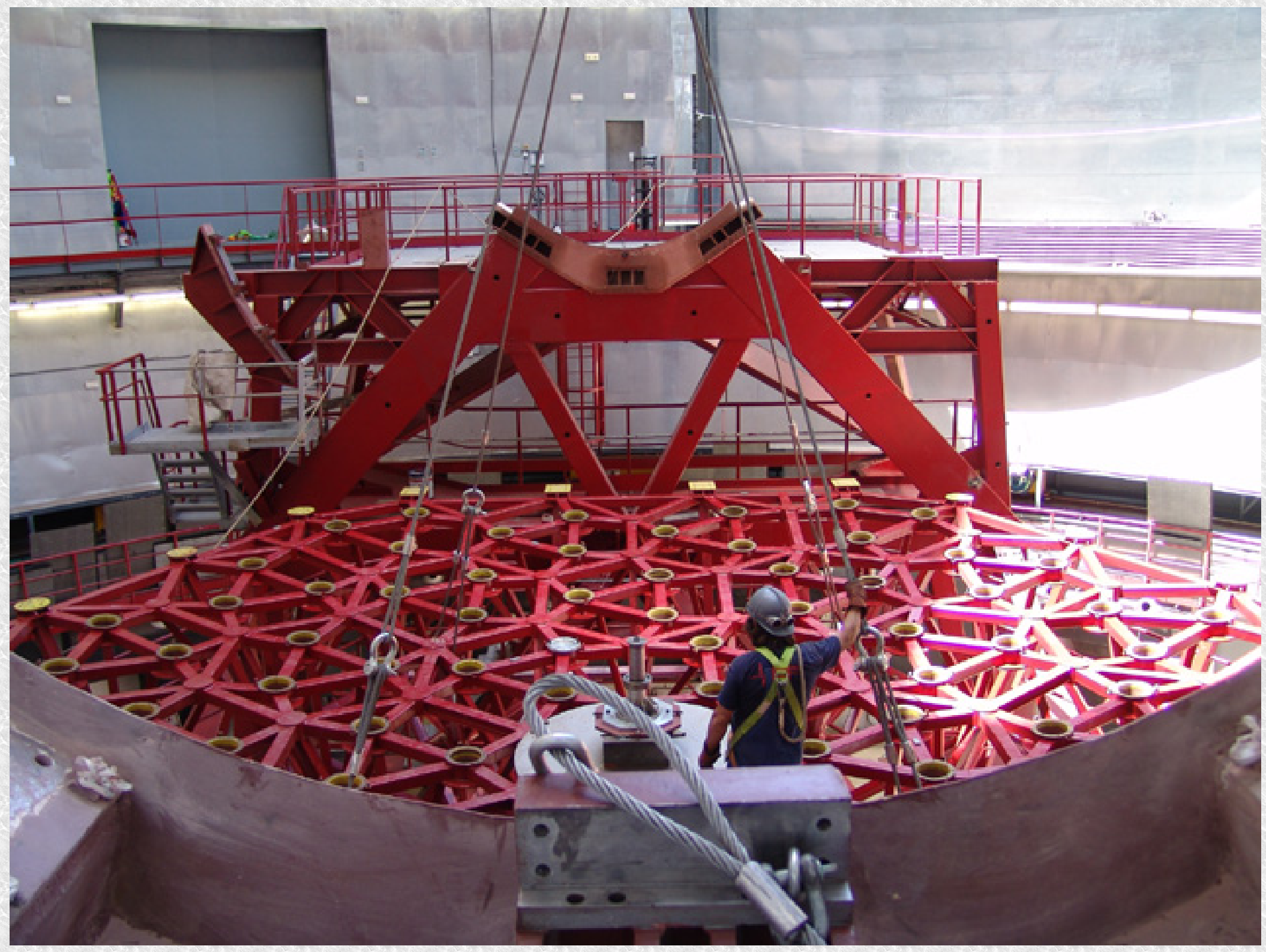


10.4 méteres szegmentált típus  
“first light” ~2005











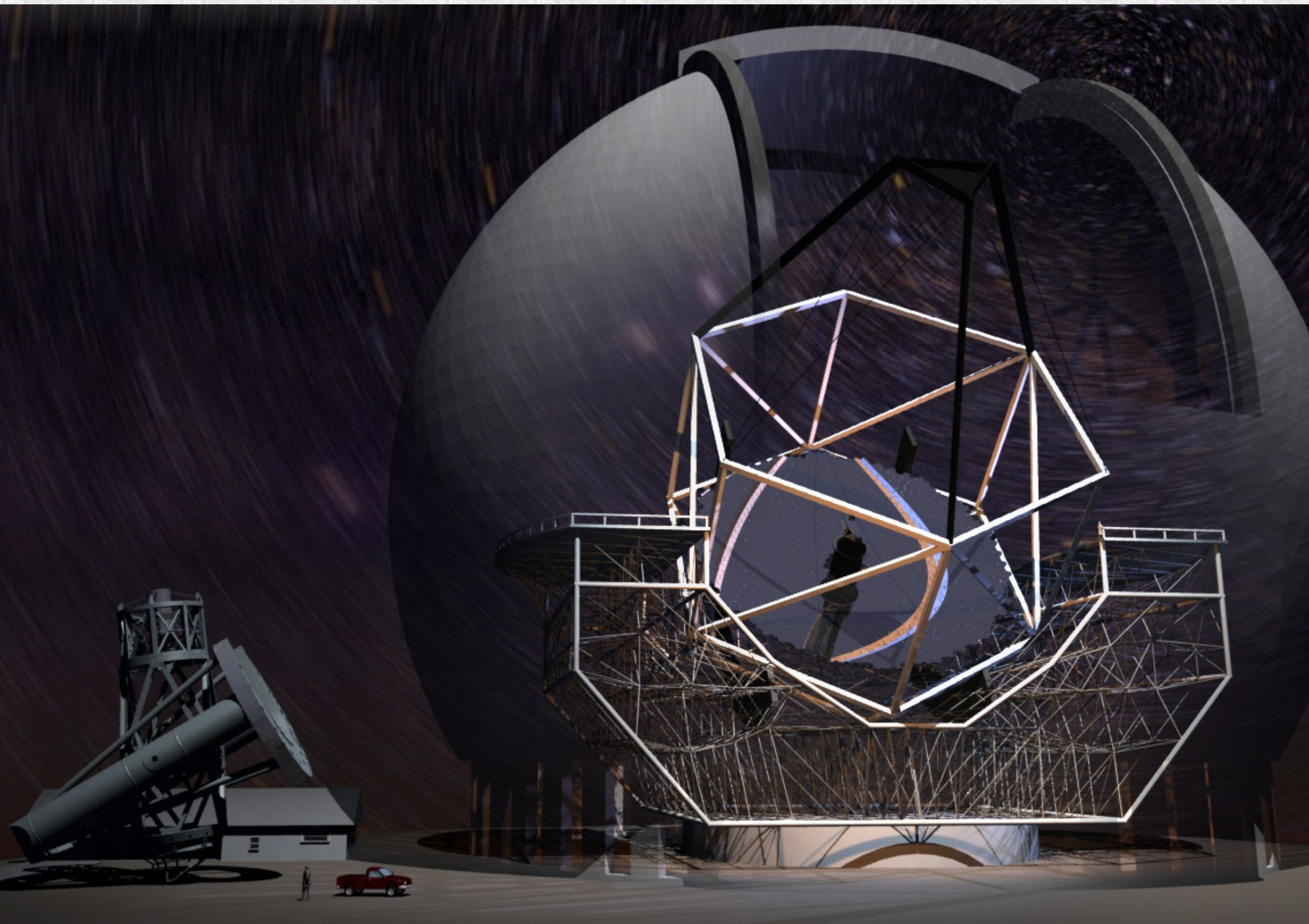
# Thirty Meter Telescope

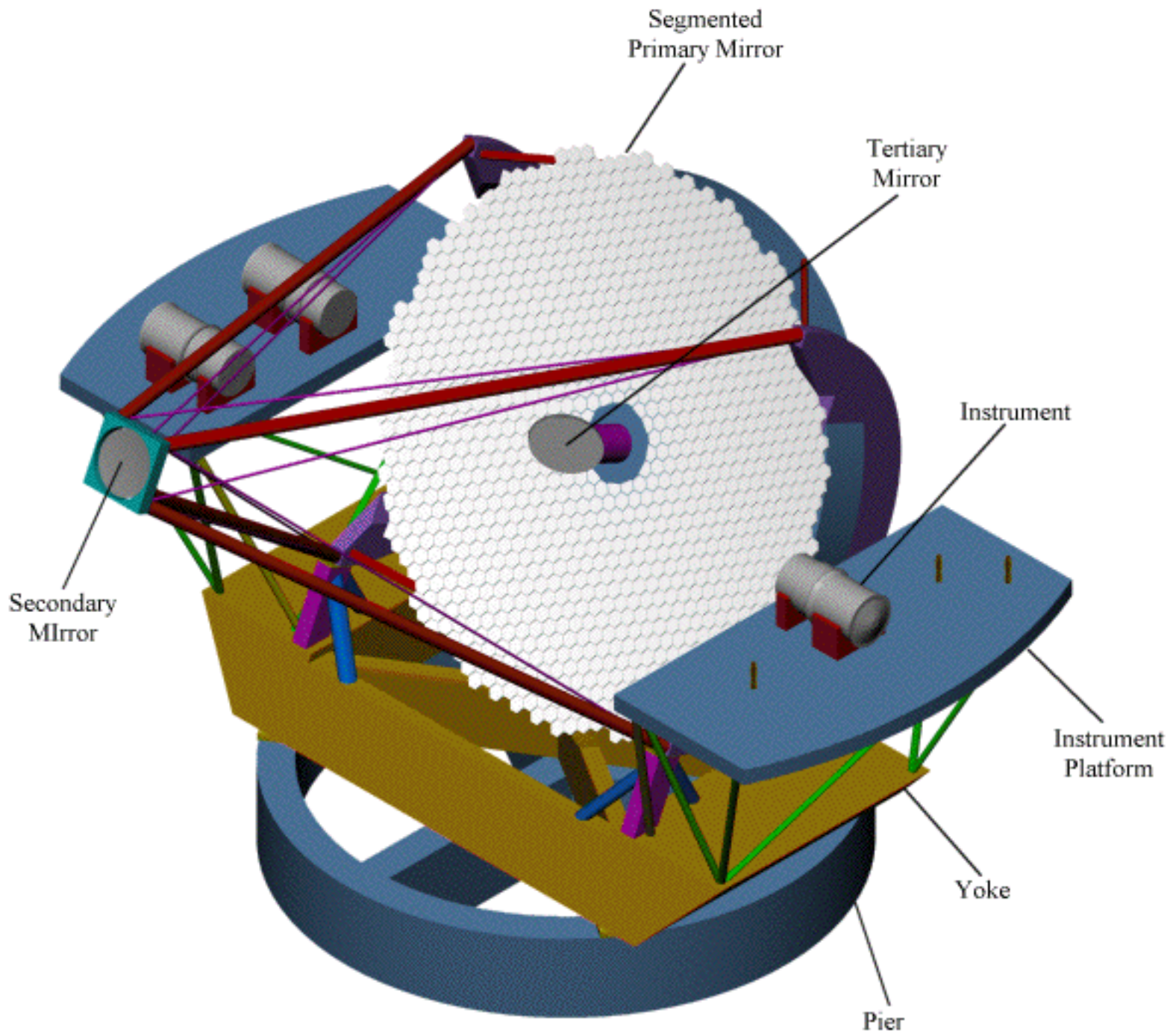
The TMT is a collaboration of:

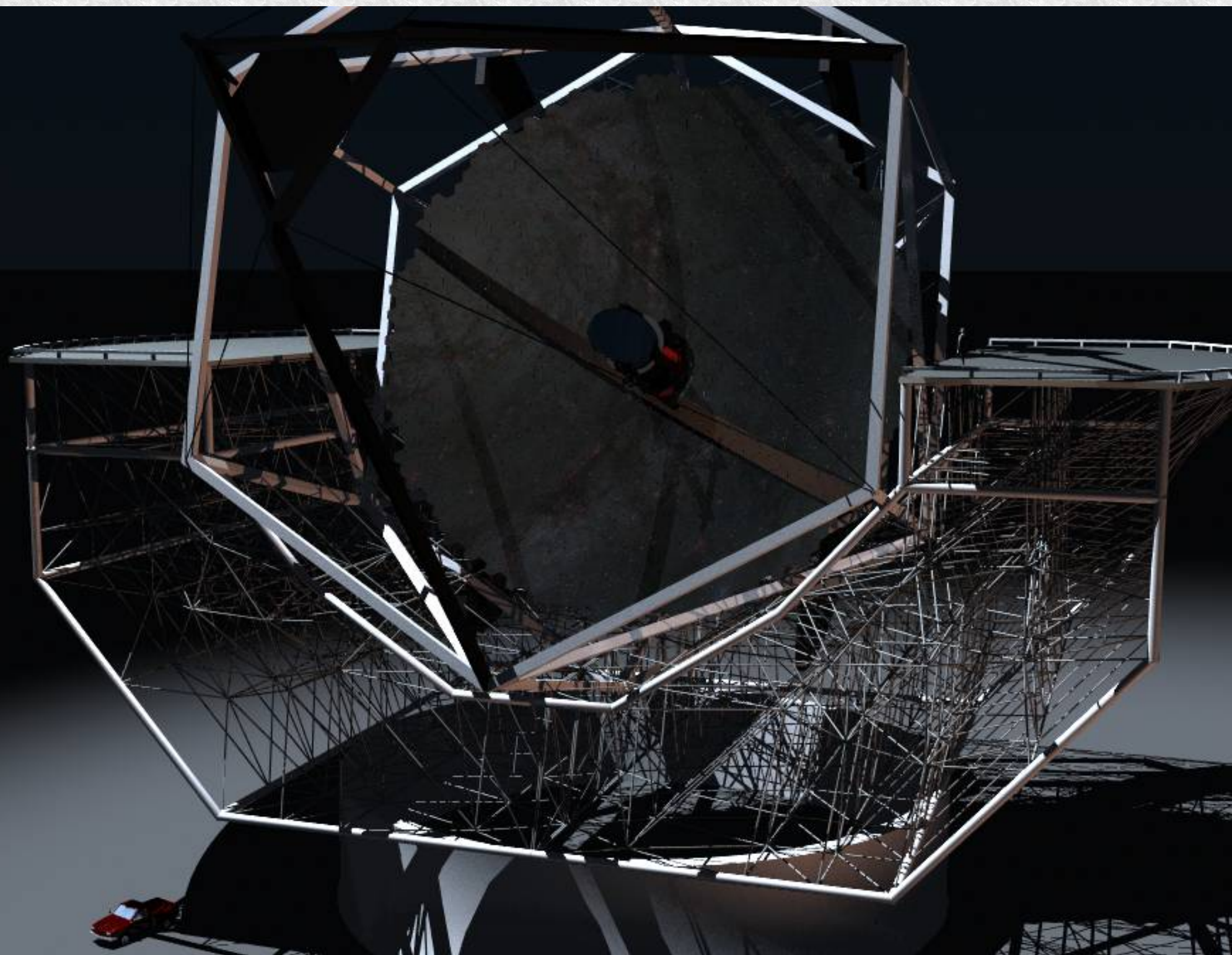
- the Associated Universities for Research in Astronomy (AURA) and its Giant Segmented Mirror Telescope (GSMT) project,
- the Association of Canadian Universities for Research in Astronomy (ACURA) and its Very Large Optical Telescope (VLOT) project.
- the California Extremely Large Telescope (CELT) Corporation, a partnership of the University of California and the California Institute of Technology

The goals of the next 3 to 4 years are to:

- establish a management structure to manage the current design effort and prepare for the final design and construction phases
- collect the data required to select a site
- complete the conceptual design of the telescope, adaptive optics systems, and an initial suite of instruments.
- establish a cost estimate with uncertainties on the order of 10%
- prepare for and complete a Conceptual Design Review









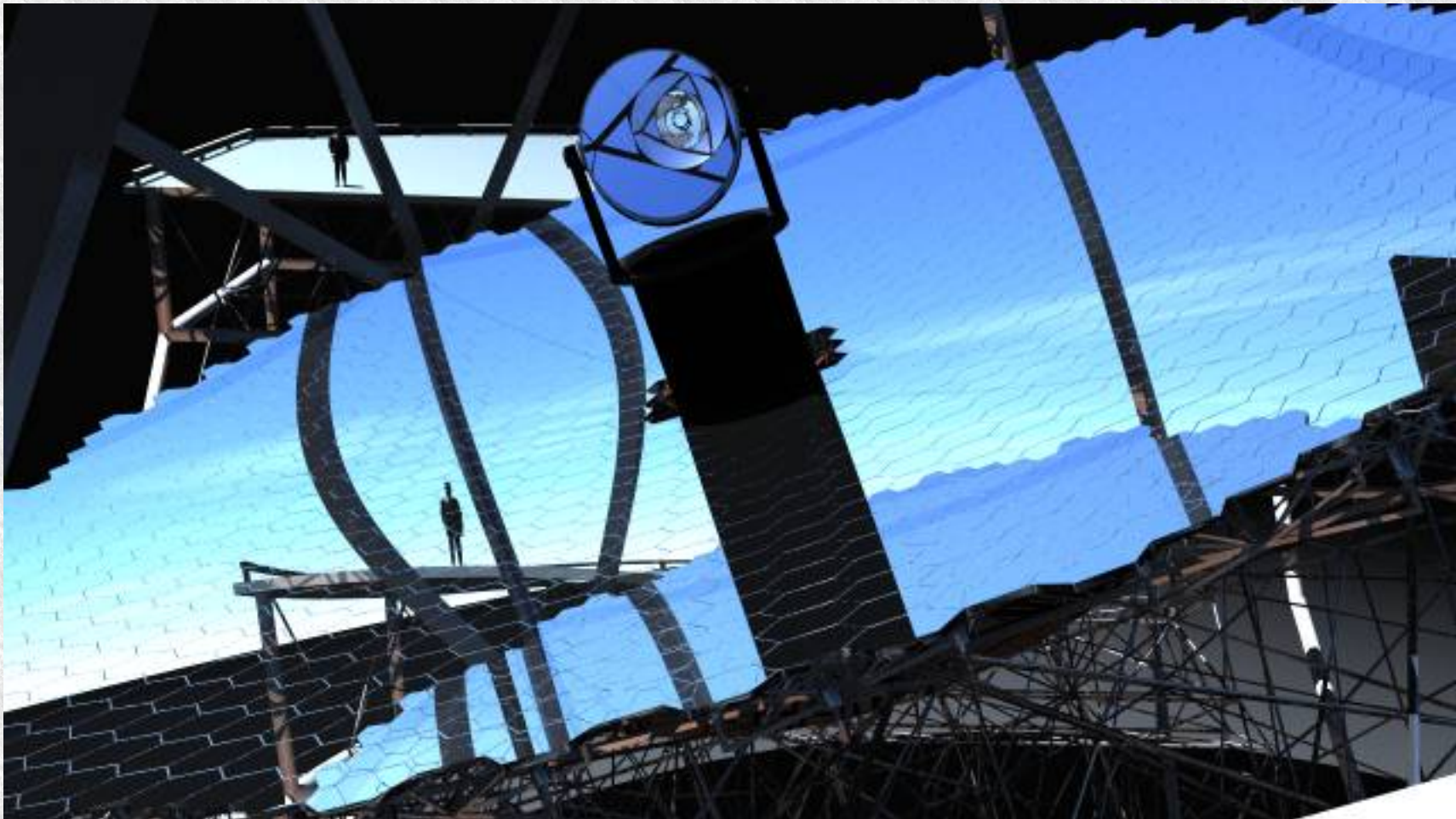
# Thirty Meter Telescope





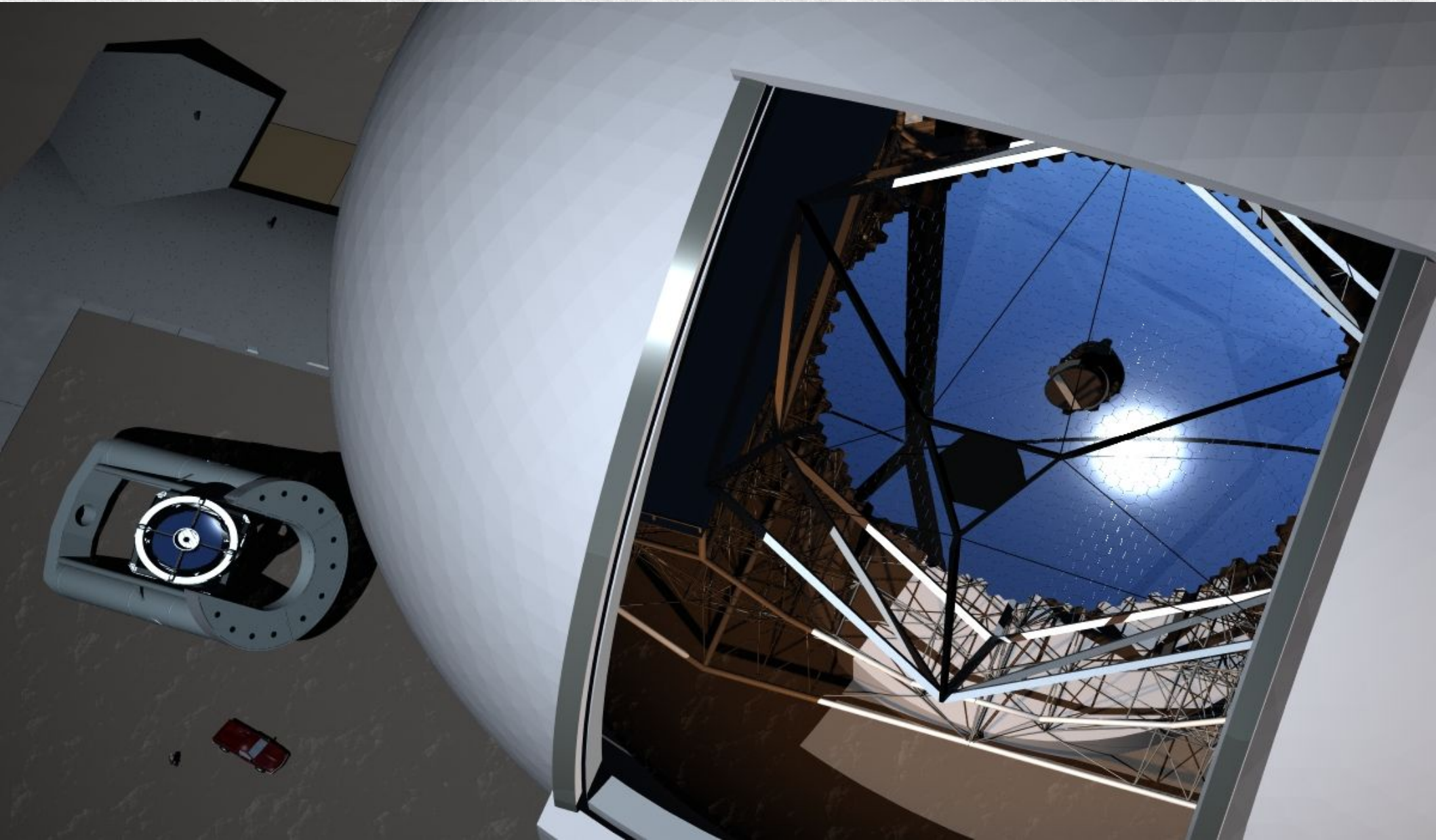


# Thirty Meter Telescope





# Thirty Meter Telescope

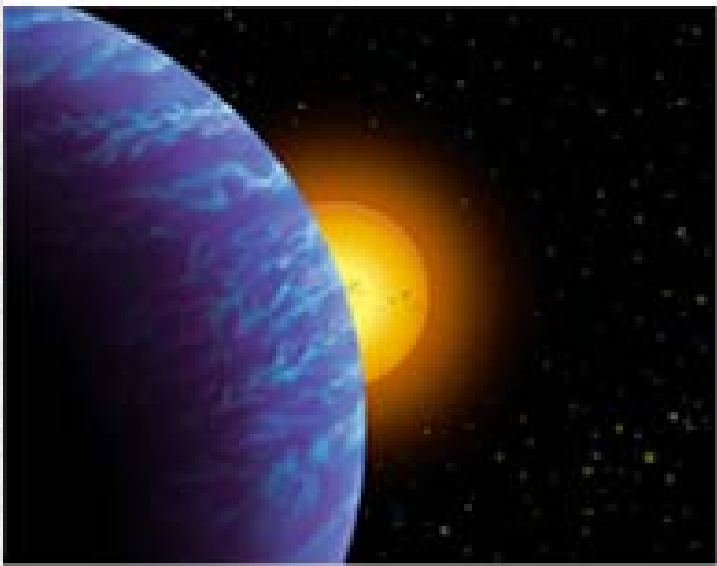




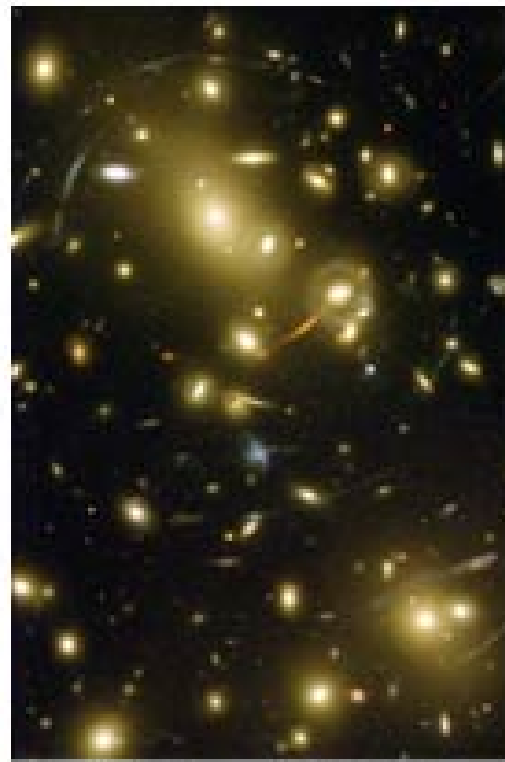
## GMT Partner Institutions:

- \* Carnegie Observatories
- \* Harvard University
- \* Massachusetts Institute of Technology
- \* Smithsonian Astrophysical Observatory
- \* Texas A&M University
- \* University of Arizona
- \* University of Michigan
- \* University of Texas at Austin

**A GMT...**



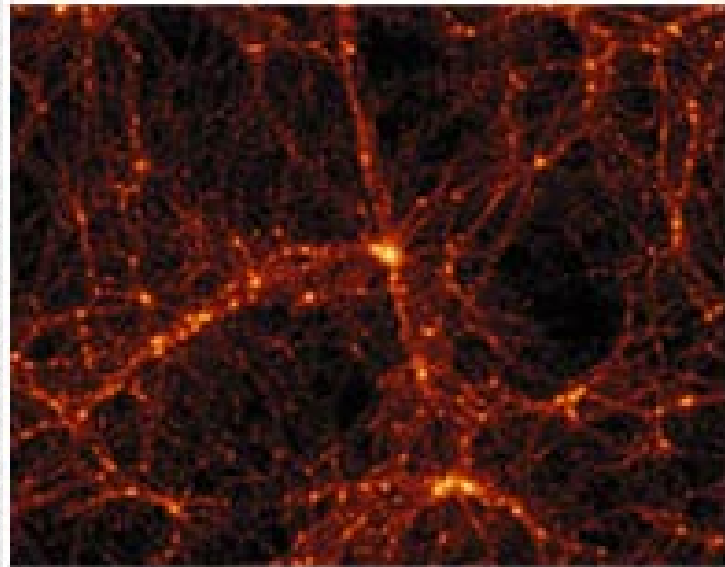
*Young Planets*



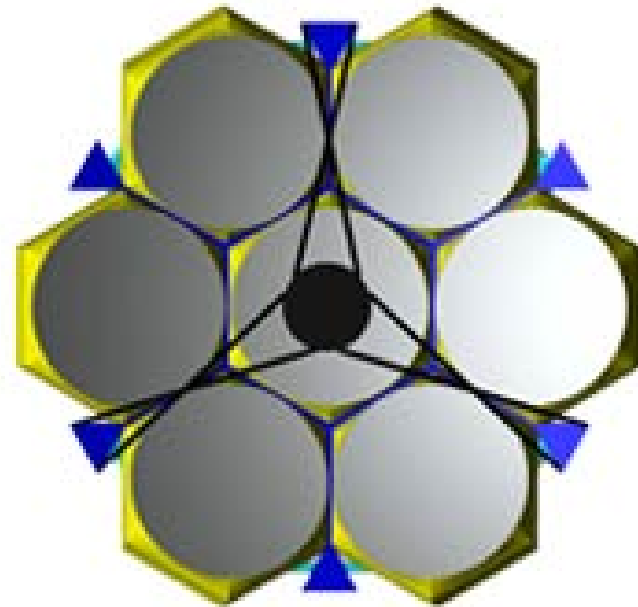
*Dark Matter & Dark Energy*



*Black Holes*

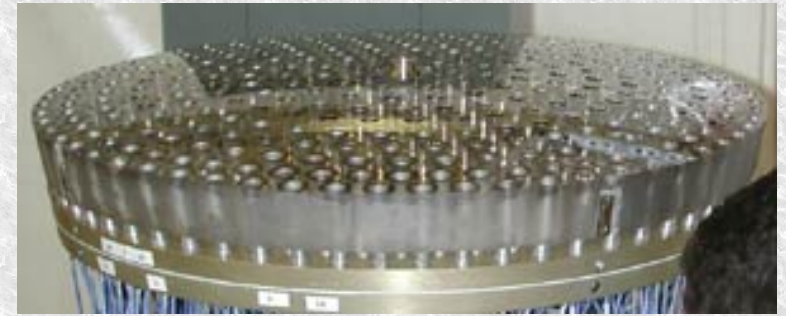


*The Early Universe*



*The Future of Discovery*

**GMT**

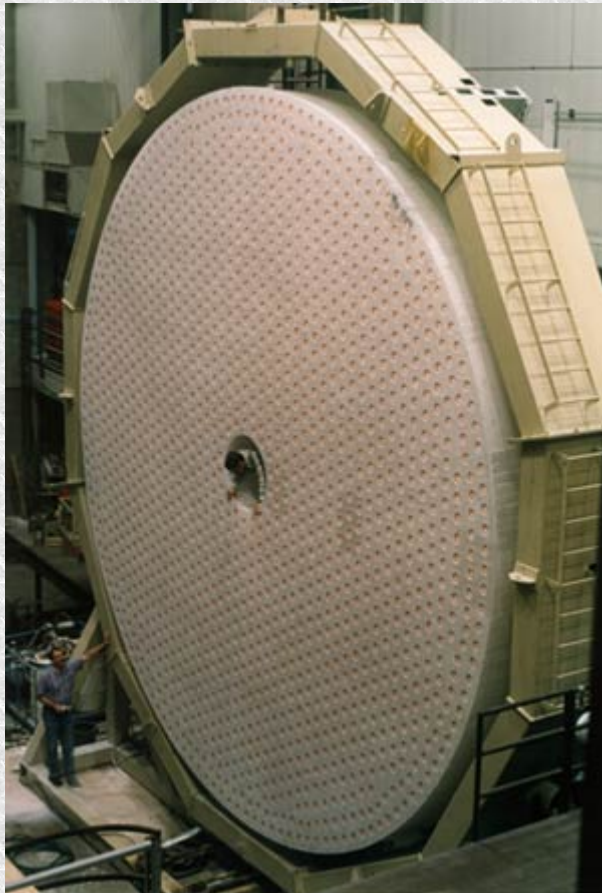


### **Primary Mirror:**

- \* 7 - 8.4m diameter segments
- \* 388 m<sup>2</sup> total collecting area
- \* 21.4m equivalent aperture
- \* 0.009" diffraction-limit at 1 $\mu$ m
- \* f/0.7 - 18m focal length

### **Adaptive Secondary Mirror:**

- \* f/10 Gregorian
- \* 7 adaptive membranes
- \* 2mm face plates
- \* 4700 actuators
- \* 30' GLAO correction
- \* 20" full AO correction



## **Telescope Mount:**

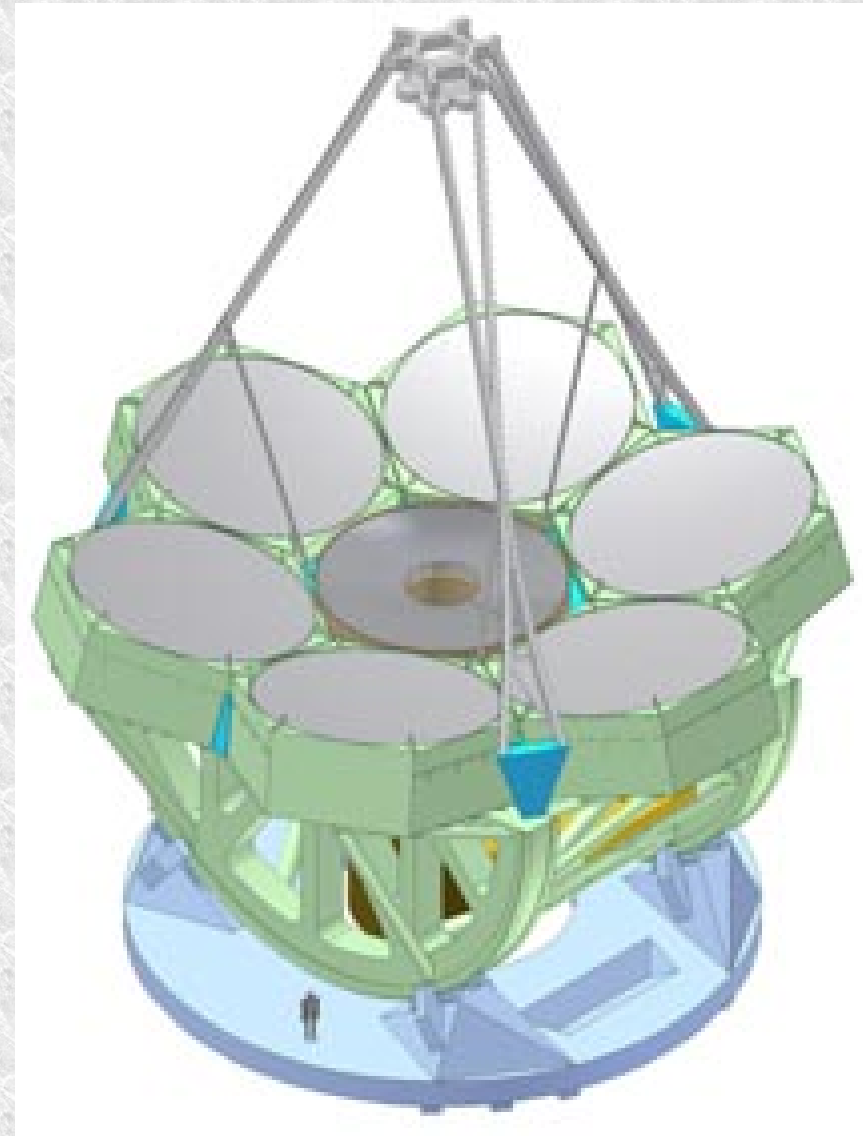
- \* Alt-Az design
- \* C-ring elevation structure
- \* Low mass, high stiffness
- \* Light weight, low wind area secondary support

## **Instruments:**

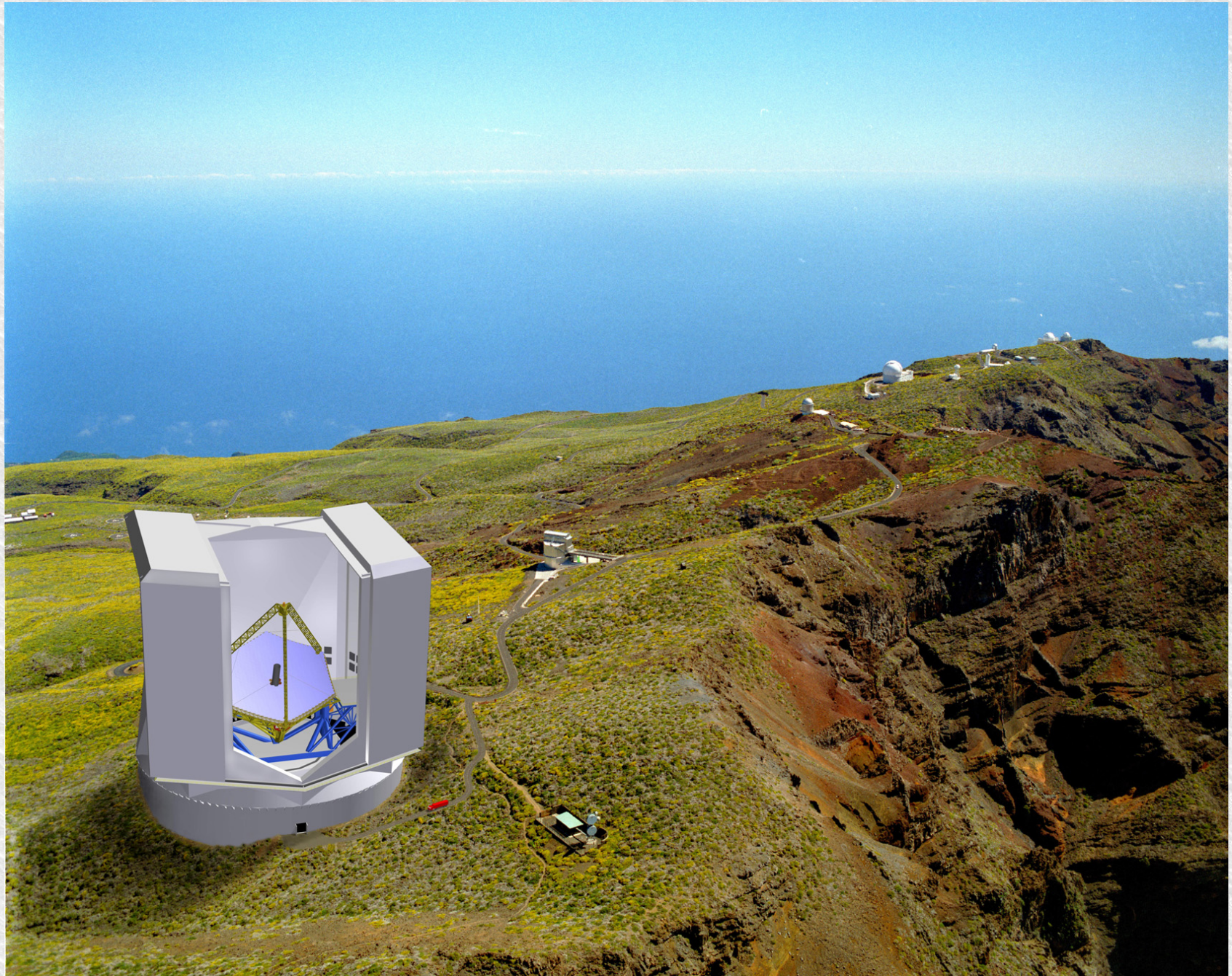
- \* Wide-field optical spectrometer
- \* AO-fed near-IR IFU spectrometer
- \* Mid-IR imager and spectrometer
- \* High dispersion spectrometer

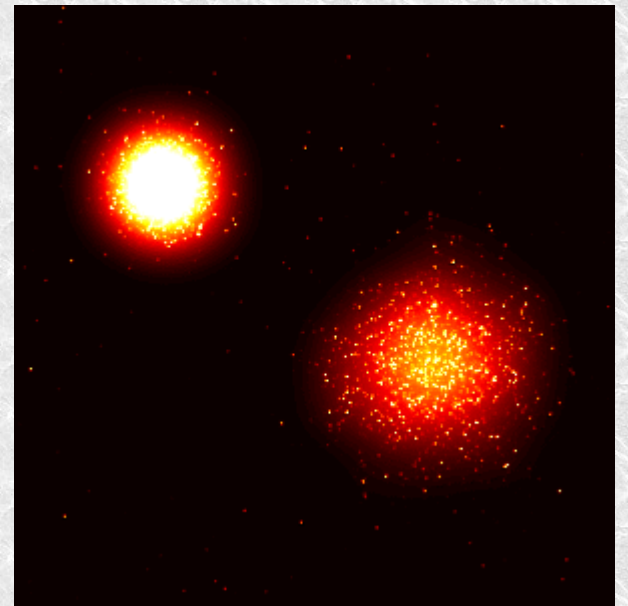
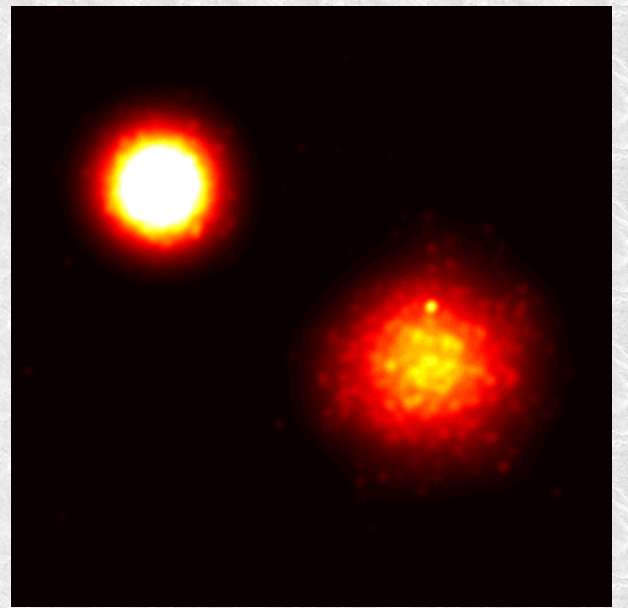
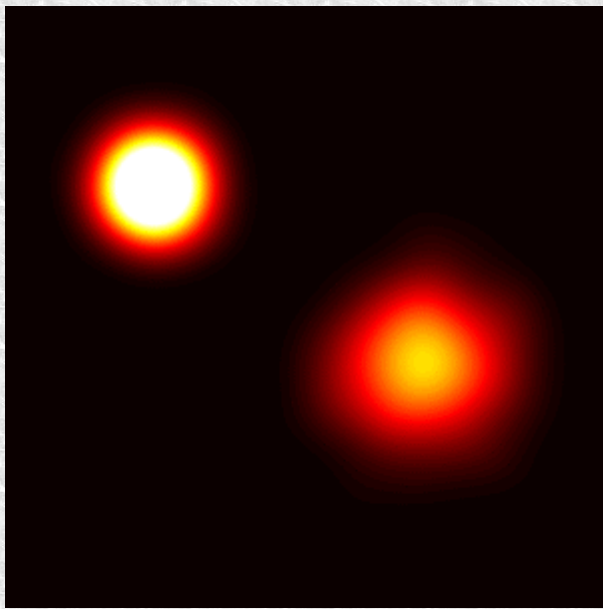
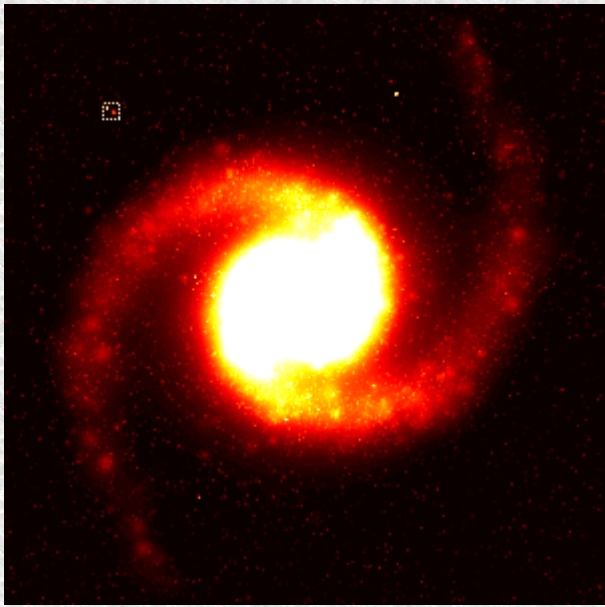
## **Site:**

- \* Central or Northern Chile
- \* Dark skies
- \* Optimum image quality



# Euro50





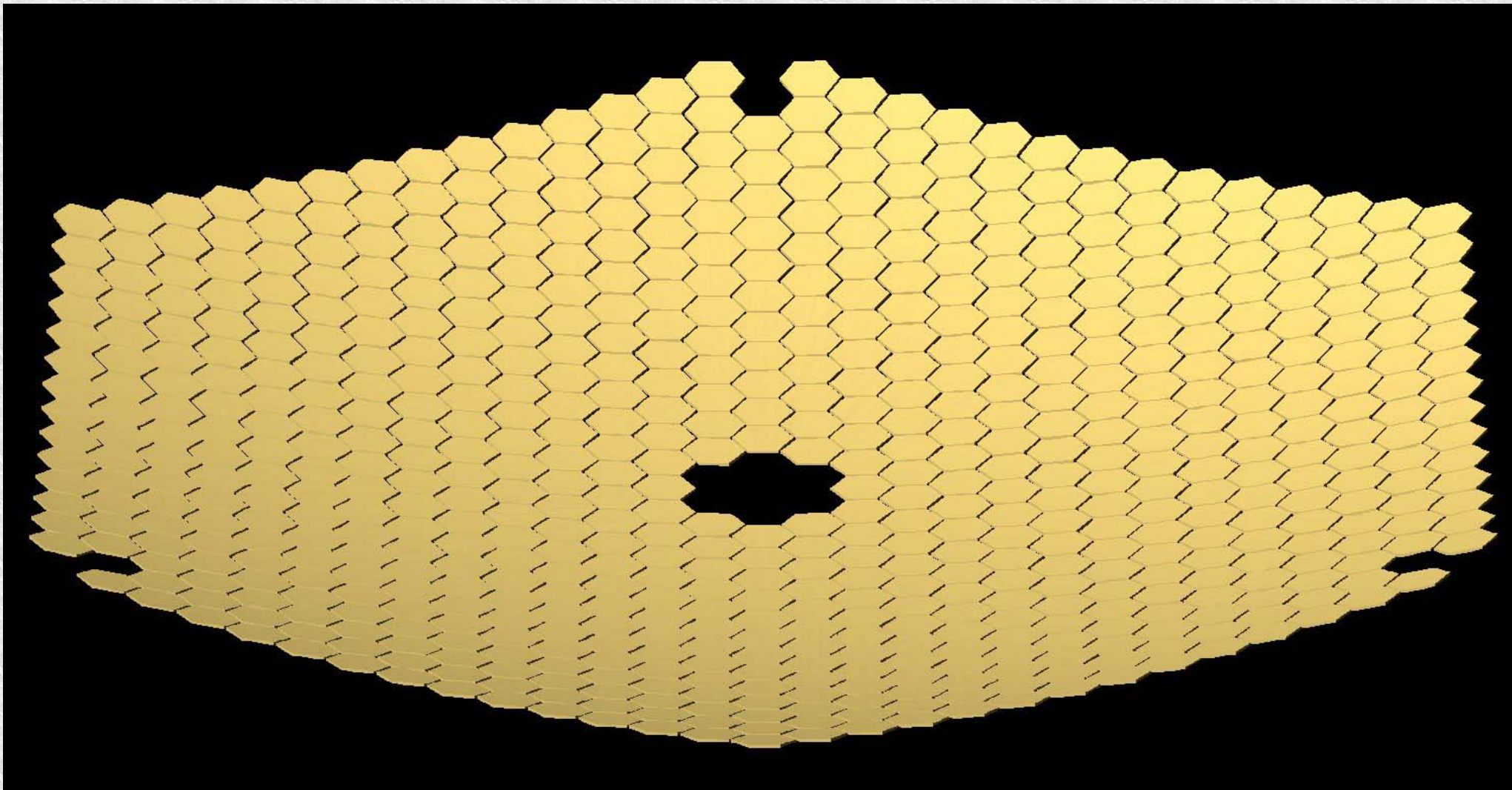


Equivalent primary mirror diameter m 50  
Observing range Azimuth deg 540  
Observing range Altitude deg 20-91  
Slewing speed deg/s 3  
Resolution with AO, K-band arcsec Strehl >0.4  
Image quality without AO CIR 0.8 at 0.4" FWHM seeing & 1' field  
Wavelength range microns 0.35-20 (optionally 28)  
Wavelength range AO Optimized for K-band but operable down to 1 micron  
Limiting magnitude, K-band, AO 34.4  
Limiting magnitude, visible, future AO 37.7  
Limiting magnitude, visible, seeing limited 32.2

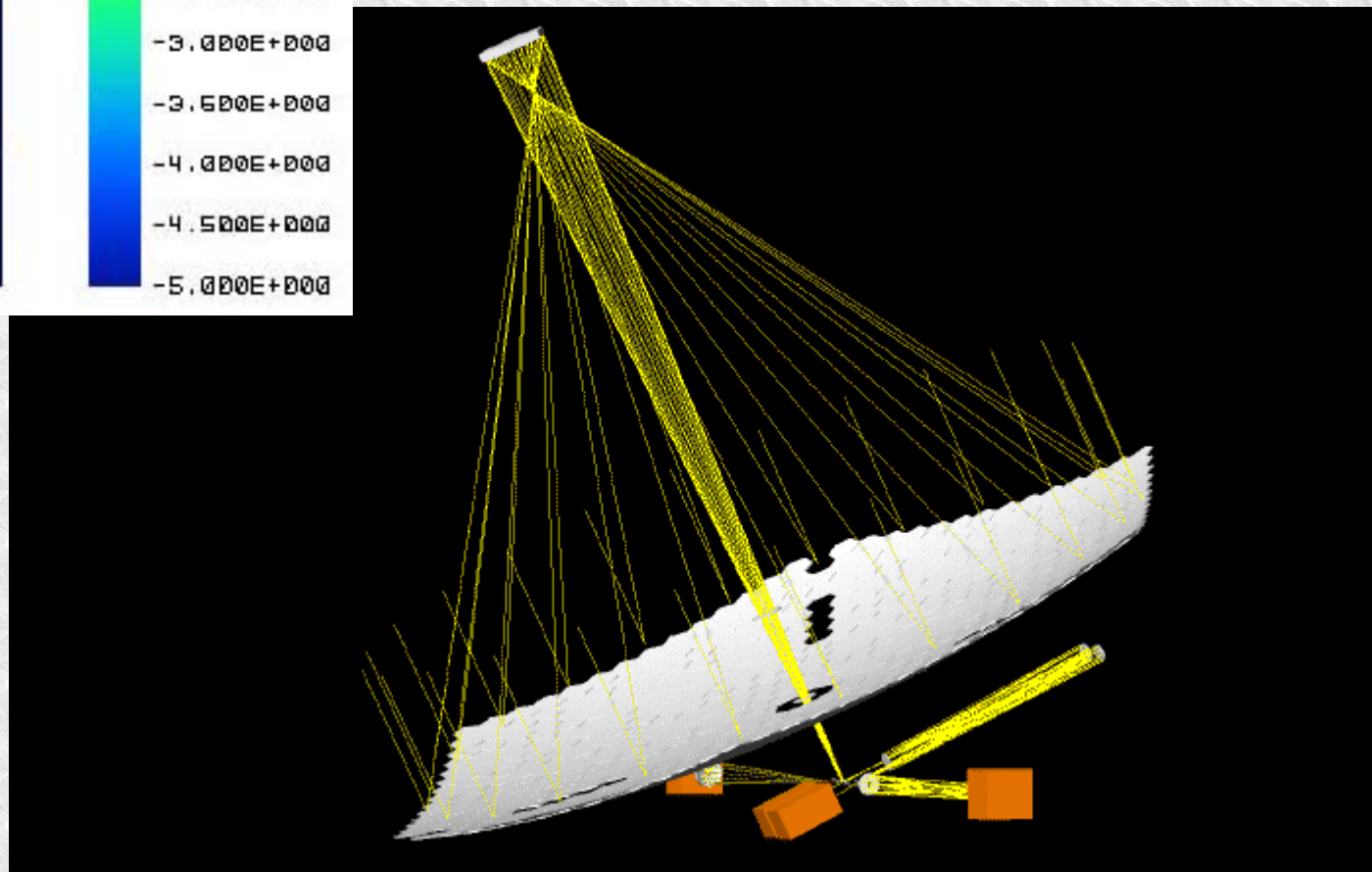
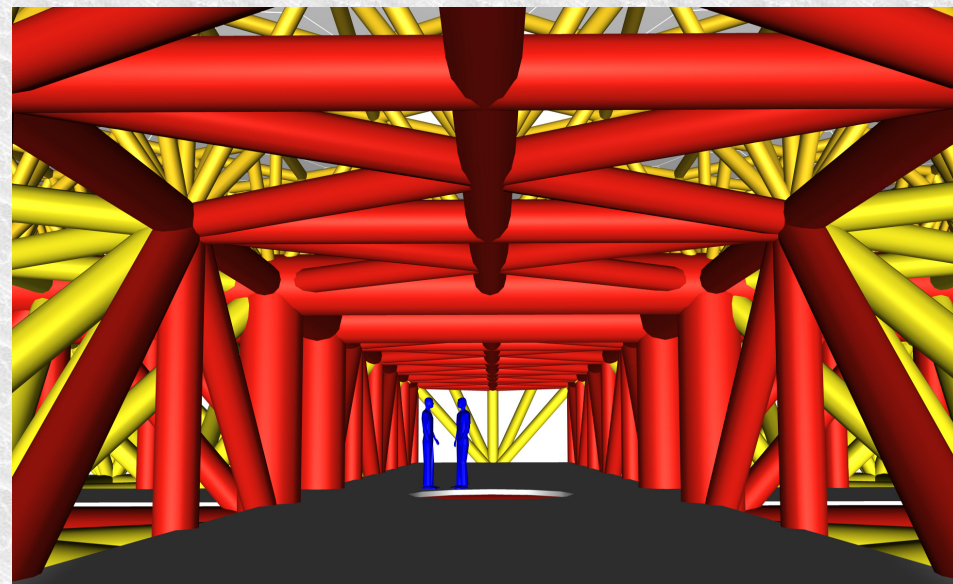
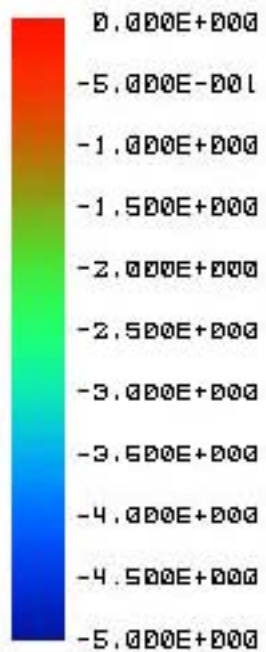
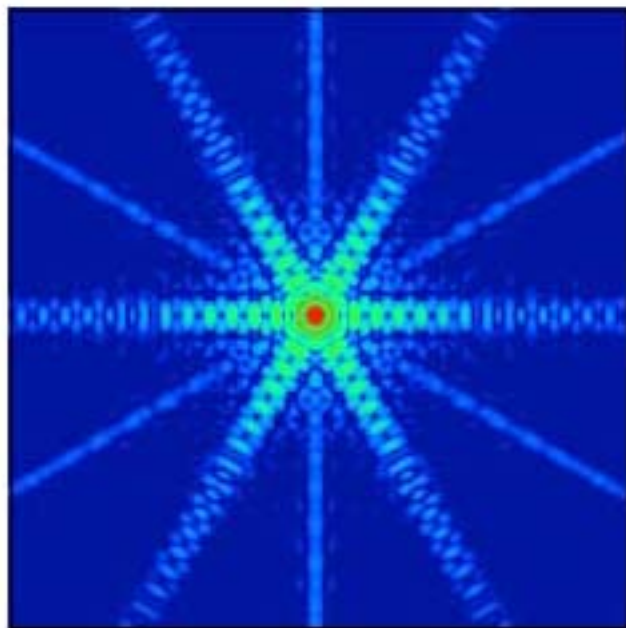
Telescope mass tons appr. 3500  
Telescope height m appr. 92  
Wind, observing, full performance m/s max. 12 mean, 10 m above ground  
Wind, observing, reduced performance m/s max. 18 mean, 10 m above ground  
Wind speed, survival m/s 55 mean, 10 m above ground  
Bearings hydrostatic  
Drive motors direct-drive torque motors

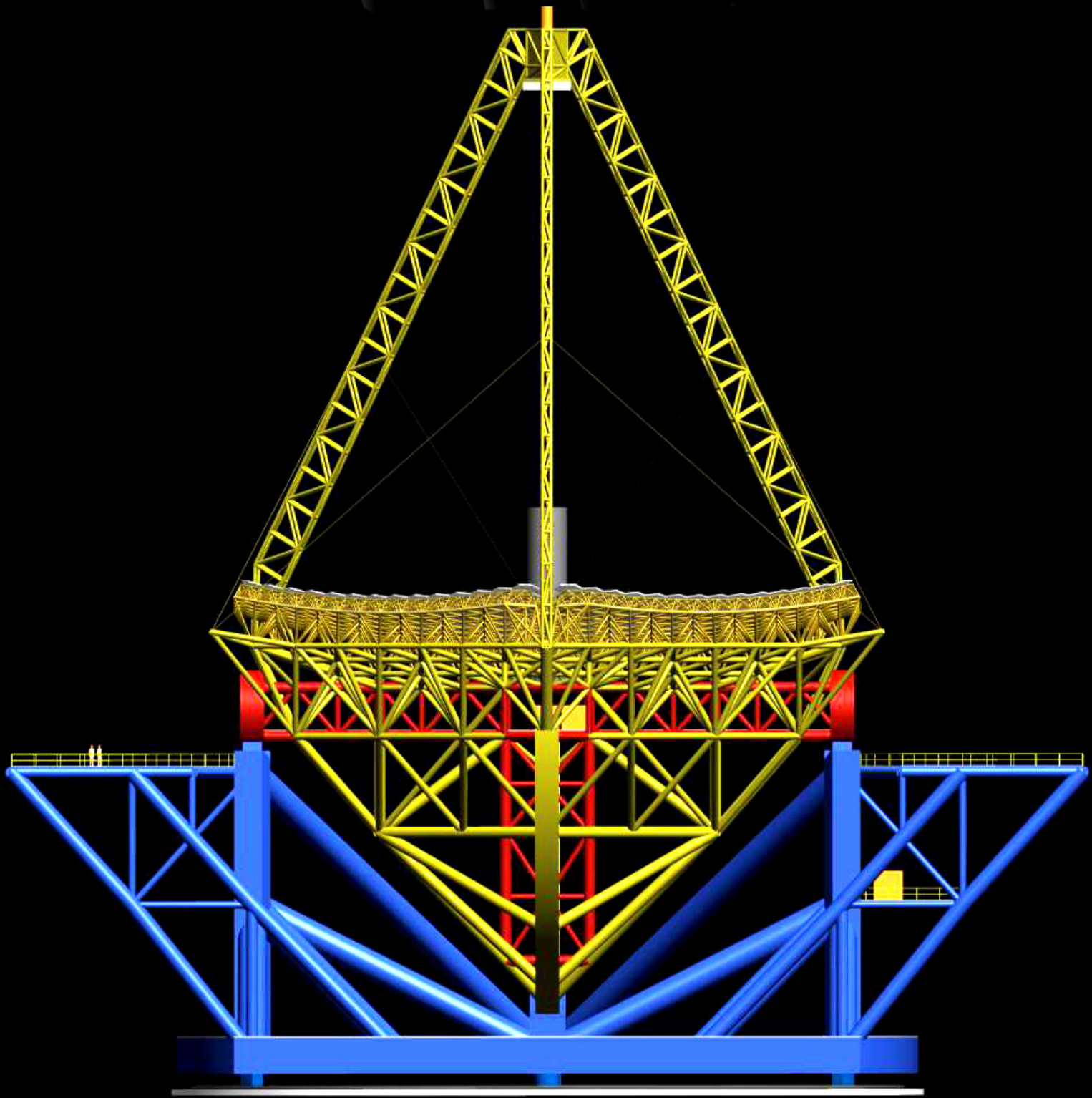
A főtükr:

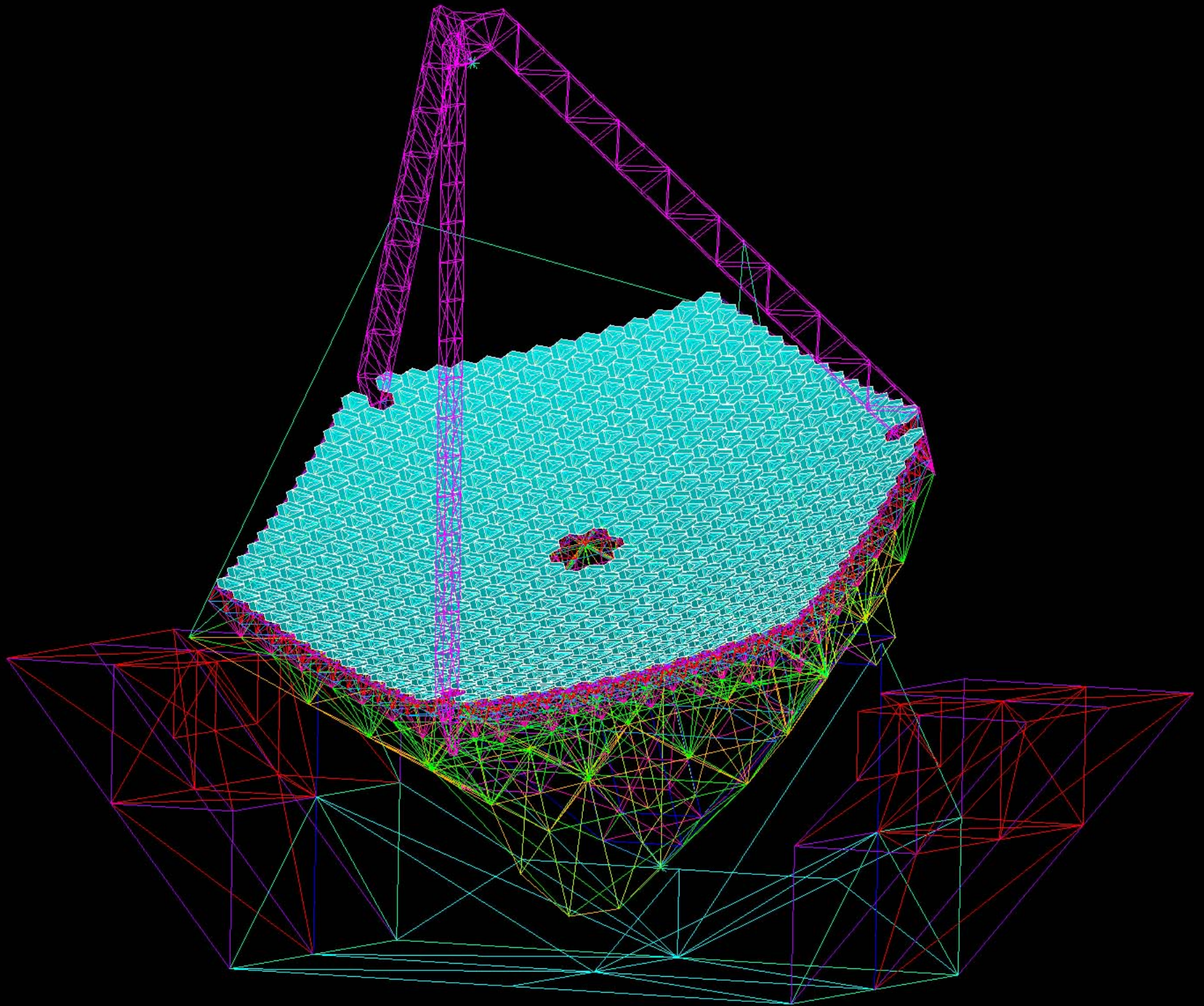
618 db, 2 méteres szegmens

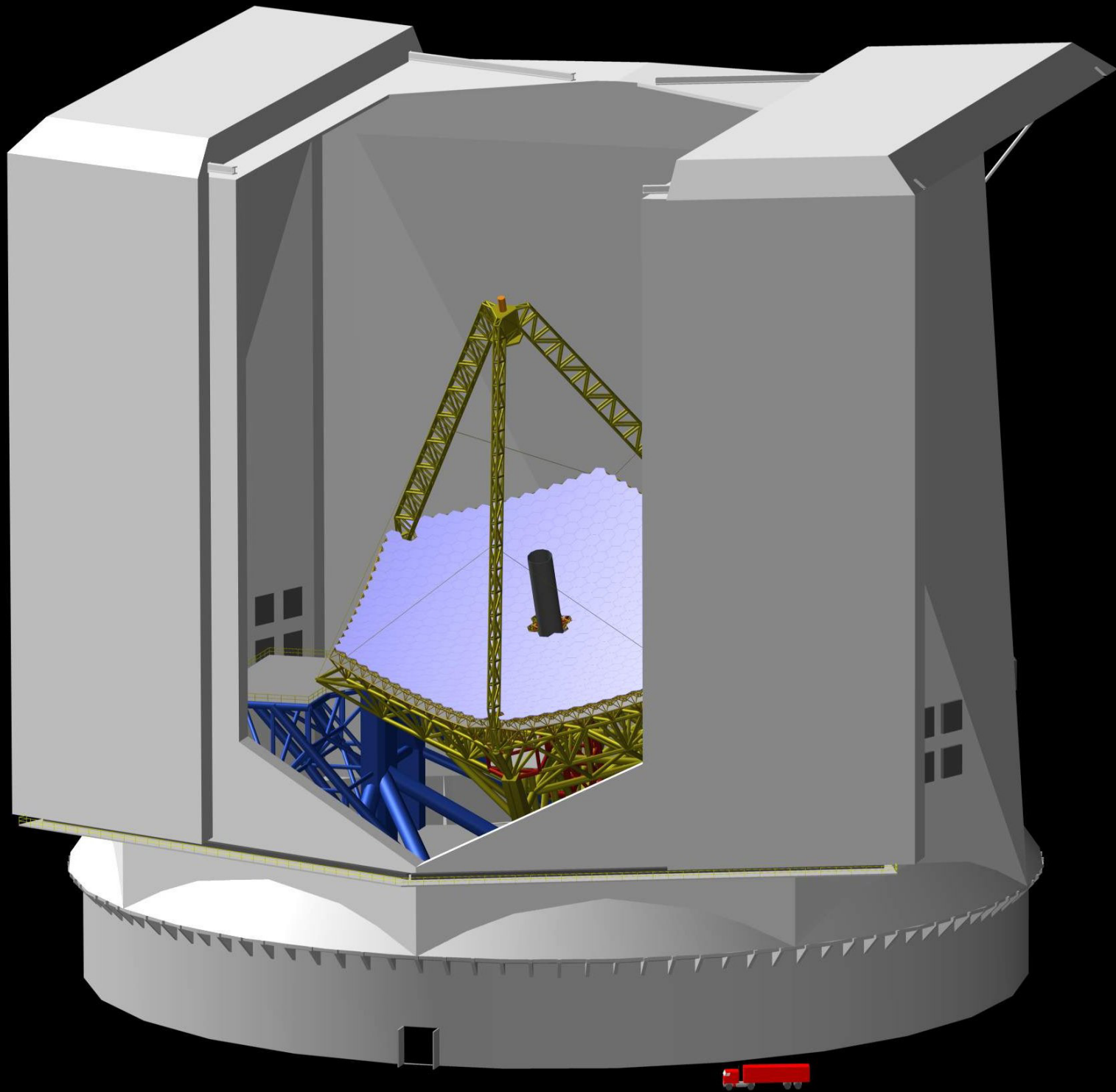


különleges diffrakciós kép:

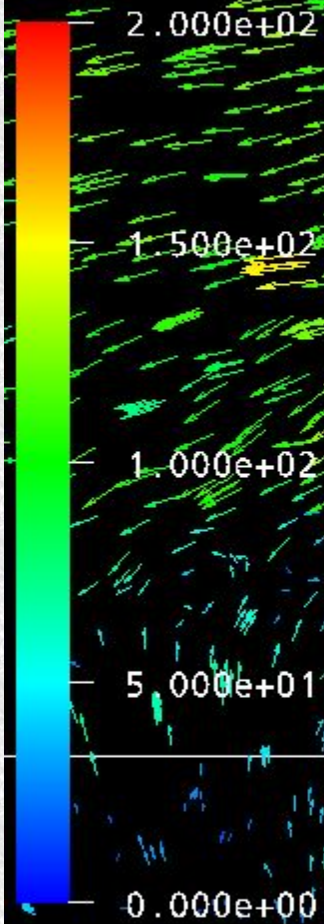




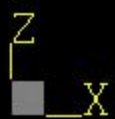




Velocity  
(Vector 1)



[m · s<sup>-1</sup>]



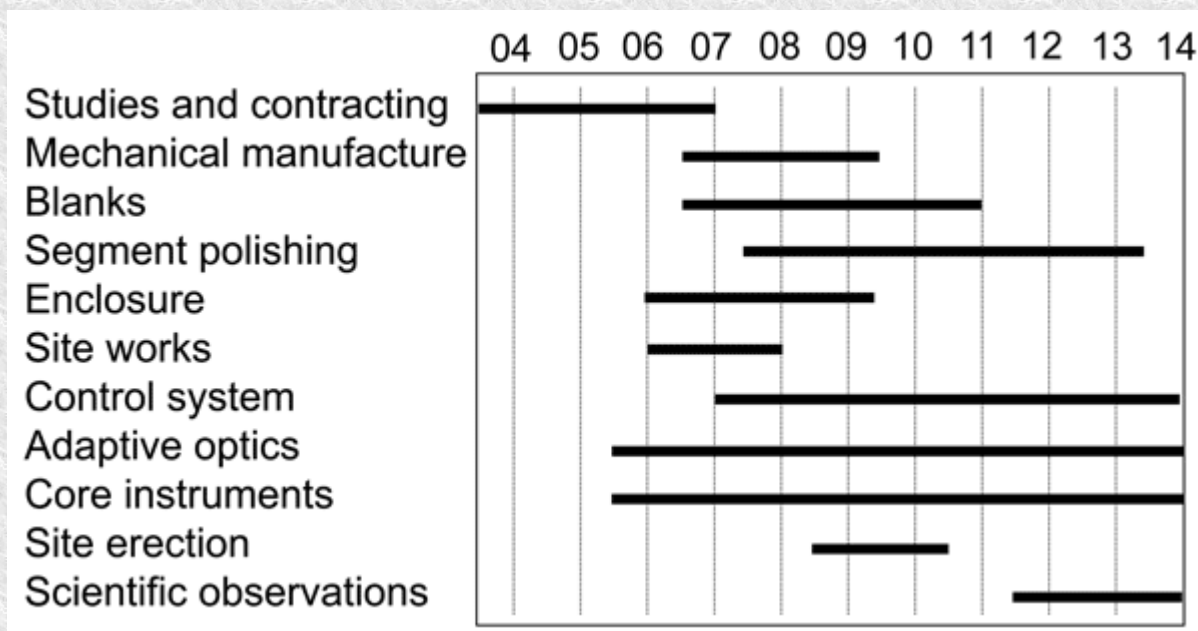




Primary and secondary mirrors	209
Mechanics	31
Control system	22
Adaptive optics & LGS?s	44
Enclosure	125
Site development	5
Two simple science instruments	28
Project group	50
Contingency, 15%	77
Total, M euro 2003	<b>594</b>

*A költségek...*

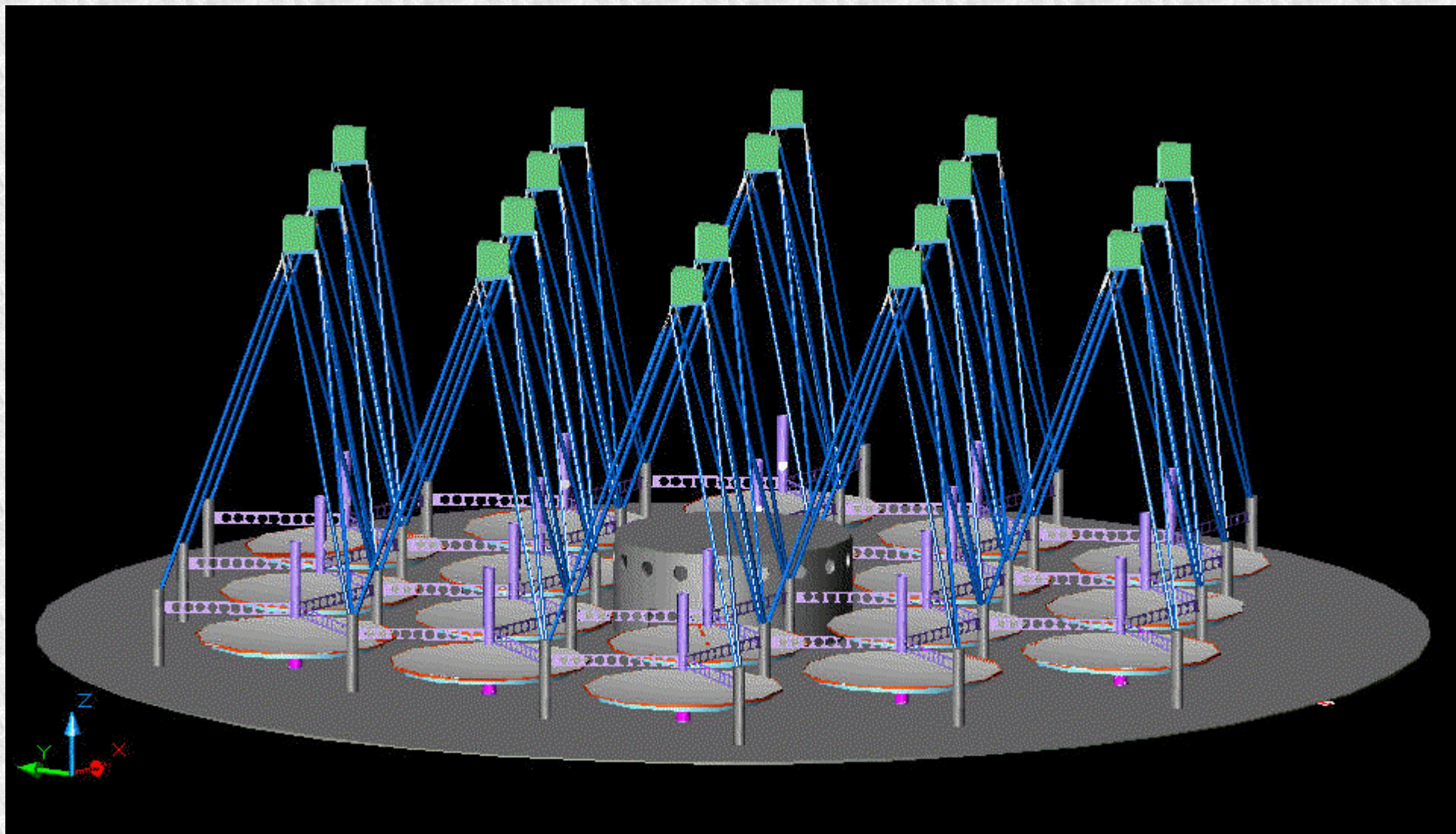
*és a tervezés ütemterve:*

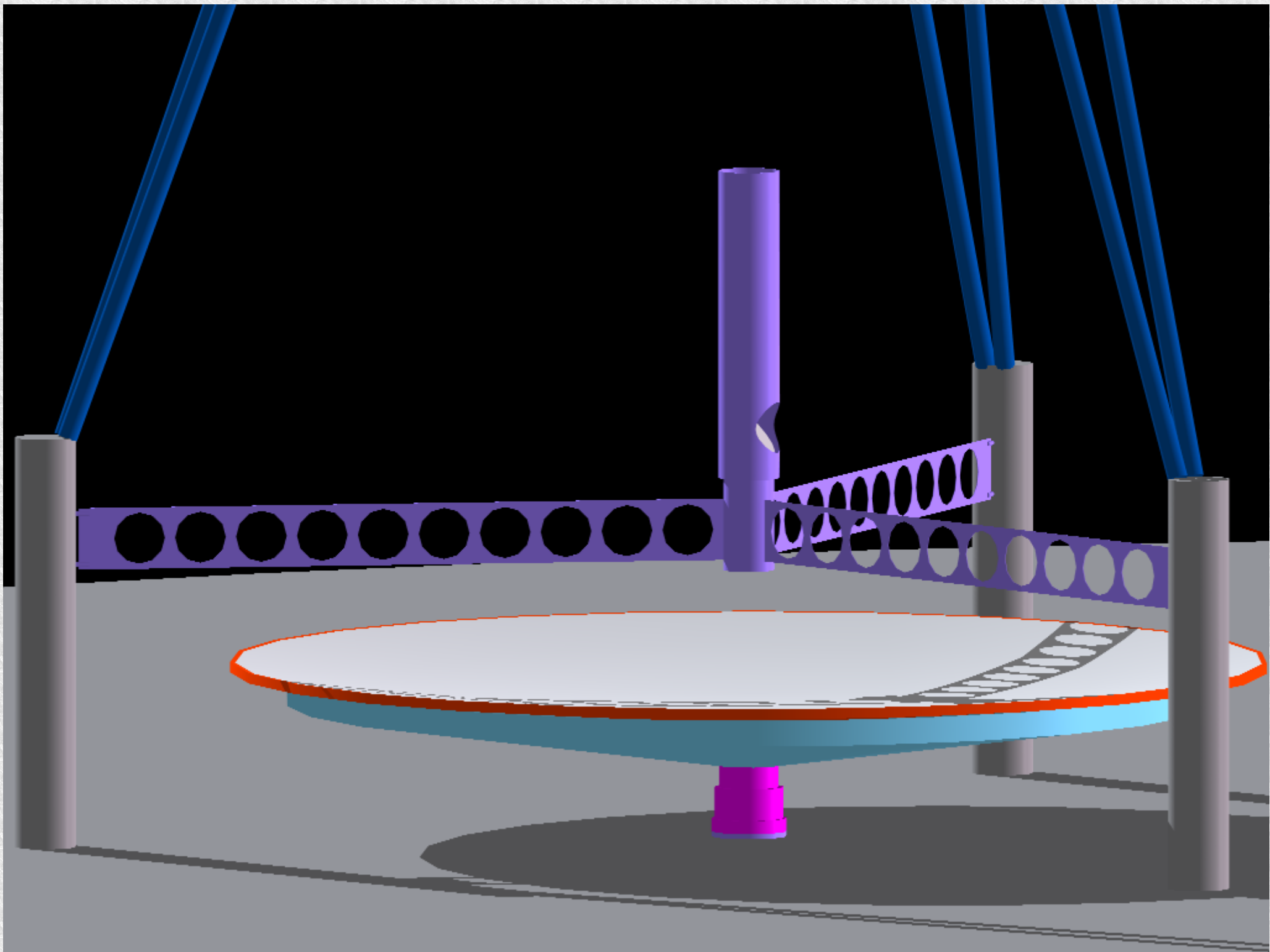




# Large-Aperture Mirror Array

18 db., 10 méteres folyékony tükör





futottak még kategória...

Giant Segmented Mirror Telescope

