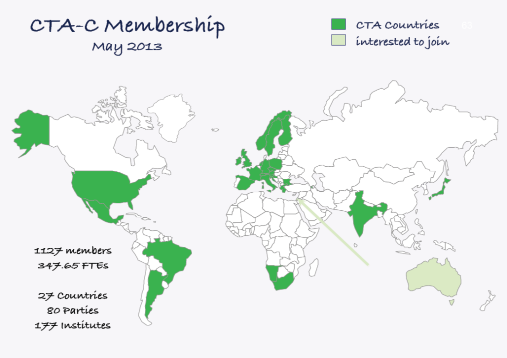
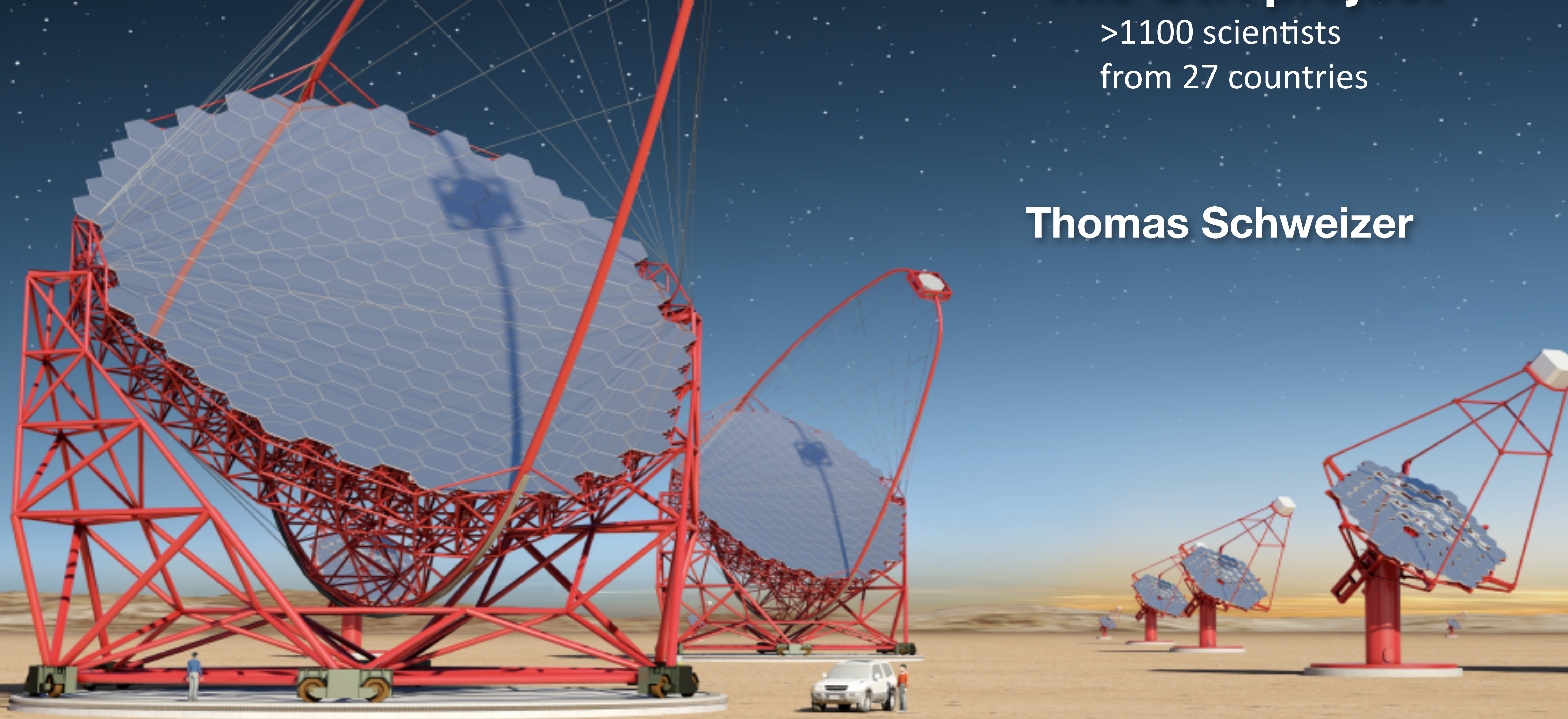


cta
cherenkov telescope array

The CTA project

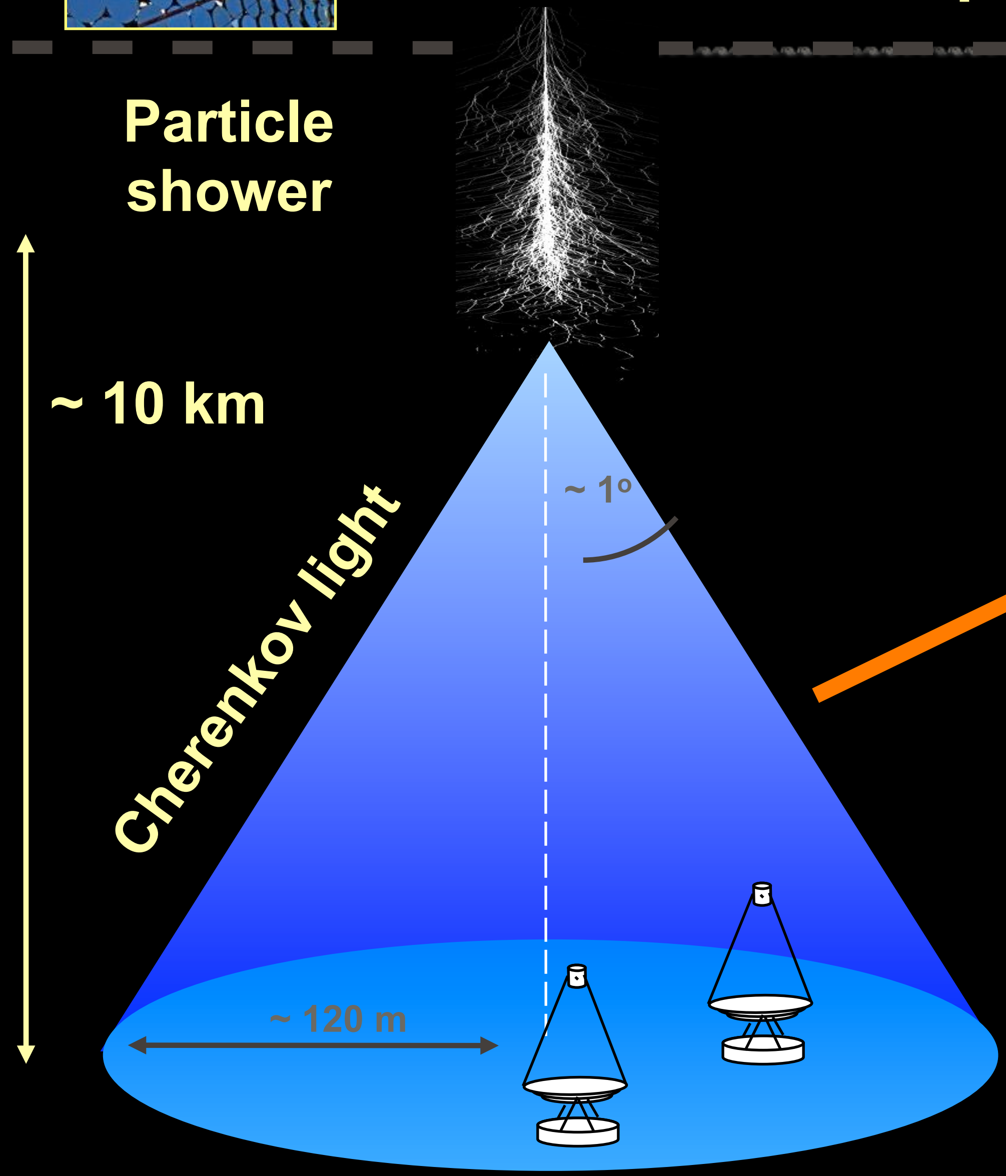
>1100 scientists
from 27 countries

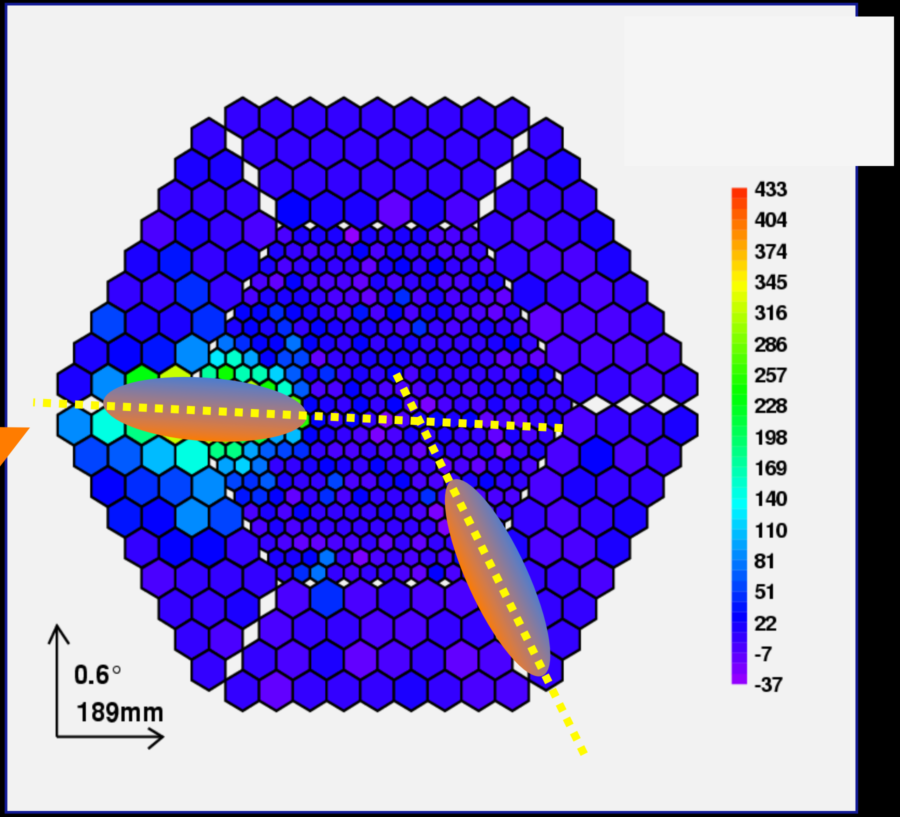
Thomas Schweizer



Eckart Lorenz

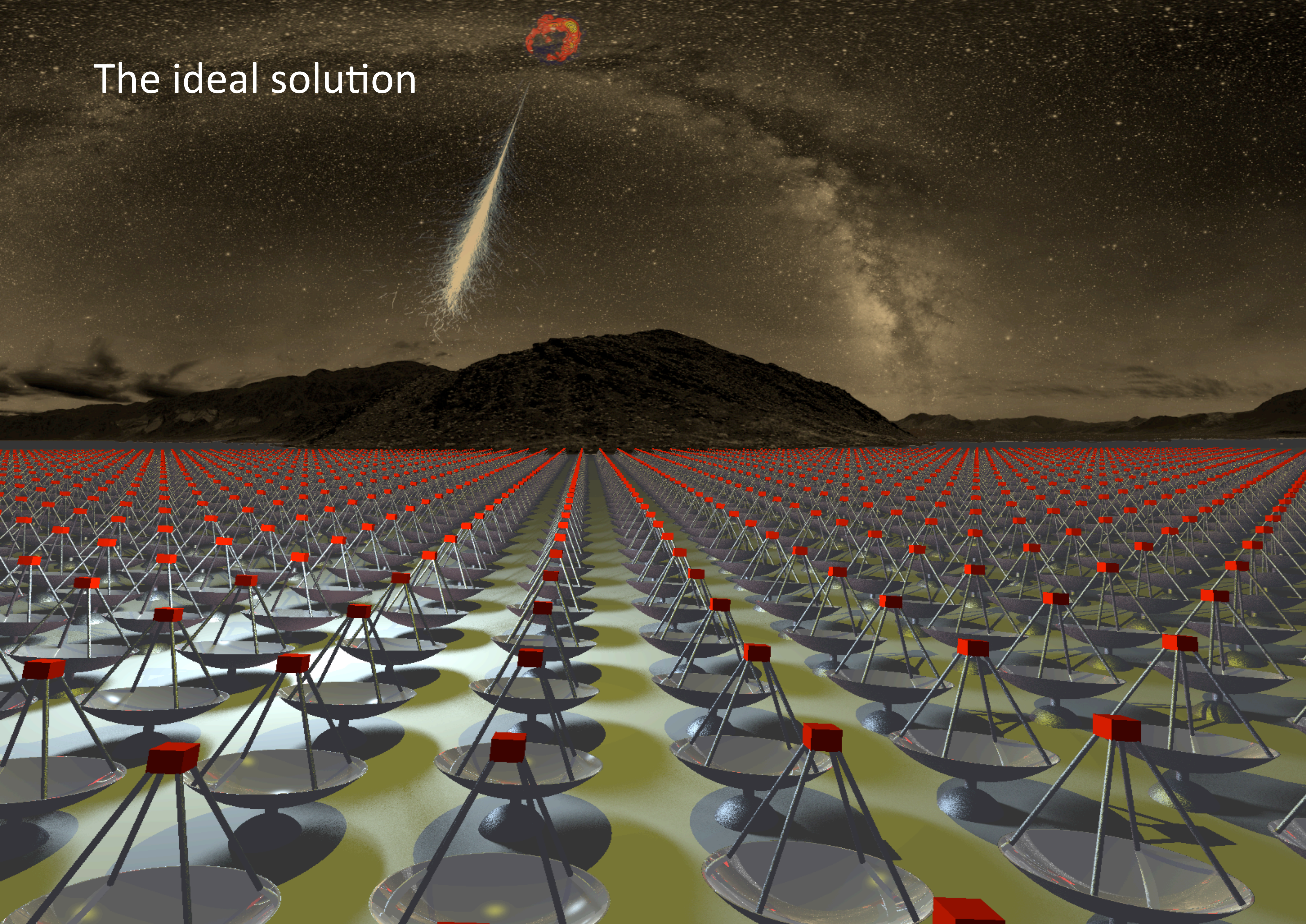
The Imaging Cherenkov Technique in stereo

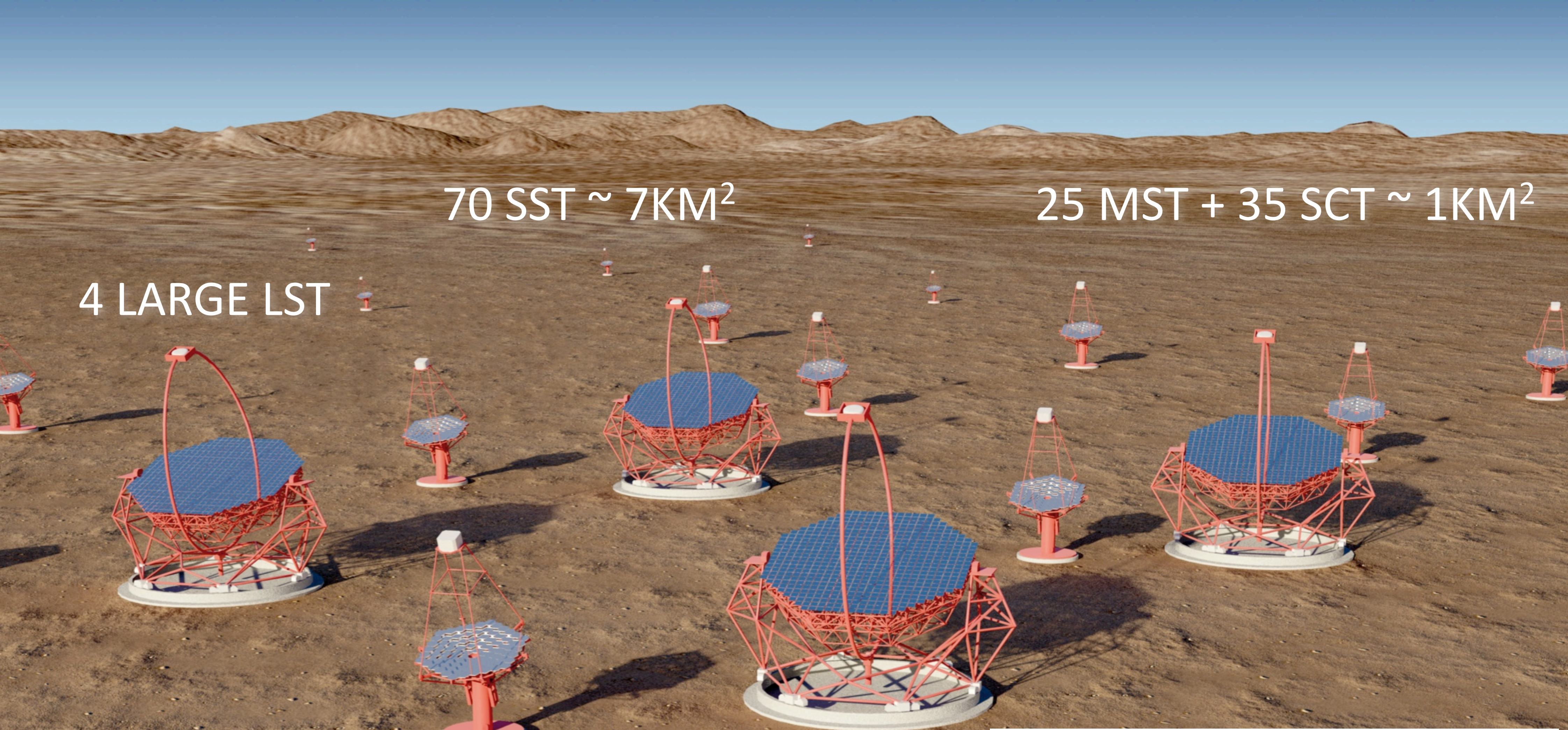




Better background reduction
Better angular resolution
Better energy resolution

The ideal solution



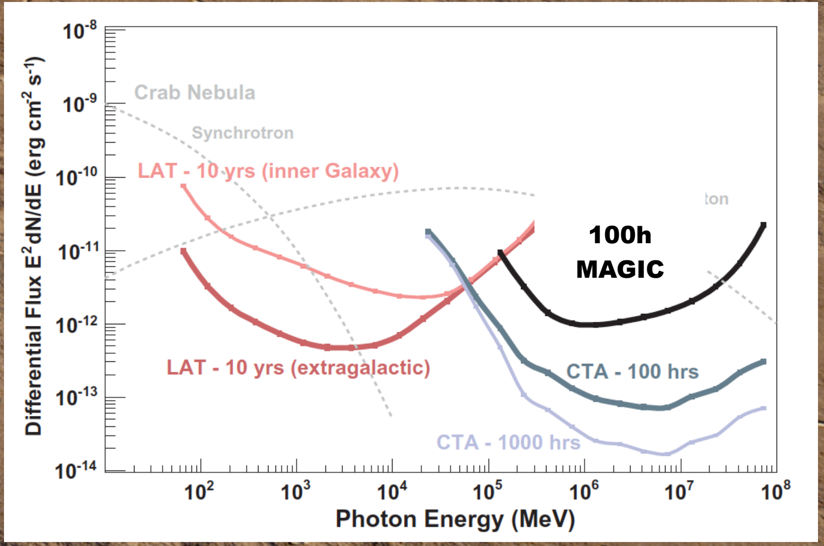


70 SST ~ 7KM^2

25 MST + 35 SCT ~ 1KM^2

4 LARGE LST

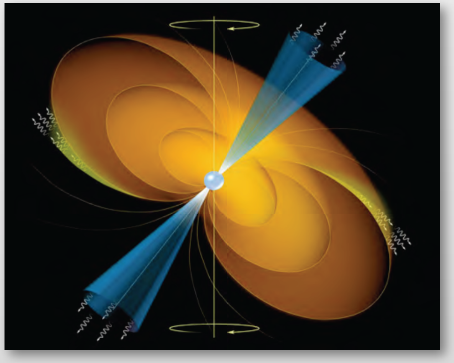
CURRENT LAYOUT PROPOSAL

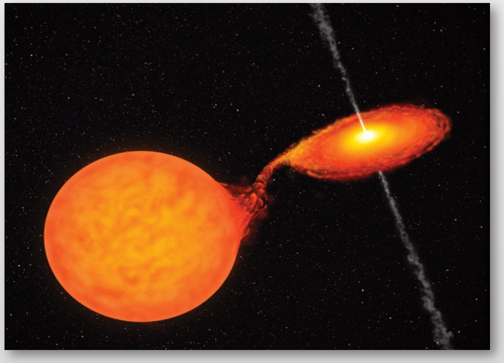


Rich Science cases with LSTs


High redshift AGNs (z<2)


GRBs (z<4)


Pulsars


Binaries and transients

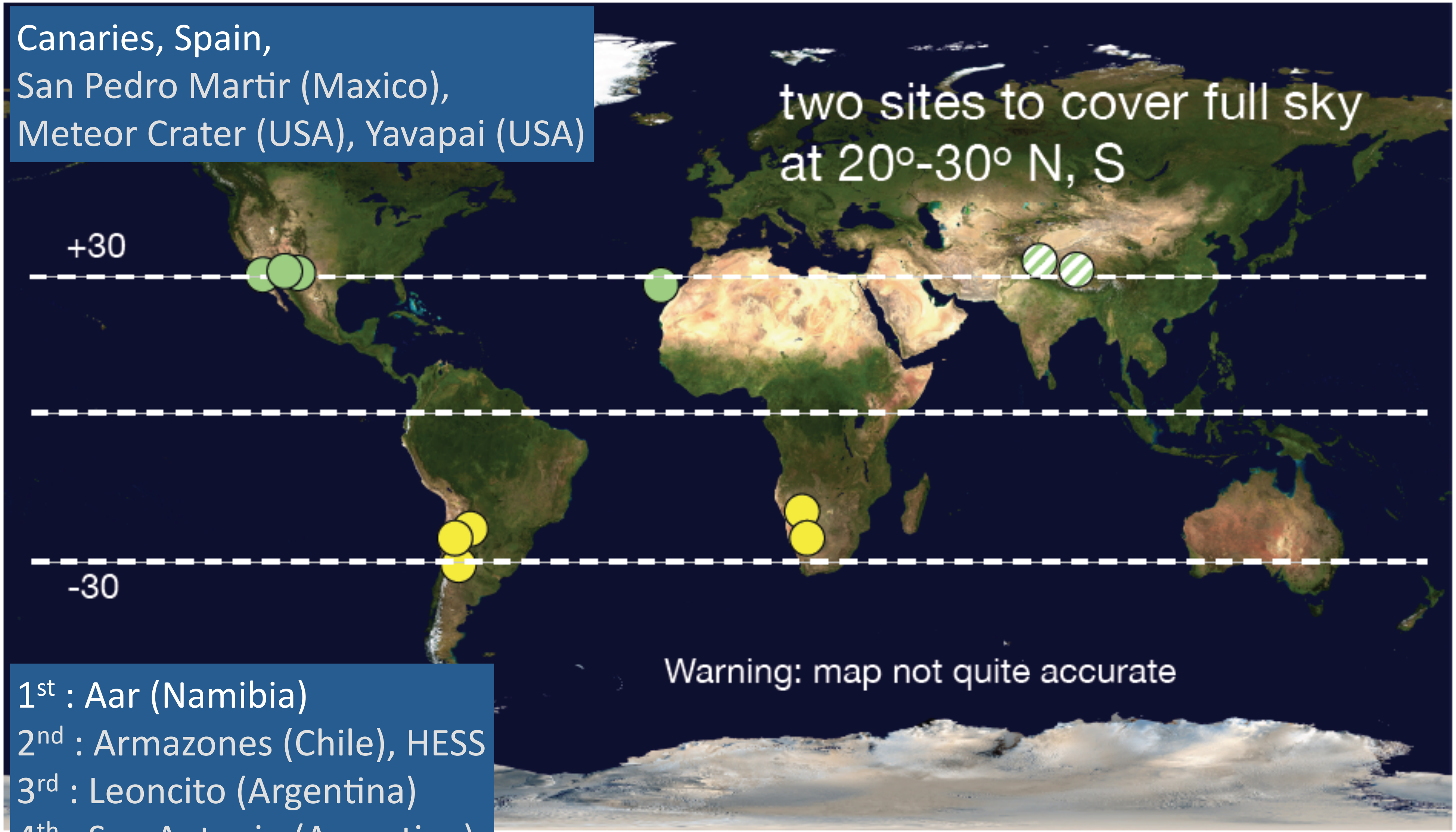
- LST should be optimized in the energy range between 20 - 200 GeV
- Low energy threshold
  - Trigger threshold: 15-20 GeV
  - Analysis threshold: 20-30 GeV

- key physics cases:
  - High-redshift AGNs and GRBs, Expand the Gamma Ray Horizon
  - Binaries, Pulsars and other type of transients at low energy

CTA Project office made a proposition and CB agreed during the CTA meeting in Warsaw on 23-27 September

SITE CANDIDATES

Sites will be selected in March 2014



Canaries, Spain,
San Pedro Martir (Maxico),
Meteor Crater (USA), Yavapai (USA)

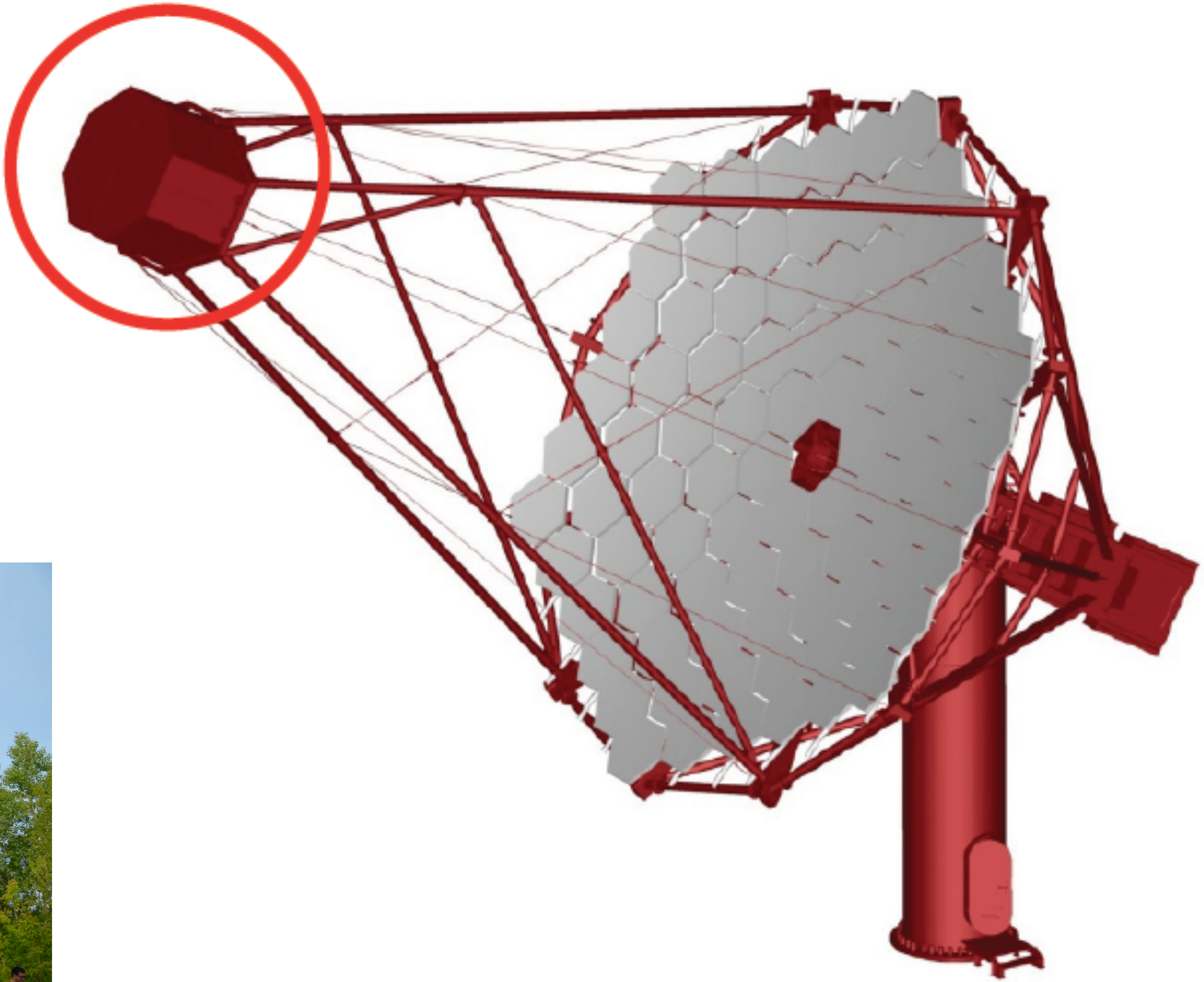
1st : Aar (Namibia)
2nd : Armazones (Chile), HESS
3rd : Leoncito (Argentina)
4th : San Antonio (Argentina)

MEDIUM-SIZED 12 M TELESCOPE

OPTIMIZED FOR THE 100 GEV TO ~10 TEV RANGE

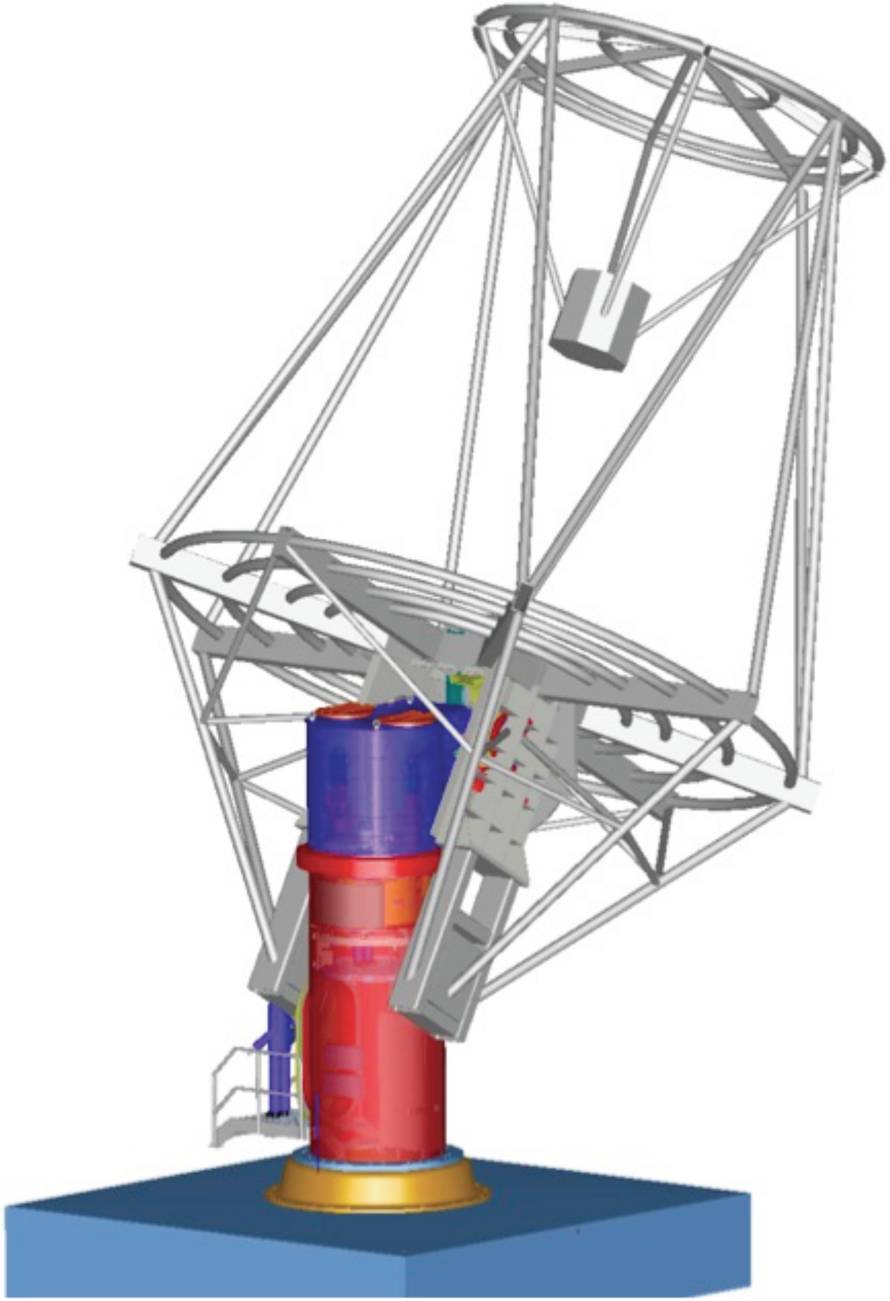
100 m^2 dish area
16 m focal length
1.2 m mirror facets

7-8º field of view
~2000 x 0.18º pixels



MEDIUM-SIZED DUAL MIRROR TEL.

EXTENDING THE MST ARRAY



9.7 m diameter
50 m^2 dish area
5.6 m focal length

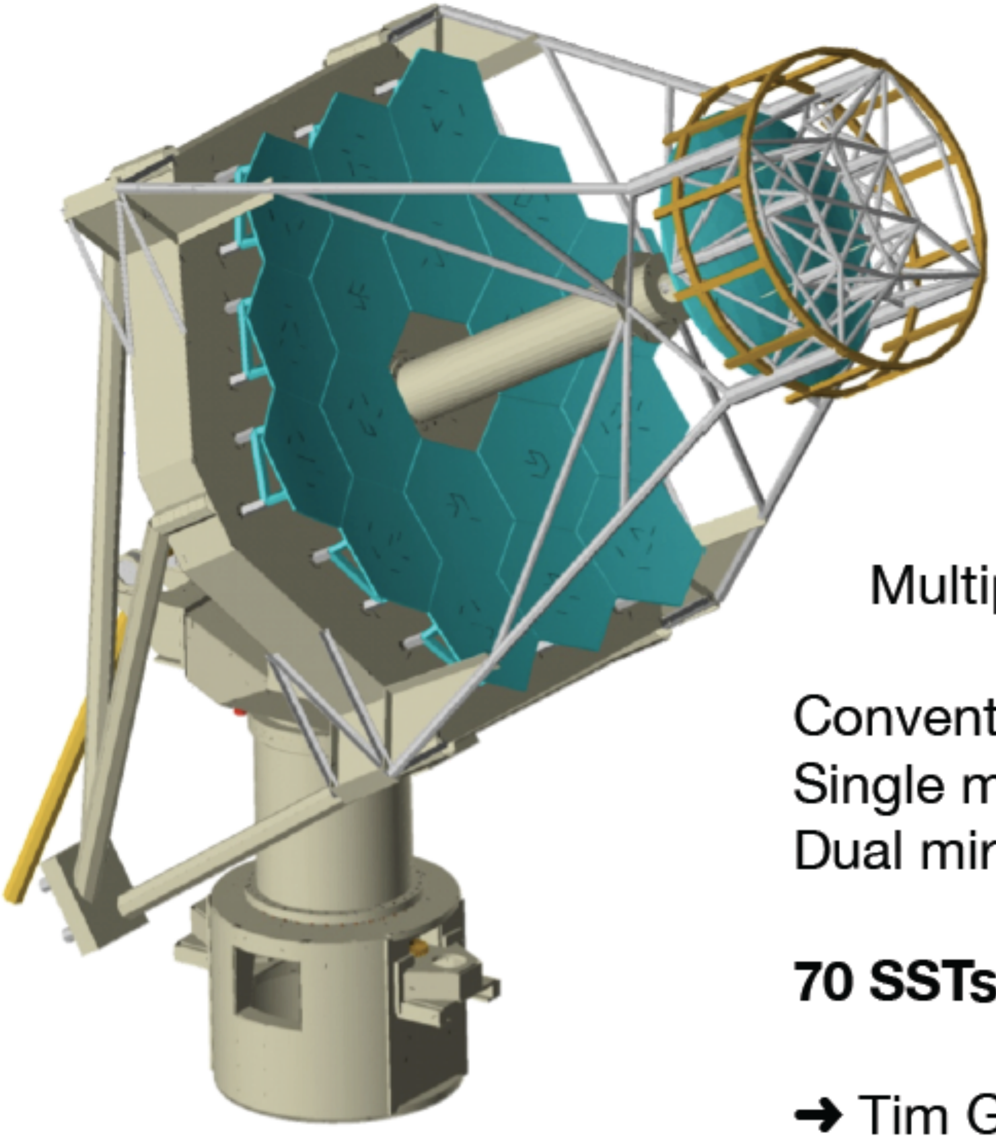
8-9° field of view
11000 x 0.07° pixels

Extend South array
by adding 36 SCTs
contributed mostly by US

➜ Vladimir Vassiliev

SMALL TELESCOPE

OPTIMIZED FOR THE RANGE ABOVE 10 TEV



ASTRI Design
4.3 m mirror
9.6° foV
0.25° pixels

Multiple options under study:

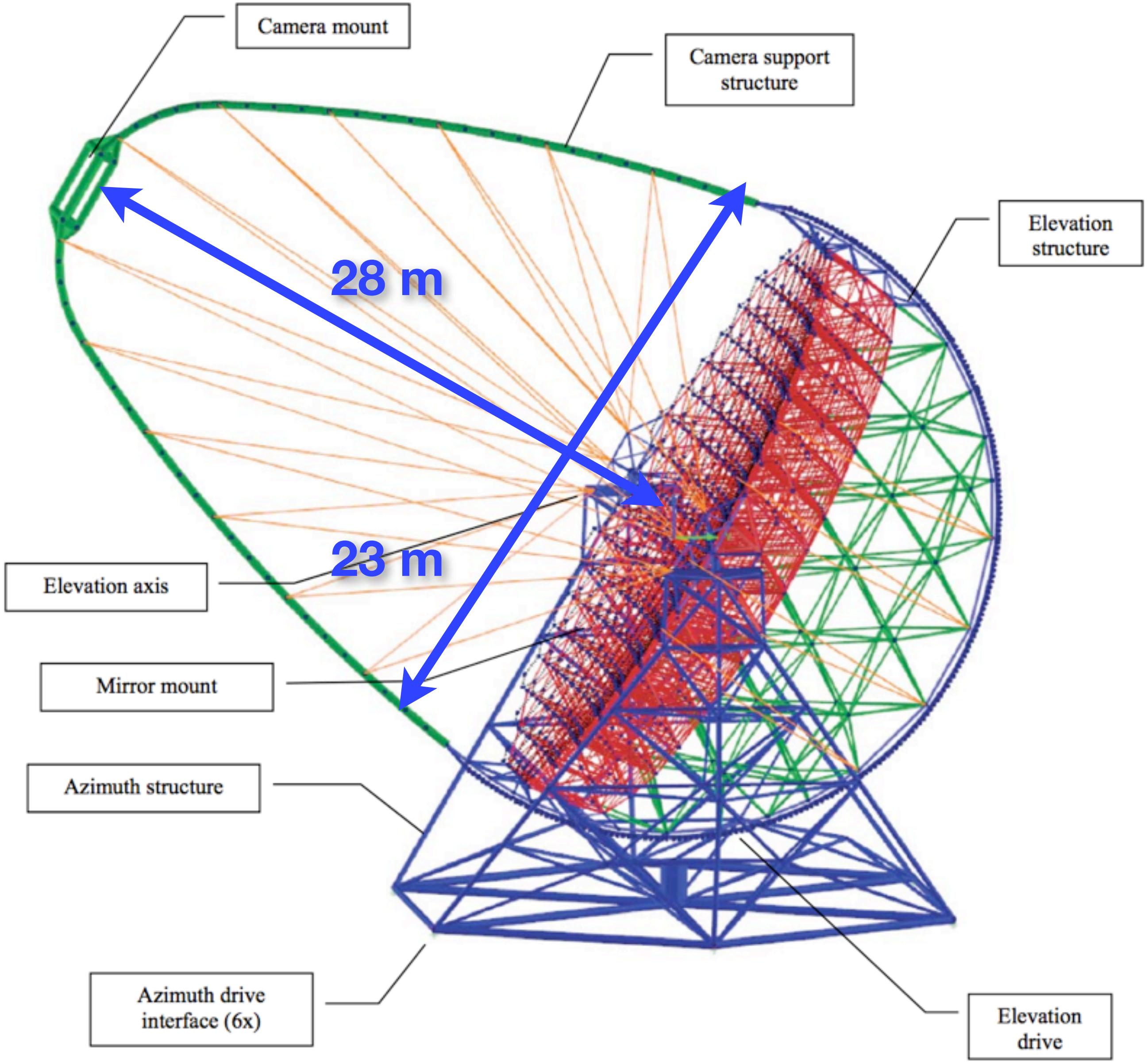
Conventional single mirror, PMT camera
Single mirror, silicon sensor camera
Dual mirror optics, silicon & MAPMT camera

70 SSTs on Southern site

➜ Tim Greenshaw

Look for PeVatron in our galaxy

LST Telescope components

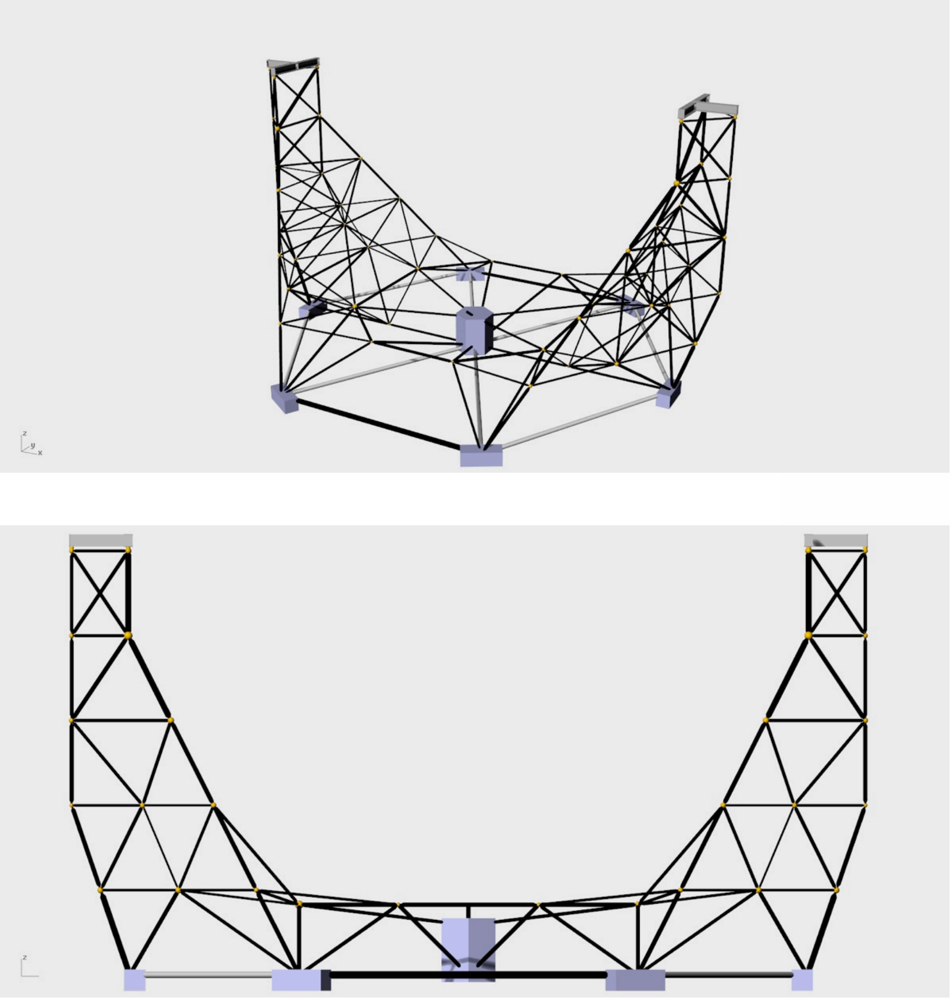


Involved groups/countries:

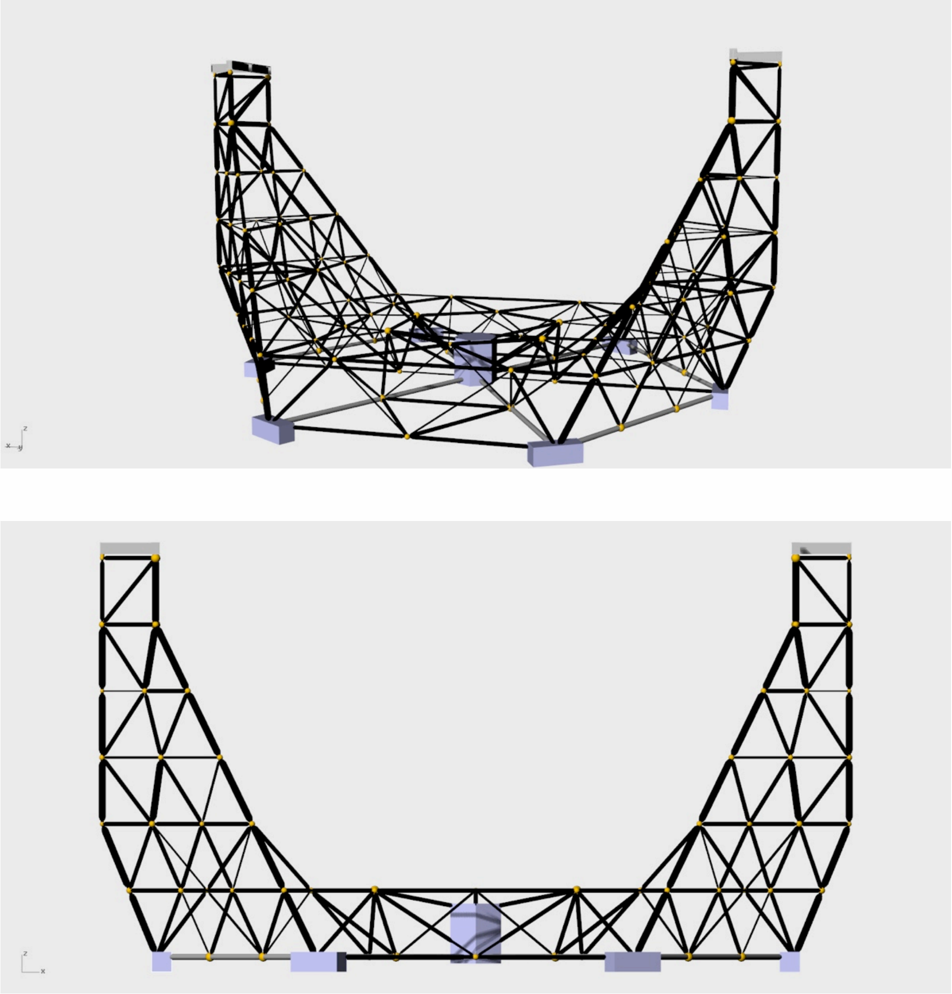
- MPI Munich:
    - Telescope design +
      LST project coordination
        - Dish structure
        - Understructure
- IFAE, Barcelona, Spain:
    - Rail system + Foundation
    - Boggies + Drive system
- LAPP, Annecy, France
    - Arch design
    - Camera Frame
    - Drive electronics
- Ciemat, Madrid, Spain:
    - Camera Body
- Spain, several institutes
    - Trigger electronics + Data transfer
- Japan:
    - Mirrors
    - Readout electronics

Understructure in steel and subdivision into more elements increases stiffness and redundancy

188 Elements in substructure

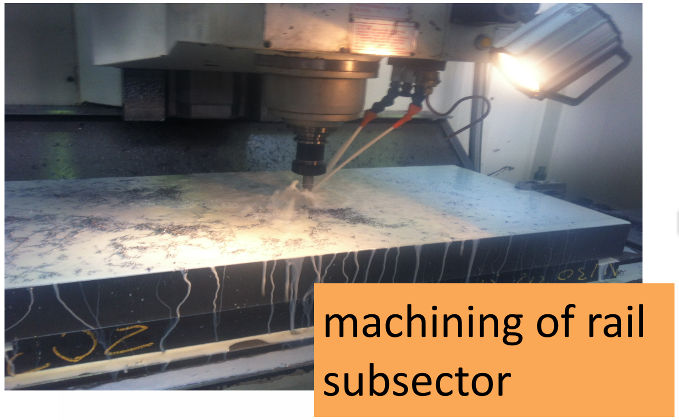


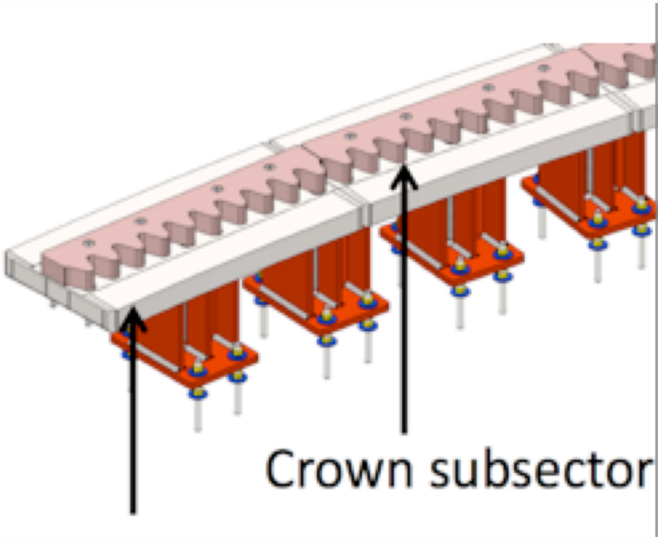
378 Elements in substructure

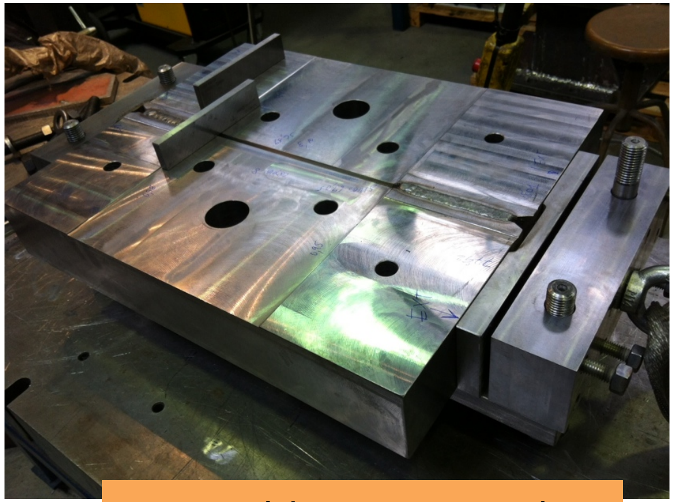


Rail system status

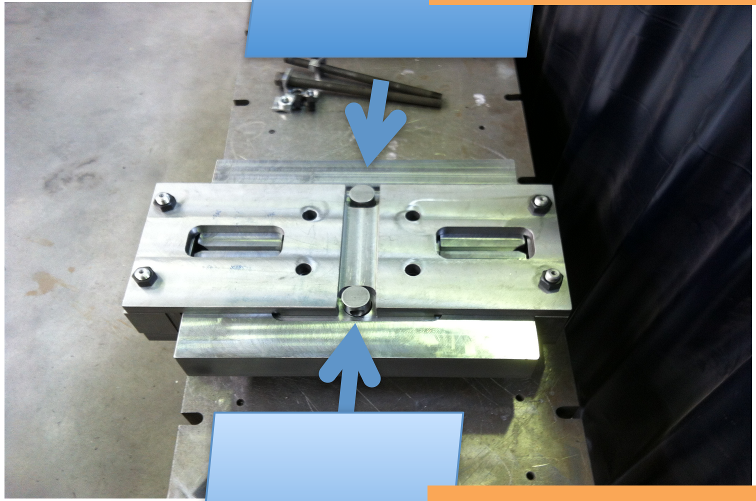
- **The first 1m long rail subsectors have been machined for the construction of the test setup.**
- **The 1m long rail subsectors are welded together with a custom welding tool**
- **Several pedestal sectors have been produced already**

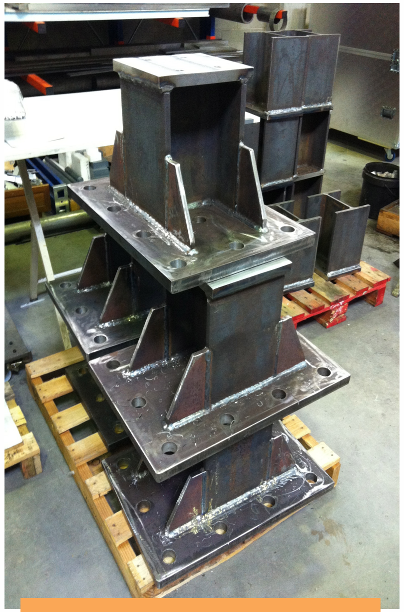

machining of rail subsector



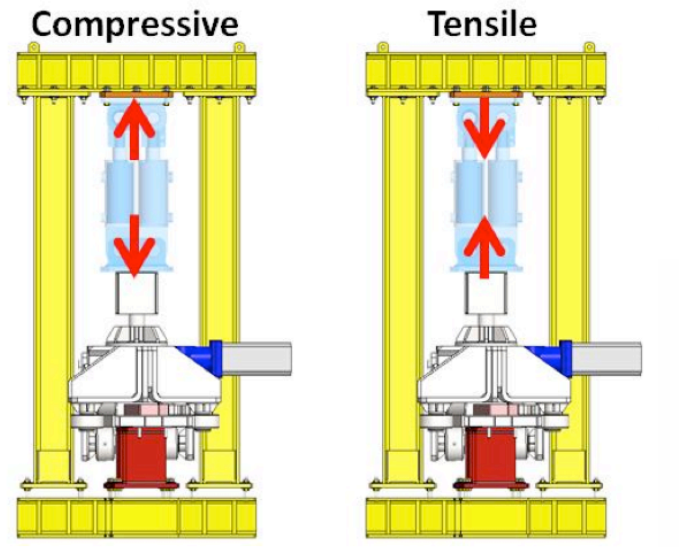

First welding test result

1 m long rail section

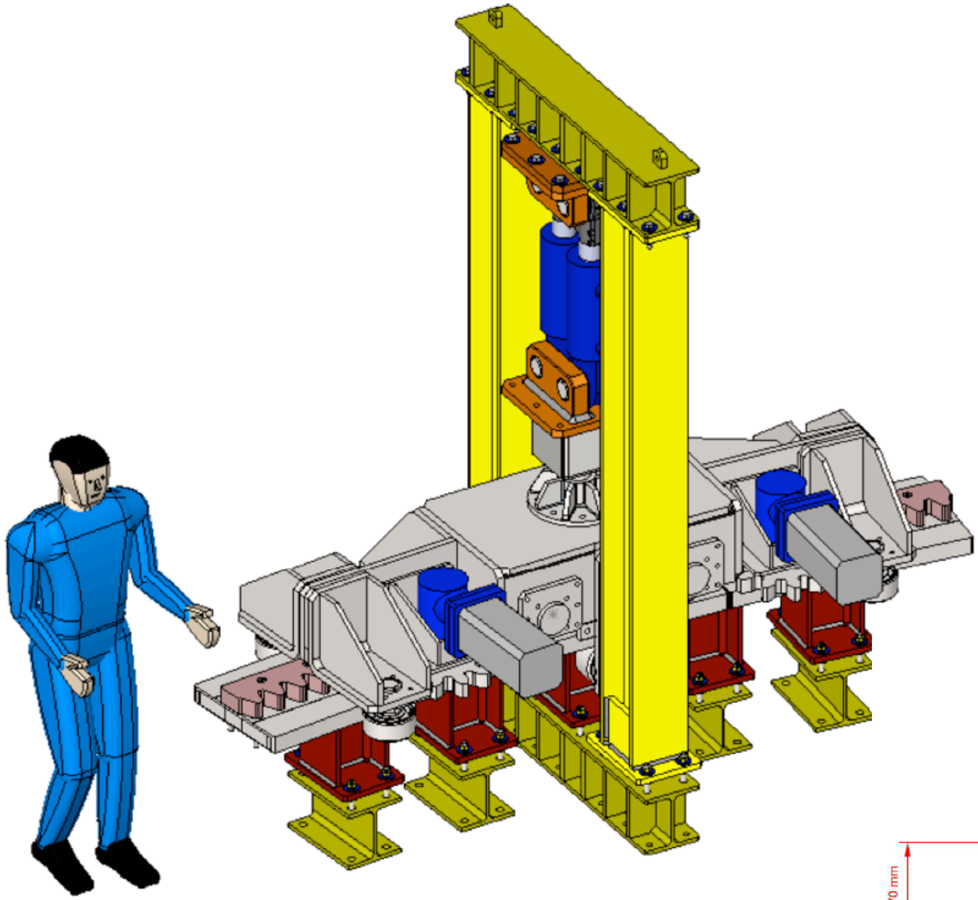

1 m long rail section

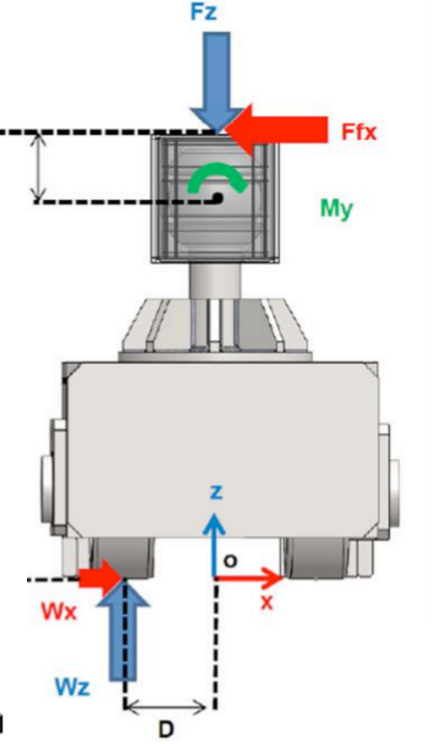

first pedestals

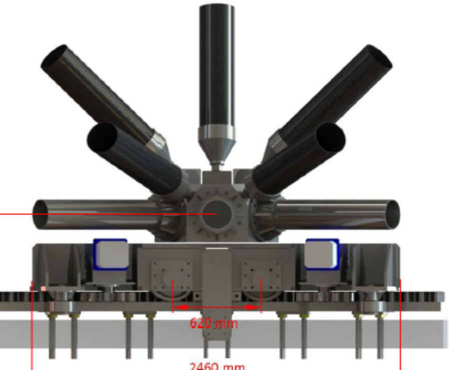
Tests to be performed on prototype boggie



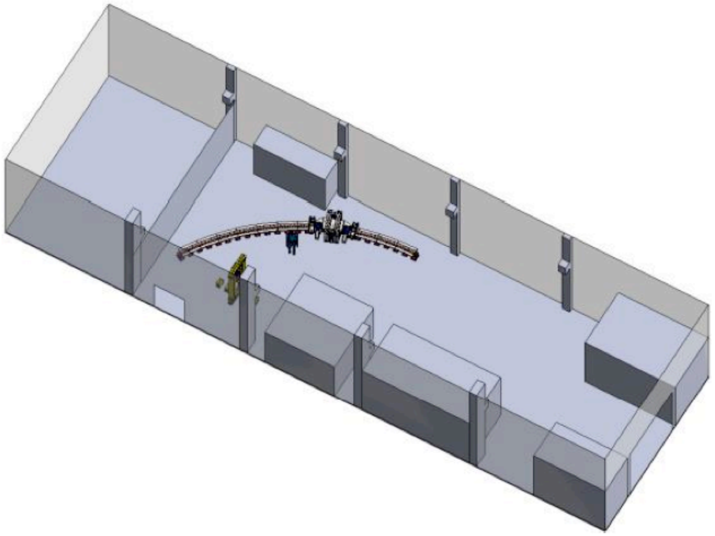
Compressive load: 80 tons
Tensile load: 40 tons



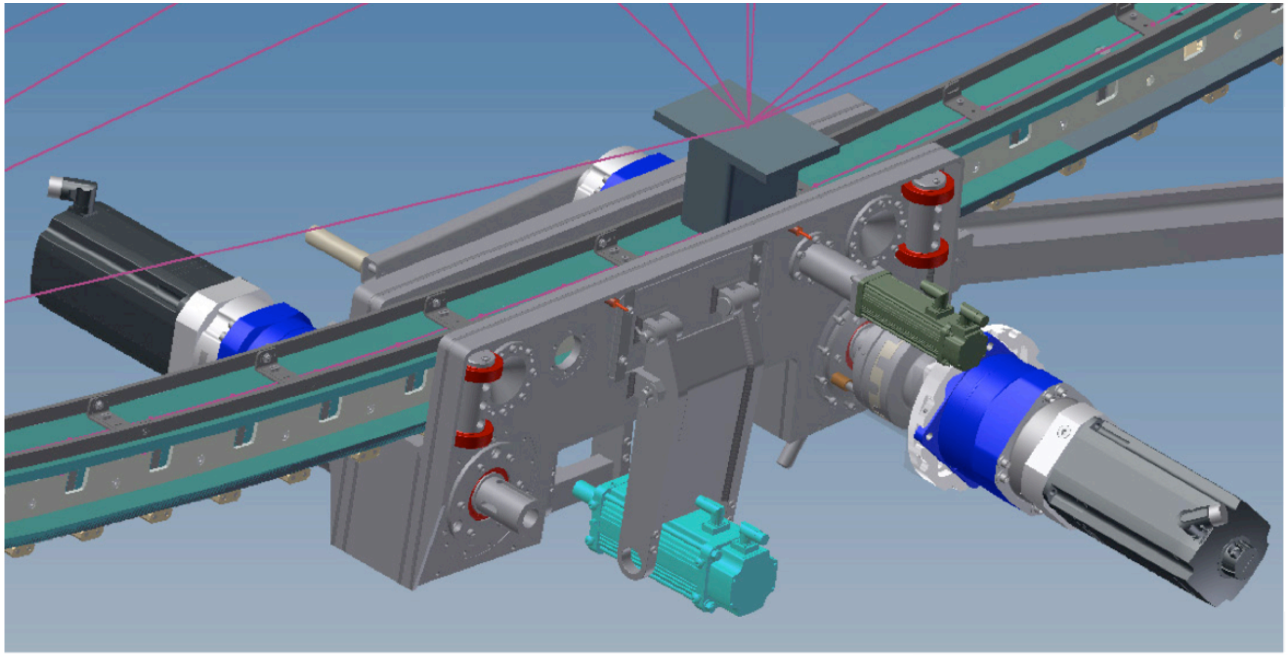


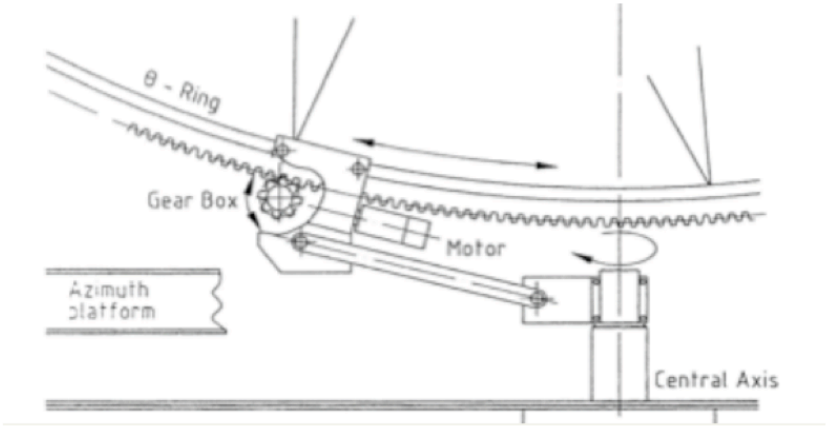


Test setup in IFAE workshop



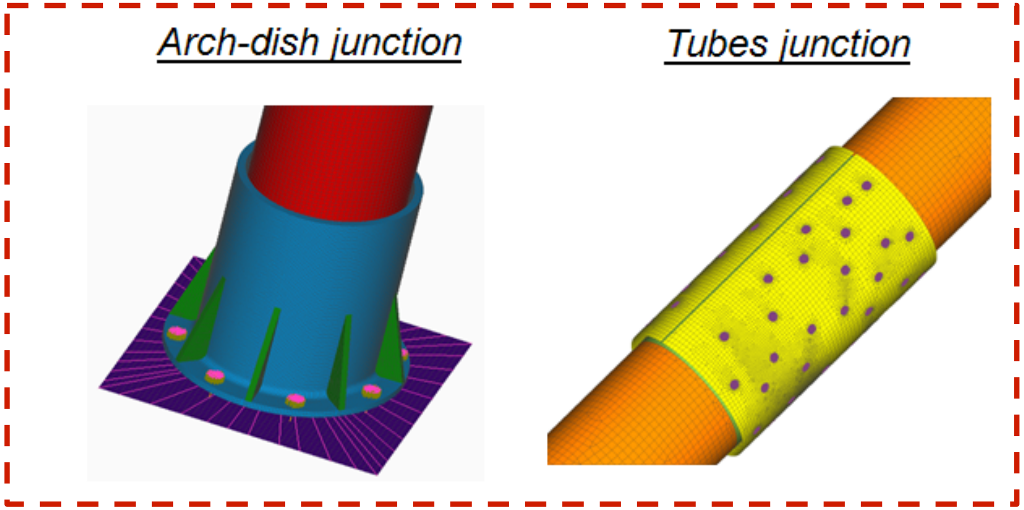
Elevation drive: MPI

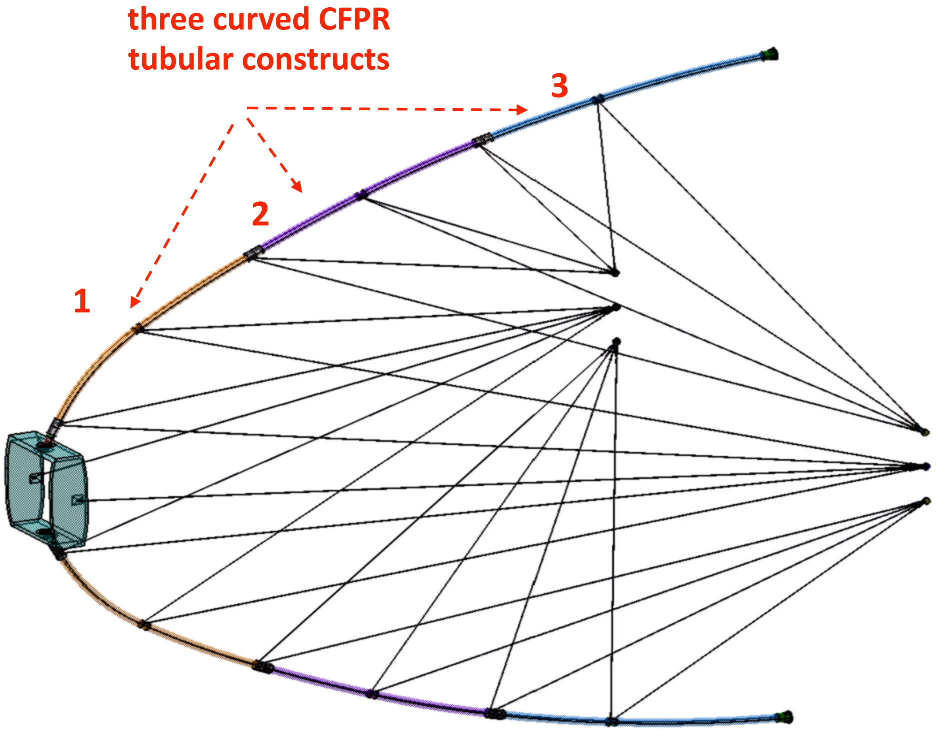




Compression tests of elements

The Arch-dish junction and the tubes junction have been tested in compression tests



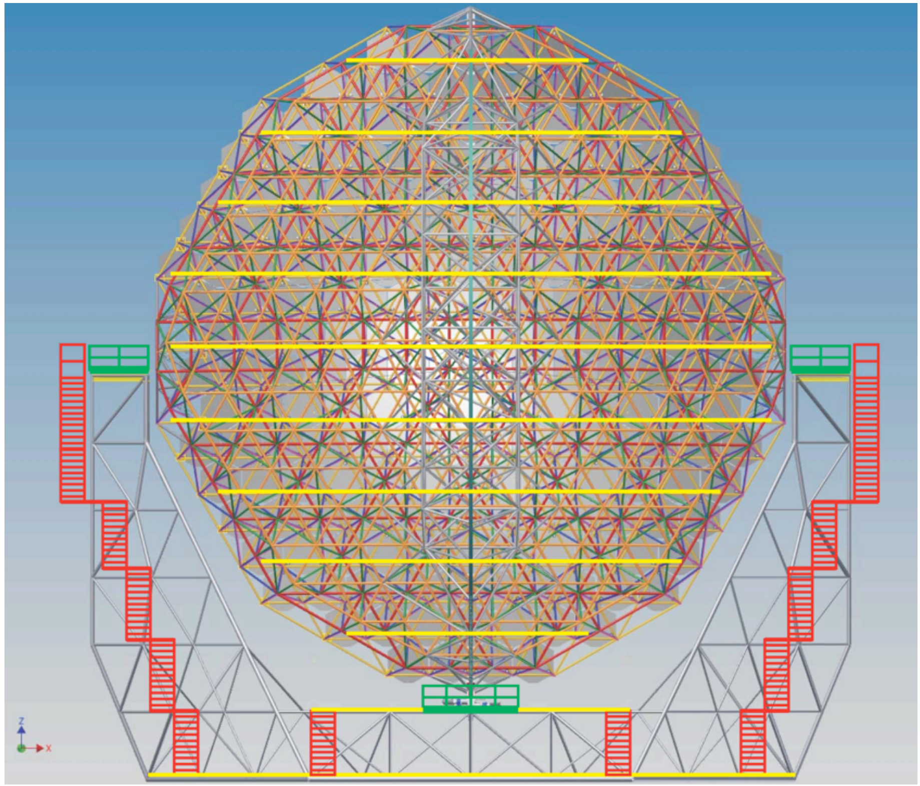


The result:

- The tube junction broke at 400t load
- The Arch-dish junction showed first cracks at 100t, maximum was 260t

The load that the arch dish junction has to survive each is about 30t. This is a safety factor of 3

Catwalks and safety access

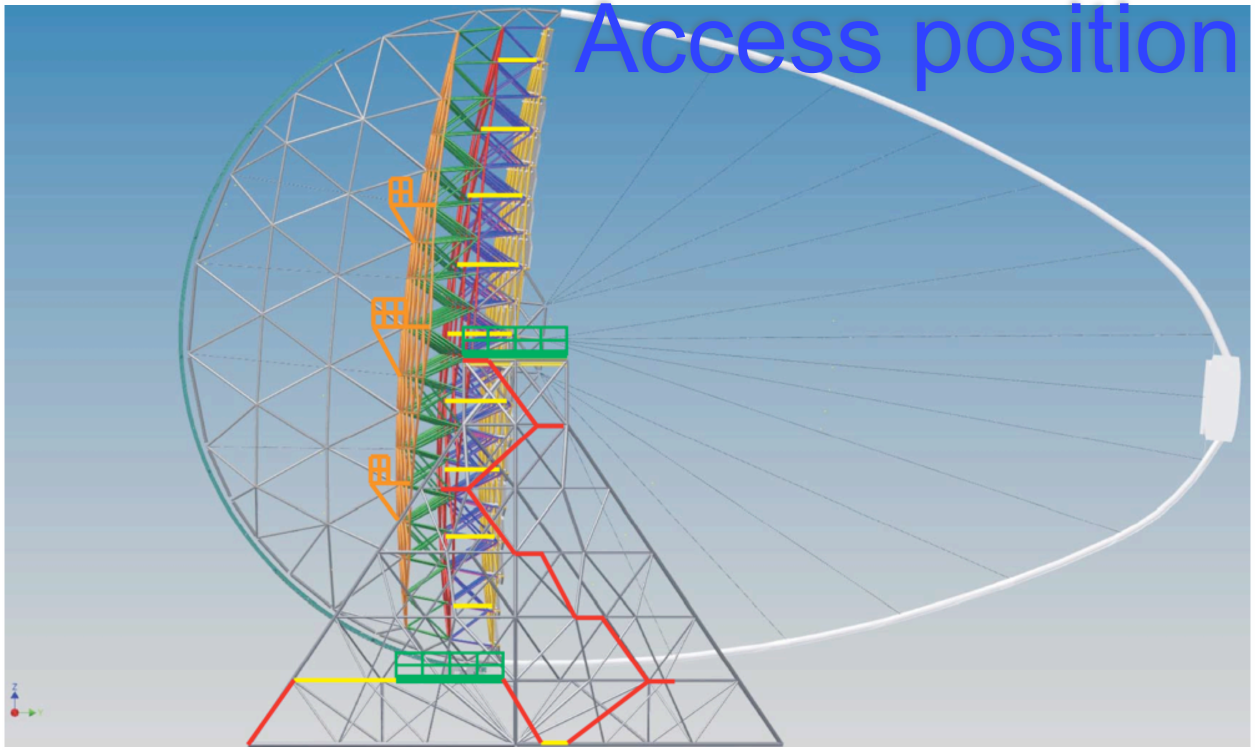


- The main access is over several etages of staircases on the left and right tower in the understructure.

- There will be 9 catwalks inside the dish, also connected by staircases or ladders

- There will be 3 catwalks on the backside of the dish for comfortable moving and transporting of heavy items.

- All access will be designed for maximal human safety



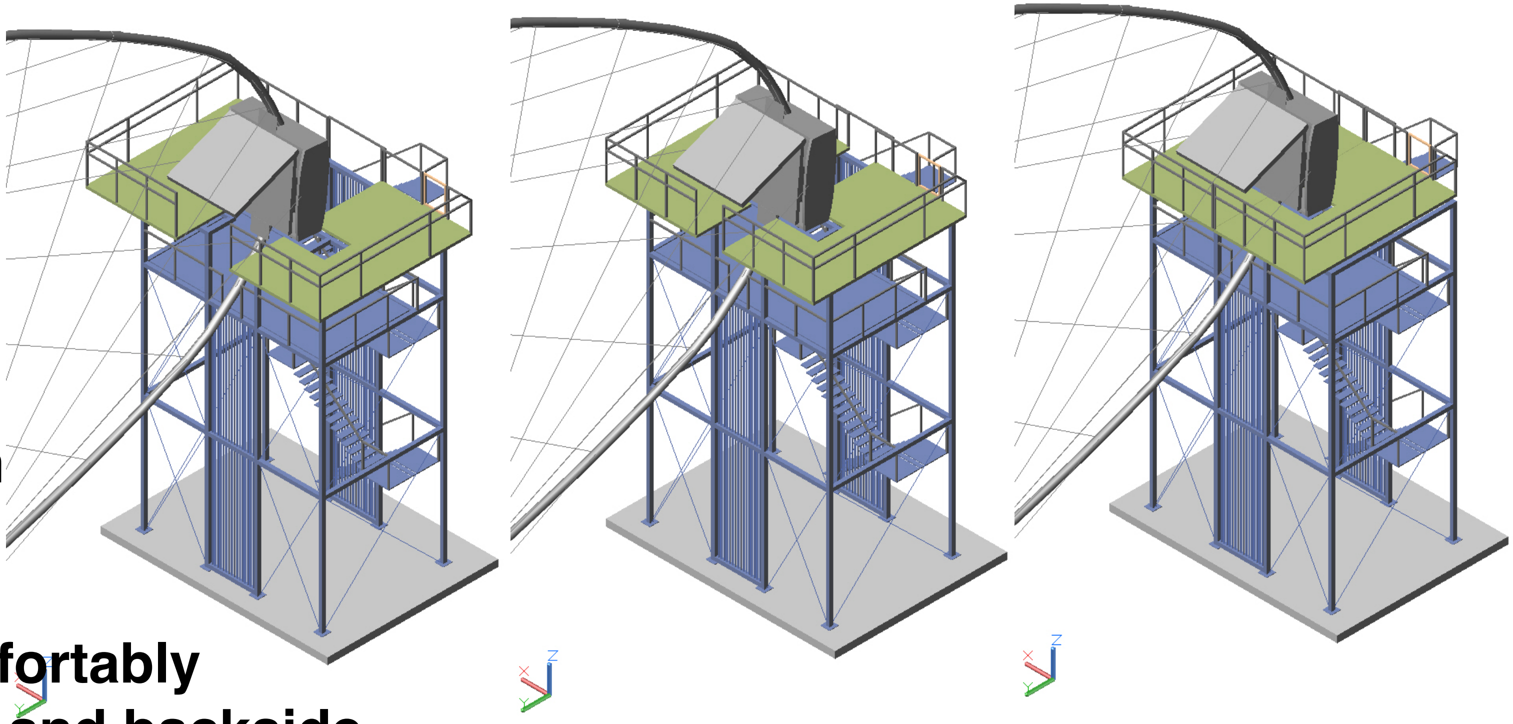
Access to the camera and design of access tower

- During the parking procedure, the platform closes from left and right side.
- The entrance to the platform is secured by a key-locking-system

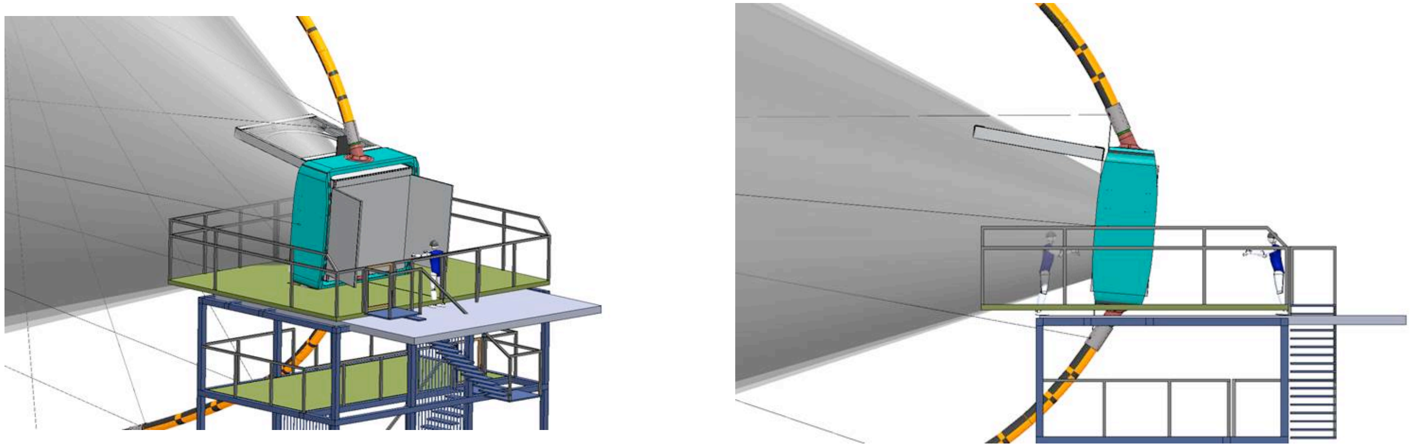
- The camera can be comfortably accessed from the front and backside

- All access will be designed for maximal human safety

Camera locking sequence



Camera access

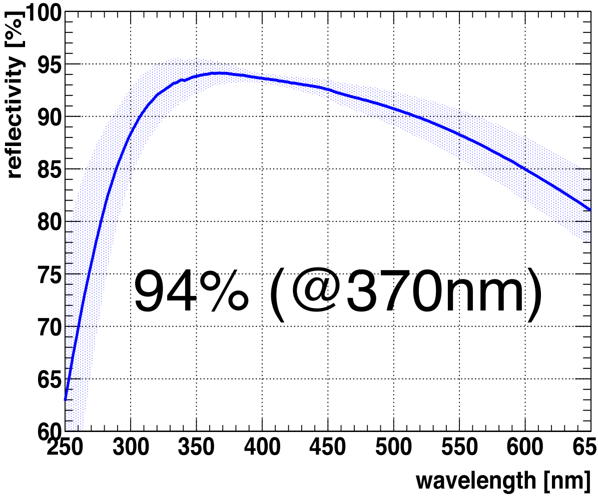


LST Mirrors of 1510 mm and
Dynamic AMC System (actuators and CCD Camera)

Specifications

- R: 56.0 – 58.4 m
- D80(@1f) : 16.6mm (1/3 pixel)
- Weight: 47 kg

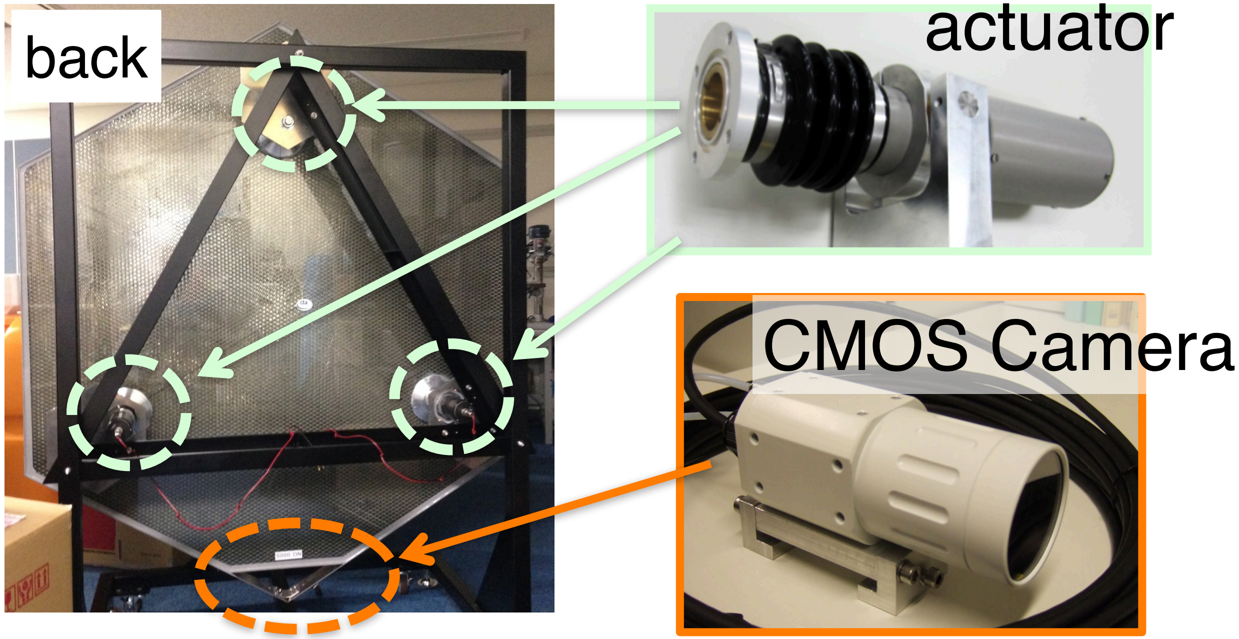
Mirror coating: Sputtering ($Cr+Al+SiO_2+HfO_2+SiO_2$)



Dynamical AMC System

IP68 CMOS Camera monitors the mirror direction within ±15 arcsec

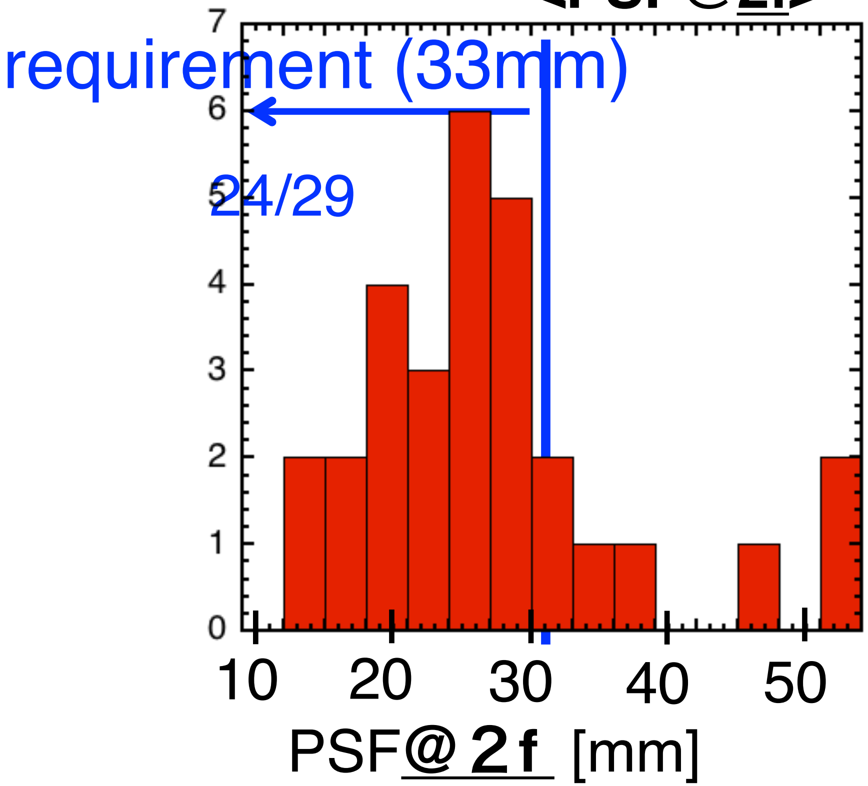
Actuators control the mirror facet direction with an accuracy of ±15 arcsec



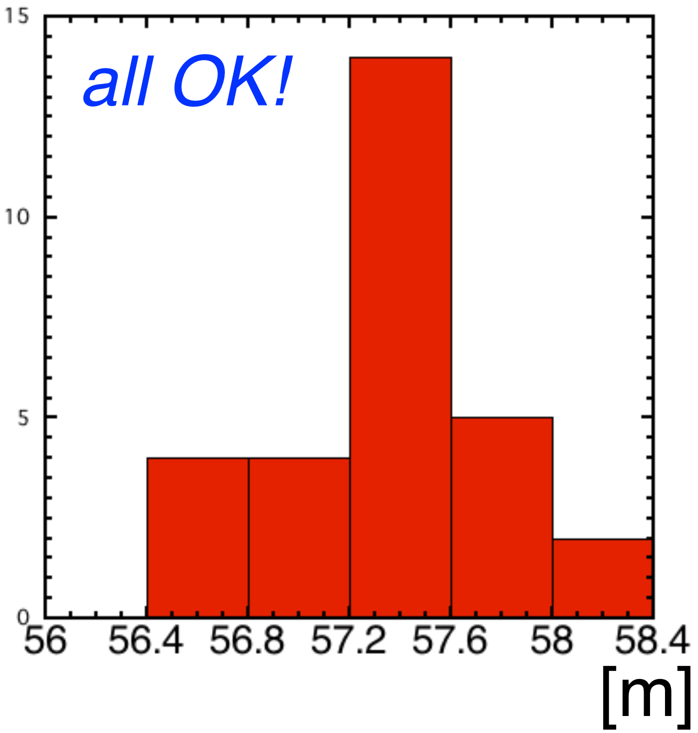
PSF (D80) and Radius of curvature

- Results of 29 mirrors based on PMD measurements
- The reproducibility radius if curvature : ΔR~0.3m

<PSF@2f>



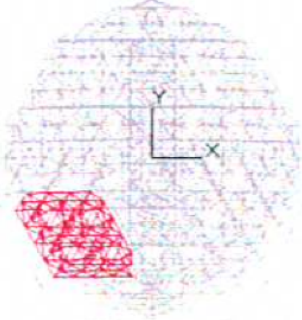
<curvature radius>

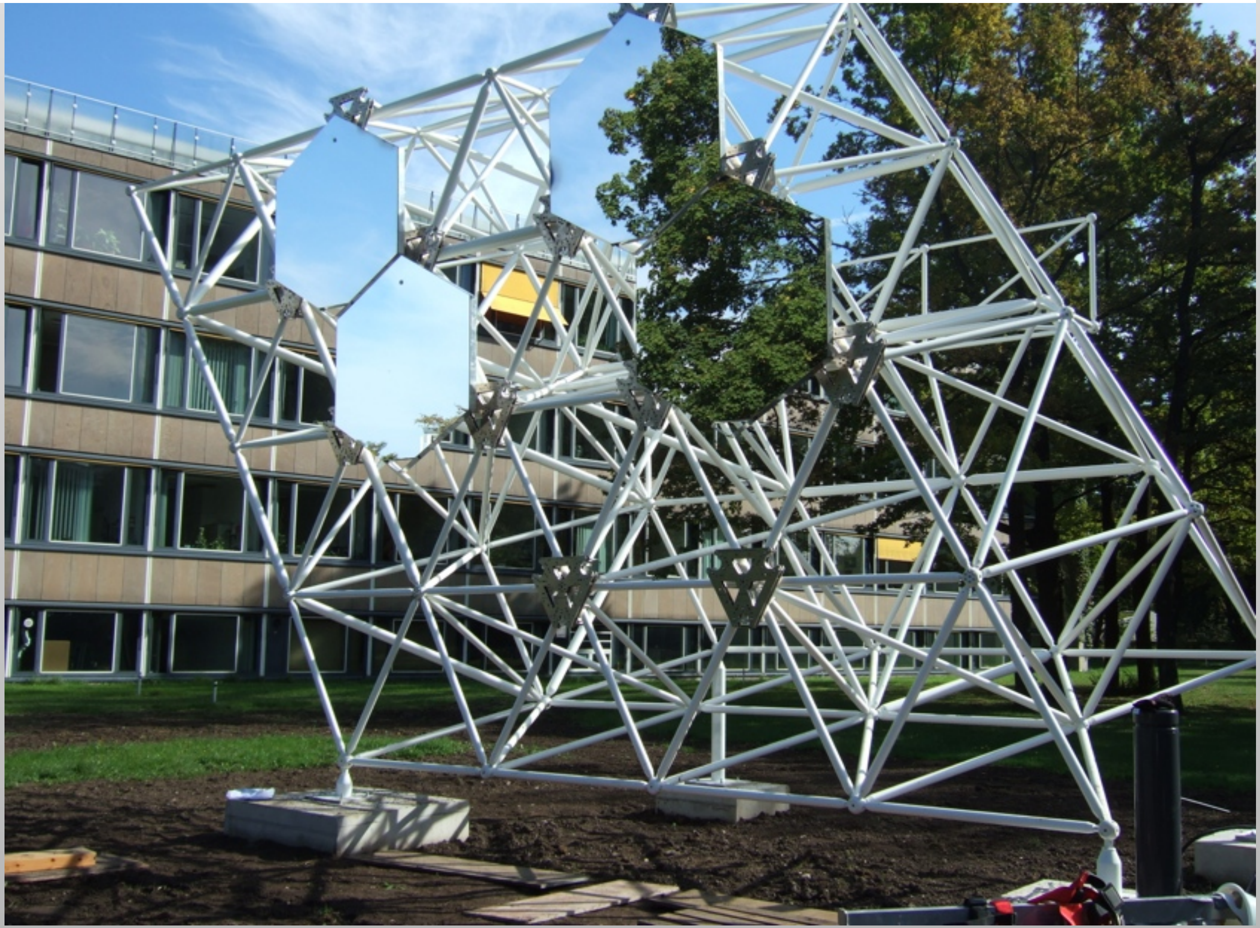


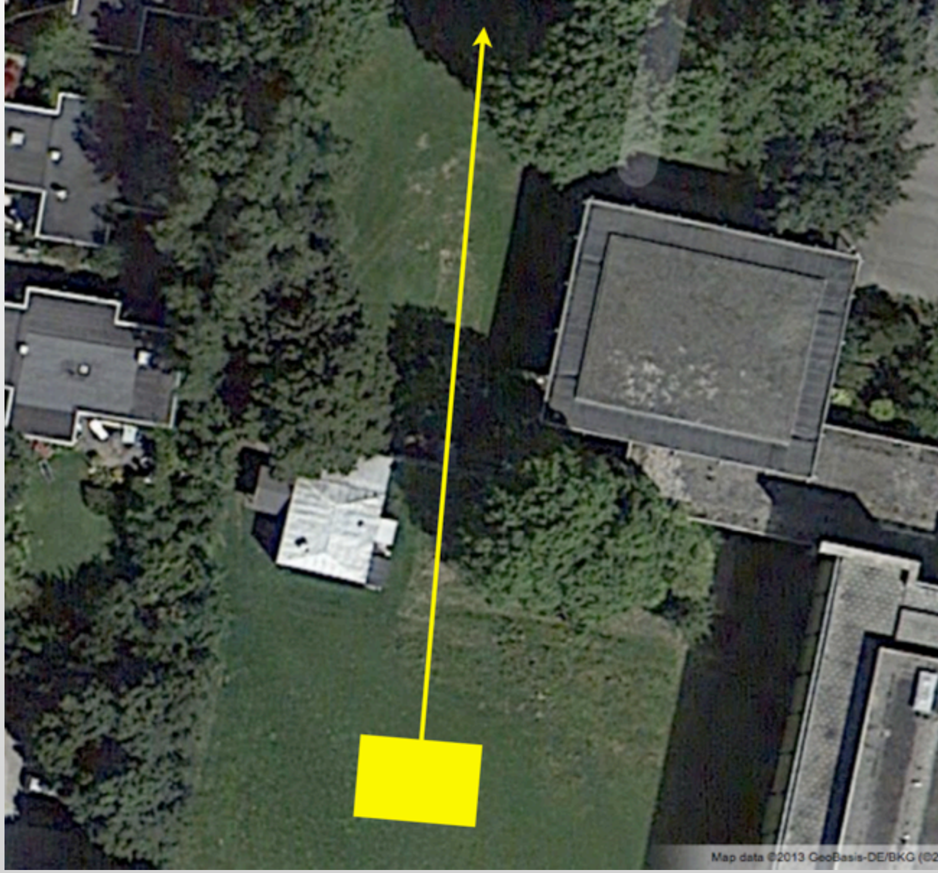
the company had already improved their technique

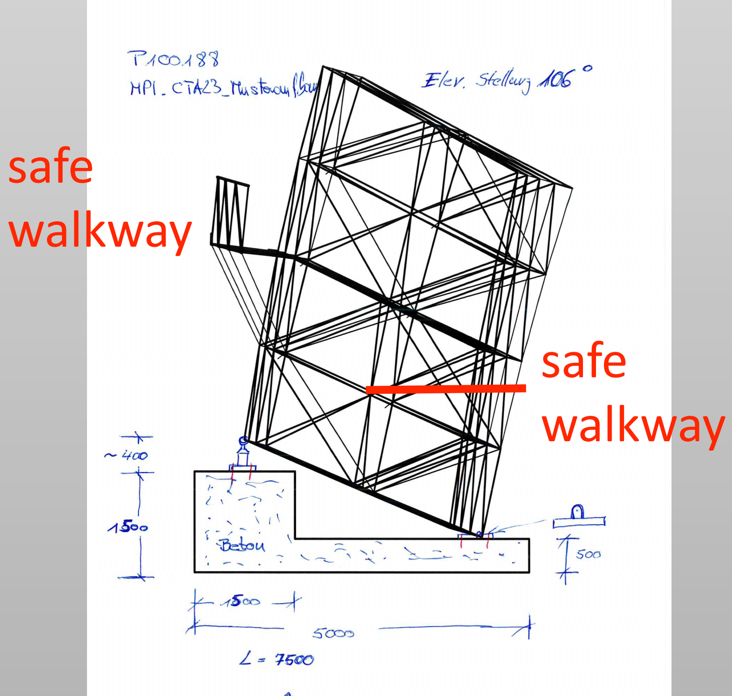
Much better yield rate can be expected for next productions

Segment of dish structure in MPI back yard: Testbed for mirror mounting, AMC control and design of catwalks and safe access









Testing mirror mounting procedure

Two Possibilities of mounting the interface plates

Fixing on tubes

Fixing only on knot, front and back

- Time needed to mount all interface plates on LST: 7 people, one week
- Time needed for mirror mounting: 5 people: 2.5 - 3 weeks

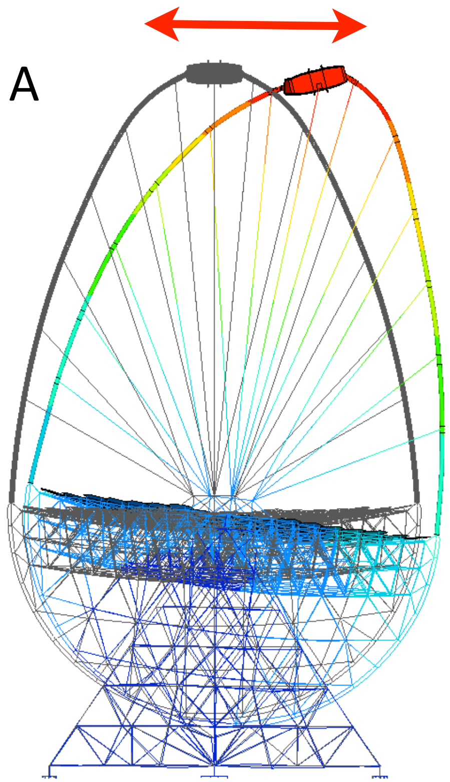
Mounting fix point on mirror

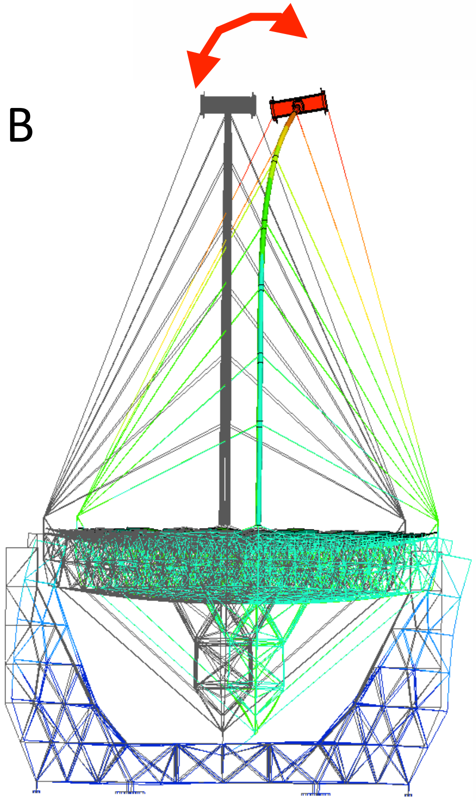
Mounting procedure

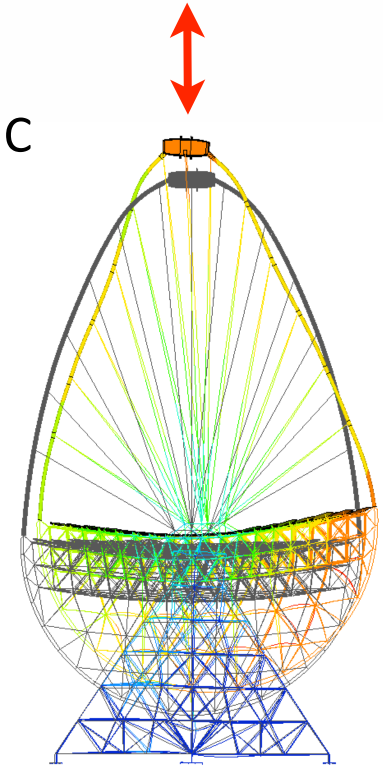
Dynamic FEA simulations

Summary of Fundamental Modes

	Mode Description	**Elevation**				
		0 deg	**30 deg**	**60 deg**	**90 deg**	**100 deg**
A	1st Lateral mode along elevation axis	1.678	1.673	1.663	1.664	1.772
B	1st Rotational mode about elevation axis	1.916	1.938	1.905	1.836	2.403
C	1st Vertical mode about zenith axis	3.451	3.342	3.384	3.376	

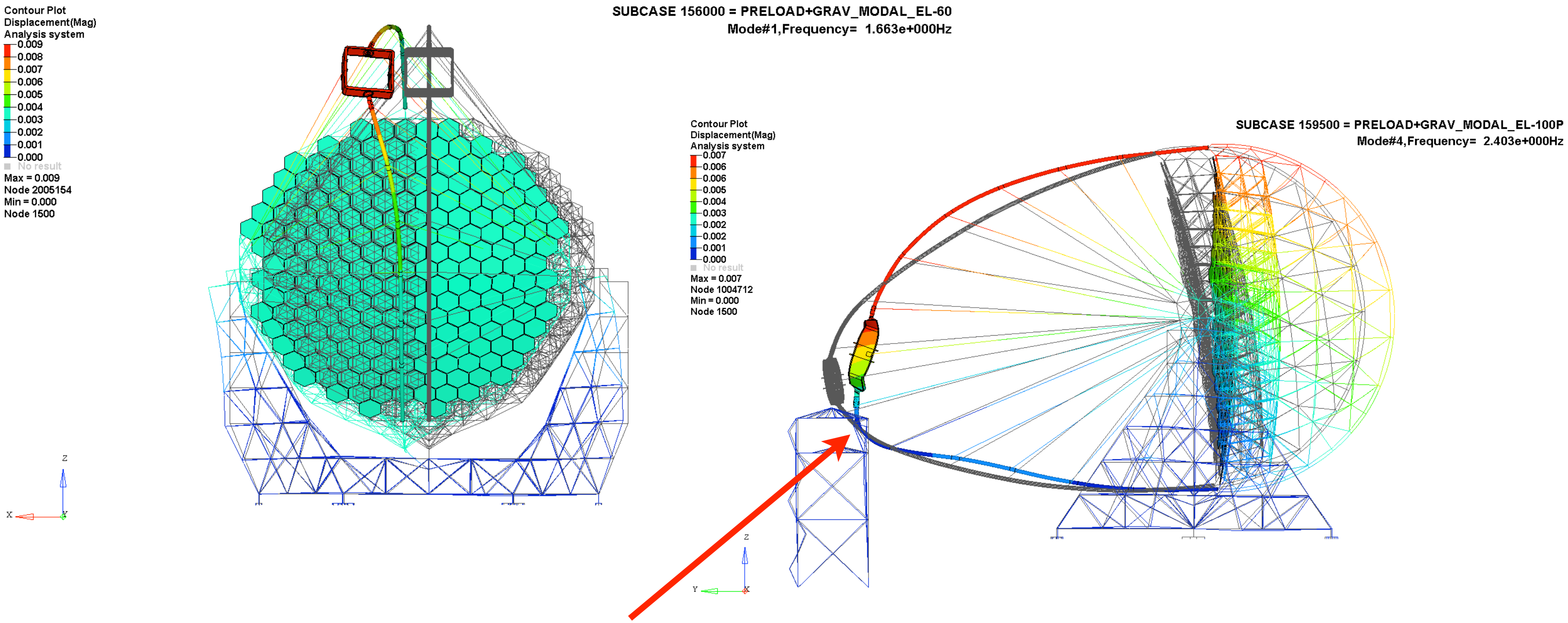






NATURAL MODES in parking position

Mode Description	Elevation				
	0 deg	30 deg	60 deg	90 deg	100 deg
1st Lateral mode along elevation axis	1.678	1.673	1.663	1.664	1.772
1st Rotational mode about elevation axis	1.916	1.938	1.905	1.836	2.403
1st Vertical mode about zenith axis	3.451	3.342	3.384	3.376	



Arch locking point at access tower

RESERVE FACTORS AND FAILURE INDICES
PRELOAD + GRAV + TEMP + WIND

GROUP	RF (PL+GRAV+TEMP+WIND) - LIM/ULT ENVELOPE				
	EL-00	EL-30	EL-60	EL-90	EL-100P
Ground Steel Tubes	2.73	2.77	2.84	2.85	1.17
Ground Steel Cones	3.18	3.17	3.10	2.99	1.71
Ground Steel Pins	1.85	1.85	1.81	1.76	1.08
Dish Steel Tubes	1.53	1.59	1.74	2.11	1.11
Dish Steel Cones	1.75	1.85	2.02	2.36	1.44
Dish Steel Pins	2.32	2.26	2.10	2.01	1.12
Elev Chain Steel	3.44	3.27	3.52	3.62	1.54
Dish Alu Tubes	4.72	4.75	4.75	4.76	4.27
Dish Alu Cones	5.13	5.03	5.15	5.15	4.52
Dish Alu Pins	1.28	1.06	1.32	1.34	1.11
Dish CFK Tubes	8.76	8.45	8.08	7.64	5.53
Dish CFK Cones	4.16	4.01	3.74	3.17	2.13
Dish CFK-Alu Pins	1.47	1.59	1.44	1.37	1.07
Tower Structure	9.41	9.41	9.41	9.41	3.10

FAILURE INDEX	F.I. MAX						MAX VALUE
	EL-00	EL-30	EL-60	EL-90	EL-100P	EL-100P ICE	
TSAI-WU	0.321	0.380	0.460	0.586	0.920	0.728	0.920
ILS	0.287	0.326	0.458	0.555	0.838	0.583	0.838

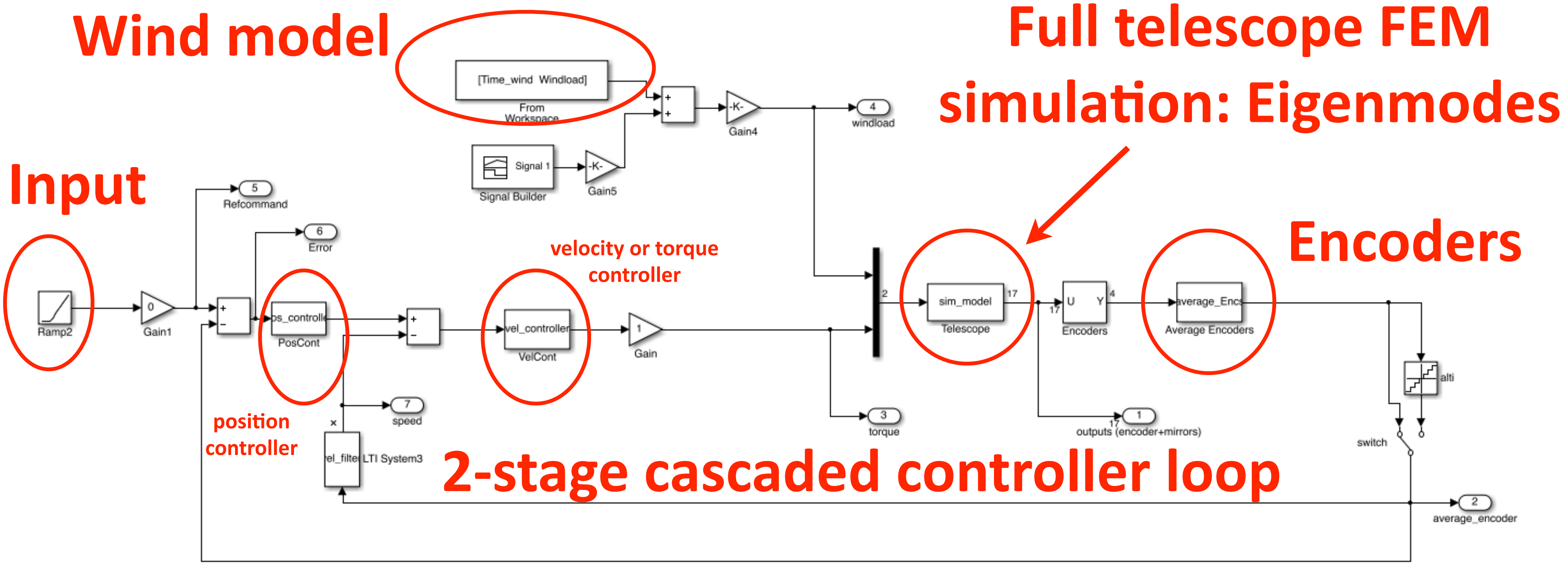
No problems in design

RESPONSE TO SEISMIC ACCELERATION

PEAK RESPONSES				
COMPONENT	NODE ID	MAX ACC [g]	LOAD CASE	NOTE
CENTRAL PIN 4	1500	0.01	SEISMIC EL=0° AZ = 0°	OUTPUT IN GLOBAL COORD
HEAVY BOGIE 5	1501	0.45	SEISMIC EL=0° AZ = 0°	*OUTPUT IN CYLINDRICAL COORD*
LIGHT BOGIE 7	1502	0.40	SEISMIC EL=30° AZ = 0°	*OUTPUT IN CYLINDRICAL COORD*
LIGHT BOGIE 6	1503	0.40	SEISMIC EL=30° AZ = 0°	*OUTPUT IN CYLINDRICAL COORD*
HEAVY BOGIE 3	1504	0.45	SEISMIC EL=0° AZ = 0°	*OUTPUT IN CYLINDRICAL COORD*
LIGHT BOGIE 1	1505	0.42	SEISMIC EL=100° PARKED AZ = 0°	*OUTPUT IN CYLINDRICAL COORD*
LIGHT BOGIE 2	1506	0.42	SEISMIC EL=100° PARKED AZ = 0°	*OUTPUT IN CYLINDRICAL COORD*
CAMERA	**2000**	**4.30**	**SEISMIC EL=90° AZ = 90°**	OUTPUT IN GLOBAL COORD
ELEVATION AXIS (+X)	2001	1.13	SEISMIC EL=100° PARKED AZ = 0°	OUTPUT IN GLOBAL COORD
ELEVATION AXIS (-X)	2002	1.12	SEISMIC EL=100° PARKED AZ = 0°	OUTPUT IN GLOBAL COORD
ARCH-DISH INTERFACE (-Y)	2003	2.04	SEISMIC EL=100° PARKED AZ = 90°	OUTPUT IN GLOBAL COORD
ARCH-DISH INTERFACE (+Y)	2004	1.70	SEISMIC EL=0° AZ = 90°	OUTPUT IN GLOBAL COORD
ARCH CONSTRAINT (EL-100P ONLY)	5100	1.65	SEISMIC EL=100° PARKED AZ = 90°	OUTPUT IN GLOBAL COORD
ELEVATION DRIVE	10XXX	1.48	SEISMIC EL=60° AZ = 90°	OUTPUT IN GLOBAL COORD
CENTRAL MIRROR	20000	1.30	SEISMIC EL=100° PARKED AZ = 90°	OUTPUT IN GLOBAL COORD
ELEVATION DRIVE SUPPORT	405005	0.79	SEISMIC EL=0° AZ = 90°	OUTPUT IN GLOBAL COORD
TOWER TOP	5000101	1.34	SEISMIC TOWER ALONE AZ = 0°	OUTPUT IN GLOBAL COORD

Control analysis, design and simulation for large LST telescope

- Simulation of the telescope structure in closed-loop
- Tracking, response to wind load, servo control imperfections and noise, deformation of optical elements such as M1 and Camera
- Using FEM dynamical models for design and simulation of the axes
- Using Matlab/Simulink for controller design and closed-loop simulation of axes
- Verify the dynamic responses and estimate motions of different elements of the telescope structure, e.g. M1, Camera, central axis etc.



Wind model

Input

Full telescope FEM simulation: Eigenmodes

Encoders

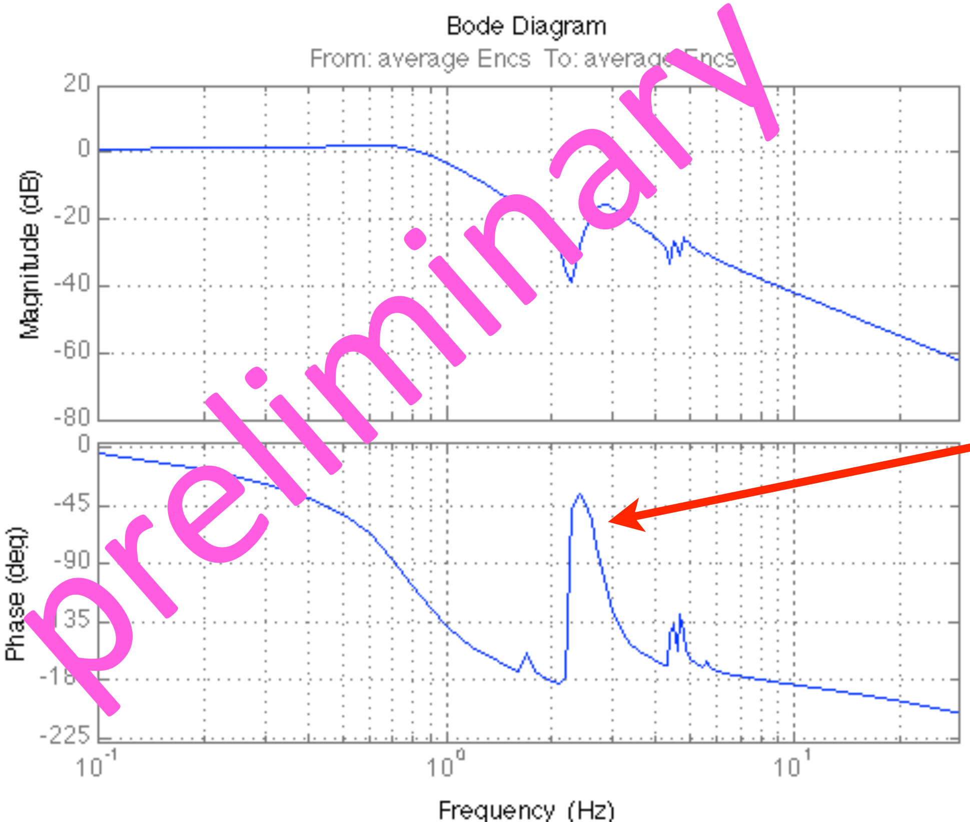
velocity or torque controller

position controller

2-stage cascaded controller loop

The control diagram (using Simulink)

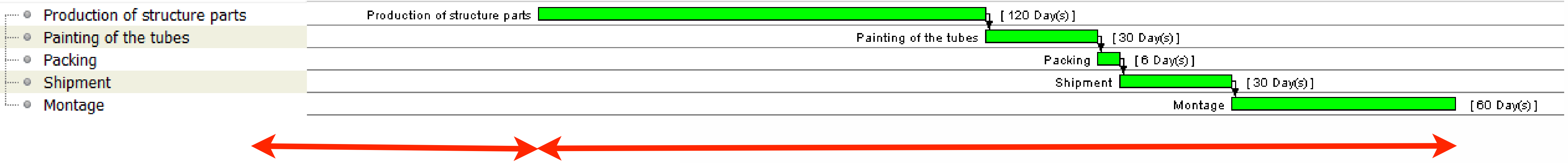
- **Example: Azimuth axis control**
- Master/slave control of bogies (4 motors) based on a cascaded velocity and position control loops
- Average encoder reading of 4 motors is used as velocity and position feedback signals and the control command is applied similarly on all motors
- FEM model: Open-loop frequency response for controller design
- Design PI controllers for velocity and position loops with standard robustness margins
- A closed-loop bandwidth of about 1Hz



Oscillations may start at Eigenmode frequencies of the telescope, if not correctly designed

Tendering and ordering

- The tendering started end of November. The lawyers of the Max-Planck-Society have recommended a limited tendering consisting of an announcement of intent at European level, followed by negotiations with companies that fullfill certain criteria afterwards. It is aimed to order the structure in January or February.
- We are now waiting for the response of several companies that show interest in the construction of the LST structure.
- The approximate schedule is the following



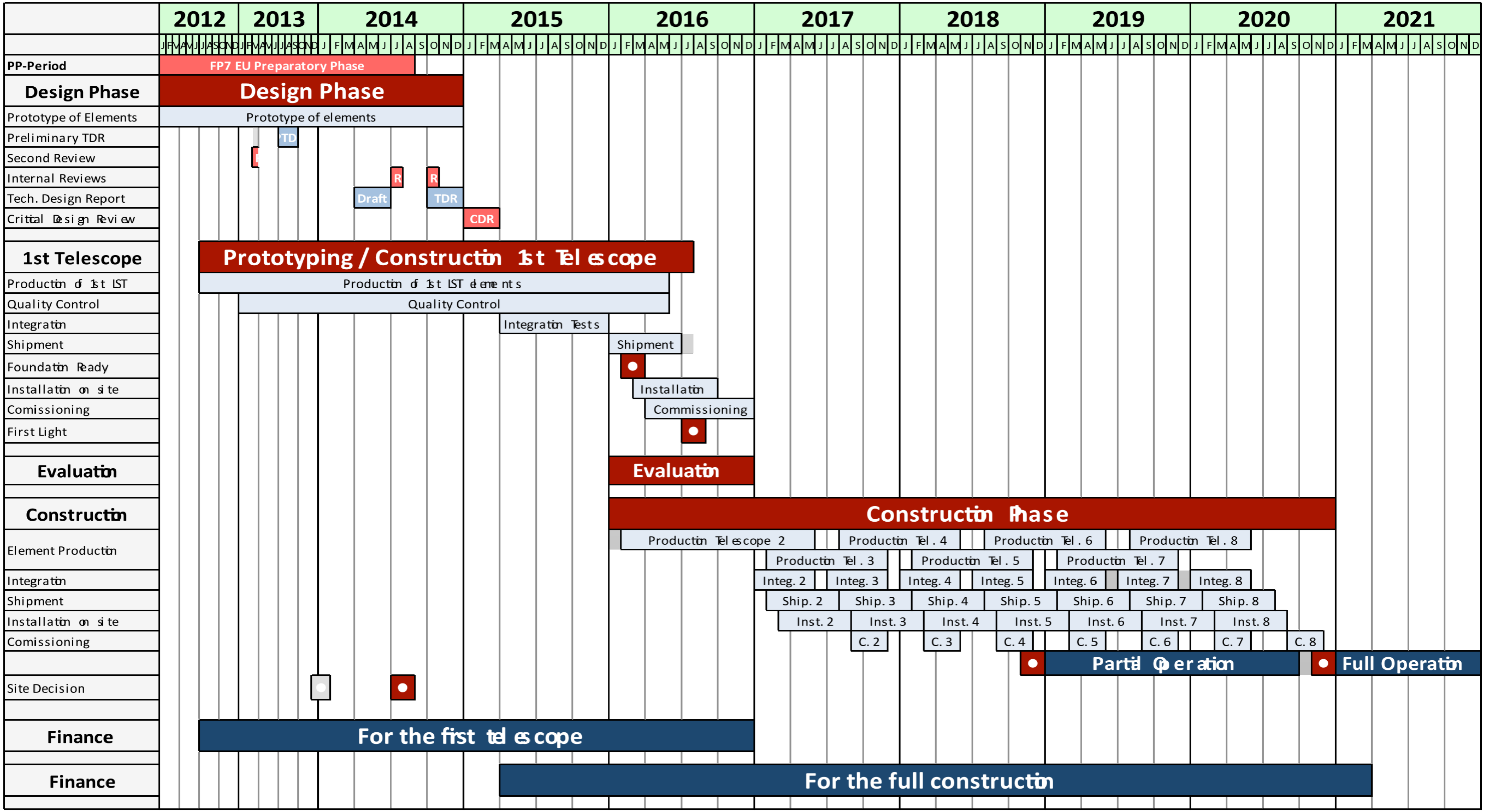
detail design 4-5 months

production and shipment about 8-9 months

- If we order end of January 2015 we could install it around April 2016

Schedule of the LST construction

LST Construction (June 2014)



2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

PP-Period: FP7 EU Preparatory Phase

Design Phase: Design Phase
- Prototype of Elements: Prototype of elements
- Preliminary TDR: TD
- Second Review
- Internal Reviews: R, R
- Tech. Design Report: Draft, TDR
- Critical Design Review: CDR

1st Telescope: Prototyping / Construction 1st Telescope
- Production of 1st LST: Production of 1st LST elements
- Quality Control: Quality Control
- Integration: Integration Tests
- Shipment: Shipment
- Foundation Ready: ●
- Installation on site: Installation
- Comissioning: Commissioning
- First Light: ●

Evaluation: Evaluation

Construction: Construction Phase
- Element Production: Production Telescope 2, Production Tel. 3, Production Tel. 4, Production Tel. 5, Production Tel. 6, Production Tel. 7, Production Tel. 8
- Integration: Integ. 2, Integ. 3, Integ. 4, Integ. 5, Integ. 6, Integ. 7, Integ. 8
- Shipment: Ship. 2, Ship. 3, Ship. 4, Ship. 5, Ship. 6, Ship. 7, Ship. 8
- Installation on site: Inst. 2, Inst. 3, Inst. 4, Inst. 5, Inst. 6, Inst. 7, Inst. 8
- Comissioning: C. 2, C. 3, C. 4, C. 5, C. 6, C. 7, C. 8
- ● Partial Operation ● Full Operation

Site Decision: ●

Finance: For the first telescope

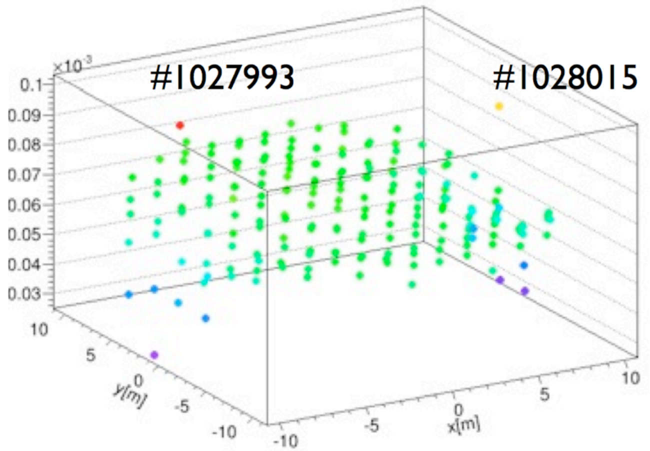
Finance: For the full construction

The end

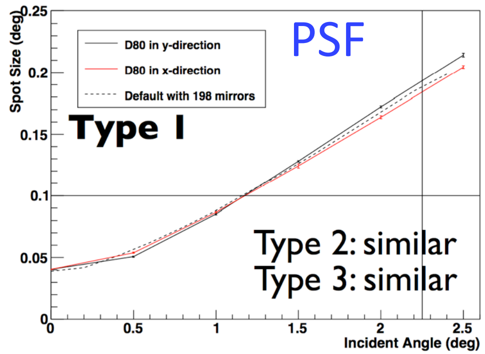
Worsening of optical PSF and POINTING due to static deflection and dynamical excitation of the dish for operational wind speed by Koji Noda

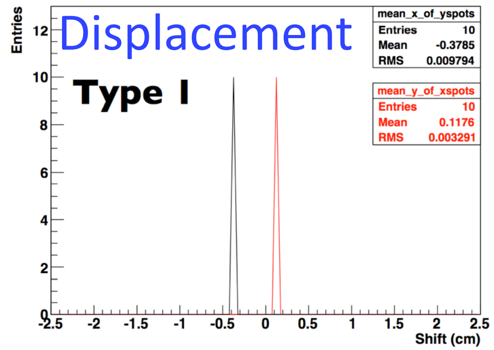
- The dynamic response of the structure during operational wind speed (up to 60 km/h) has been studies
- The influence of the wind induces vibrations in the dish and static displacements
- Results:
  - The vibrations of the mirrors do not significantly worsen the optical PSF
  - There is static displacement of the camera as well as due to the dish, but it can be corrected by the LST pointing alignment system and starguider

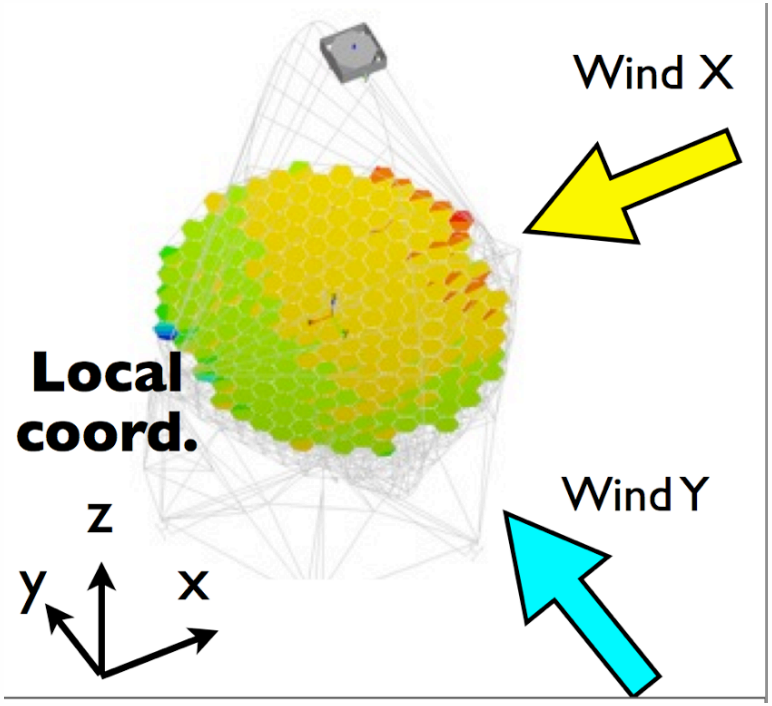
Static deflection

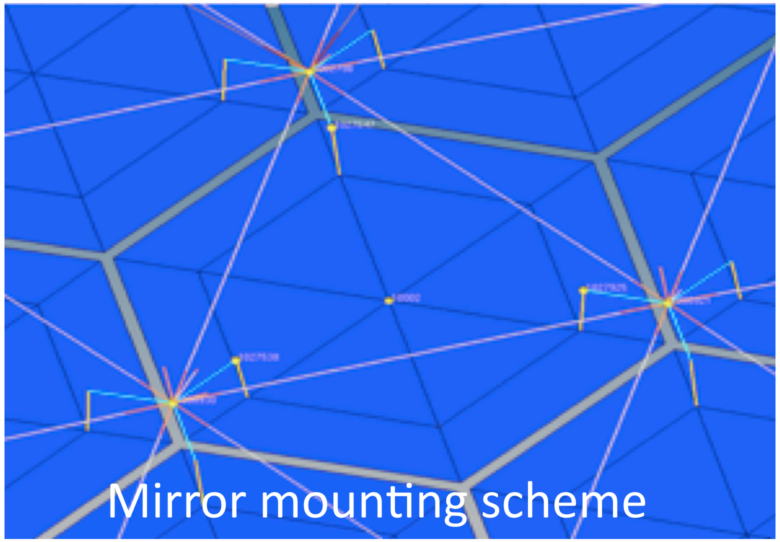


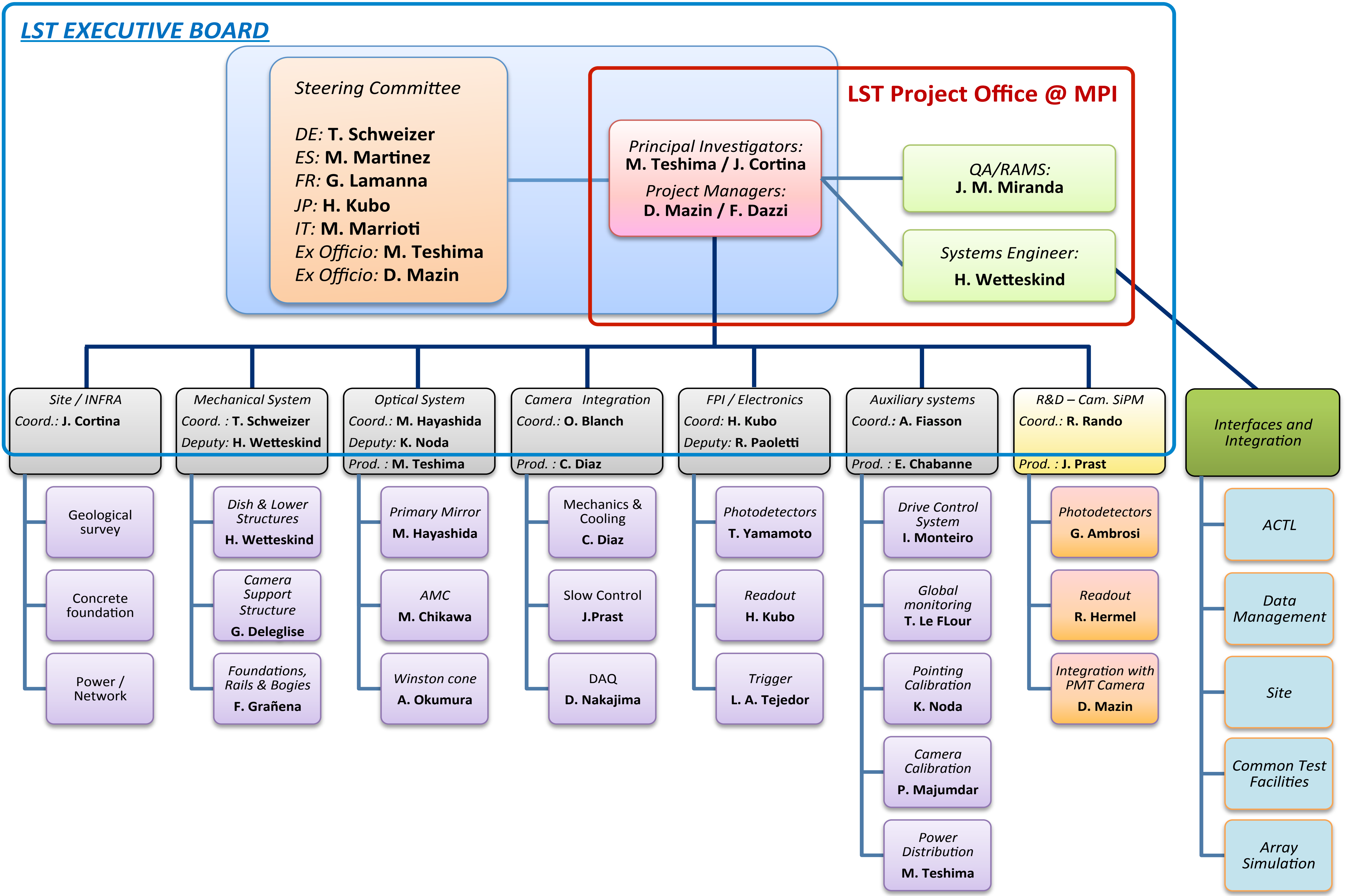
Dynamic excitation








Mirror mounting scheme



LST EXECUTIVE BOARD

Steering Committee

DE: **T. Schweizer**
ES: **M. Martinez**
FR: **G. Lamanna**
JP: **H. Kubo**
IT: **M. Marrioti**
Ex Officio: **M. Teshima**
Ex Officio: **D. Mazin**

LST Project Office @ MPI

Principal Investigators:
M. Teshima / J. Cortina
Project Managers:
D. Mazin / F. Dazzi

QA/RAMS:
J. M. Miranda

Systems Engineer:
H. Wetteskind

Site / INFRA
Coord.: **J. Cortina**

- Geological survey
- Concrete foundation
- Power / Network

Mechanical System
Coord. : **T. Schweizer**
Deputy: **H. Wetteskind**

- *Dish & Lower Structures* **H. Wetteskind**
- *Camera Support Structure* **G. Deleglise**
- *Foundations, Rails & Bogies* **F. Grañena**

Optical System
Coord.: **M. Hayashida**
Deputy: **K. Noda**
Prod. : **M. Teshima**

- *Primary Mirror* **M. Hayashida**
- *AMC* **M. Chikawa**
- *Winston cone* **A. Okumura**

Camera Integration
Coord.: **O. Blanch**
Prod. : **C. Diaz**

- Mechanics & Cooling **C. Diaz**
- Slow Control **J.Prast**
- DAQ **D. Nakajima**

FPI / Electronics
Coord: **H. Kubo**
Deputy: **R. Paoletti**

- *Photodetectors* **T. Yamamoto**
- *Readout* **H. Kubo**
- *Trigger* **L. A. Tejedor**

Auxiliary systems
Coord.: **A. Fiasson**
Prod. : **E. Chabanne**

- *Drive Control System* **I. Monteiro**
- *Global monitoring* **T. Le FLour**
- *Pointing Calibration* **K. Noda**
- *Camera Calibration* **P. Majumdar**
- *Power Distribution* **M. Teshima**

R&D – Cam. SiPM
Coord.: **R. Rando**
Prod. : **J. Prast**

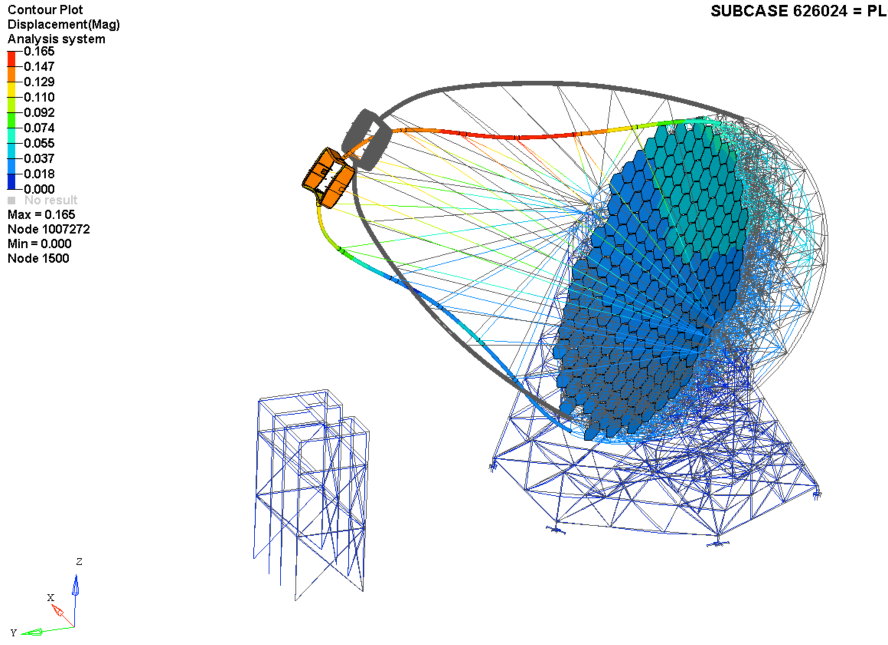
- *Photodetectors* **G. Ambrosi**
- *Readout* **R. Hermel**
- *Integration with PMT Camera* **D. Mazin**

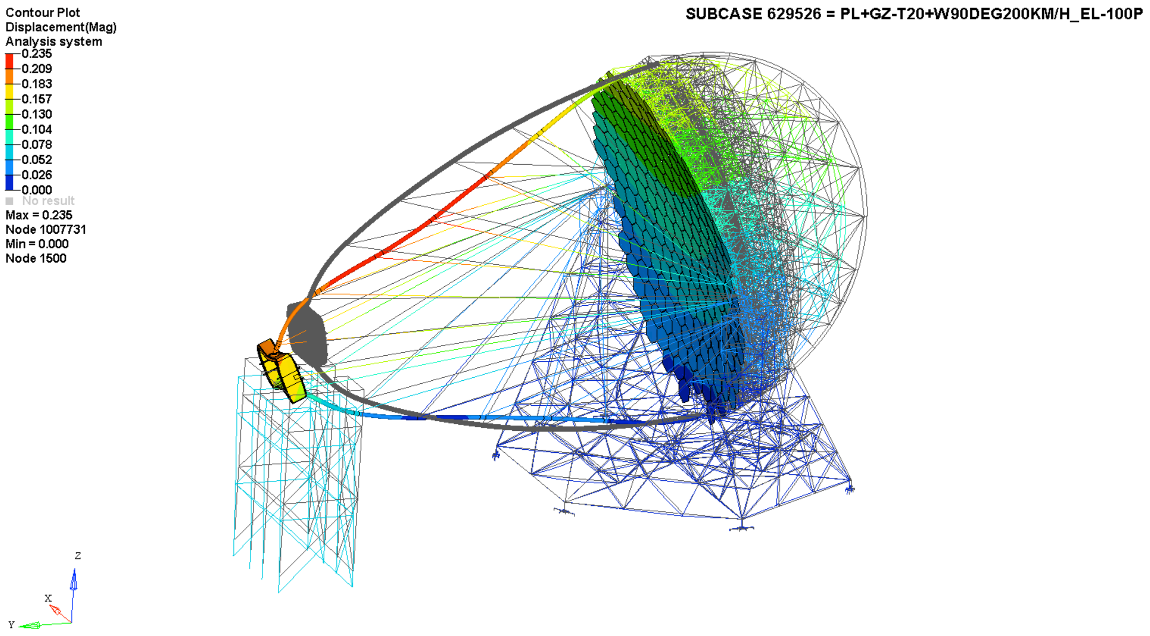
Interfaces and Integration

- *ACTL*
- *Data Management*
- *Site*
- *Common Test Facilities*
- *Array Simulation*

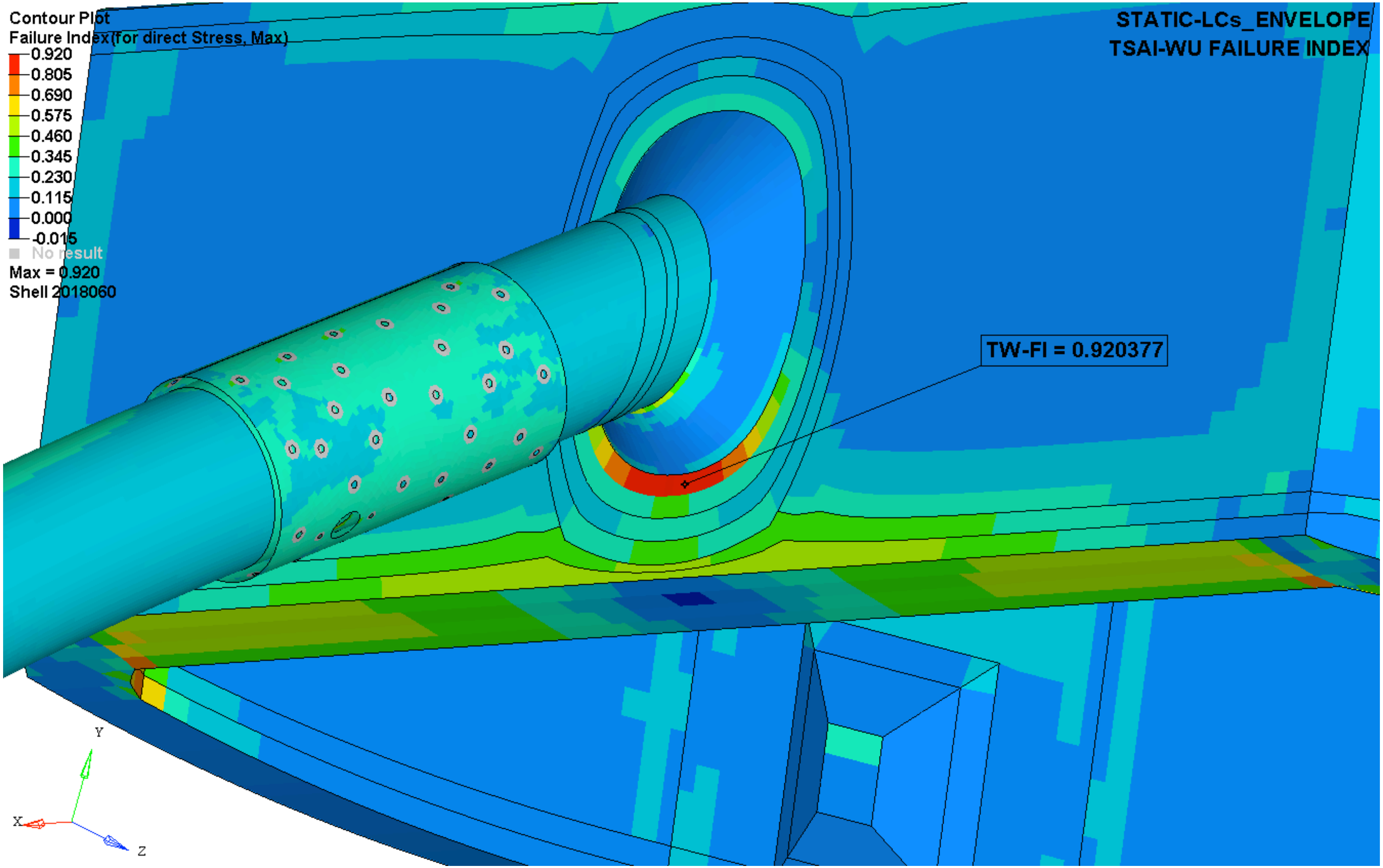
ENVELOPE DISPLACEMENTS

Load Case	Elevation (deg)	Displacement (mm)
Preload + Gravity + Wind 83.5 km/h (limit and ultimate LCs)	0	104
	60	165
Preload + Gravity + Wind 200 km/h (limit and ultimate LCs)	100	235

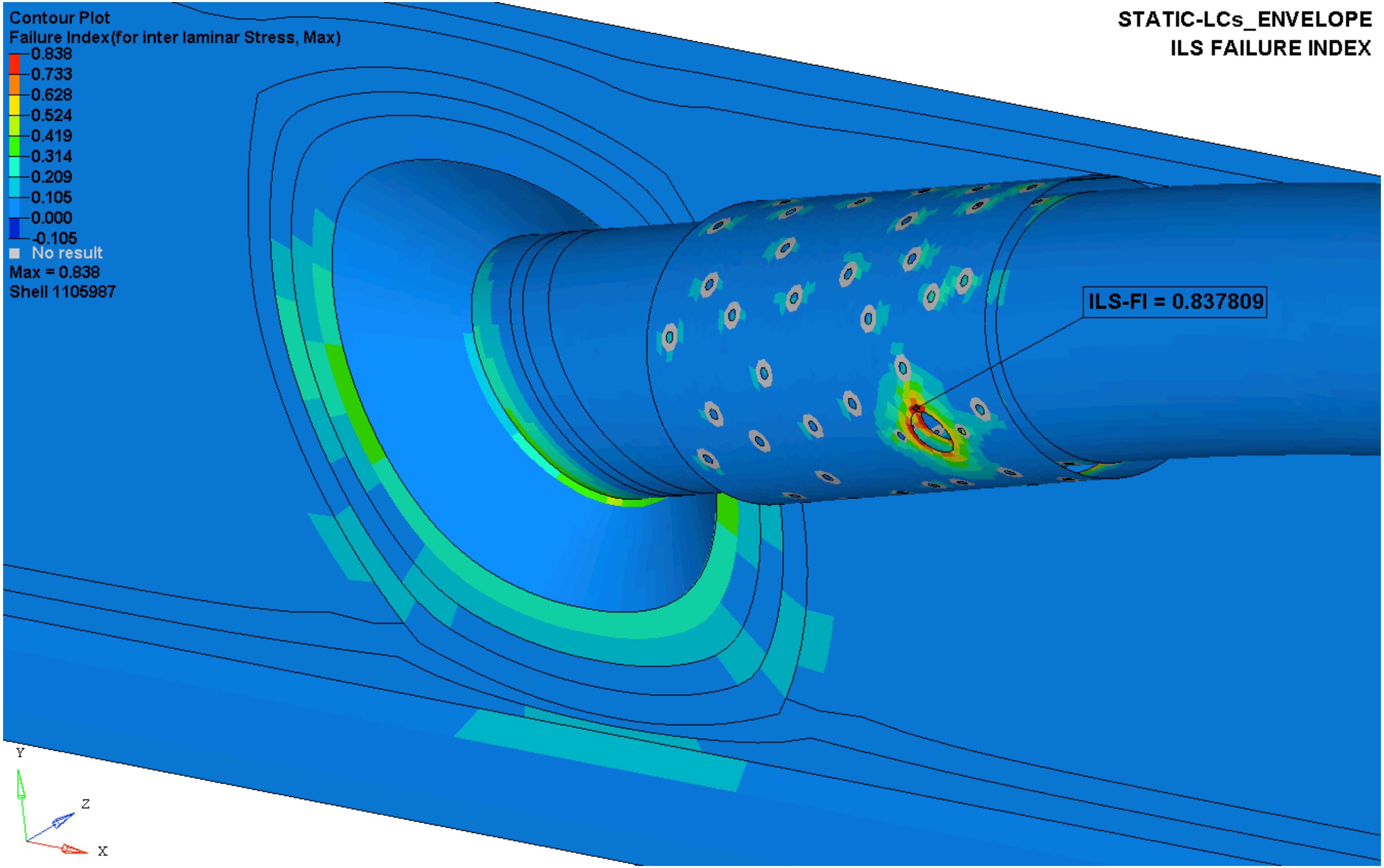




ENVELOPE - *ARCH & CAMERA TSAI-WU F.I. (detail)*



ENVELOPE - *ARCH & CAMERA ILS F.I. (detail)*



Conclusions Finite element analysis

- The all over FEM simulations are in good shape now, no weak points apart from the chain fixation of the elevation drive.
- The arch and frame have been simulated with a detailed model including all layers of carbon fibre. This was important for the arch-frame connection.
- The arch frame connection can hold the very high acceleration of 4.3g during an earthquake in Chile. But, to be safe, a force-release mechanism will be built in at the elevation drive, such that the elevation eigenmode is less excited during earthquake.
- The arch will be locked at the arch below the camera frame with a certain freedom in direction of the optical axis.
- The dish is pushed back by about 24cm during storm.
- The access tower bends by about 10cm during storm.
  The arch will be fixed by a spring and a damping mechanism, that allows about 10cm movement during maximal forces of the storm wind gusts