SST mechanical designs: preliminary evaluations for D~C and S~C options

Rodolfo Canestrari, Giovanni Pareschi, Paolo Conconi

INAF-Astronomical Observatory of Brera

This work has been performed under INAF supervision in collaboration with:

Giancarlo Parodi, Francesco Martelli

BCV progetti s.r.l.

Raffaele Tomelleri, Pierfrancesco Rossettini

Tomelleri s.r.l.

TOMELLERI S.R.L.
Viale del Lavoro 12/a
37069 VILLAFRANCA (VR) ITALY
Phone: +39-045-6304744/6304812
Fax: +39-045-6303657
Web site: www.tomelleri.com

Presentation Outline

1. Davies-Cotton class Telescope
    a. General specifications
    b. Conceptual design
    c. FE Analyses:
        a. Gravity effects
        b. Wind effects
        c. Eigenfrequencies search
    d. Final remarks

2. Schwarzschild-Couder class Telescope
    a. General specifications
    b. Conceptual design
    c. FE Analyses:
        a. Model description
        b. Eigenfrequencies search
    d. Final remarks

All the proposed concepts have to be considered preliminary. Designs could be subjected to changes and revisions

	D-C 7m	S-C 4m	S-C 7m	3-MT 4m	3-MT 7m
Focal length	10500 mm	2000 mm	3500 mm	2000 mm	3500 mm
Lever arm	10500+det	2300 mm	4000 mm	600 mm	1050 mm
$\theta_{EE(90)}$	2x3°	2x2.5°	2x2.5°	2x5°	2x5°
Detector	Single-pixel 36 mm	Multi-pixel 7 mm	Single-pixel 12 mm	Multi-pixel 7 mm	Single-pixel 12 mm
PMT units	1200	75	1200	75	1200
1-vignetting	90% 1-refl	70% 2-refl	70% 2-refl	70% 3-refl	70% 3-refl
Total throughput	77%	51%	51%	43%	43%
Structure cost	10	1	4	1	4
Array (tel. number)	20	100	30	118	35
Mirror sags (1x1m) - M1 - M2 - M3	12 mm	25 mm 230 mm	14 mm 130 mm	40 mm 92 mm 160/80 mm	46 mm 106 mm 184/92 mm

Davies-Cotton Telescope

Main general specifications

Ø7m class telescope

Single mirror f=10.5m

Mirror curvature radius: 21m

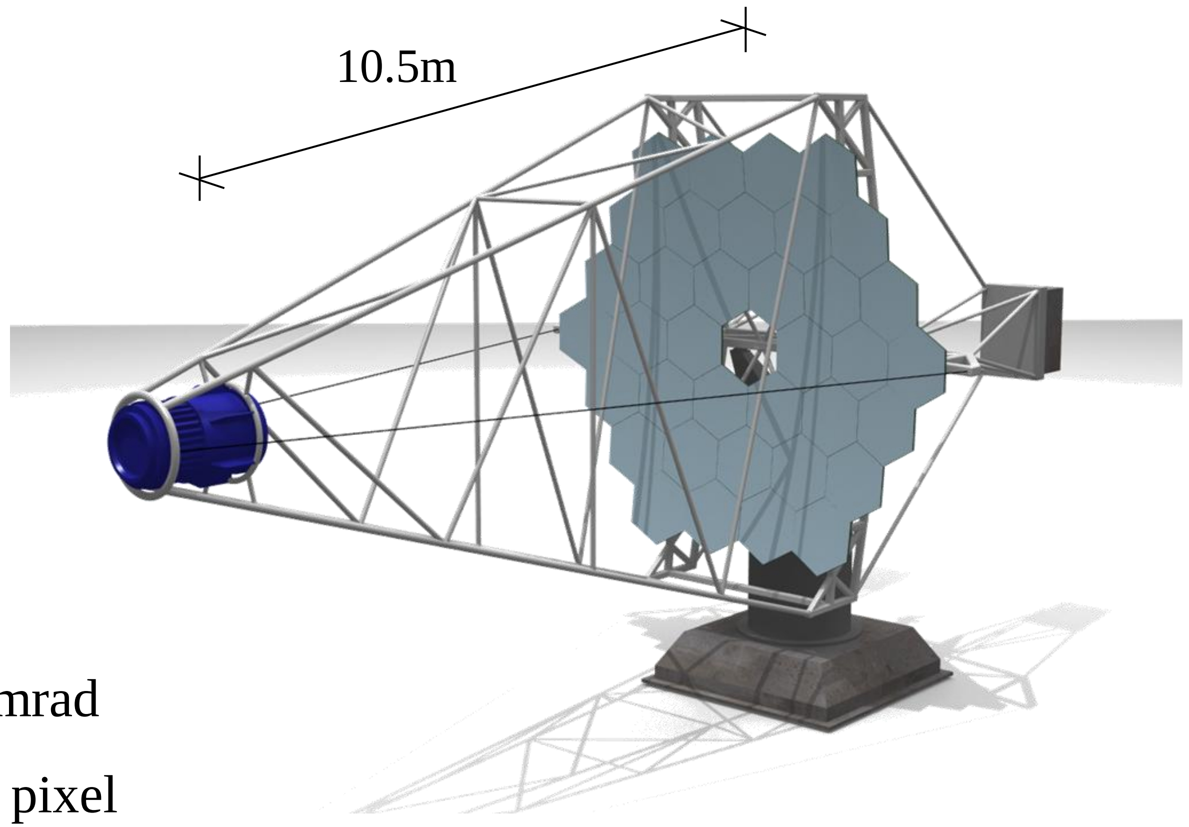
Camera mass: 1.6tons

Field of view: 8°

Operating Wind: 50Km/h

Dish contribution to PSF* < 1mrad

Camera displacement 0.5PMT pixel



**PSF being computed as the RMS of ray deviation at focal plane*

Davies-Cotton Telescope

Conceptual Design

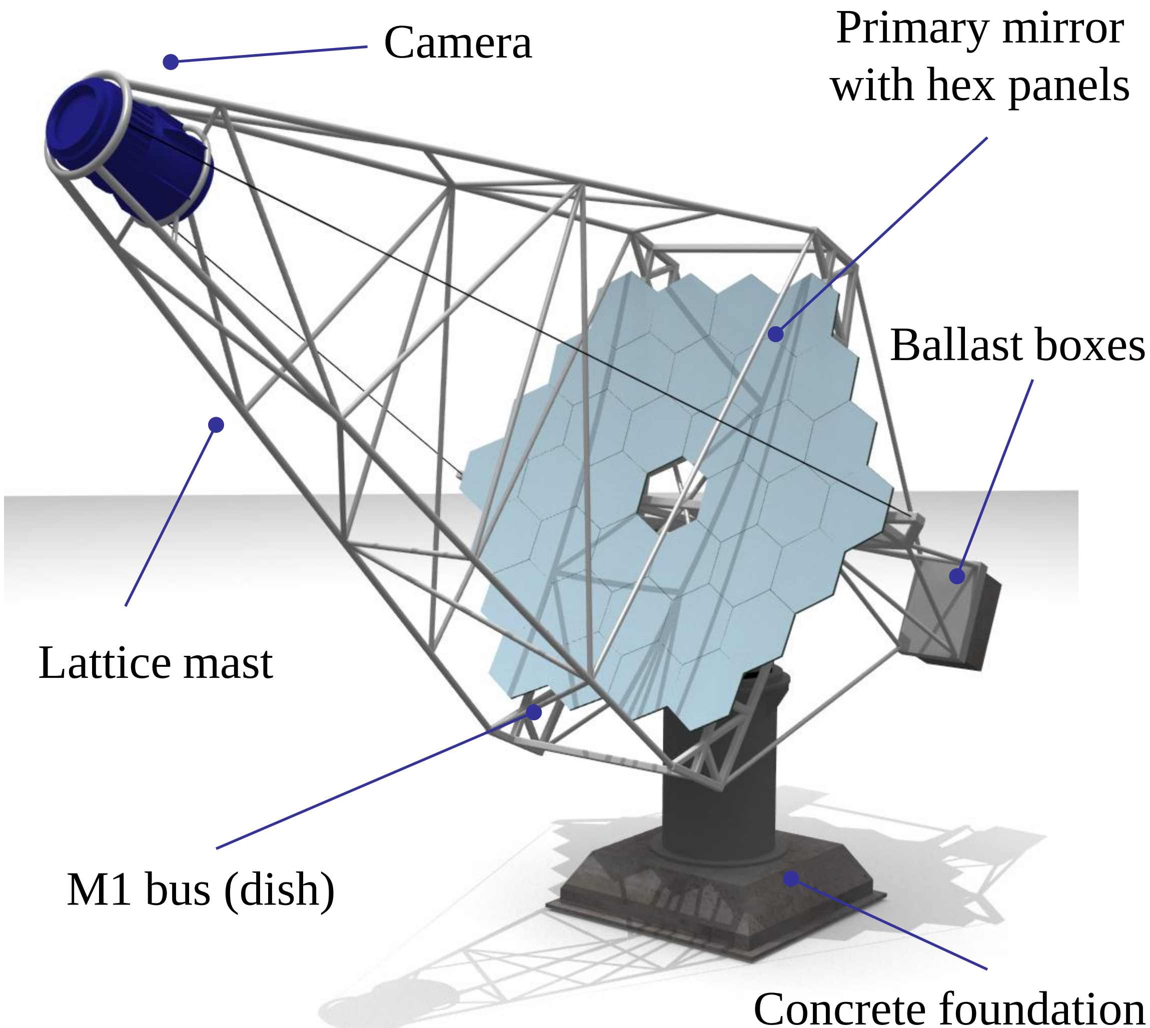
Main features

Alt-Azimuthal mounting.

Axial and lateral loads transmitted to the concrete foundations through pintle bearing.

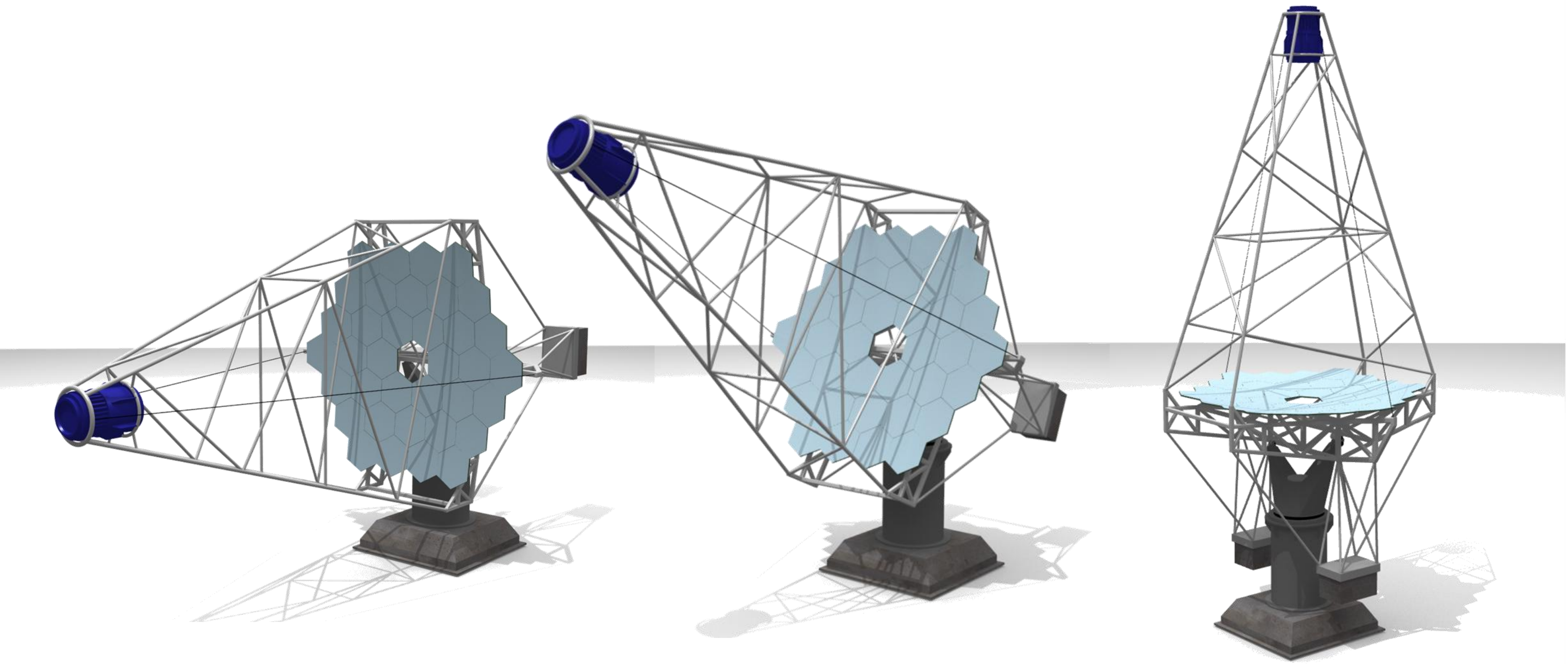
Elevation lattice mast structure with tendons interfaced with steel azimuth fork

Ballast boxes envisaged as counterweights to grant correct balancing around elevation axis.



Davies-Cotton Telescope

Conceptual Design

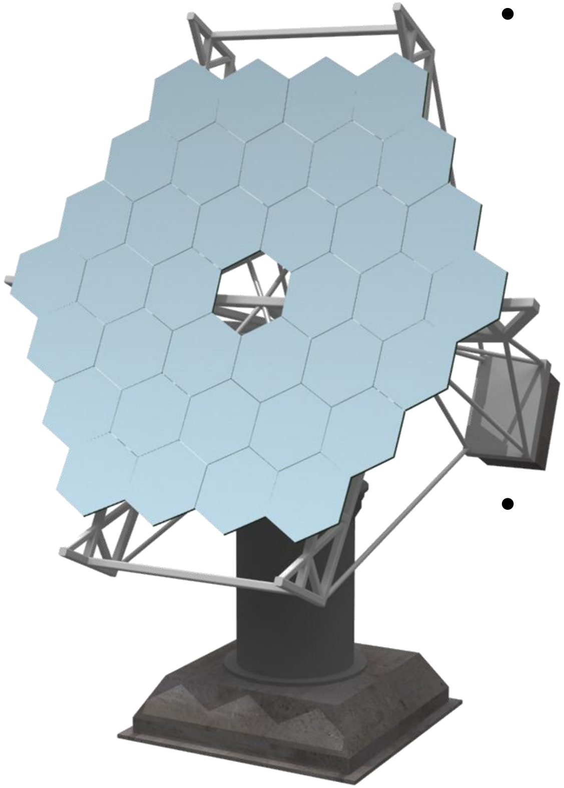


Elevation 0° **Elevation 30°** **Elevation 90°**

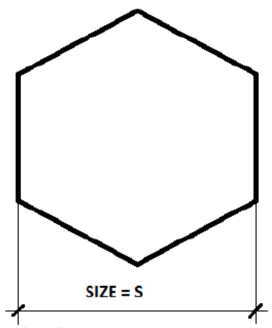
Davies-Cotton Telescope

Conceptual Design

Primary Mirror

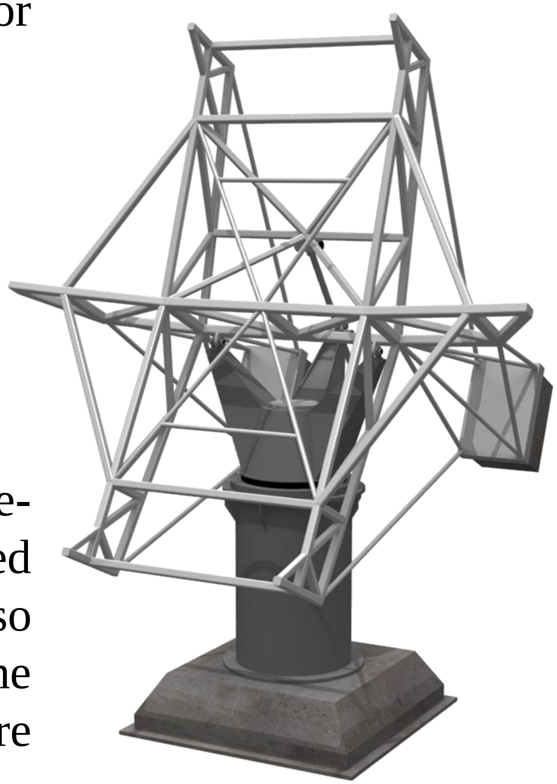


- 36 Hexagonal shaped sandwich mirror panels



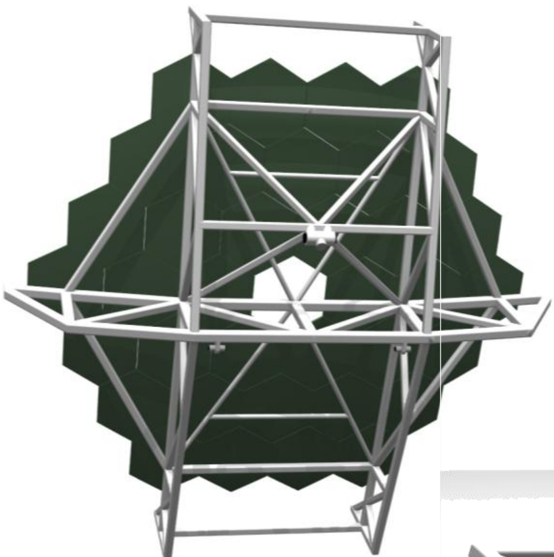
S ≈ 1.2m

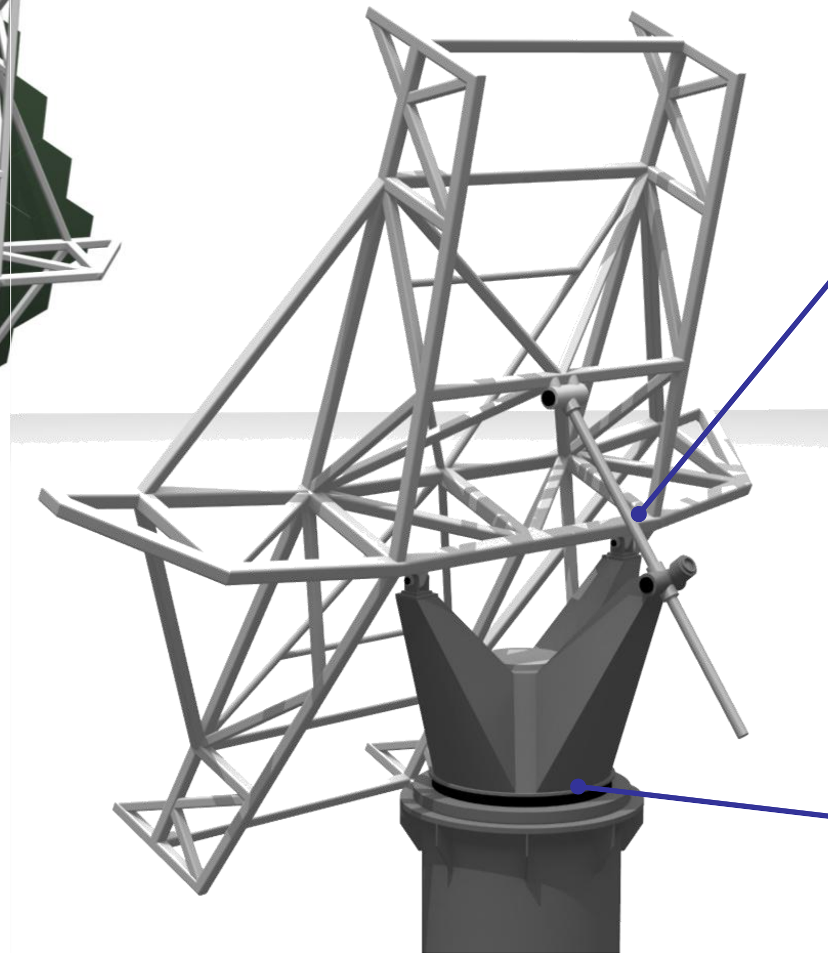
(TBC)



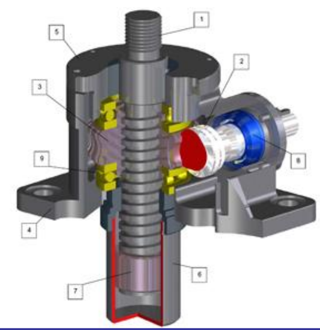
- Positioning of each sector active-controlled through 2 actuators + 1 fixed point mounted on a "tripod" also accommodating the interface with the structure or an intermediate structure layer accommodating panel supports
- Lattice supporting dish

Conceptual Design



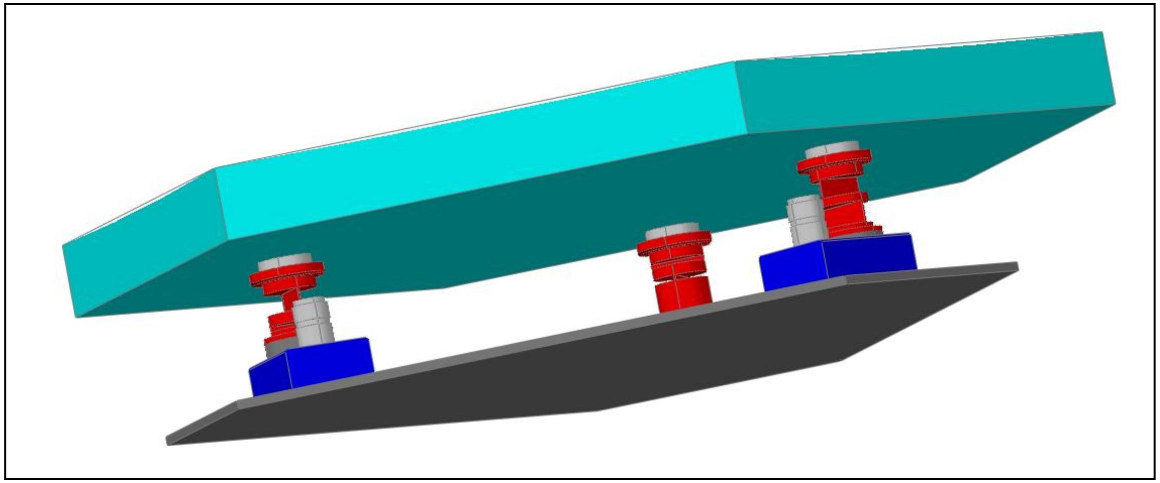


- Elevation motion performed through a worm drive



- Azimuthal positioning controlled through gears and drives on the pintle bearing (accessible from foundation room).

Mirror actuators



2 actuators + 1 fixed point for tip/tilt movement.

<u>Fixed point:</u>

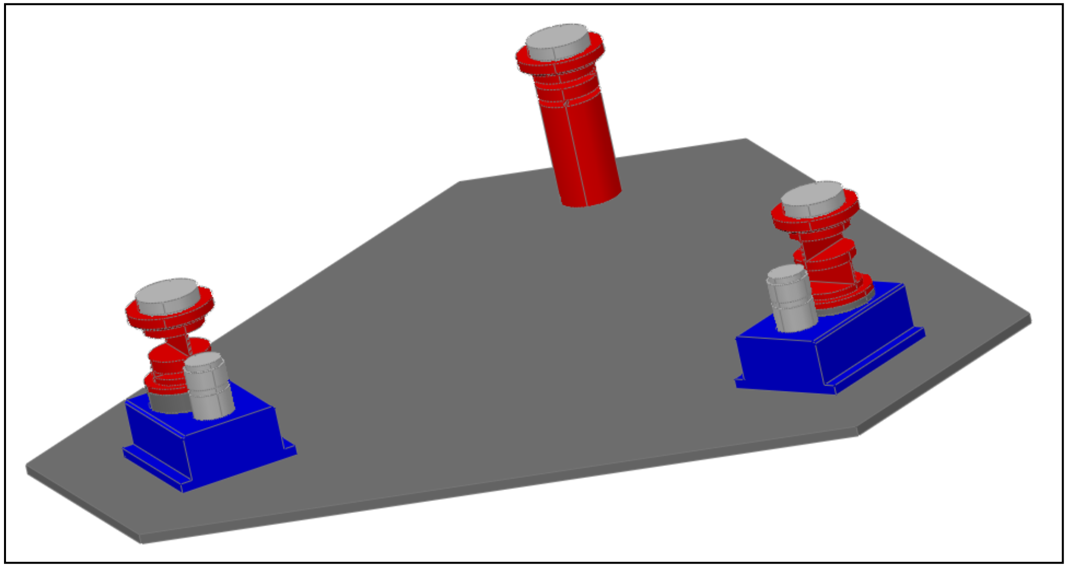
- orthogonal foils to give flexibility along *x* and *y* (for tilt) and rigidity along *z*

<u>Actuators:</u>

- linear actuator with gearmotor;

- elongated orthogonal foils block mirror translation without inserting additional loads;

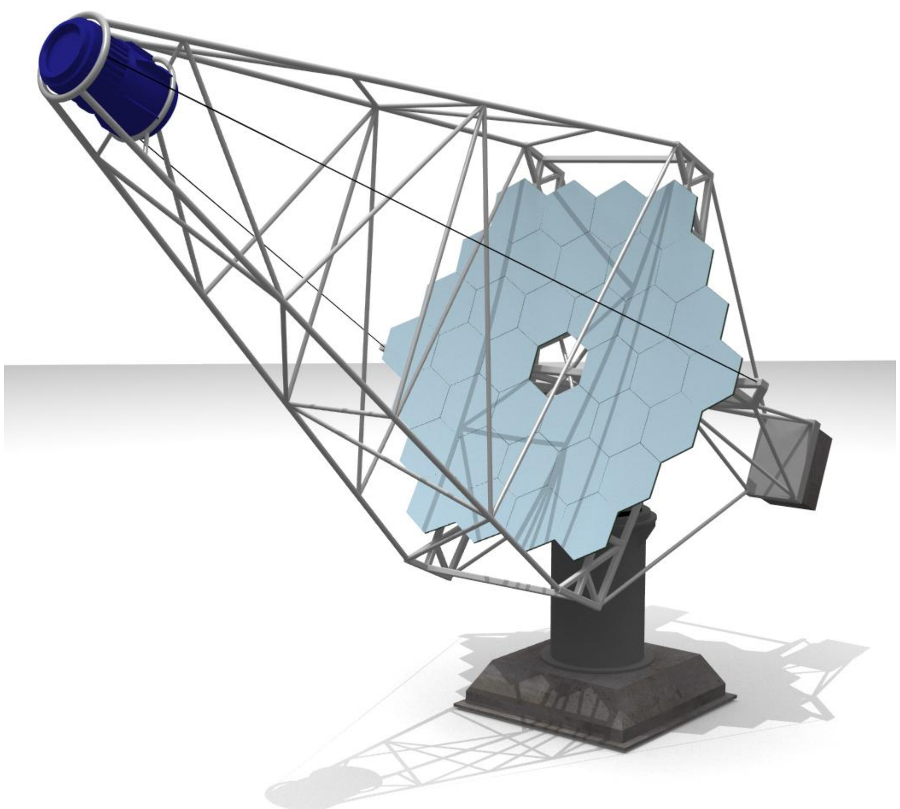
- relative positioning (no encoder) to save money

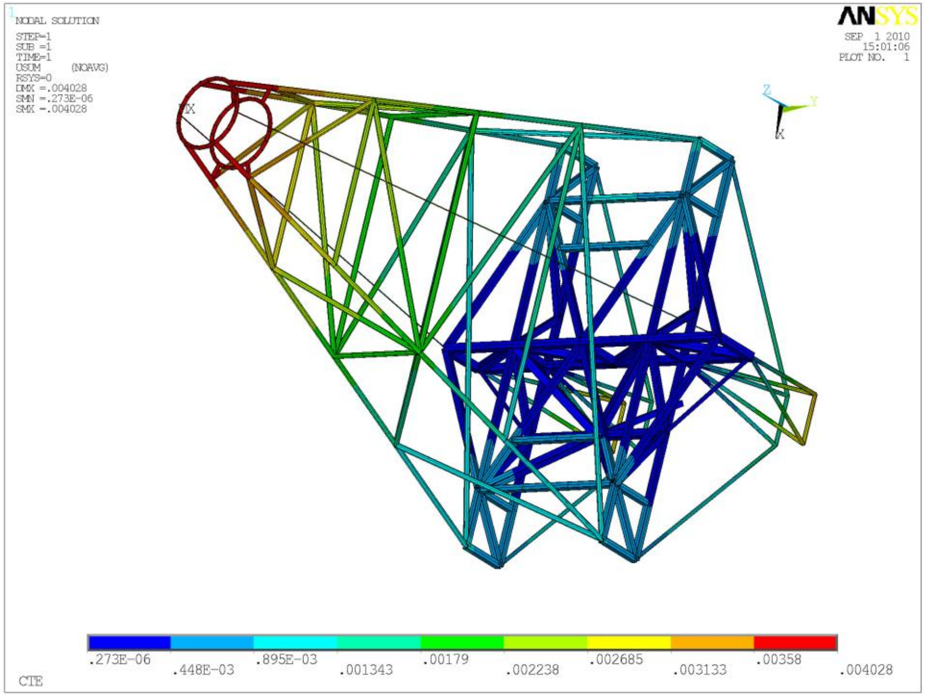


Davies-Cotton Telescope

FE Analyses: Gravity effects

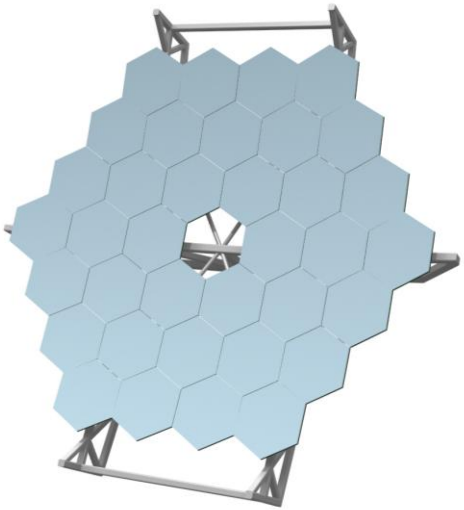
Telescope FEM implemented; Analyses performed in order to evaluate deflections related to gravity effects

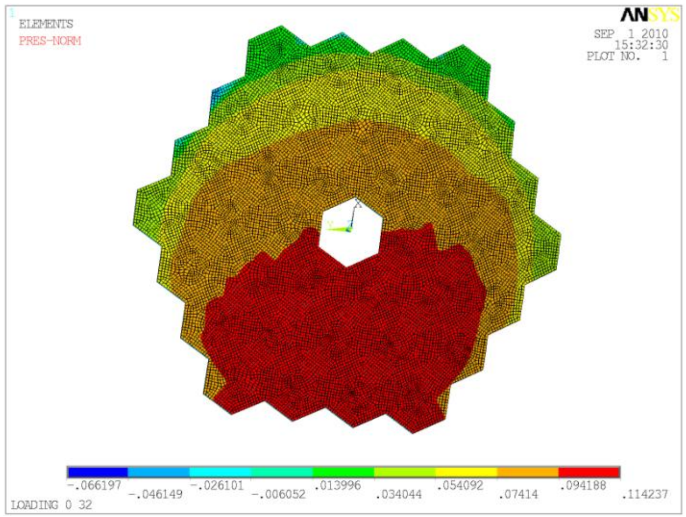


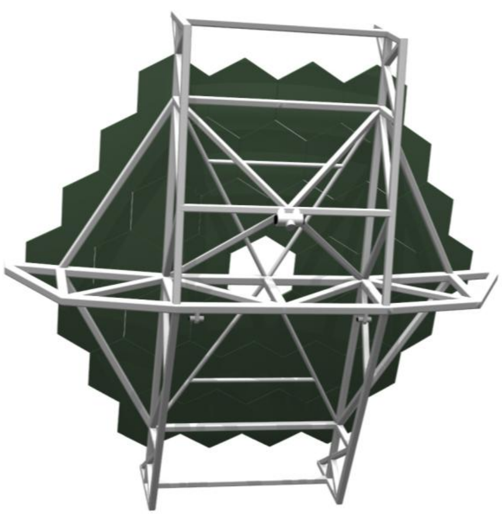


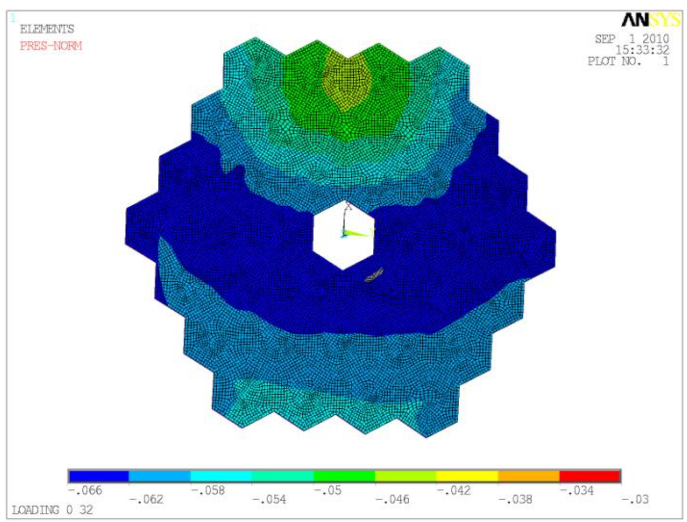
Davies-Cotton Telescope

FE Analyses: Wind effects







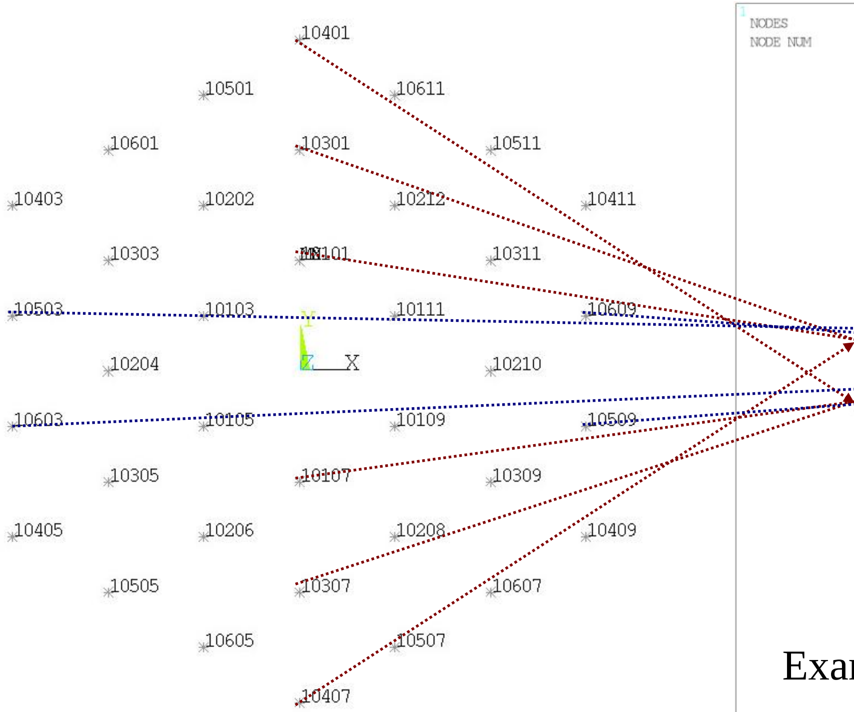


1. Mirror panels FEM implemented
2. Entity of wind pressure on the mirror evaluated through proper analyses
3. Forces and moments resulting from integration of pressures onto single sectors applied to whole telescope FEM
4. Deflections related to wind effects onto the panels and mast predicted

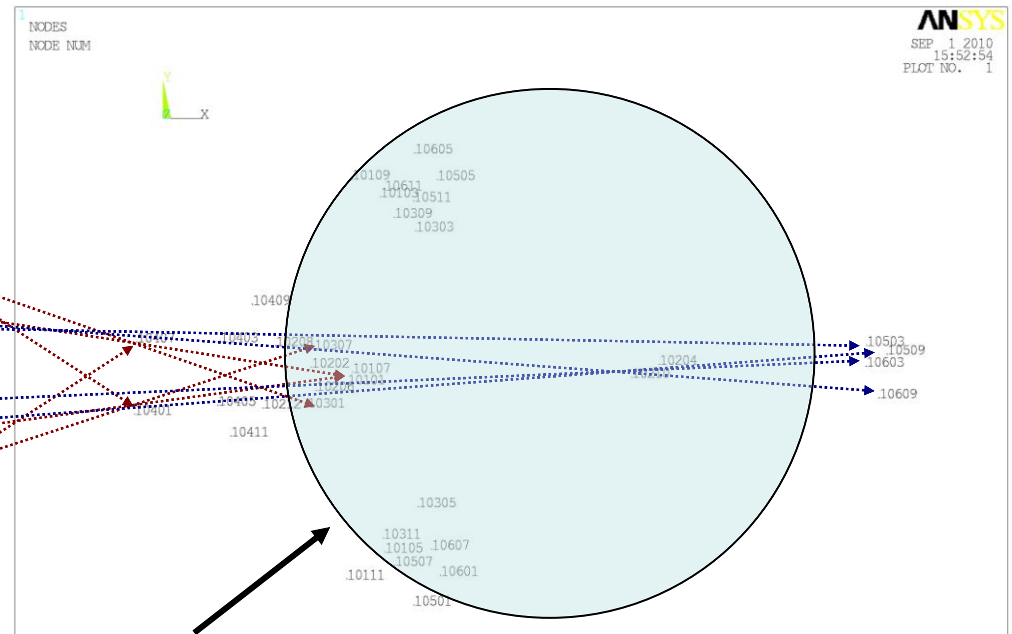
Davies-Cotton Telescope

FE Analyses: Prediction of optical degradation at camera focal plane

Displacements and rotations of mirror panels and camera retrieved (Gravity & Wind effects)
Rough estimation of image at focal plane performed, RMS computed

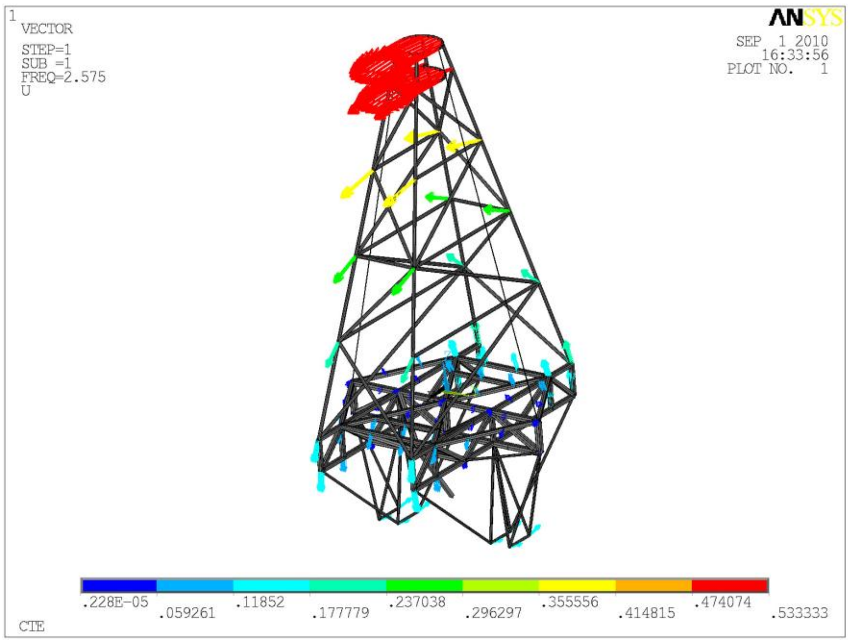


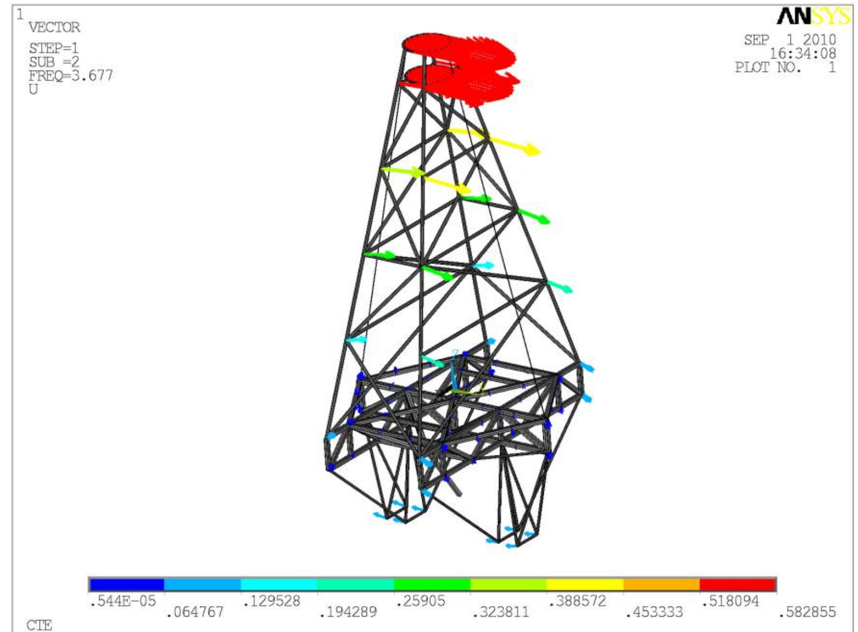
Mirror panels position and numbering



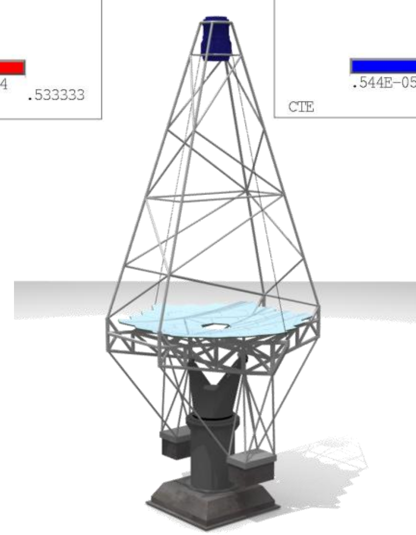
Example of predicted image spot for in-axis radiation
RMS < 0.3 mrad (vs 1 mrad)

FE Analyses: Eigenfrequencies search





Mode 1: 2.6Hz
Global rotation around elevation axis
Eigen-frequency mainly related to worm-drive stiffness



Mode 2: 3.7Hz
Global lateral bending
Eigen-frequency mainly related to lattice mast stiffness

Final remarks

General design

1. Simple and basic design.
2. Simple Mirror with sandwich panel sectors
3. Altitude pointing performed through worm drive assembly
4. Azimuthal pointing performed through gears and drives

Preliminary FE Analyses

1. Panel and camera displacements/rotations due to gravity and wind leading to a PSF < 1mrad
2. First eigenfrequency above 2.5Hz : general design acceptable but still to be improved; 3Hz goal accessible

Main general specifications

Ø4m class telescope

Two-mirror telescope

M1 curvature radius: ~10m

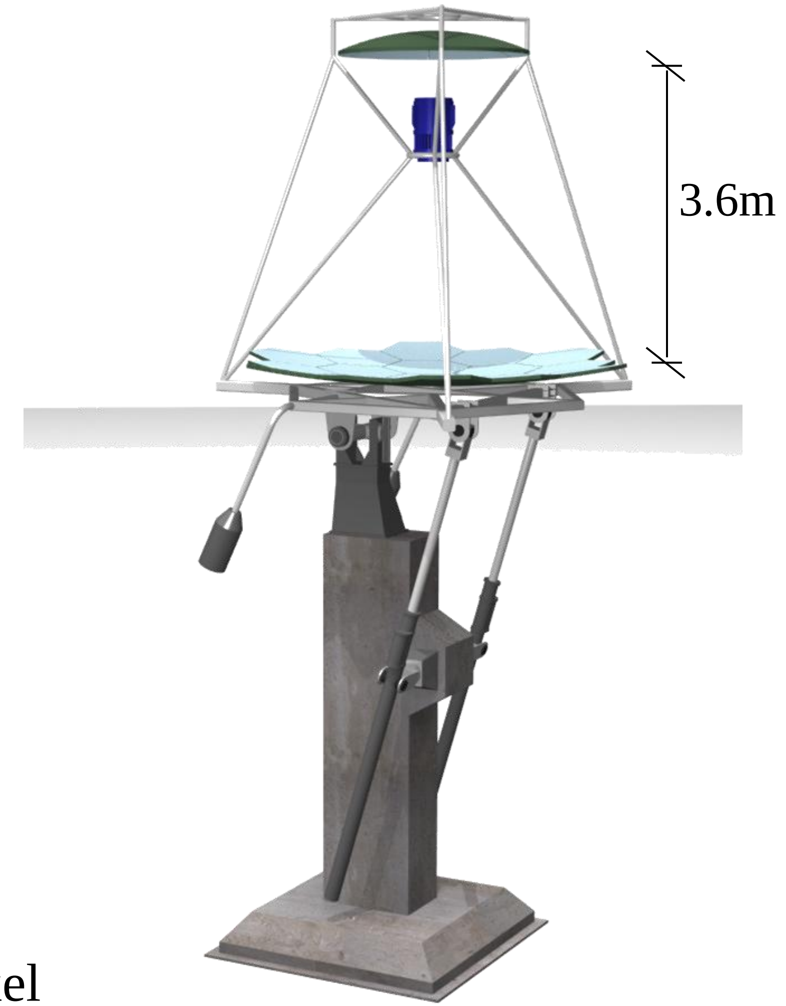
M2 curvature radius: ~2.5m

Camera mass: 100 Kg

Operating Wind: 50Km/h

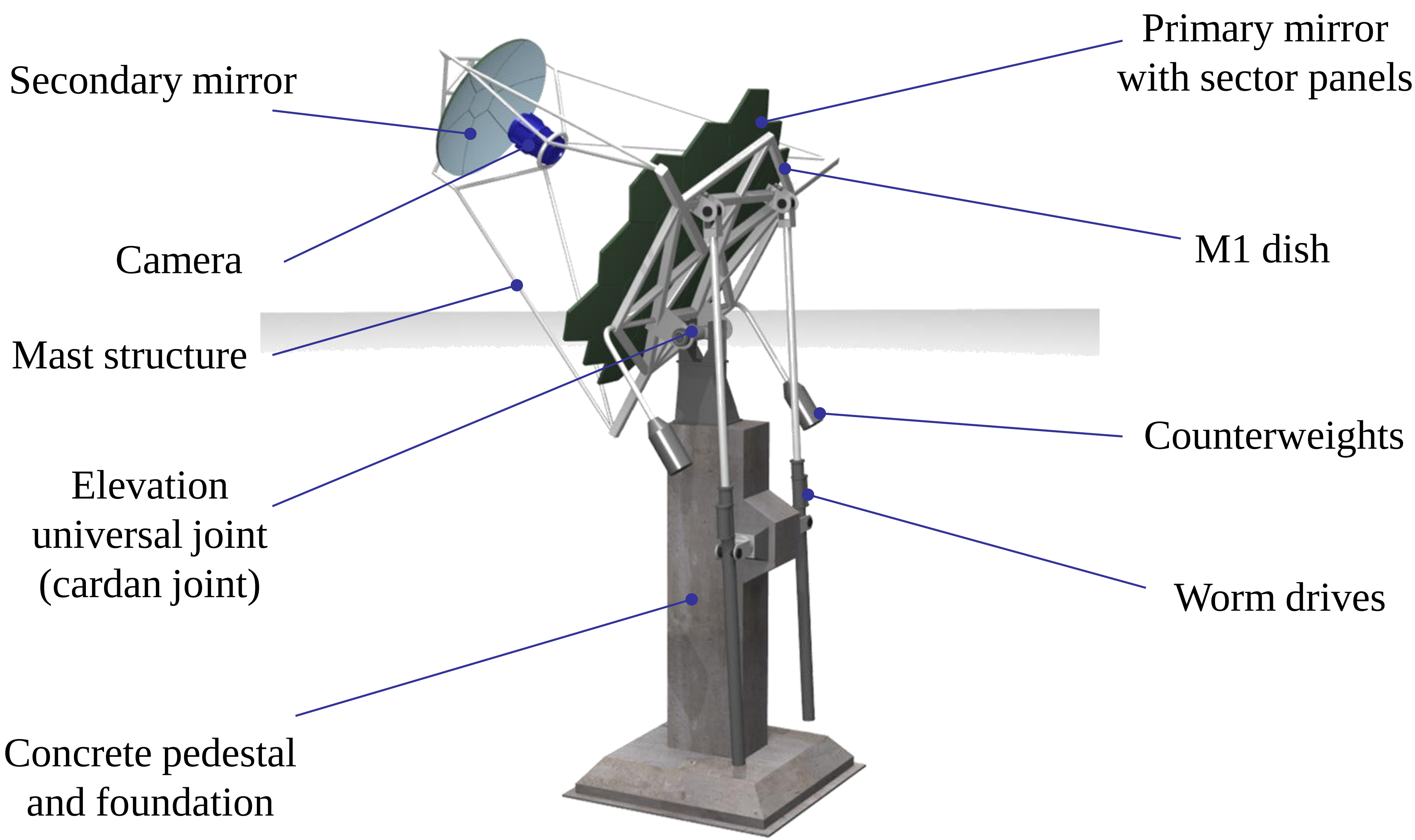
Contribution to PSF < 1mrad

Camera displacement 0.5PMT pixel



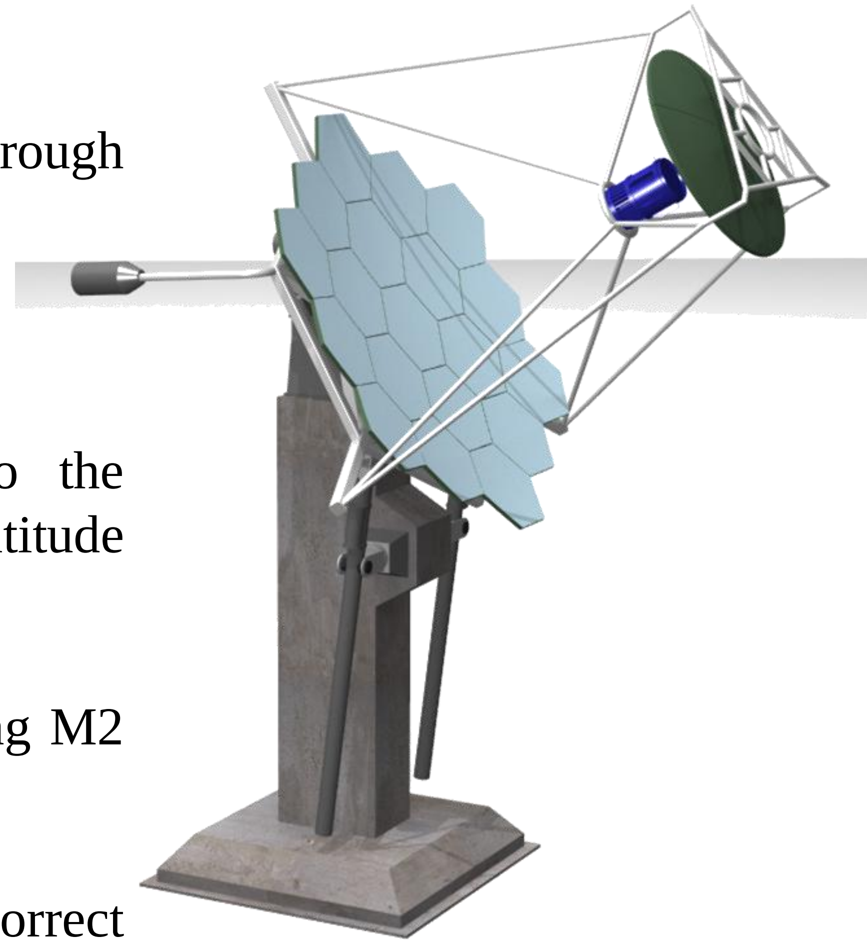
Schwarzschild-Couder Telescope

Conceptual Design



Conceptual Design

Main features



1. "Cardan" mount, pointing performed through worm drive system only:
   Allowed elevations: 30° to 90°
   Azimuth pointing: -180° to 180°

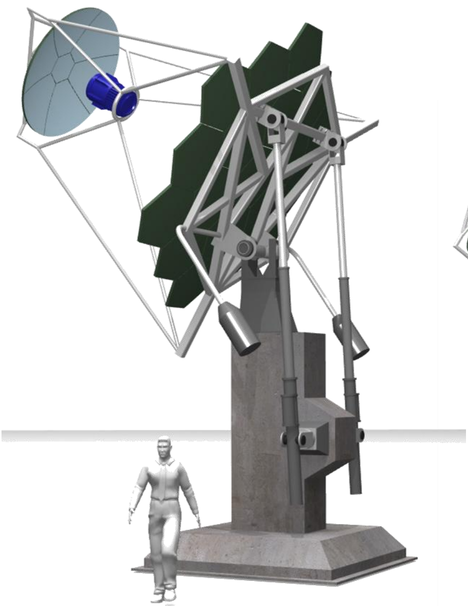
2. Axial and lateral loads transmitted to the concrete foundations through universal altitude joint and worm-drives

3. Simple elevation mast structure supporting M2 and Camera

4. Counterweights envisaged to grant correct balancing around universal joint.

Schwarzschild-Couder Telescope

Conceptual Design (alternatives)

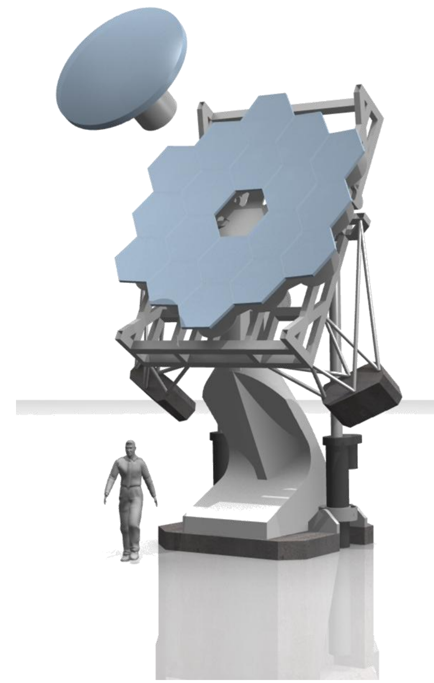


Layout A)

with telescopic worm drives

Layout A)

Layout B)



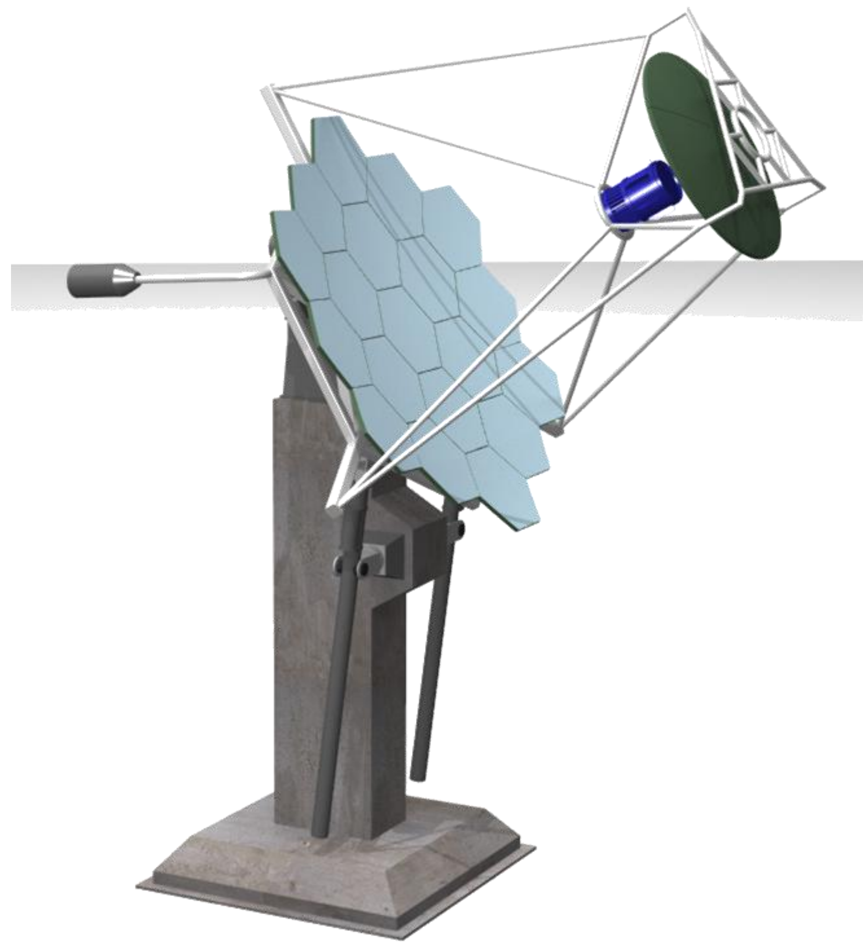
Layout B)

with sunken pedestal

Conceptual Design

In the meantime, a "classical" configuration with alt-azimuthal mounting is at present under investigation.

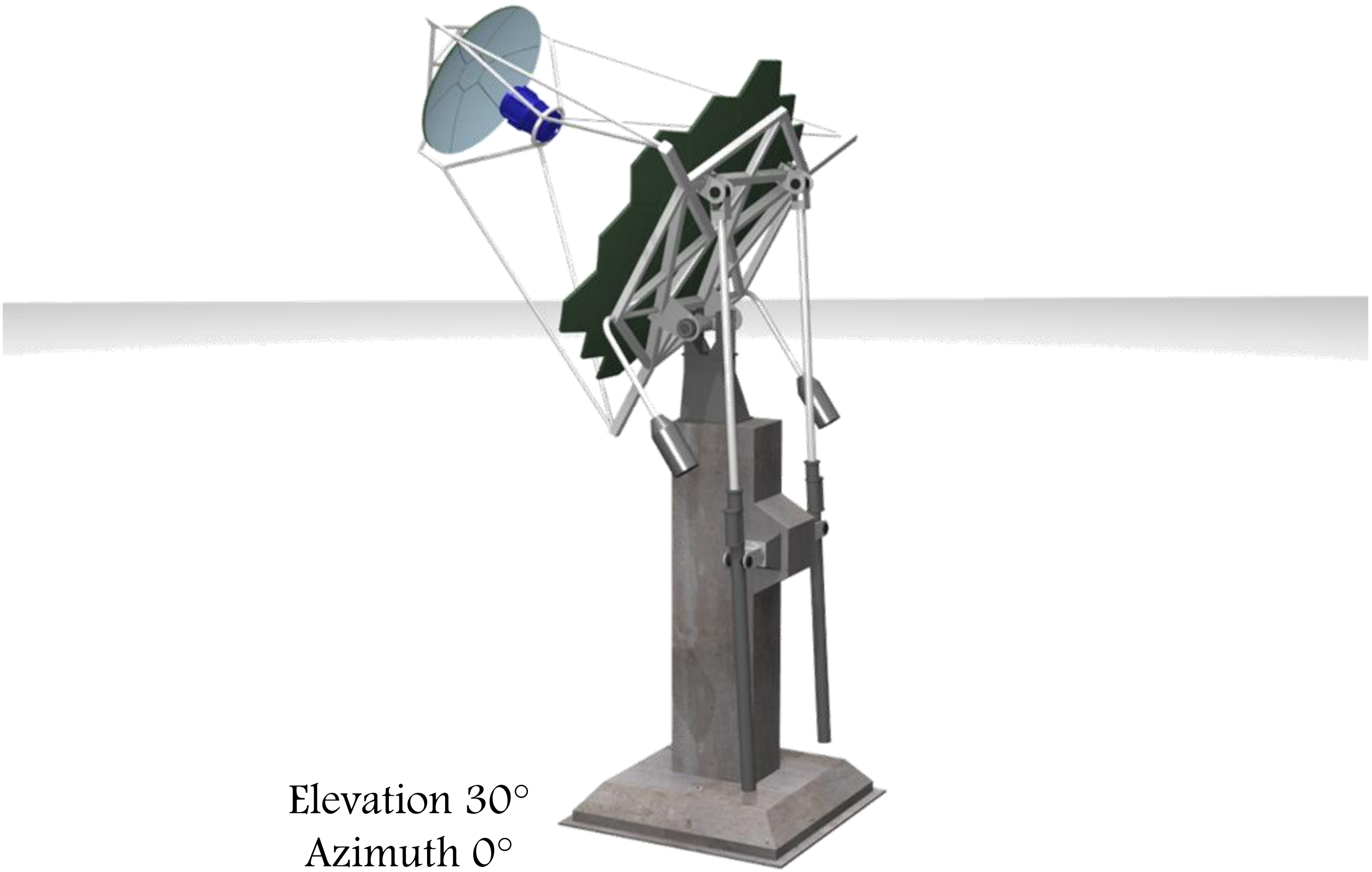
Costs and performances trade-off between the different solutions will be performed.



“Cardan” vs Alt-Az

“Cardan”		Alt-Az	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Lightweight and “essential”	Pedestal could be quite high or with a fashioned design	Well known and standard solution	Higher costs for both structure and motors
More accurate measure of the dish positioning (measured directly on the dish)	Pointing limited to >25° from horizon, mainly due to eigenfrequencies	Secondary can be lowered close to ground	Less accurate pointing and tracking (measured on gears and drives)
No tracking limits			Tracking limit at zenith
On-site assembly more easy and fast			

Conceptual Design

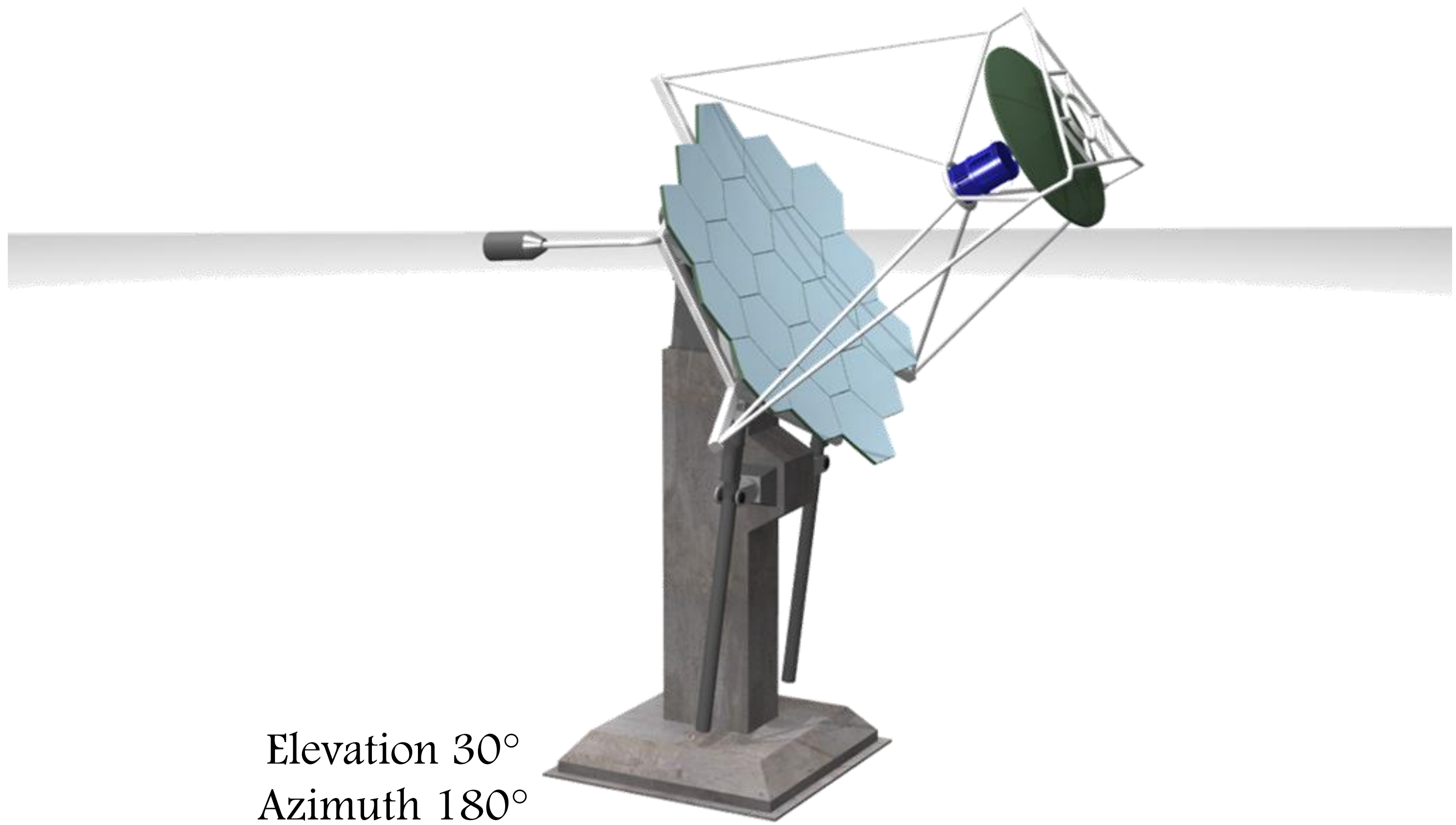


Elevation 30°
Azimuth 0°

Conceptual Design

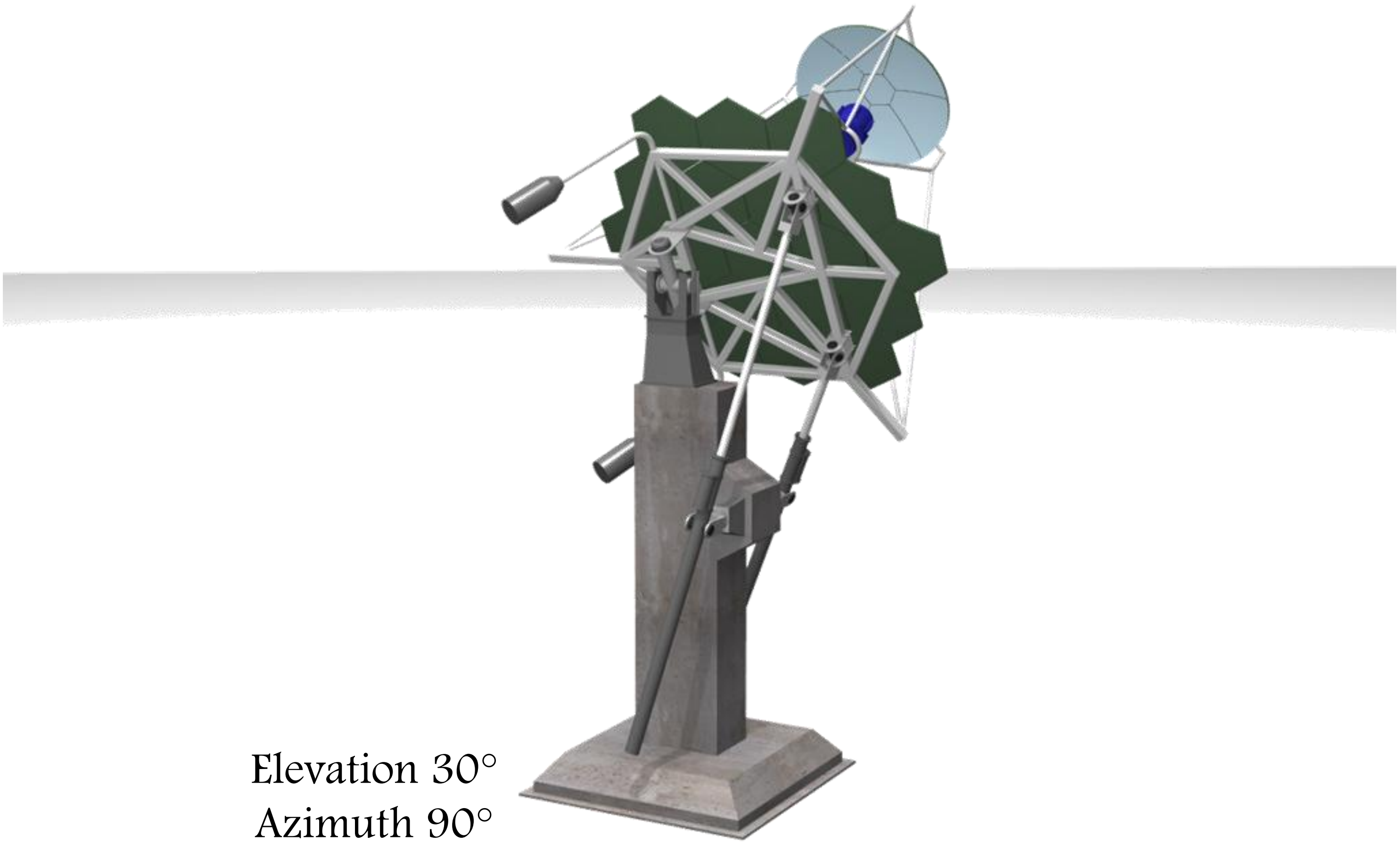
Elevation 90°
Azimuth 0°

Conceptual Design



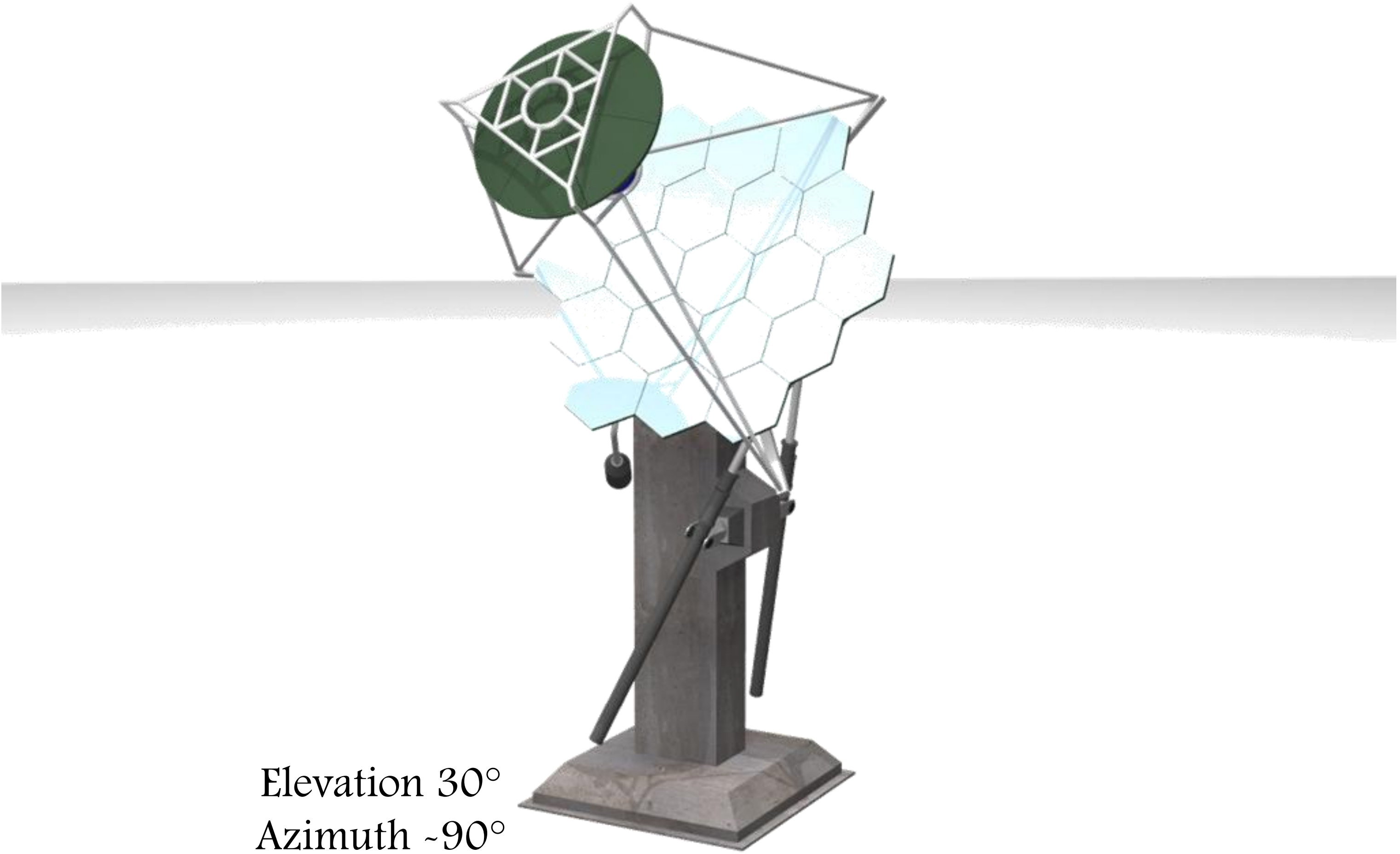
Elevation 30°
Azimuth 180°

Conceptual Design



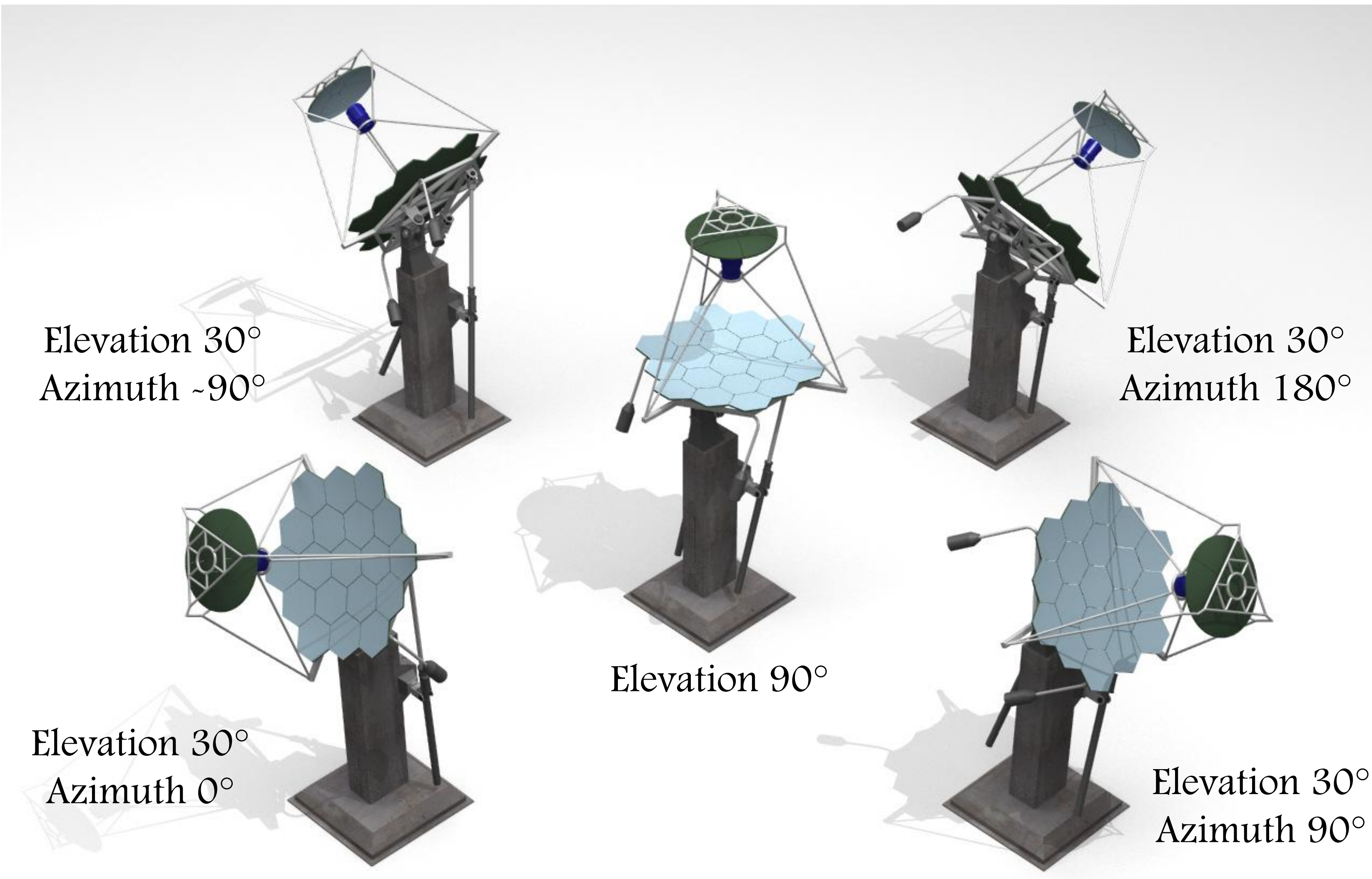
Elevation 30°
Azimuth 90°

Conceptual Design



Elevation 30°
Azimuth ~90°

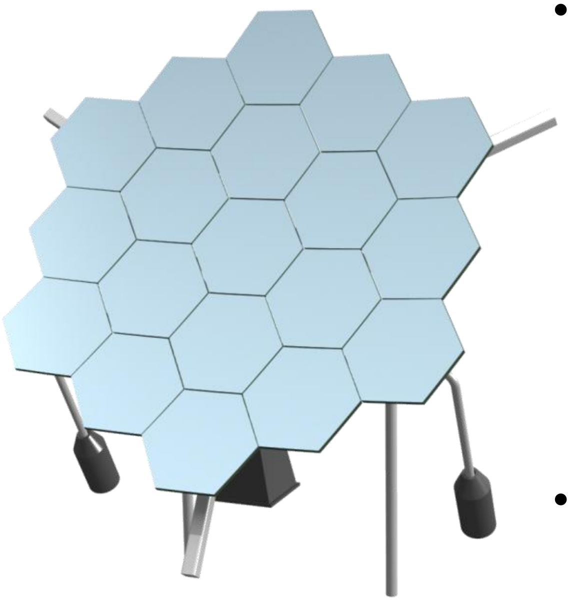
Conceptual Design



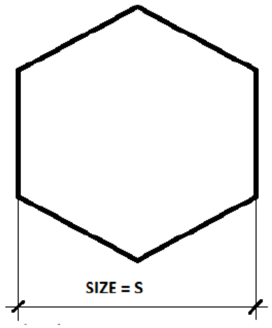
Schwarzschild-Couder Telescope

Conceptual Design

Primary mirror (M1)



- 18+(1) hexagonal/petal shaped sandwich mirror panels



S ≈ 0.85m

TBC

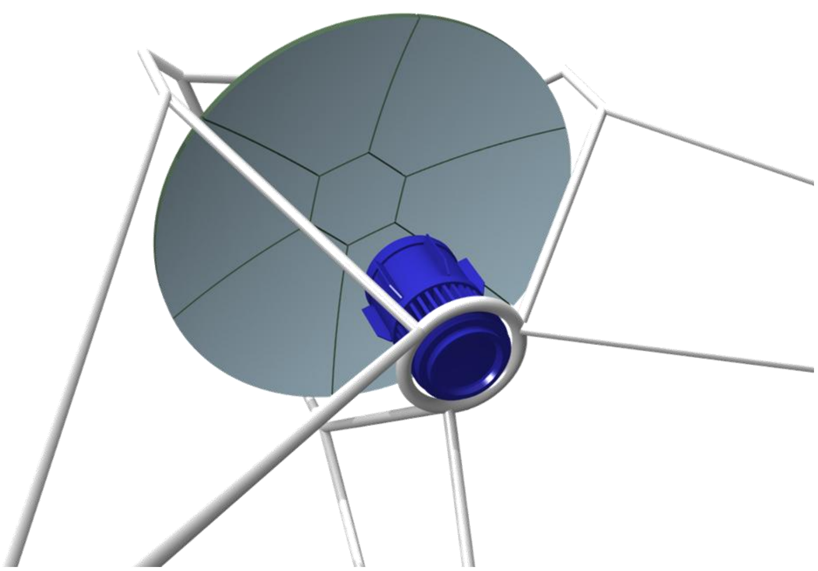
- Positioning of each sector active-controlled through 3 actuators mounted on a “plate” also accommodating the interface with the structure.

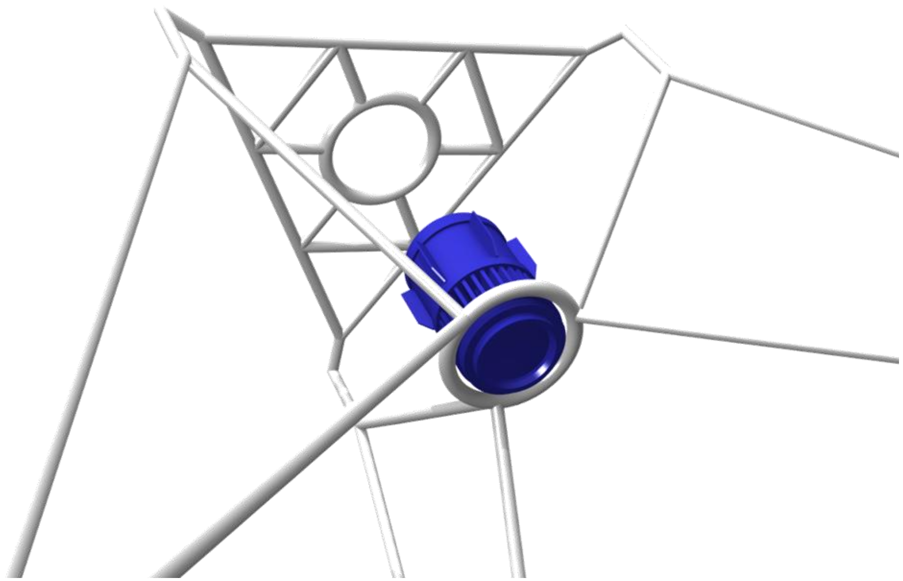
- Lattice supporting dish

Conceptual Design

Secondary mirror (M2)

- 6 sandwich mirror sectors
- Positioning of each sector active-controlled through 3 actuators mounted on a "plate" also accommodating the interface with the structure

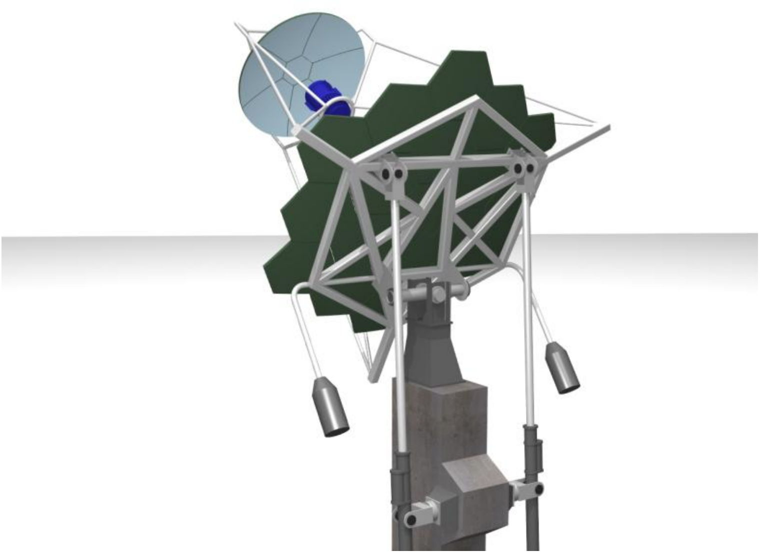


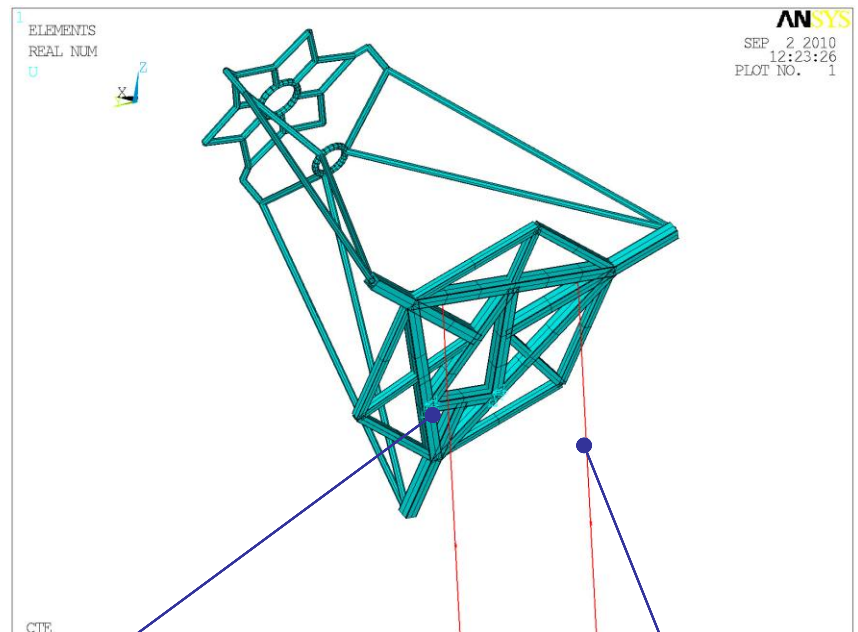


Preliminary FE Analyses: Model description

Numerical model of M1dish, mast, M2 and camera implemented.
Mirror panels and camera lumped and modeled as simple structural masses.

Concrete foundation considered as infinitely stiff.



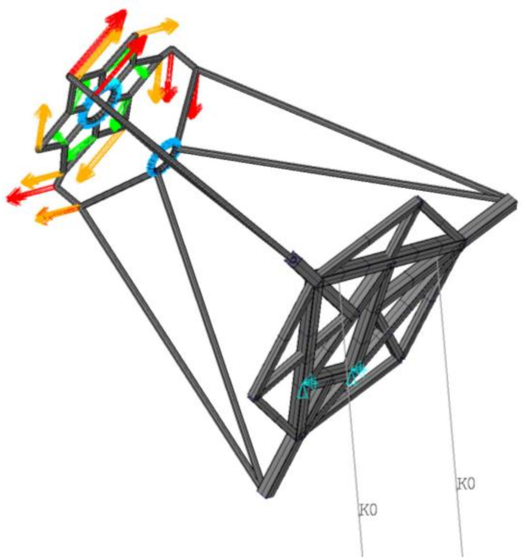


Universal joint modeled through 2 spherical hinges;
Concrete foundation considered as infinitely stiff

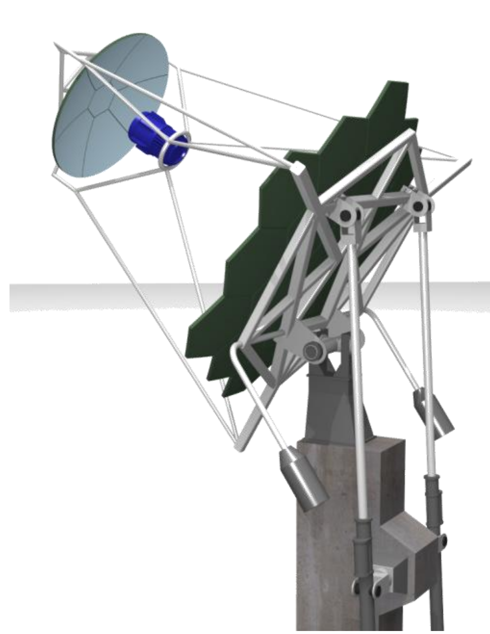
Worm-drives

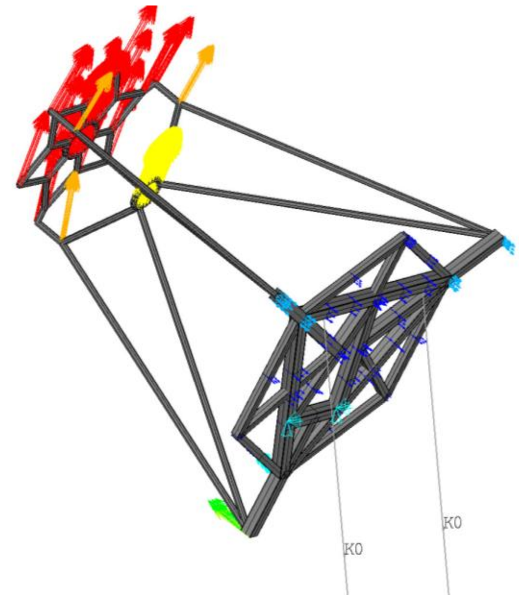
Preliminary FE Analyses: Eigenfrequencies search

(Elevation = 30°, Azimuth = 0°)



Mode 1: ~ 5.6Hz
Mast global torsion
Eigen-frequency mainly related to mast stiffness

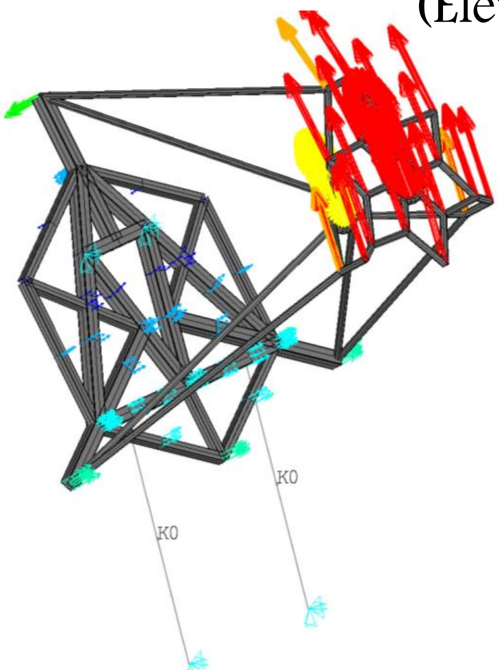


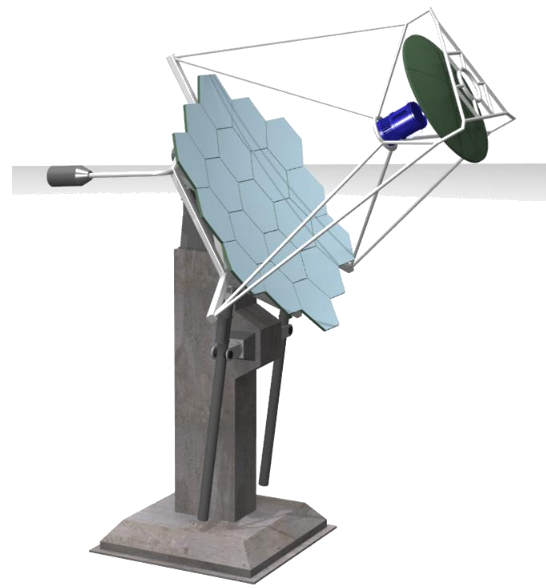


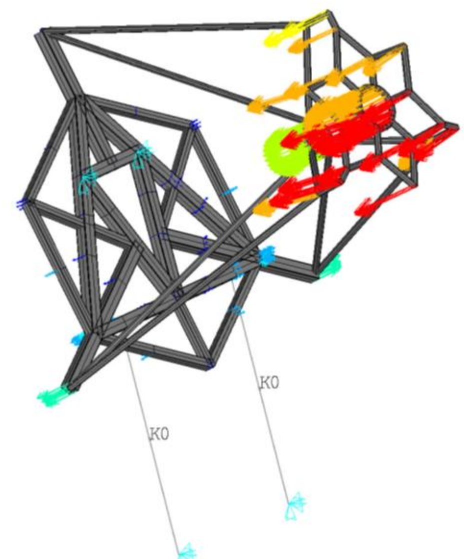
Mode 2: ~ 5.7Hz
Global rotation about the elevation universal joint
Eigen-frequency mainly related to worm-drives stiffness

Preliminary FE Analyses: Eigenfrequencies search

(Elevation = 30°, Azimuth = 180°)







Mode 1: ~4.0Hz

Global rotation about elevation universal joint

Eigen-frequency mainly related to worm-drives stiffness

Mode 2: ~5.0Hz

Mast global bending

Eigen-frequency mainly related to dish stiffness

Final remarks

General design

1. Innovative design.
2. Altitude and azimuthal pointing performed through worm drive system only.
3. Significant saving of structure mass, components number → global cost
4. "Classical" configuration with alt-az mounting under investigation.

Costs and performances Trade-off between the two solutions will be performed.

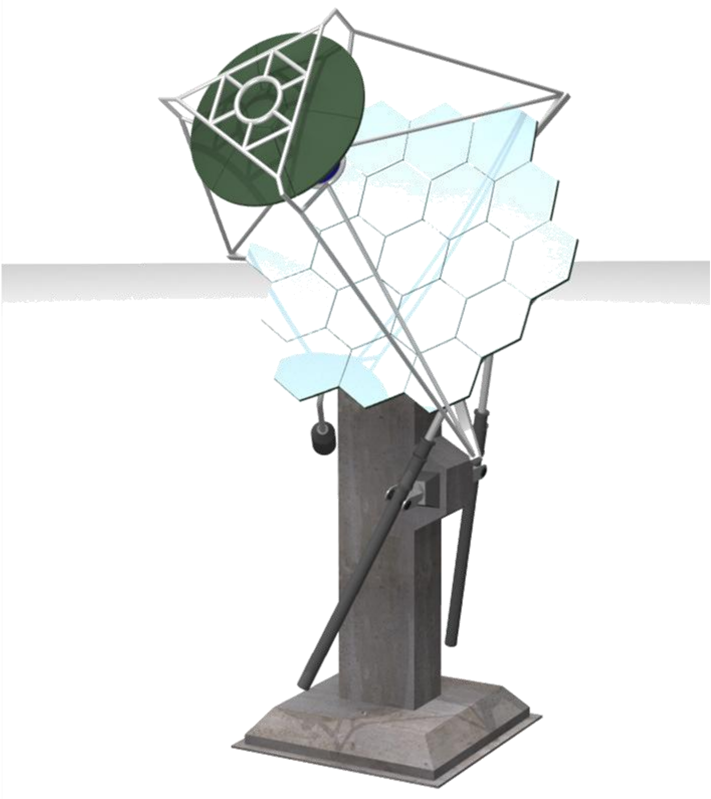
Preliminary analyses

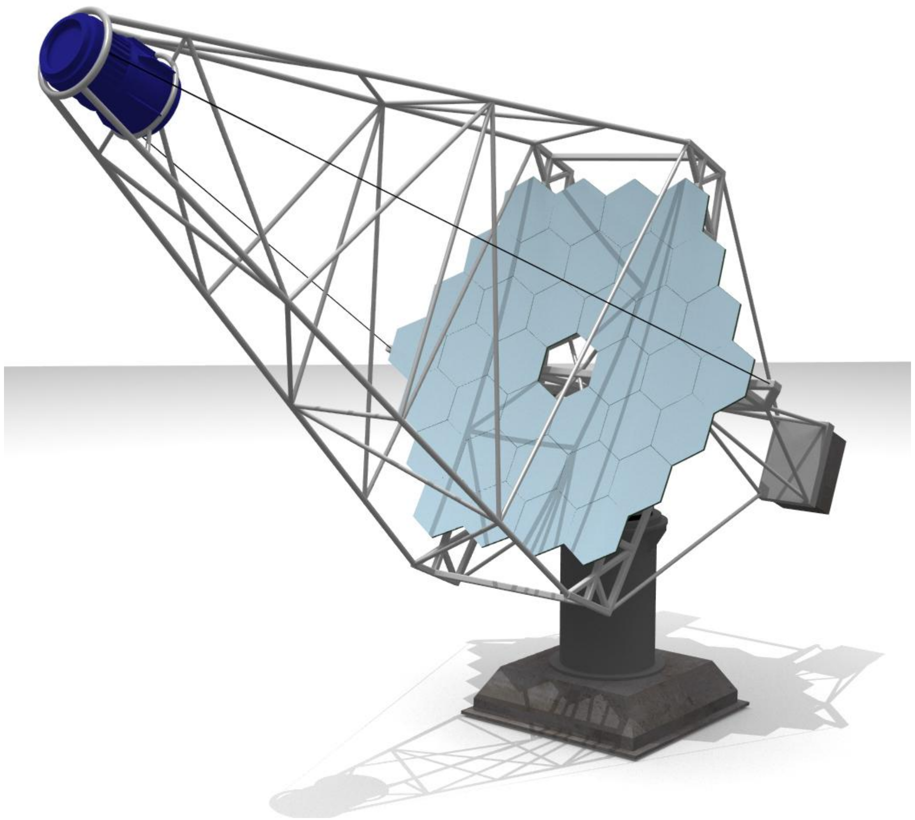
1. Panel and camera displacements/rotations due to gravity and wind leading to a PSF < 1mrad
2. First eigenfrequency above 4Hz : Value acceptable even in case of reduction when additional flexibility of joints and mechanical parts is taken into account

Final remarks

- Two design under investigation

- Both satisfy the main requirements





- Trade-off study is necessary with a global approach (not only structure)

- Need to start a feasibility study