MST Status And Plans

Including Drive And Safety Systems

Stefan Schlenstedt, DESY

CTA-SCT Meeting

SLAC, February 24, 2012

cta cherenkov telescope array

HELMHOLTZ ASSOCIATION

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MST Requirements And Design Parameters

Agreements in meetings of WP TEL (2009-2010) → Level A: Preliminary CTA System Requirements and Level B: Preliminary Sub-system Performance Requirements (Mar 27, 2011) → Requirements review will evaluate if the performance requirements for the system and sub−systems are complete and adequate to define CTA at the corresponding level (Mar 27, 2012) → CTA Requirements Level A, B, C...

- Dish diameter 12m ≙ 100m^2 mirror
- Focal length F 16m
- Dish curvature radius 19.2m (= 1.2×F)
- Camera FoV: 7-8^o ≙ 2.5 tons
- Angular pixel pitch: ~ 0.18^o

MST Requirements/Specifications Cont'd

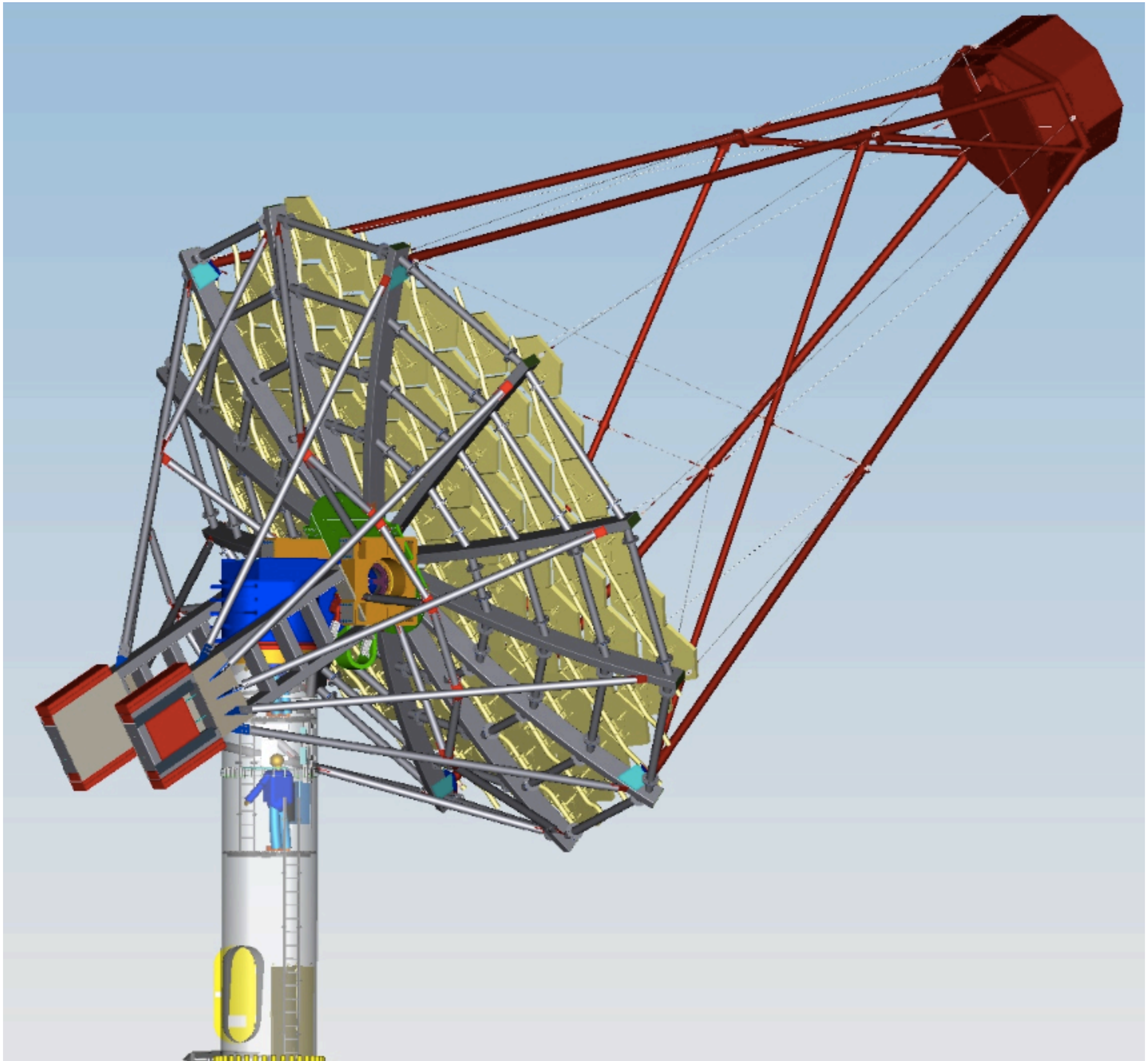
- Mirror hexagonal, 1.2m, 35 kg/m^2
- Eigenfrequency 2.5Hz
- Slewing speed   1min to any point in the sky
- Positioning Range during Observation (technical tests)
  - Elevation: at least 25–91° (–95°)
  - Azimuth: at least ±270° from parking position
- Precision of orientation of the telescope axis during astrophysical tracking < 1% of FoV on each axis ≙ 5' for the MST
- Environment: operating temperature, height, wind, seismic+lightning: -10...30°C, 1500...3800m, 50 (180) km/h, site dependent

MST Requirements Cont'd

- Mechanics share to PSF <1mrad → 80% containment diameter of the optical PSF < pixel diameter out to 80% of the camera radius
- Displacement of camera ½ pixel
- Focal plane positioning, i.e. movements
  - in z: ¼ of a pixel diameter (that causes defocus)
  - in x, y: ≤ 5% of the FoV
- Post-calibration pointing precision < 7" rms in space (5" in elevation and 5"/sin(elevation) in azimuth)
- Availability: 80% of telescopes operational > 90% of the time and 90% of the telescopes must be operational in at least 80% of the time.
- Maintenance: < 3 person hours per telescope per week
- Lifetime ~30000 hrs ≙ 13...30 years (depends on moon light operation)

MST In Process

- Structural design
- Basic decisions
- Analysis with many methods of
  - sub-assemblies
  - the telescope
- Design of sub-assemblies
- Integration of sub-assemblies for collisions
- Prototypes: drive system and quarter-dish
- First MST prototype in 2012
- Understand performance and improve design
- Prepare production of MST series



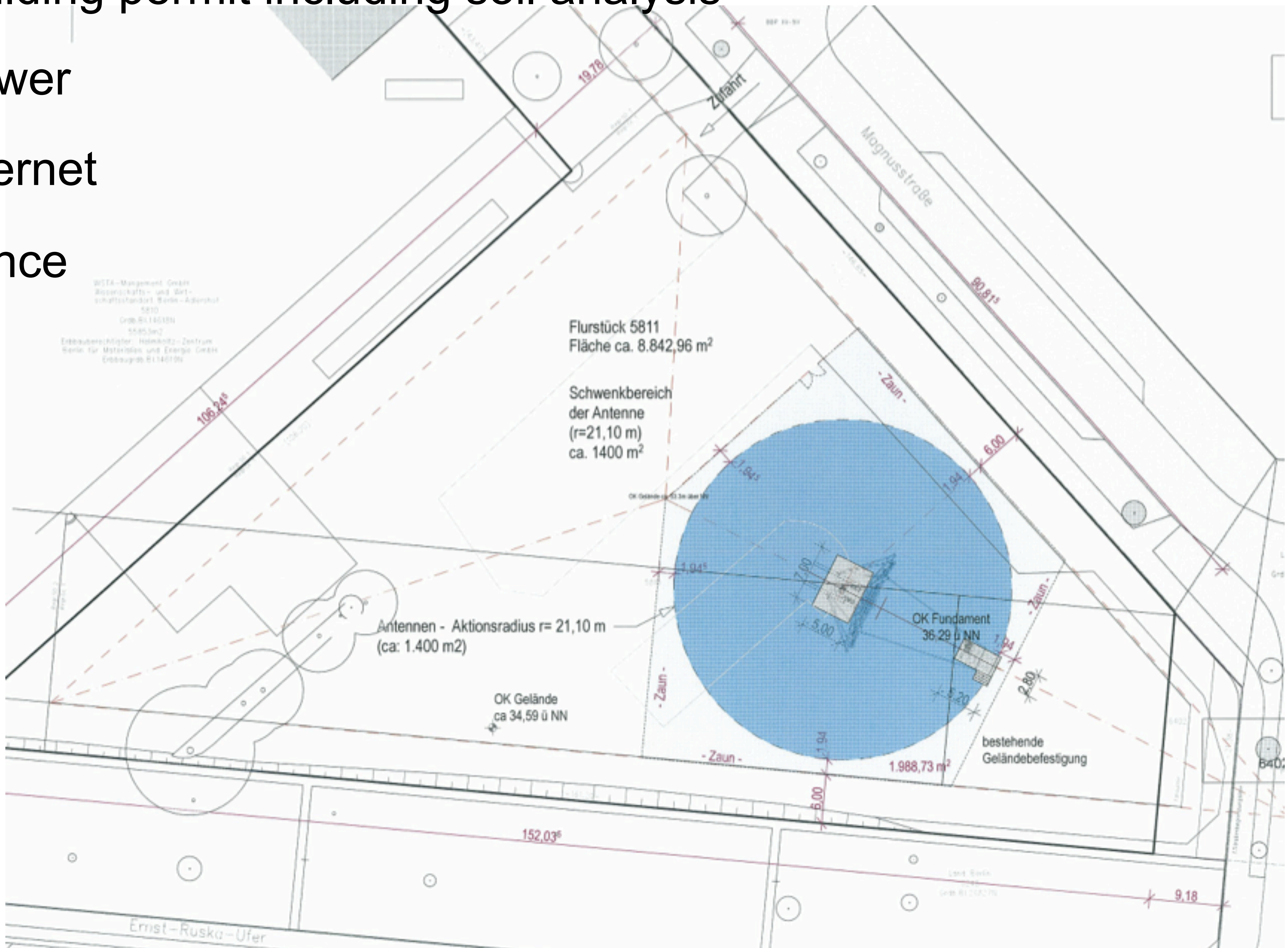
Towards MST PBS

MST-SYS MST (team leader, systems engineer, QM, documentalist)

MST-STR	foundation, tower, head, yoke, dish, counterweight, catwalks, mirror support, quadrupod, integration, cabling, site
xST-AUX	drives, safety, lightning, (energy), (ACTL)
NECTAr-CAM	readout, triggers, mechanics incl modules, DAQ
Flash-CAM	readout, triggers, mechanics incl modules, DAQ
CAM-AUX	window, Winston cones, PMTs, HV, amplifiers, cooling, drainage, clock distribution, LV, cabling, monitoring, calibration, slow control, (ACTL)
MST-MIR	mirrors, triangles, mounting
MIR-AUX	(A)MC
Calibration Surveys	structure deformations, camera sag, mirror alignment, pointing

MST Prototype Site

- Building permit including soil analysis
- Power
- Internet
- Fence



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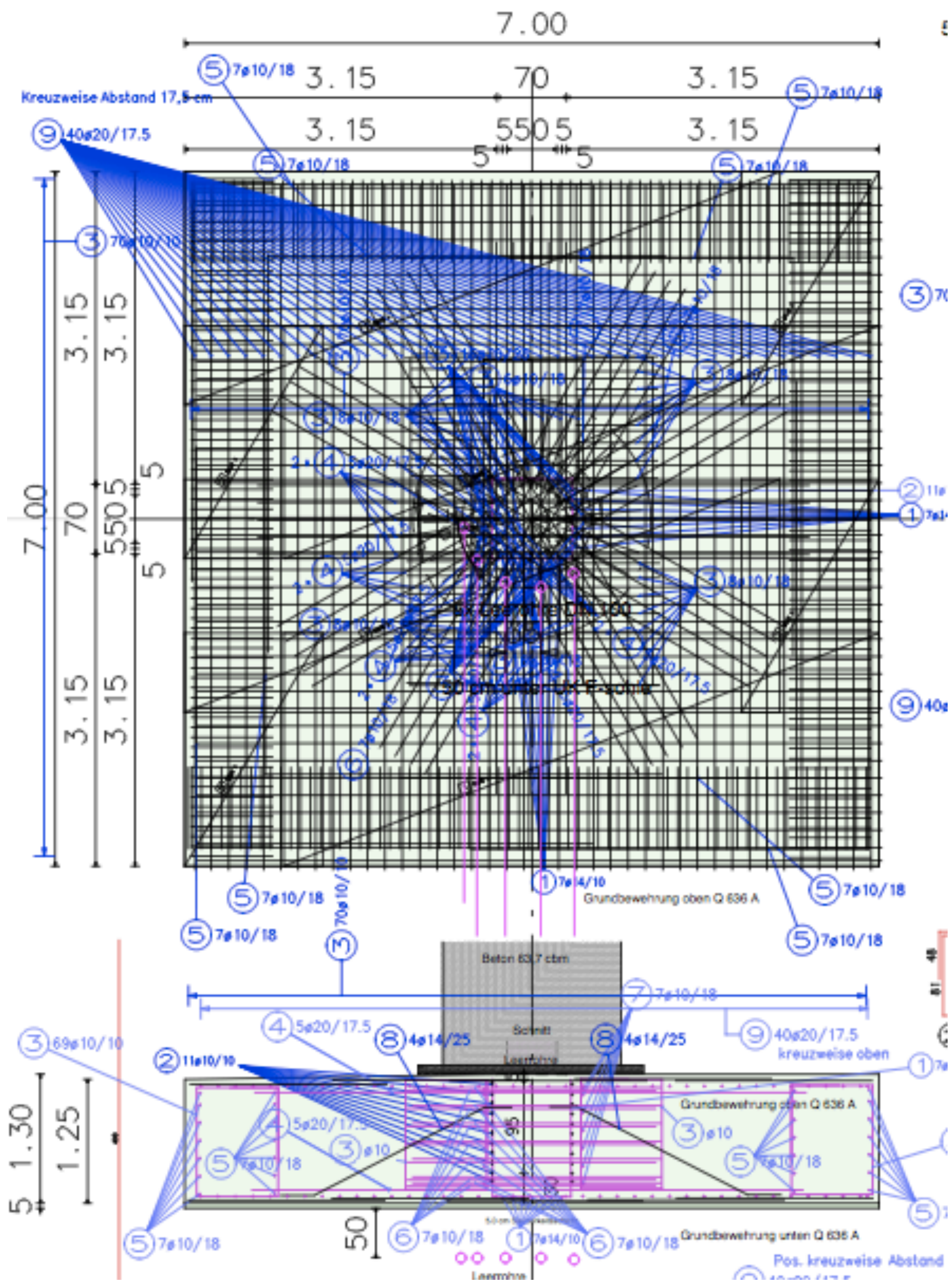
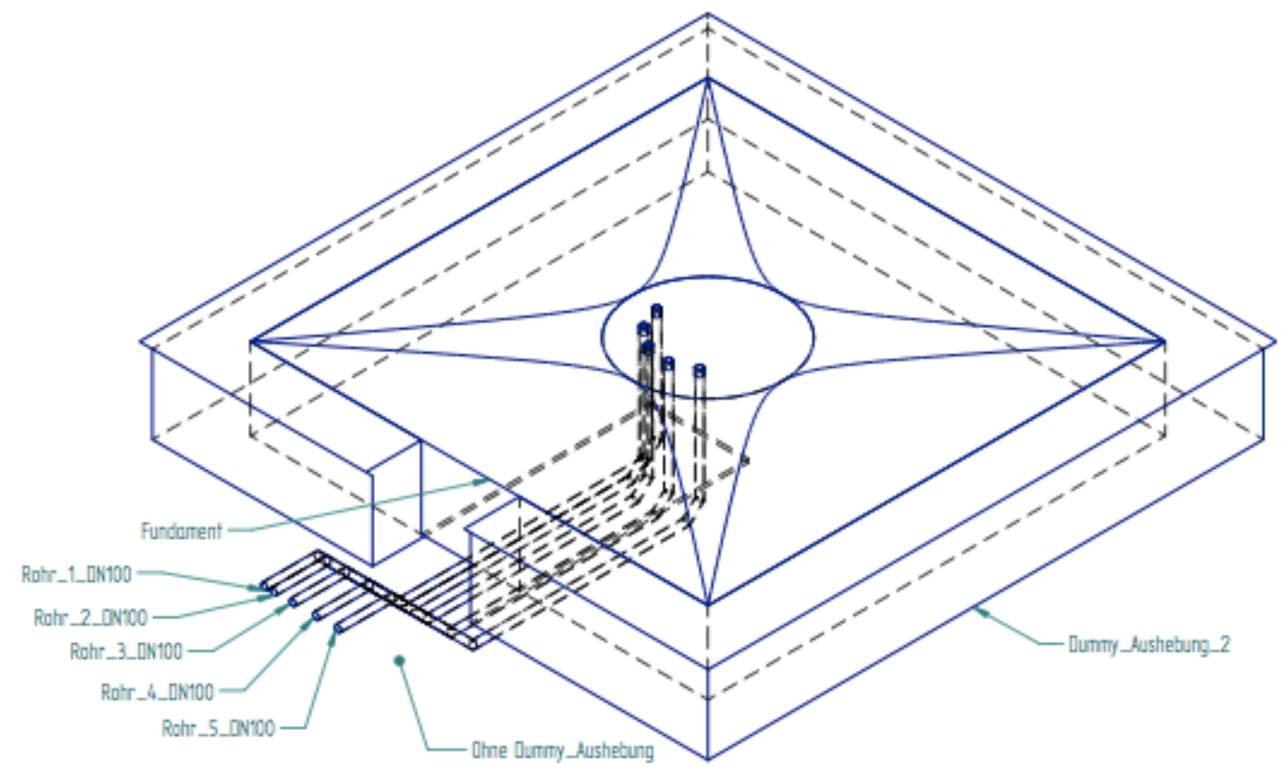
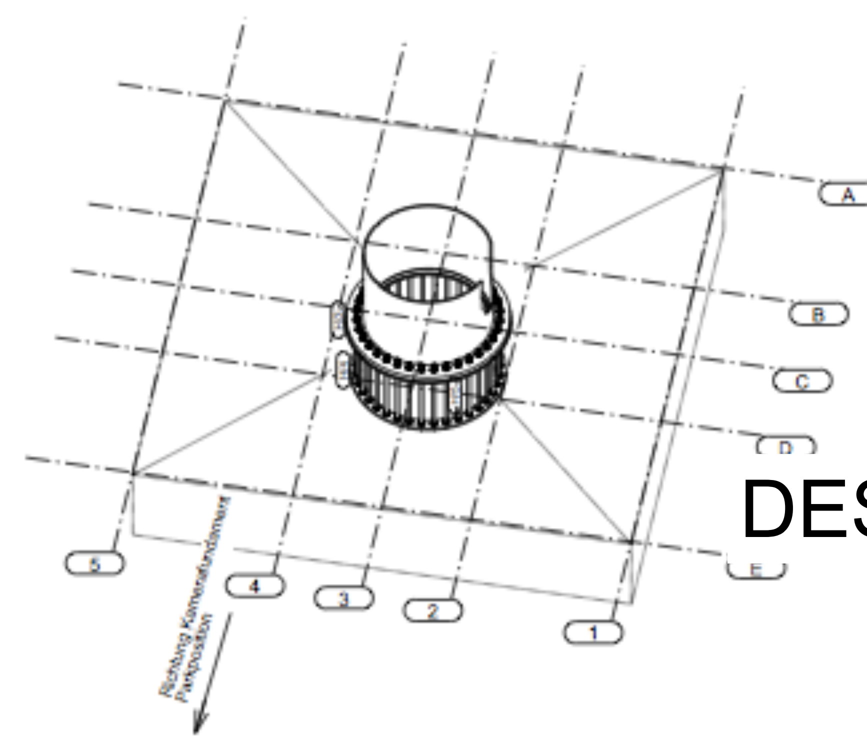
MST-STR: Tower Foundation



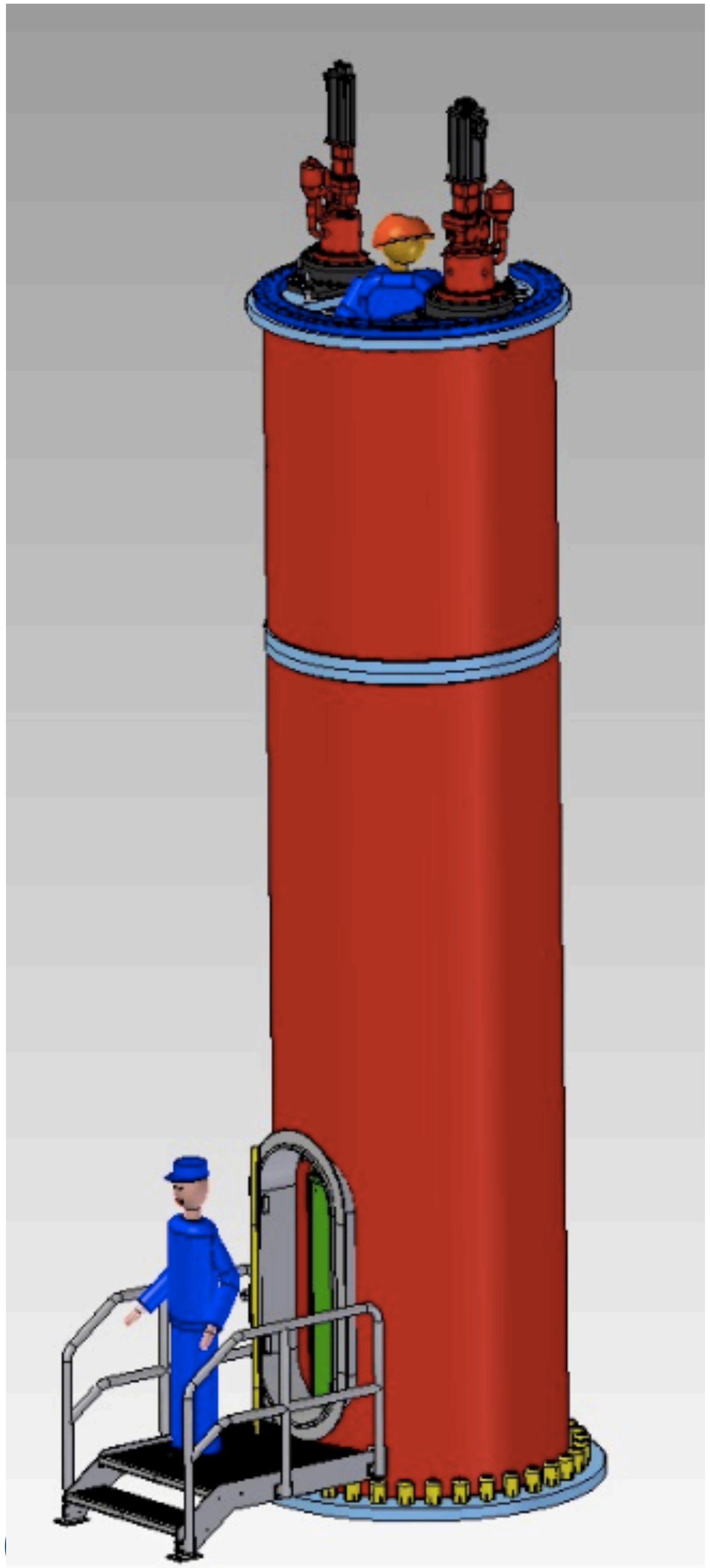


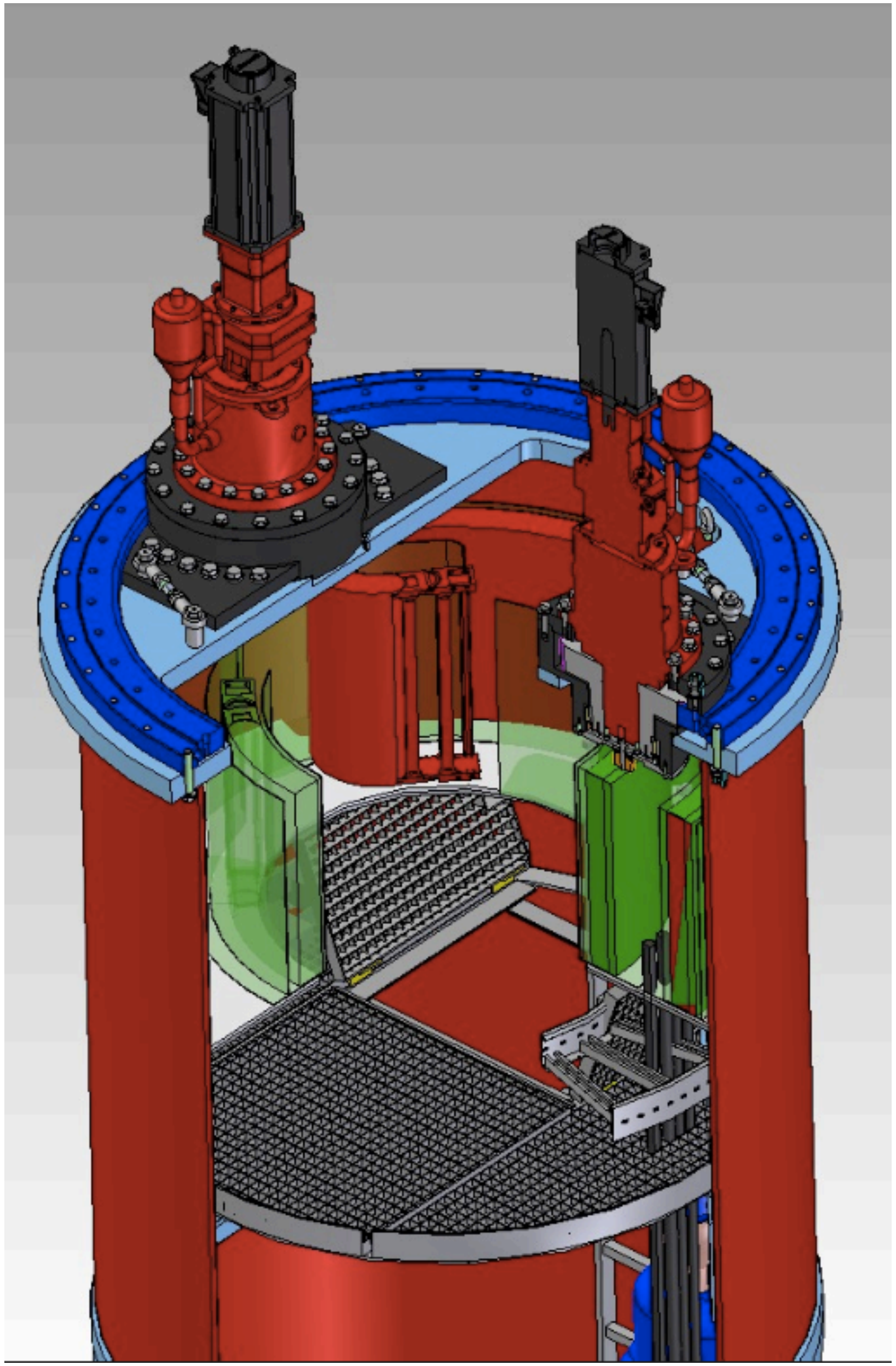


DESY

> Camera foundation not yet

MST-STR: Tower





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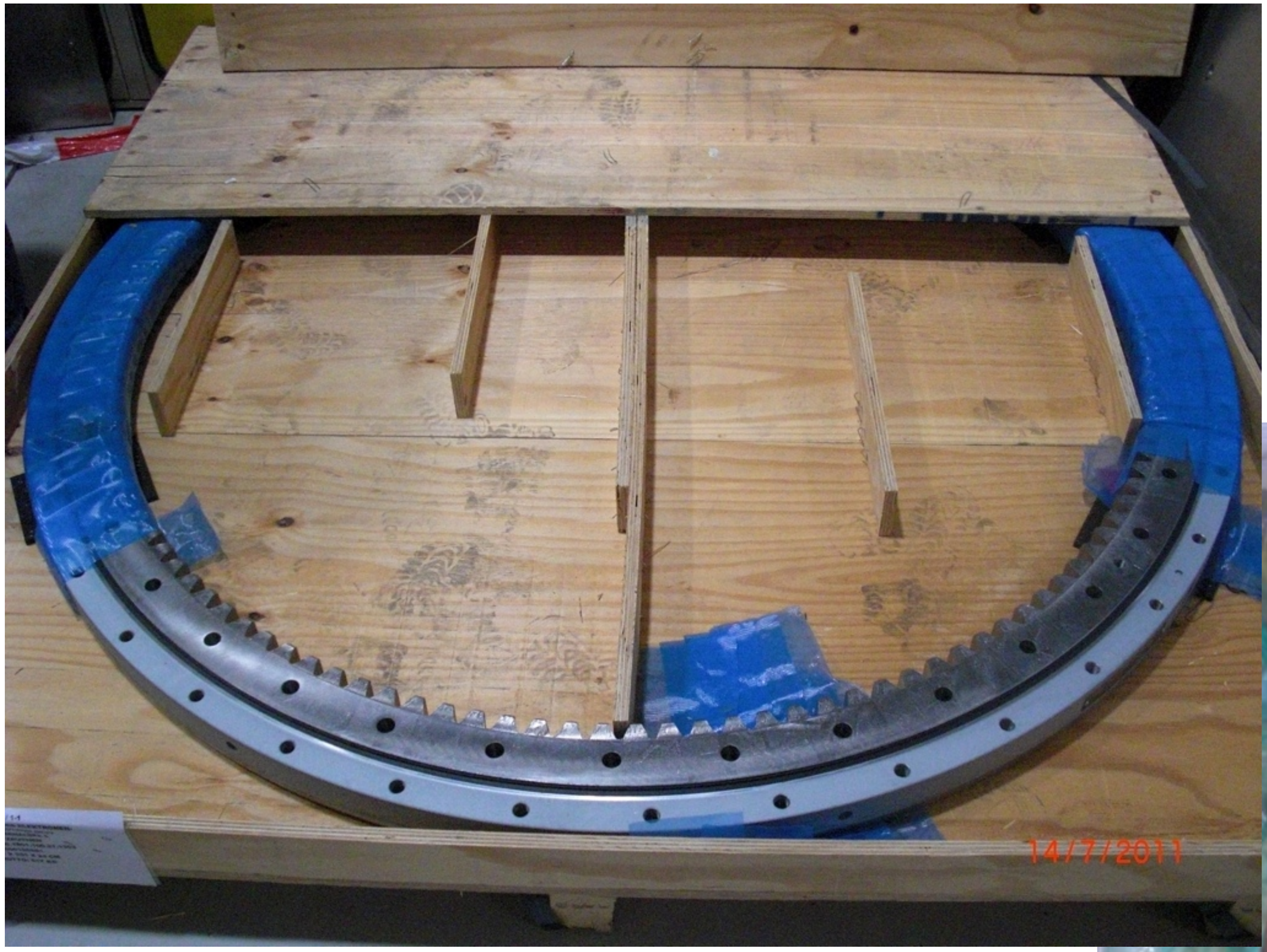
MST-STR: Azimuth And Elevation



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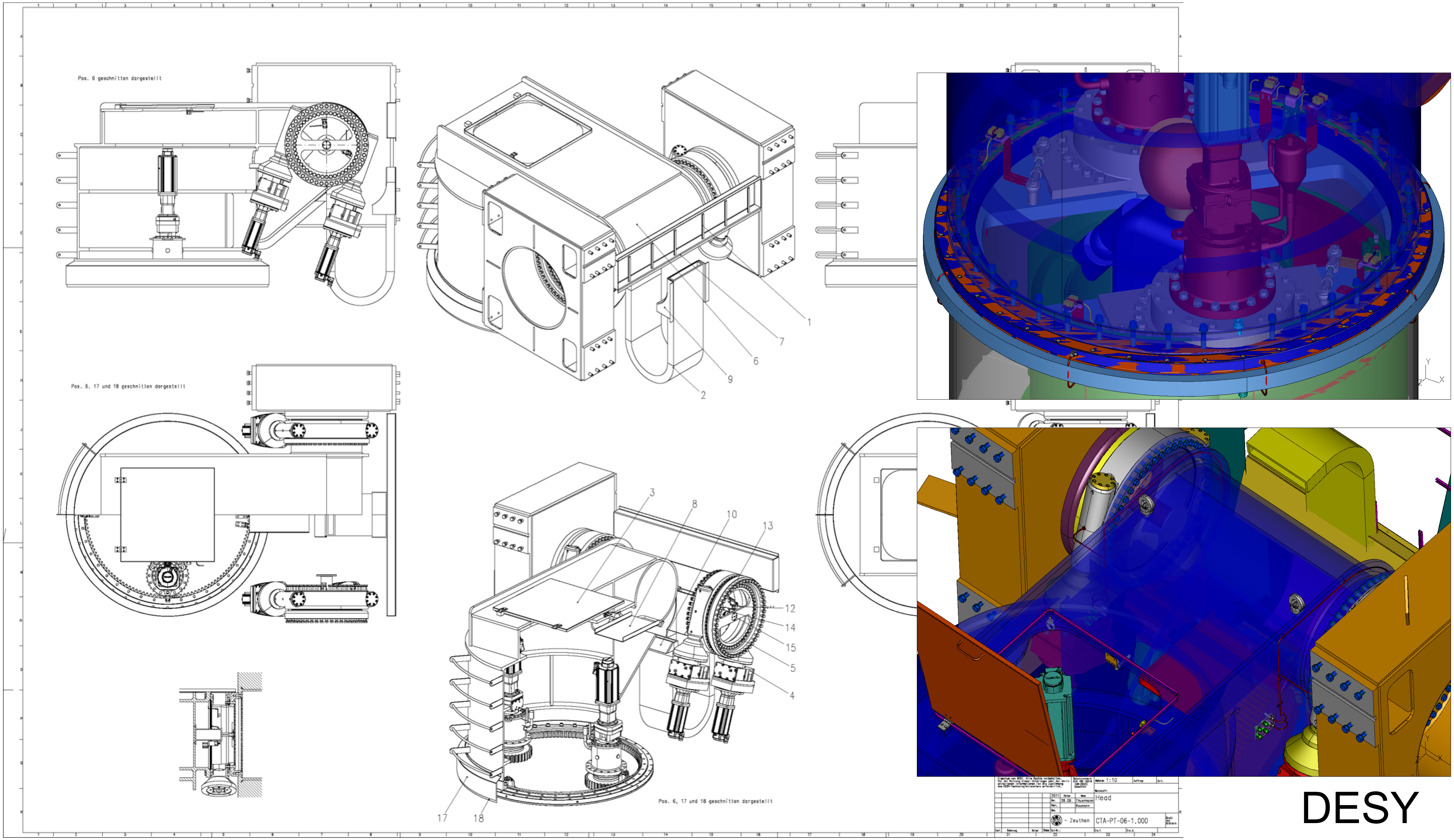
MST-STR: Head And Yoke



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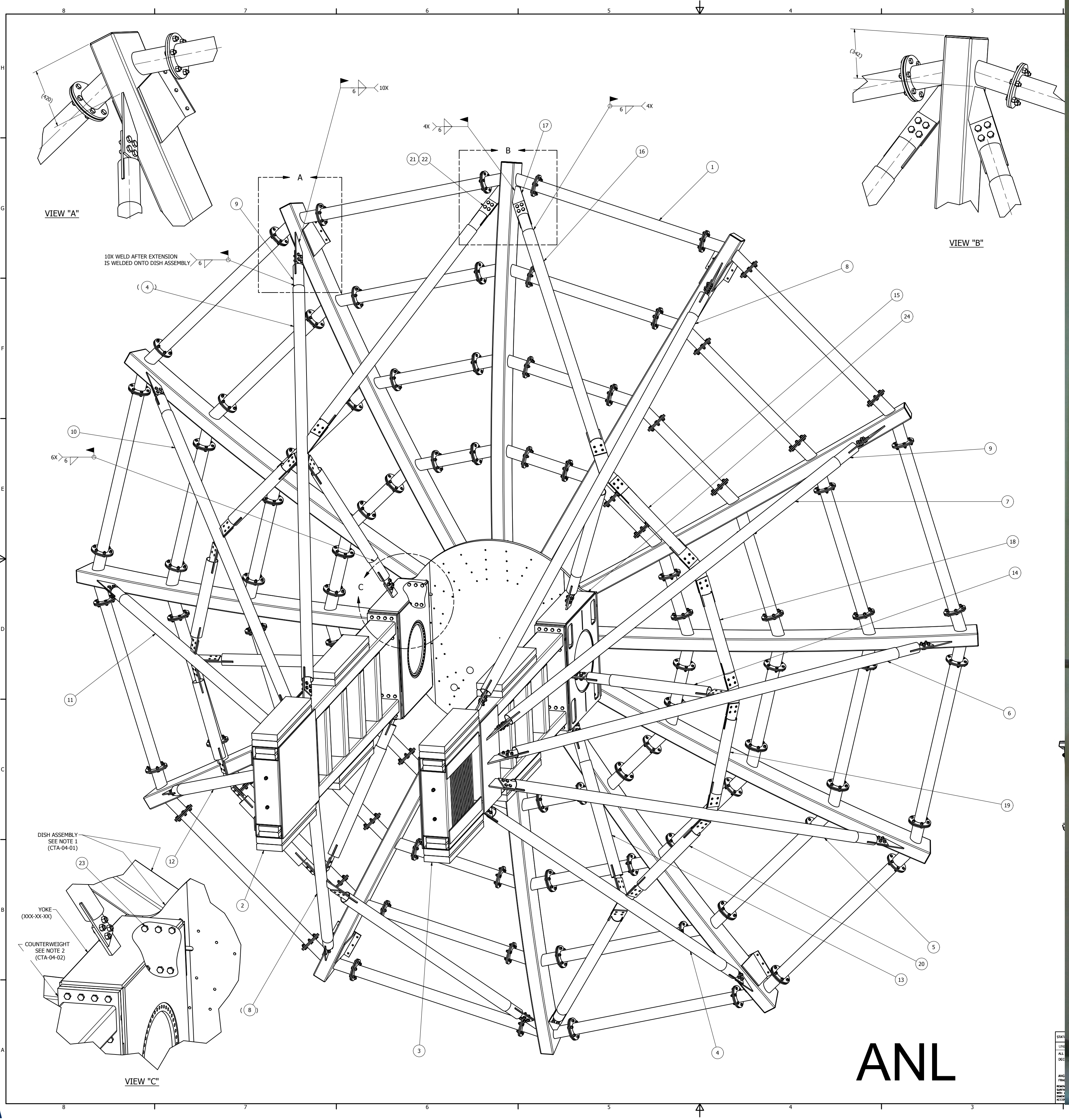
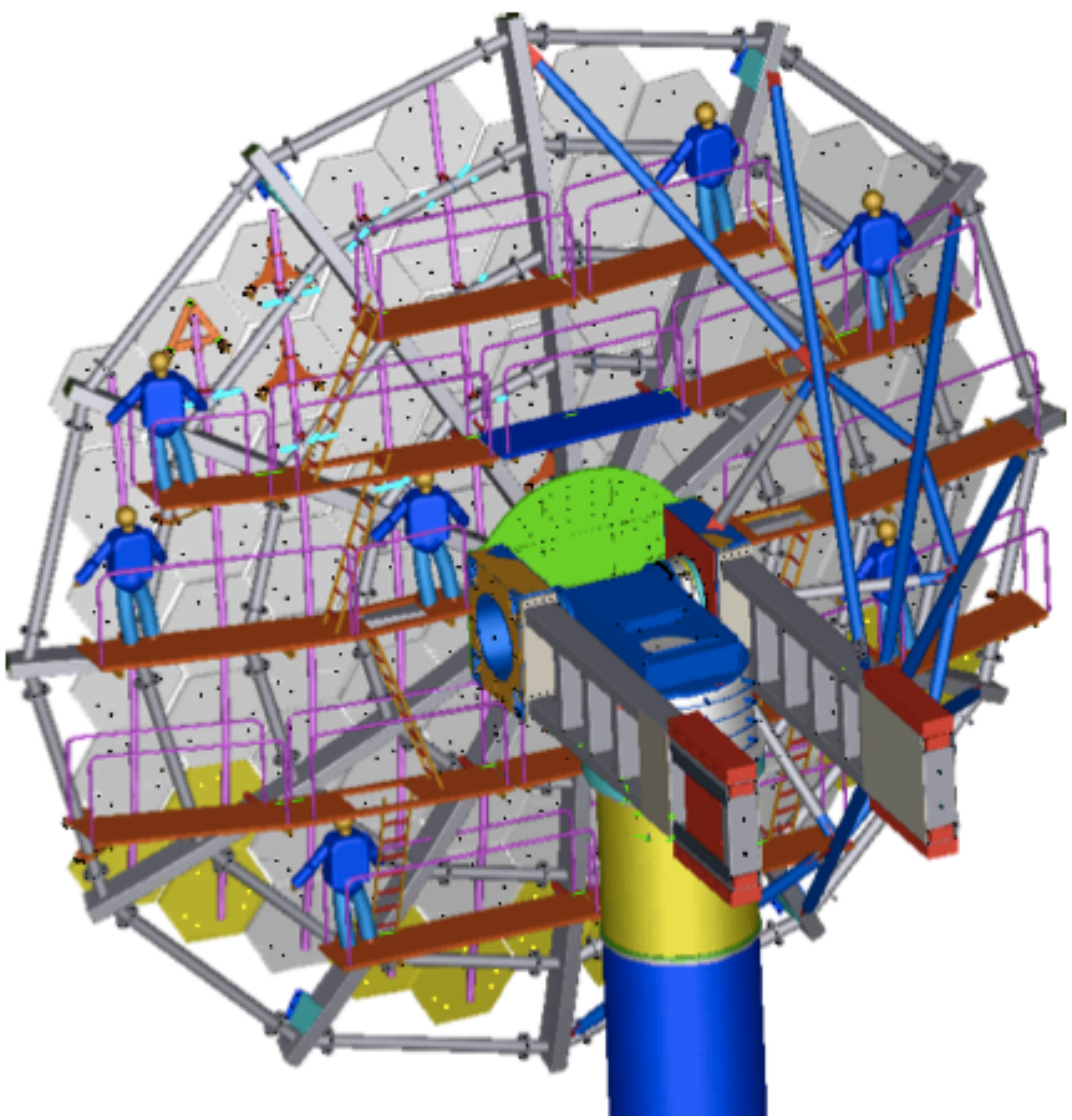
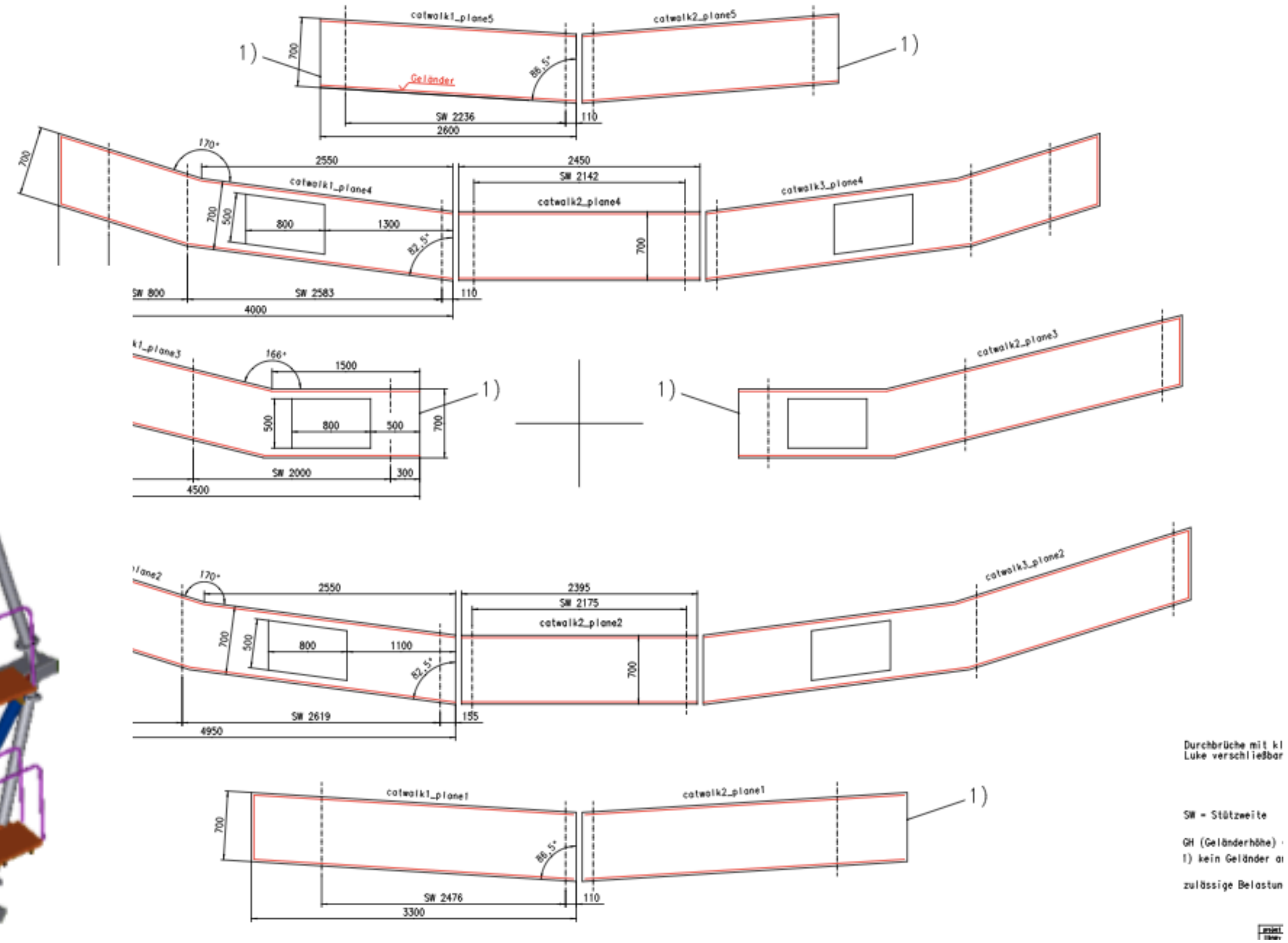
MST-STR: Dish And Counterweight



MST-STR: Catwalks

> Tested on Quarterdish





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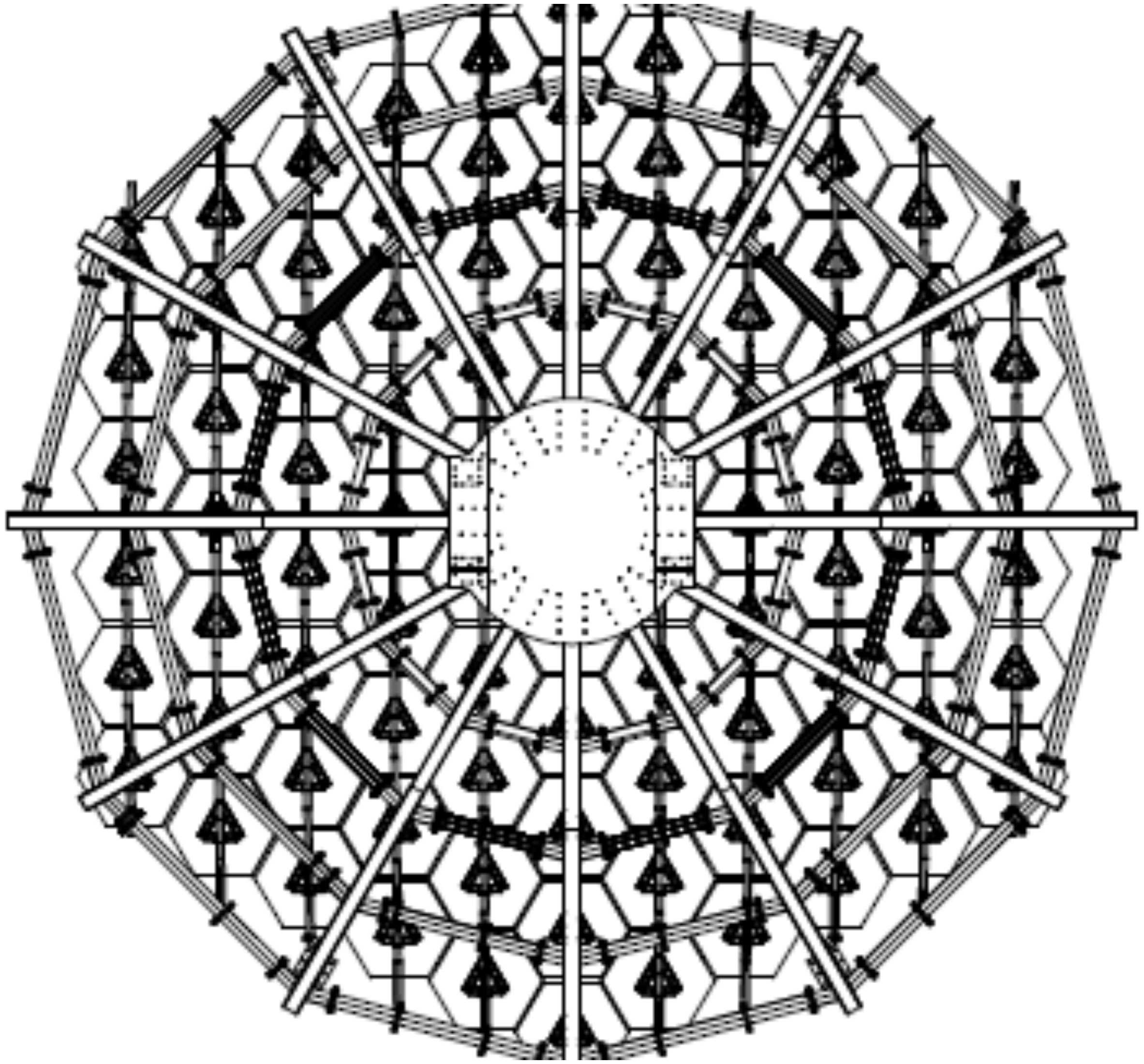
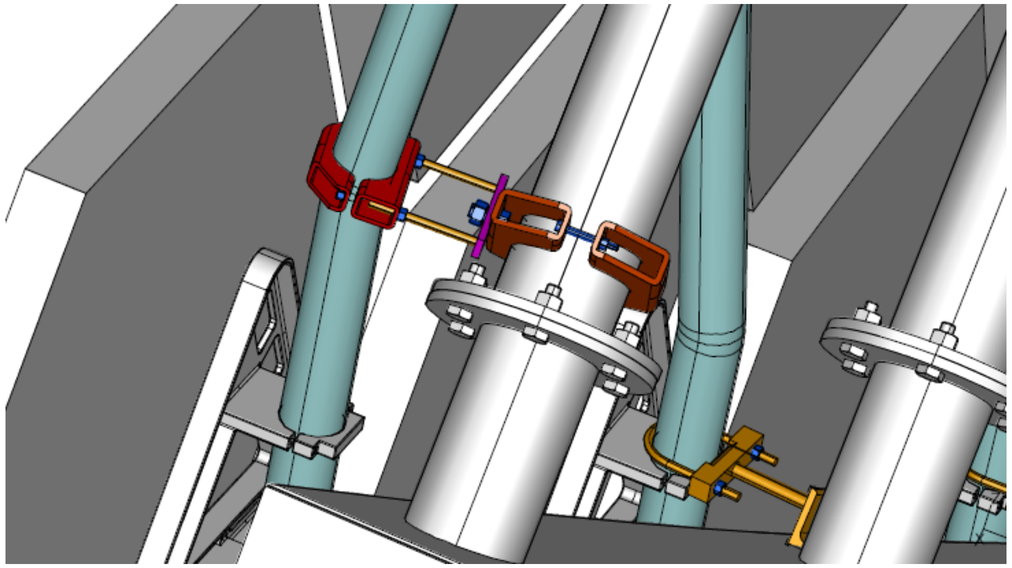
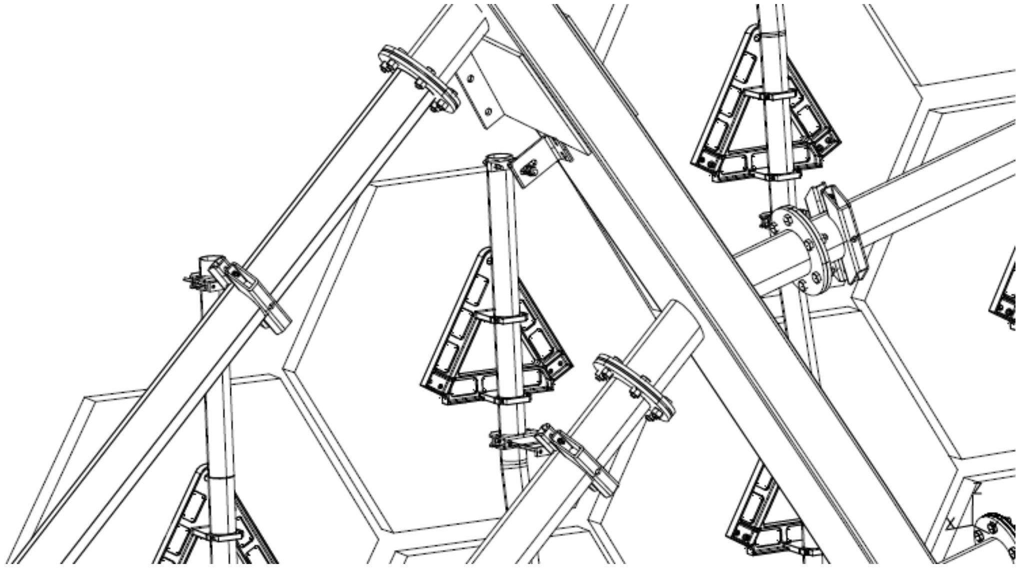
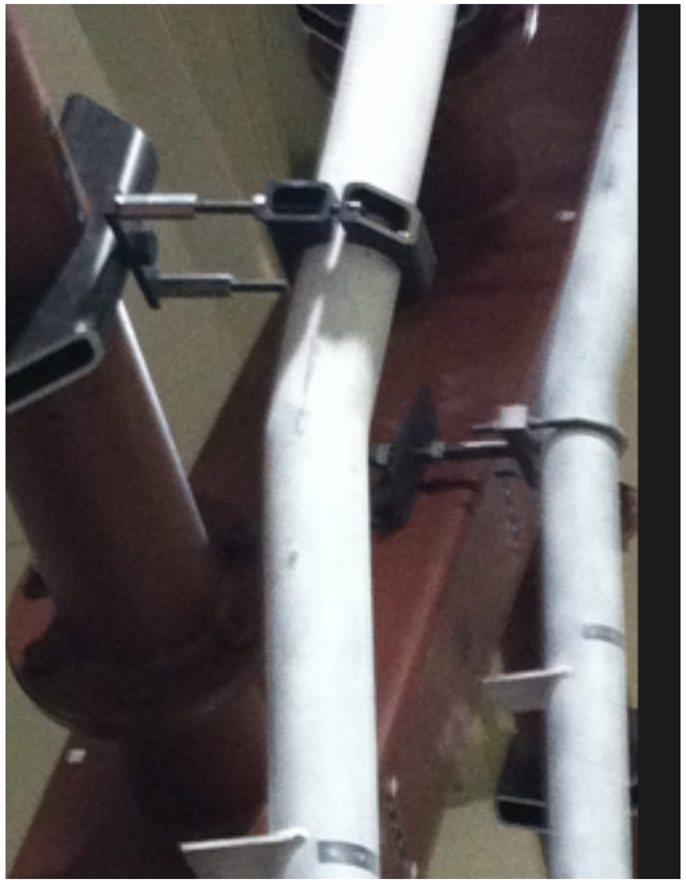
MST-STR: Mirror Support Tubes









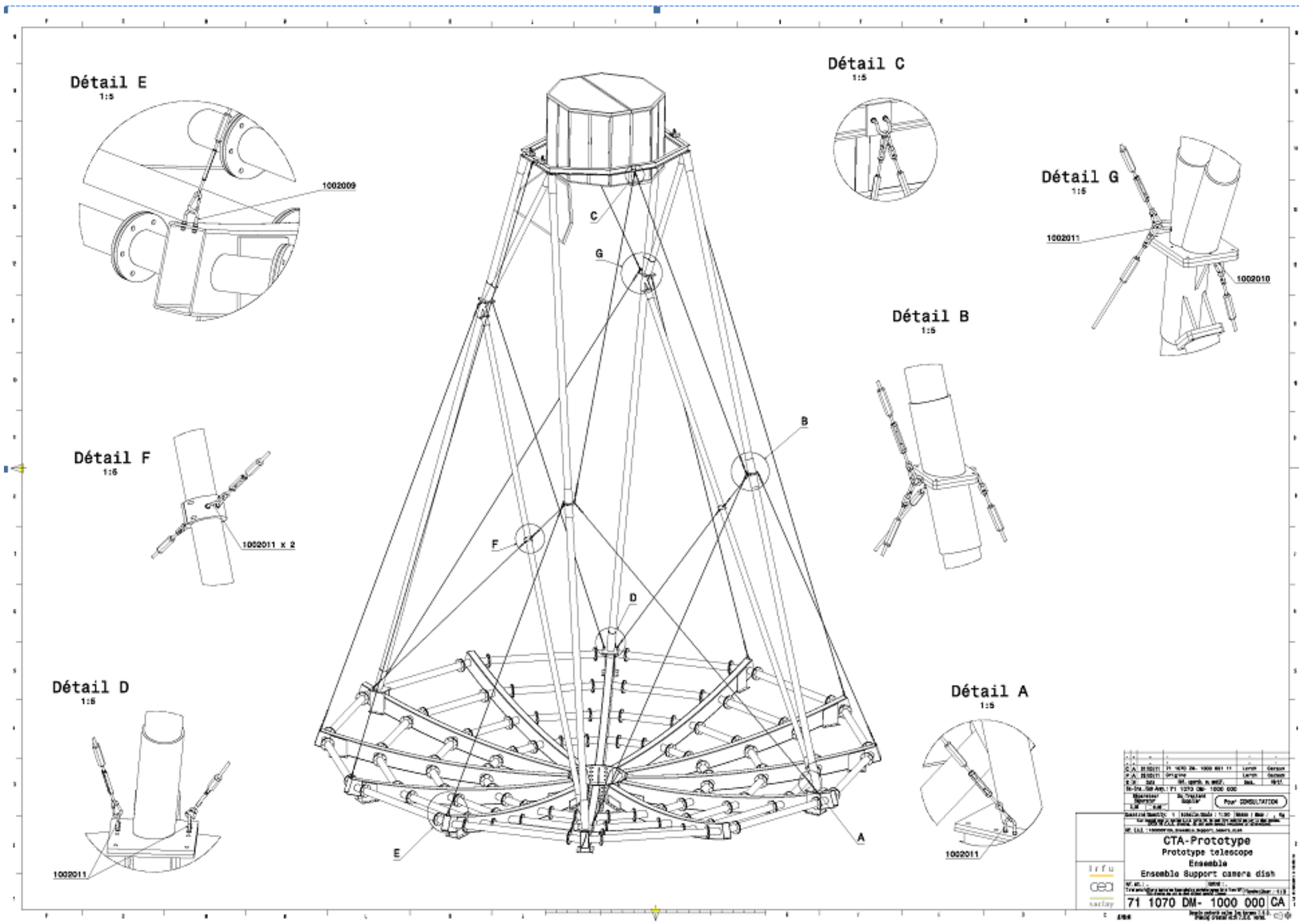
- Tested on Quarterdish

DESY

- Deformation of structure under gravity and wind load

MST-STR: Quadrupod

- K-structure to minimize displacement
- Low tension tie-rods useful for natural frequencies



CEA

Summary mass and CoG, MST

Summary - Around elvation axis

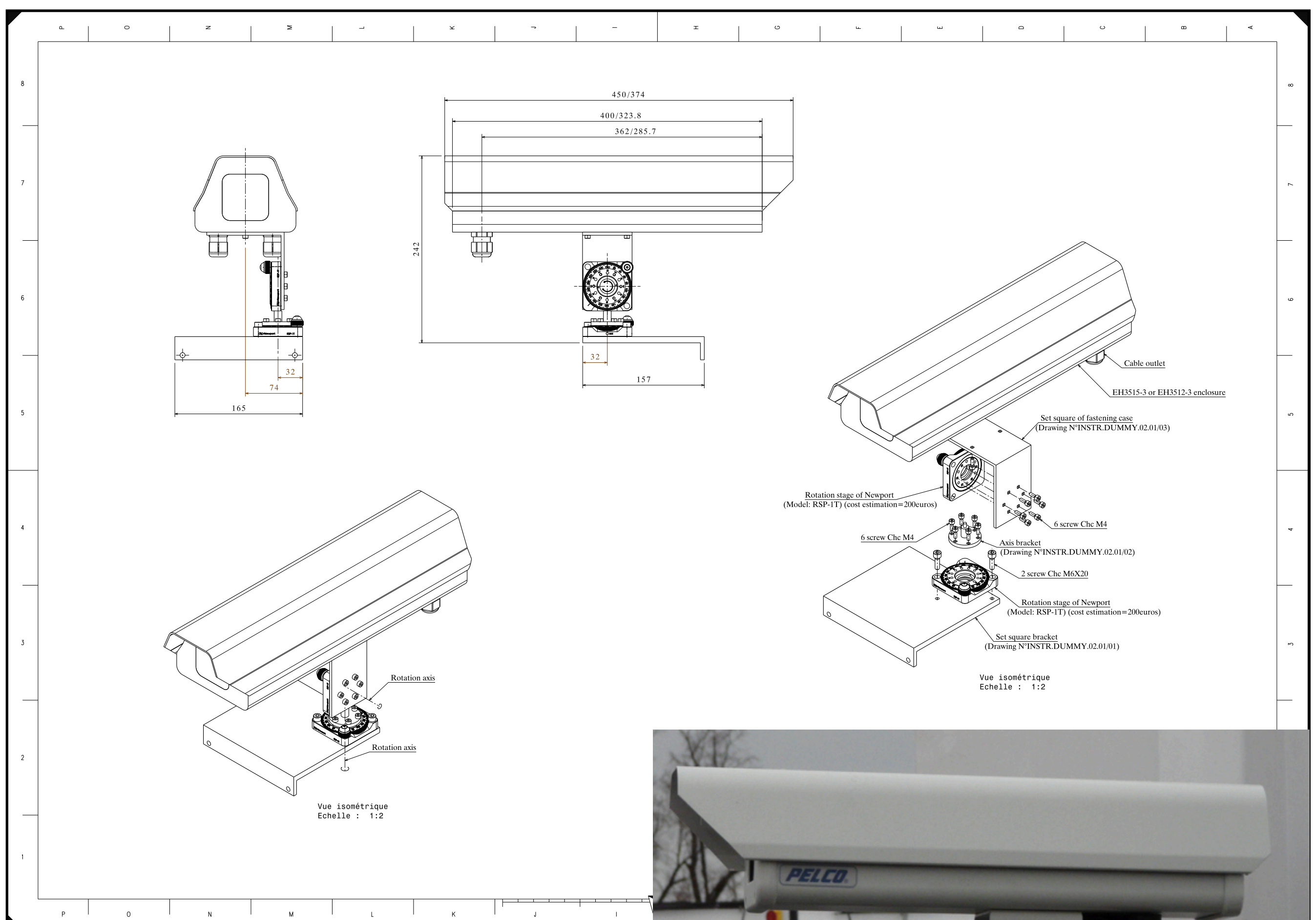
no.	parts	mass	Percentof total mass	distance	moment	Percent of total moment	remarks
		kg	%	m	kg m	%	
1	dish	35,066	46.5	0.259	9,082	6.6	including yoke
2	CW	13,682	18.1	-5.421	-74,170	-54.0	
3	*dish + CW*	*48,748*	*64.7*	*-1.335*	*-65,088*	-47.3	*information for Vic*
4	catwalk	2,000	2.7	0	0	0.0	estimated
5	head	---	---	---	---	---	not above elevation a.
6	camera	2,500	3.3	18.036	45,090	32.8	mass self defined
7	quadrupod	5,330	7.1	13.655	72,781	52.9	assumed as steel construction
8	mirrors etc.	5,143	6.8	2.044	10,512	7.6	incl. AMCs, triangles, bended tubes, clamps
9	subtotal	63,721	84.5	0.993	63,295	46.0	full but unbalanced system sum 1+2+4+6+7+8
10	CW change	11,676	15.5	-5.421	-63,295	-46.0	distance estimated like CW
11	*CW total*	*25,358*	33.6	-5.421	-137,466	-100.0	*information*
12	total	75,397	100.0		0	0.0	Sum 9 + 10

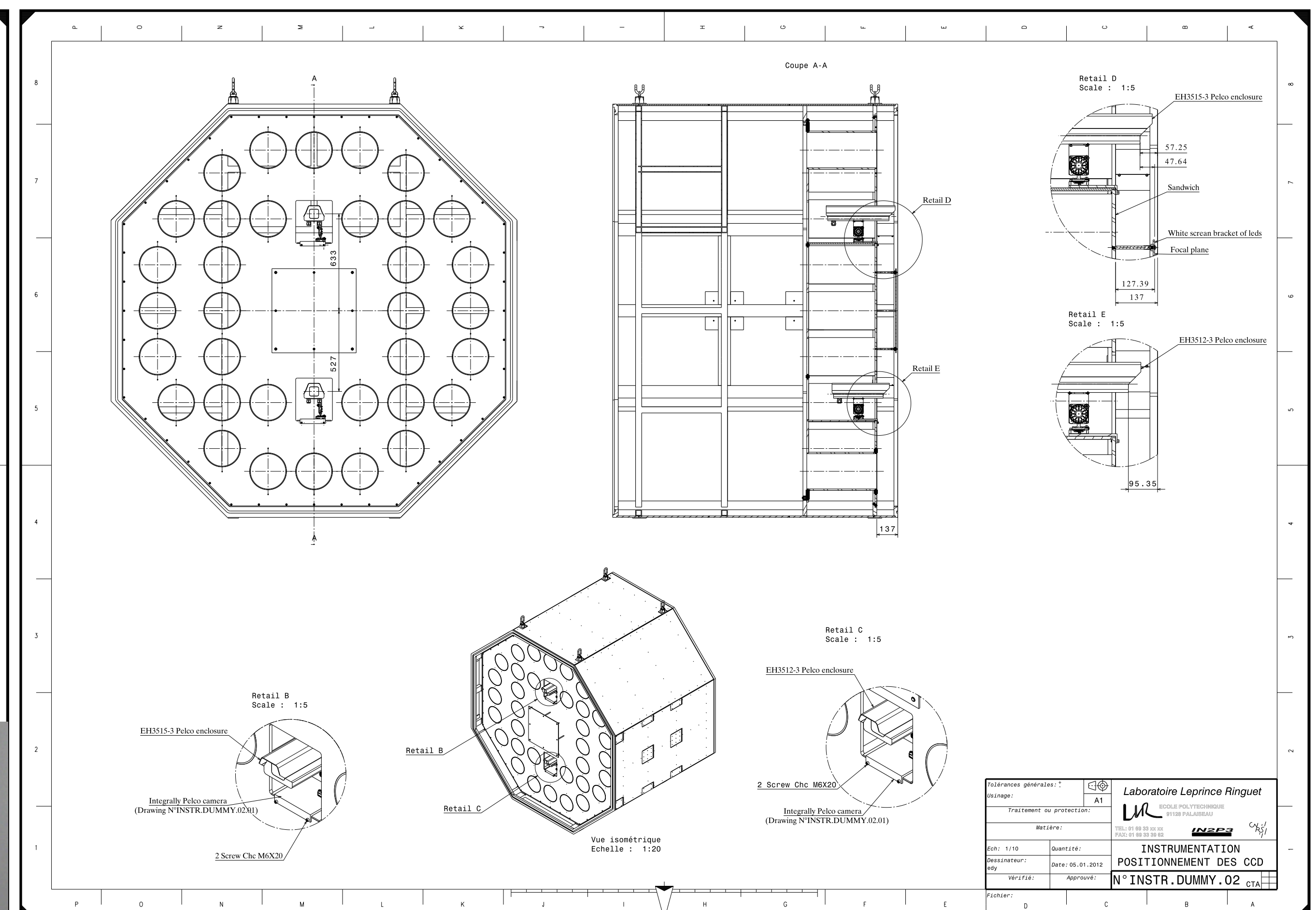
MST-STR: Alignment And Calibration

> Front of the camera: dish deformation and mirror alignment

> Centre of the dish: camera movement and mirror alignment

> Edge of the dish: pointing





DESY+LLR

MST-STR: Continuous Integration Model In EDMS

Feb 1, 2012

EDMS-Element: CTA-MST-Prototype-jt-file, D00000001964041,B,1,6
(include the jt.-file 2012-01-27-CTA_telescope_prototype_D00000000843183.jt)

Last changes:
Clamps and new benden tubes from Reiner Heller: Clamps + Bend Tubes Assembly, D00000002666111,A,1,2; clamps_and_tubes_20Jan20121.stp
Catwalks from (12.2011) from Hartmut Luedecke: Catwalk Assembly, D00000002666021,A,1,2; file; catwalk_assembly_26Jan2012.stp

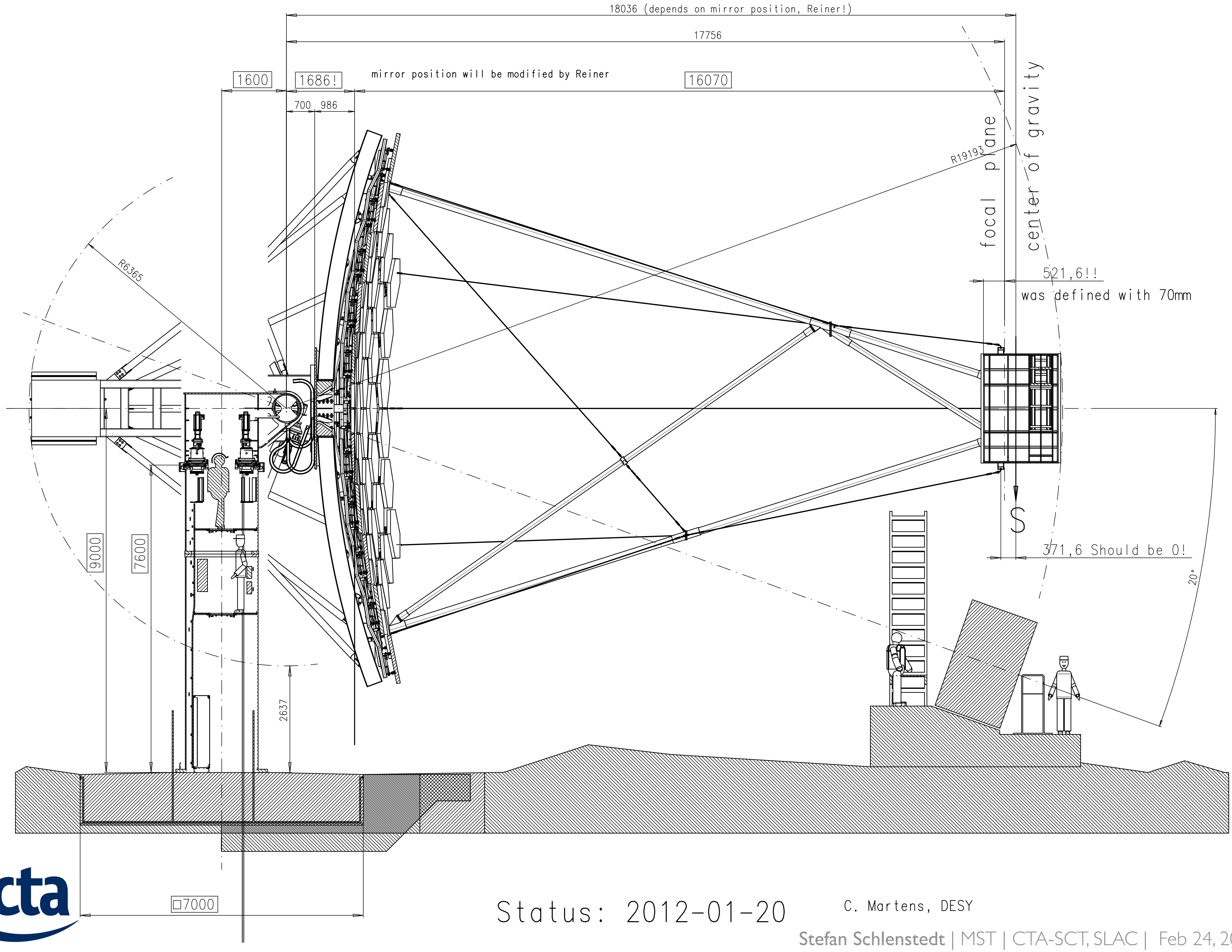
Not in 3D-Model: New dimensions of Quarupod-tubes (Victor, 5.5 and 4.5mm thicknmess for 170mm tubes and 140mm tubes). We are going to estimate then mass and COG!

Same Results from geometry-check:
Catwalk fits. Rotation have to be checked.

Mirror-Position is ok.
Hight of elevation axis: 9000mm above ground is ok.
Hight to middle of azmimut -axis: 7600 is ok.
Azimuth bearing: hight: 72mm is ok.
Distance elevation-mirrors: 1686mm is ok!
Distance elevation-axis-quadrupod connecting plates: 2284,429 (horitzontal) to define!
Focal plane from dish (mirror-plane): 19070mm is defined.
Camera center of gravity from focal plane: 280mm forseen => doesn´t fit!

DESY

MST-STR: Continuous Integration Model In EDMS



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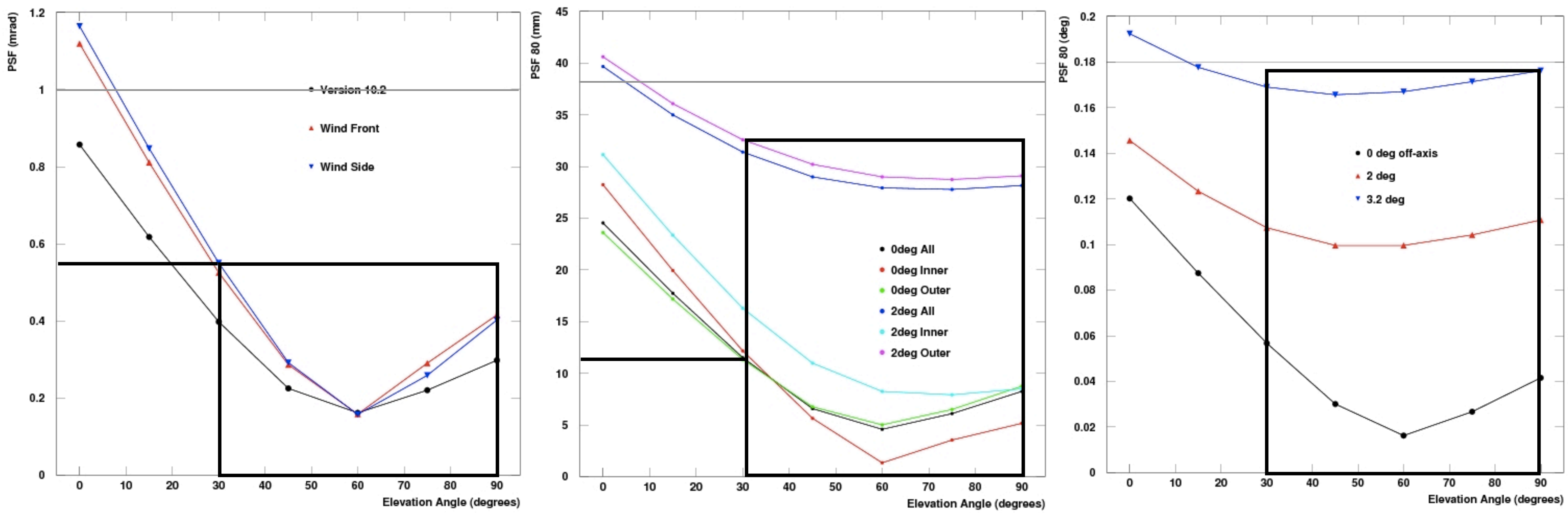
Follow-up On Requirements And Specifications

- LST proposal for precise definition of wind requirements:
  - constant wind measured at 10m height using 3 seconds averaging
  - constant + turbulent wind velocity model from Eurocode 1, part 4-1
- PSF



- Earthquakes
- Lightning protection

MSR-STR: Prepare Survey Of Prototype

Nr	Aufgabe
1	Befest. Ziele im Betonfundament
2	Messung betonfundament
3	Marken im Umfeld
4	Messung: Einmessen in Landesnetz und Lage des Betonfundaments
5	Oberer Ankerring
6	Montage Turm, shimming
7	Vermessung Lage d. Turms, u.a.unt. U. ob. Flansch, Neigung
8	ob. Flansch Azimutlager, mit 360grd Drehung
9	Mont. Head
10	Messung :Form u. Lage d. heads,Lage d. Flansch,mehrere Azimut stellungen
11	Ablage d. Azimutflansches aus der horizontalen
12	Mess. D. Elevationflansche, Ablage v. Vertikale incl Bewegung der Elevation antriebe
13	Mont. Yoke
14	mont cw
15	optional :Messung head
16	Mont catwalks am dish
17	opt.: Vermessung d. dishs vor der Montage m. mont. Rohren
18	Mont. Dish
19	opt: Vermessung des gesamten bislang mont Teleskops
20	opt. : Einbau der catwalks
21	opt:Vermessung Teleskop m.mont catwalks
22	opt: Vermessung d. quadrupod v. d. montage (V.: Saclay)
23	Montage quad
24	Montage zus. Cw Teile
25	Verm. D Tel. m. quad, evtl vs az,elev.
26	Bestimmung der Lage d Achse d. dishs
27	Montage der CCD cameras:im dish und pointing incl Just. D pointing cam.
28	evtl. Vermessung der position der Pointing camera
29	Kalibr. D. Teleskops, evtl. Kombiniert mit Vermessung, Winkelzuordnung intern zu astron. Koord
30	Montage camera dummy
31	Vermessung kompl. Tel., incl vs az.,elev.
32	wie 31 aber abh. Von folg. Einfluessen: az, elev, wind, temp., zeit

Nr	Aufgabe
33	Spiegelmontage
34	Montage zus. Cw Teile
35	wie 31,32
36	Wiederholung Pos35 nach n Monaten (n = 6, 12,…??)
37	Messung m. CCD cams
38	Fundament fuer lock
39	Vermessung Lock, Fundament und lock

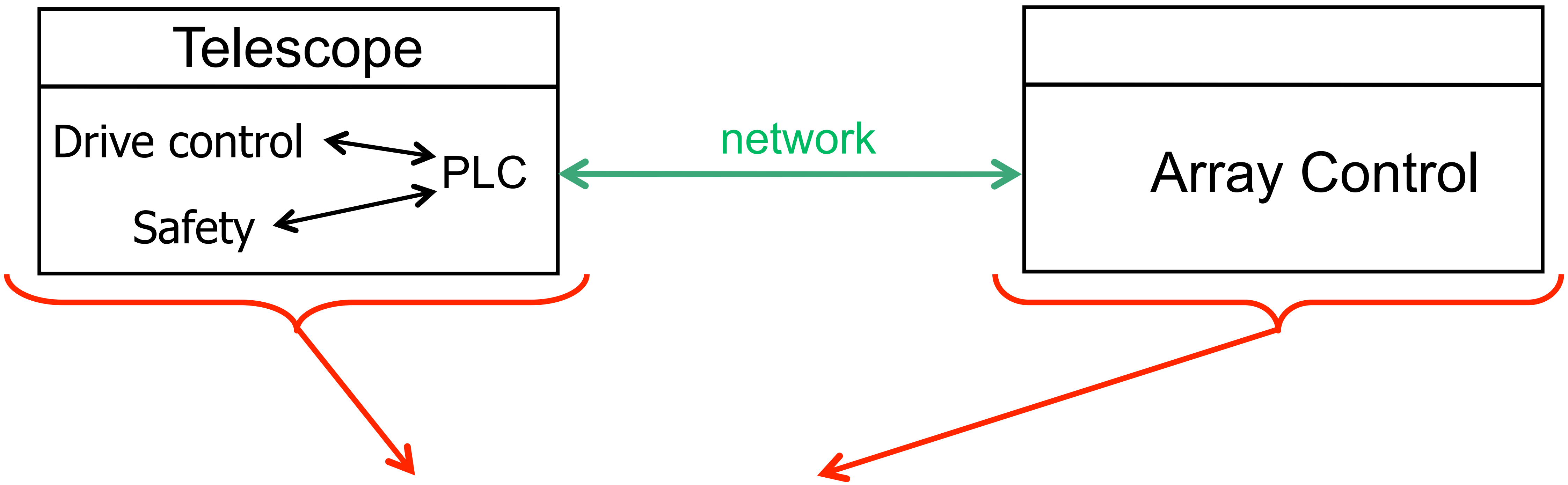
MST-STR: Drive System

- Test-stand for programming and positioning
- Plan for tests with the prototype
  - installation, cabling
  - slewing and tracking tests
    - precision, speed, oscillations, brakes, long-term reproducibility
  - safety tests stand-alone
    - malfunctioning h/w, rapid shutdown, simulated power outage
  - communication
    - access (e.g. remote, local, service)
    - operation (e.g. tracking, MoveTo, error)

DESY

Drive And Safety Concept For The MST

> Overview:



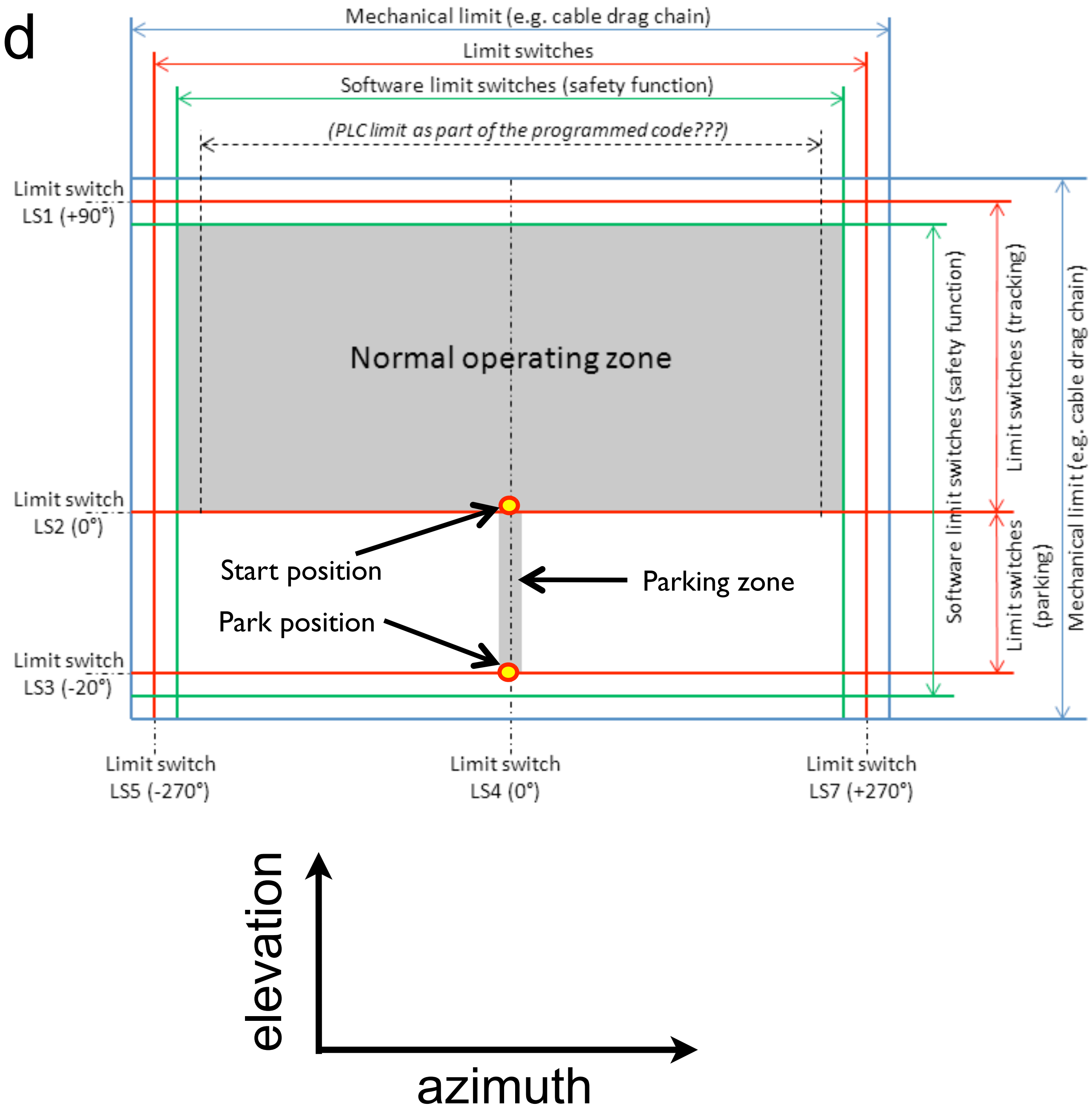
> OPC-UA communication protocol

> Structure of communication and list of variables:

- Define access to the telescope
- Execution of transmitted commands
- Transmission of errors

Operating Zones And Positions

- Normal operating zone: all kind of motions (incl. tracking) are allowed
- Parking zone: connects the 'start position' with the 'park position'
- End zone between 'normal operating zone' and 'mechanical limits'
  - motion is stopped here automatically
  - client can move an axis only back into the allowed zone



Operating Modes And Commands

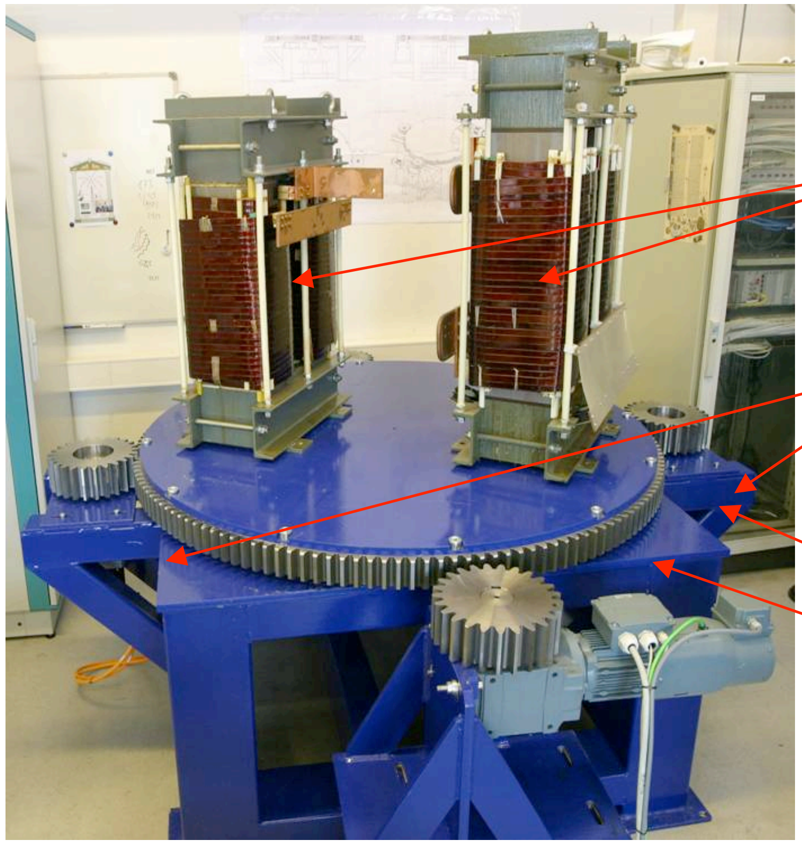
- Telescope has four operating modes

  1. Remote: initial mode that grants read-write access to 'remote client'
  2. Local: only read-access to system, can move axes with locally
  3. Automatic: PLC moves the telescope in case of critical errors
  4. Expert (override mode): e.g., deactivate limits, drives, …

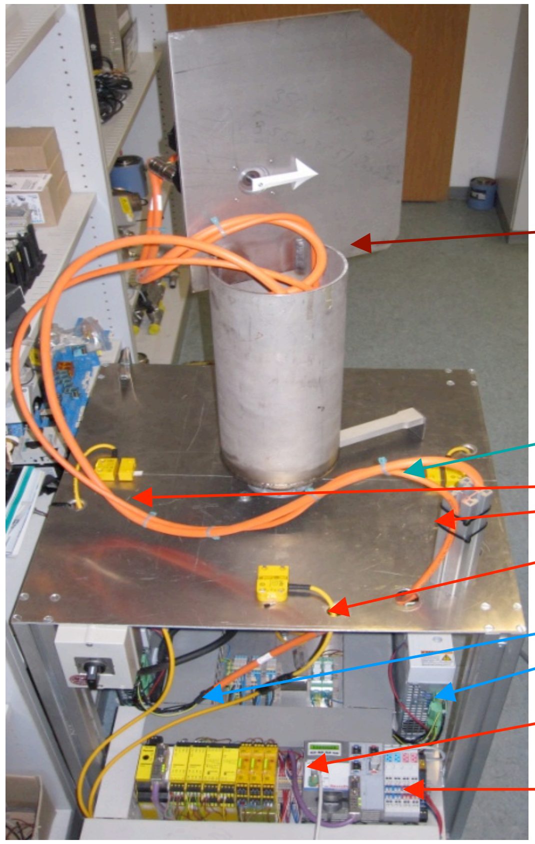
- Commands in IDL (Interface Definition Language)

  – Initialization: error check, starts motors, moves to start position, …
  – ParkPosition: moves telescope to its park position
  – MoveTo: moves telescope to a selected position
  – StopMoving: stops the motion of both axes (highest priority)
  – Tracking: 'Start Tracking' ... 'Push Track Points'...

Implementation On Lab Prototypes



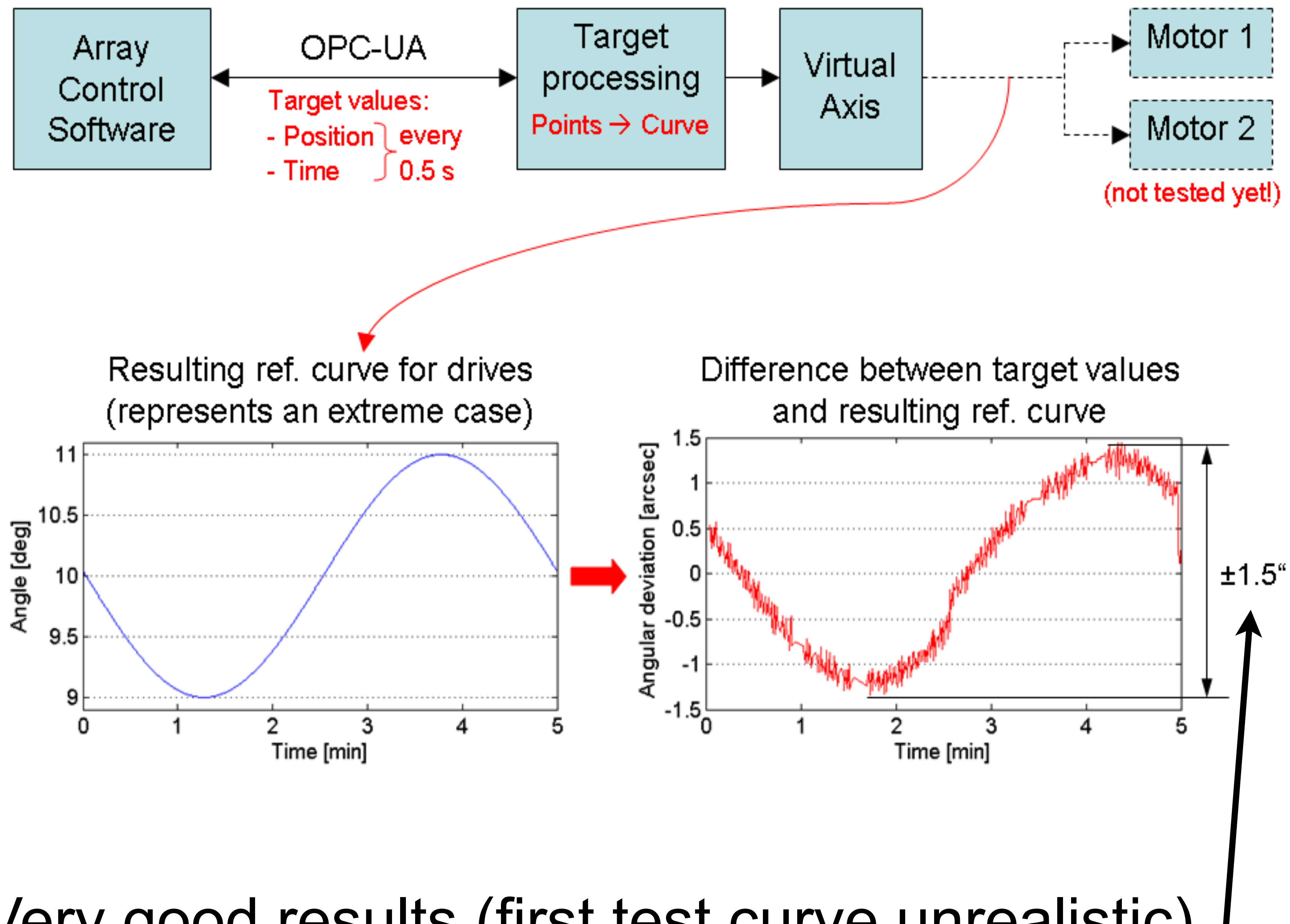
- Full test of drive concept (azimuth axis)
- Study algorithms to operate an axis with 2 drives in synchronous operation
- Investigate different encoder systems



- Program main- and safety-PLC
- Test of safety aspects (e.g. limit switch and logic)
- External & internal communication

After connection of both test stands:
Full test of the drive concept, safety aspects and communication

First Implementation Of Tracking Algorithm



- Very good results (first test curve unrealistic)
- Code implementation in the PLC ongoing
- Tests via OPC soon

Failure Modes Effects Analysis (FMEA)

- Severity from 'No effect' over 'Moderate' (loss of convenience functionality, e.g. external data communication) over 'Critical' (loss of primary function, i.e. telescope inoperable, e.g. no internal data communication) to 'Catastrophic' (Safety issue, e.g. telescope cannot be moved to a safe position or heavy environmental damage)
- Occurrence [failures / year] from 'Remote' ($<10^{-5}$, e.g. broken cable) over 'Moderate' (10^{-1}, e.g. power failure) to 'Very high' ($>10^{3}$, e.g. ethernet packet collision)
- Detection (probability of a failure) from 'Certain' (tested permanently by at least 2 independent tools, e.g. el/az position or failure safety limit switches) over 'Moderate' (tested at least once a day, e.g. parking end switch) to 'Almost impossible' (cannot be detected or is not checked, e.g. something is hit)

cta

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FMEA Example

REF	FAILURE MODE	POTENTIAL EFFECTS OF FAILURE	POTENTIAL CAUSES OF FAILURE	CURRENT DESIGN CONTROLS OR DETECTION METHODS	POTENTIALLY CORRELATED BETWEEN TELESCOPES	SEVERITY RATING	PROBABILITY RATING	CORRELATION RATING	DETECTION RATING	RISK RATING
	POWER									
MST P1	Primary grid power supply failure	Telescope inoperative	1) Cable failure in telescope array	Signal from 230V voltage monitoring relay	Yes	9	1	2	2	36
			2) Power failure in public supply network	Signal from 230V voltage monitoring relay		9	6	2	2	216
			3) Failure of mains contactor	Signal from 230V voltage monitoring relay	No	9	4	1	2	72

No telescope movement to a safe position without an intervention of a local operator

Statistical failure rate of a power failure in public grid: MTBF = 4.762a

Signal from the voltage monitoring relay is tested permanently

Changed ratings of a system/design with recommended actions:

REF	FAILURE MODE	POTENTIAL EFFECTS OF FAILURE	POTENTIAL CAUSES OF FAILURE	RECOMMENDED ACTION	ACTION TAKEN BY	SEVERITY RATING	PROBABILITY RATING	CORRELATION RATING	DETECTION RATING	RISK RATING
	POWER									
MST P1	Primary grid power supply failure	Telescope inoperative	1) Cable failure in telescope array	- Have secondary power supply (generator)		3	1	2	2	12
			2) Power failure in public supply network	- Have secondary power supply (generator)		3	6	2	2	72
			3) Failure of mains	- Have secondary power supply (generator)		3	4	1	2	24

Severity reduced from 9 to 3: due to secondary power supply

MST-CAM: NECTAr-CAM

Madrid meeting

mechanical structure
- -skeleton
- -connection to telescope
- -support of equipment

photodetection
- -light guides
- -photo-detectors
- -preamplifiers

digitization & trigger
- -digitization
- -L0/L1/Interface to central trigger
- -electronic interfaces

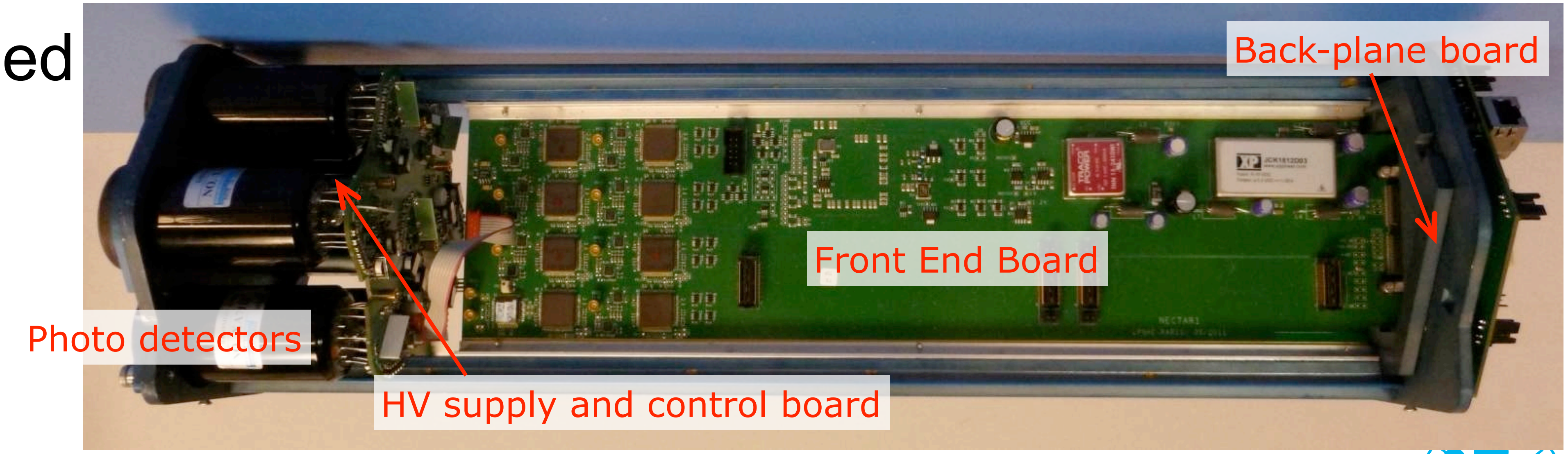
calibration
- -electronics
- -positioning

data acquisition

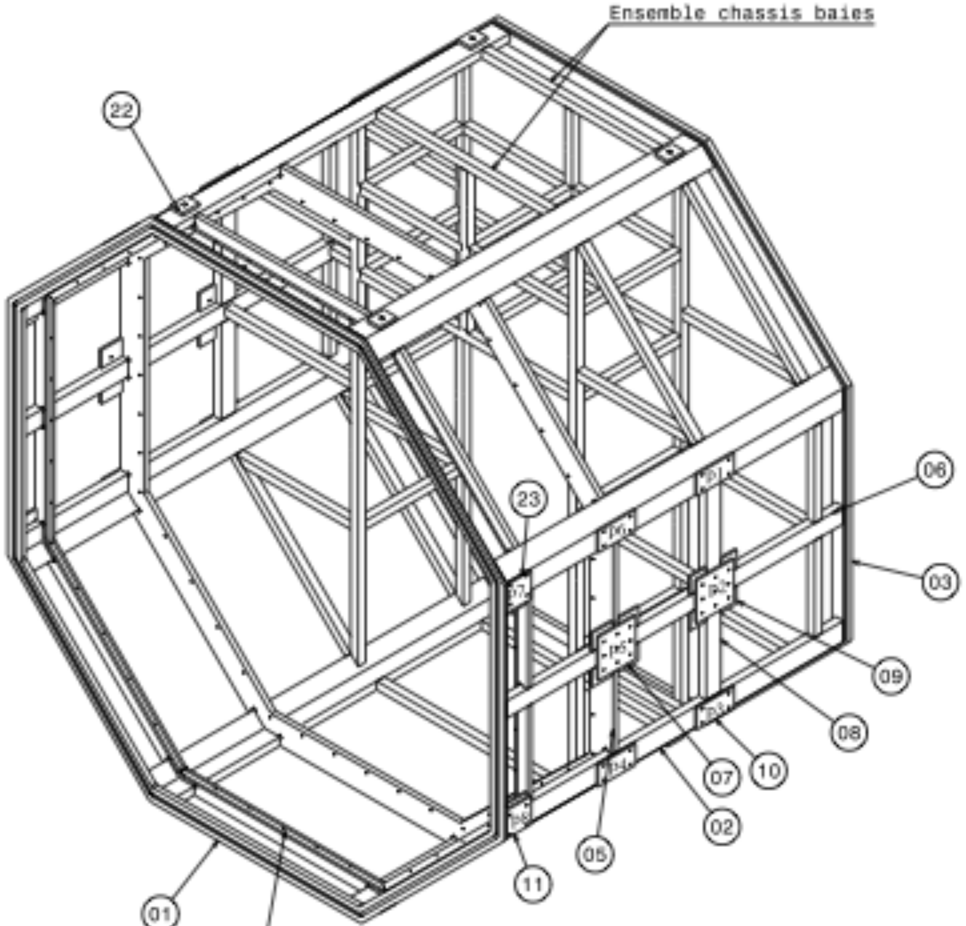
environmental protection
- -sealing
- -temperature/humidity control

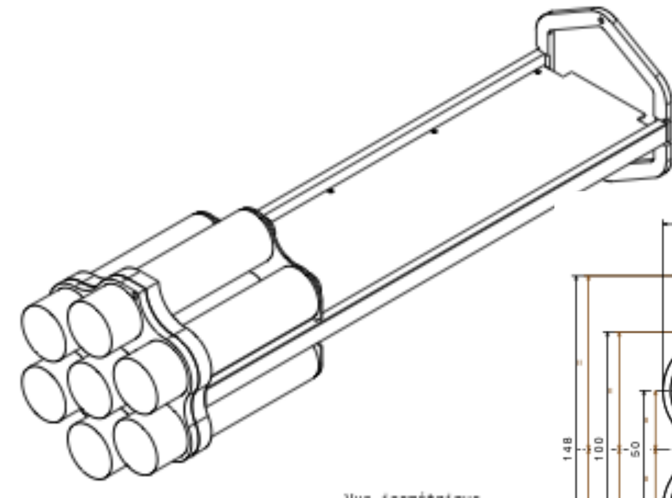
services
- -power supply
- -cooling
- -lightning prot.
- -camera safety

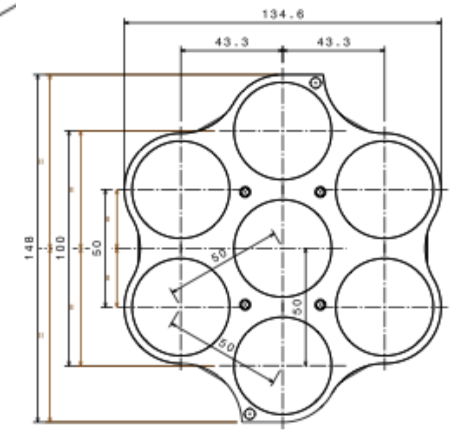
- mini-camera planned
- Cooling ~3kW
- Weight >2t with body, skin



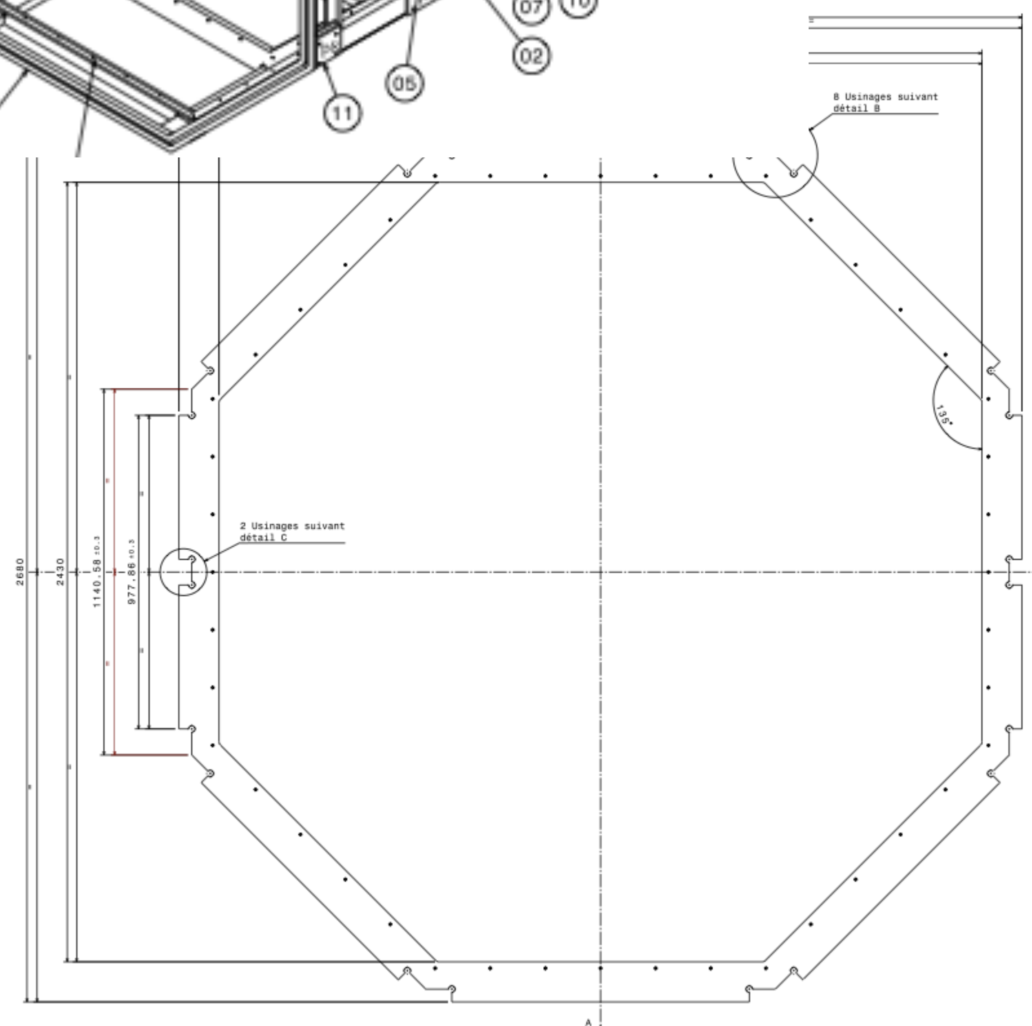
MST-CAM: NECTAr-CAM Mechanics Prototype

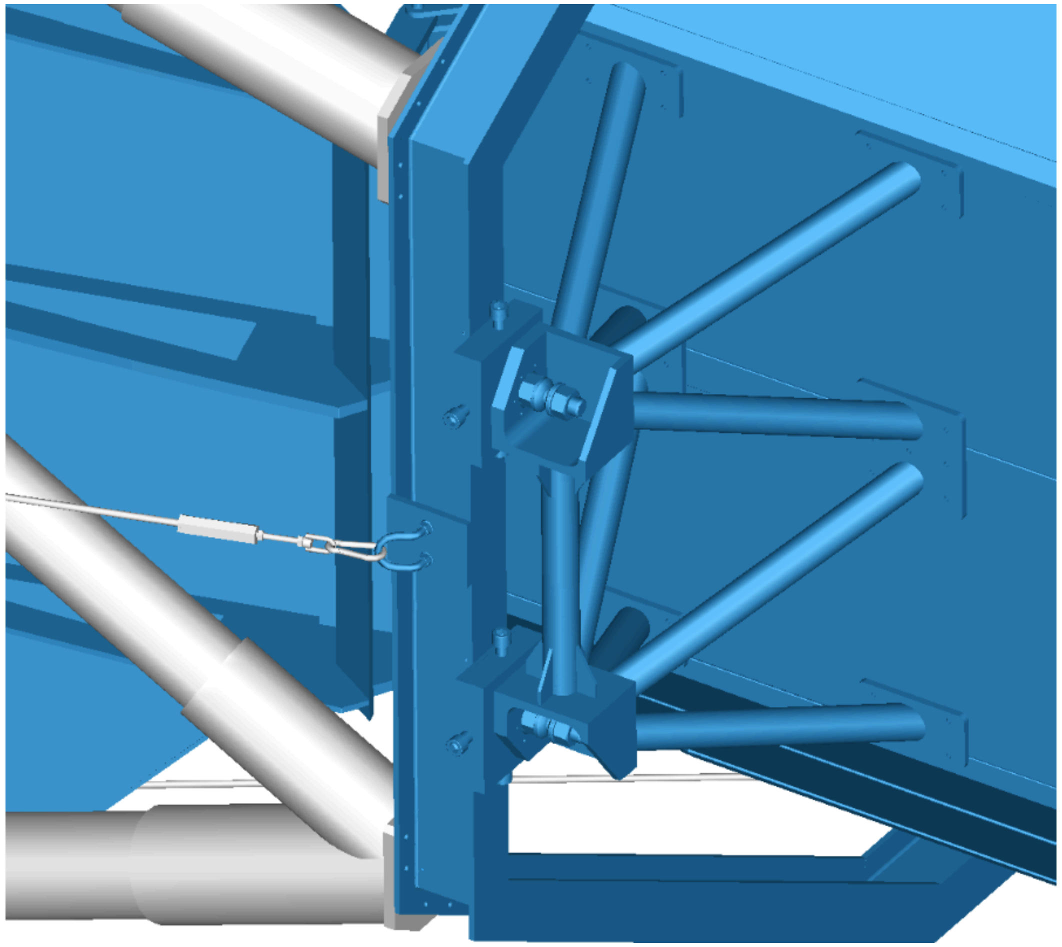






LLR



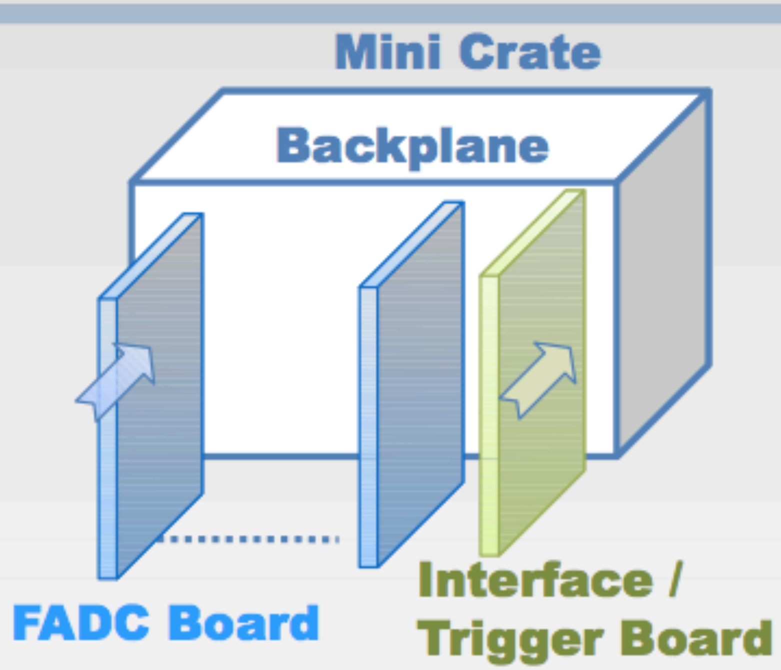


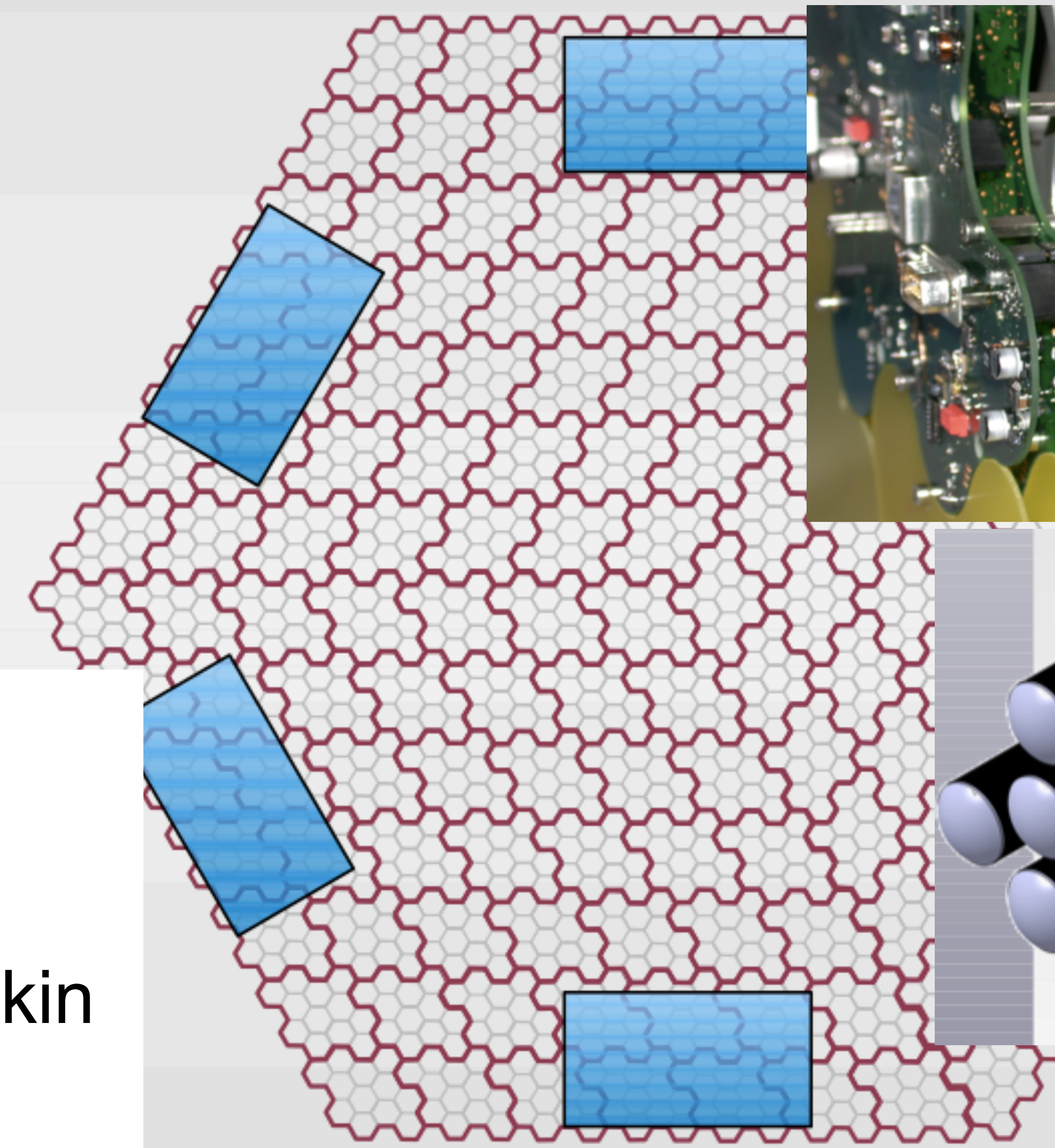
MST-CAM: FlashCam

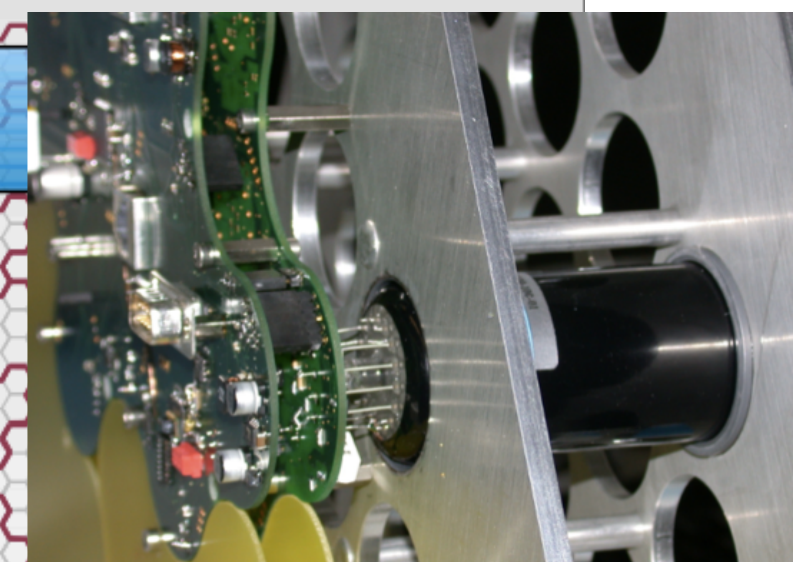
Madrid meeting

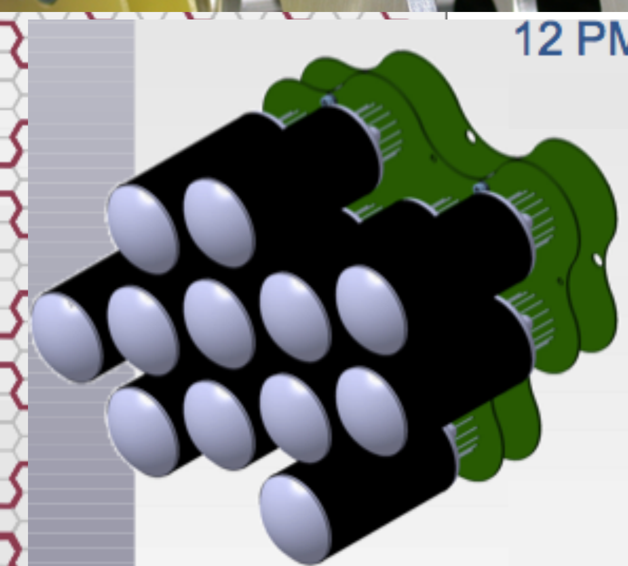
CTA Consortium Meeting, Madrid: FlashCam, a fully digital IACT camera system

Towards an MST prototype





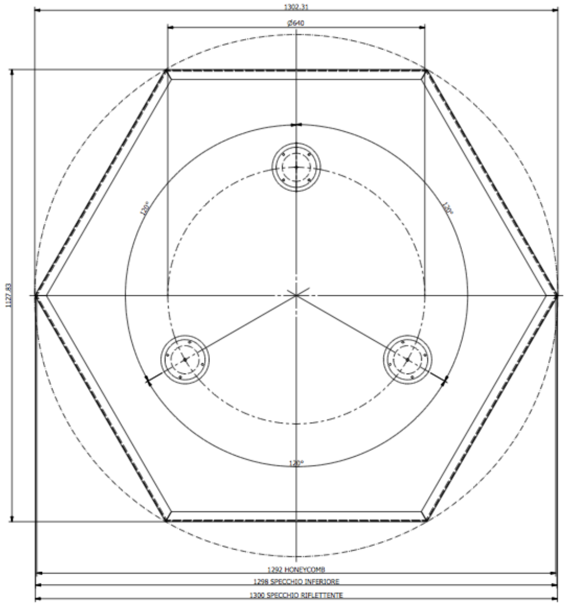




- Passive cooling ~4kW
- Weight 532 kg w/o body, skin

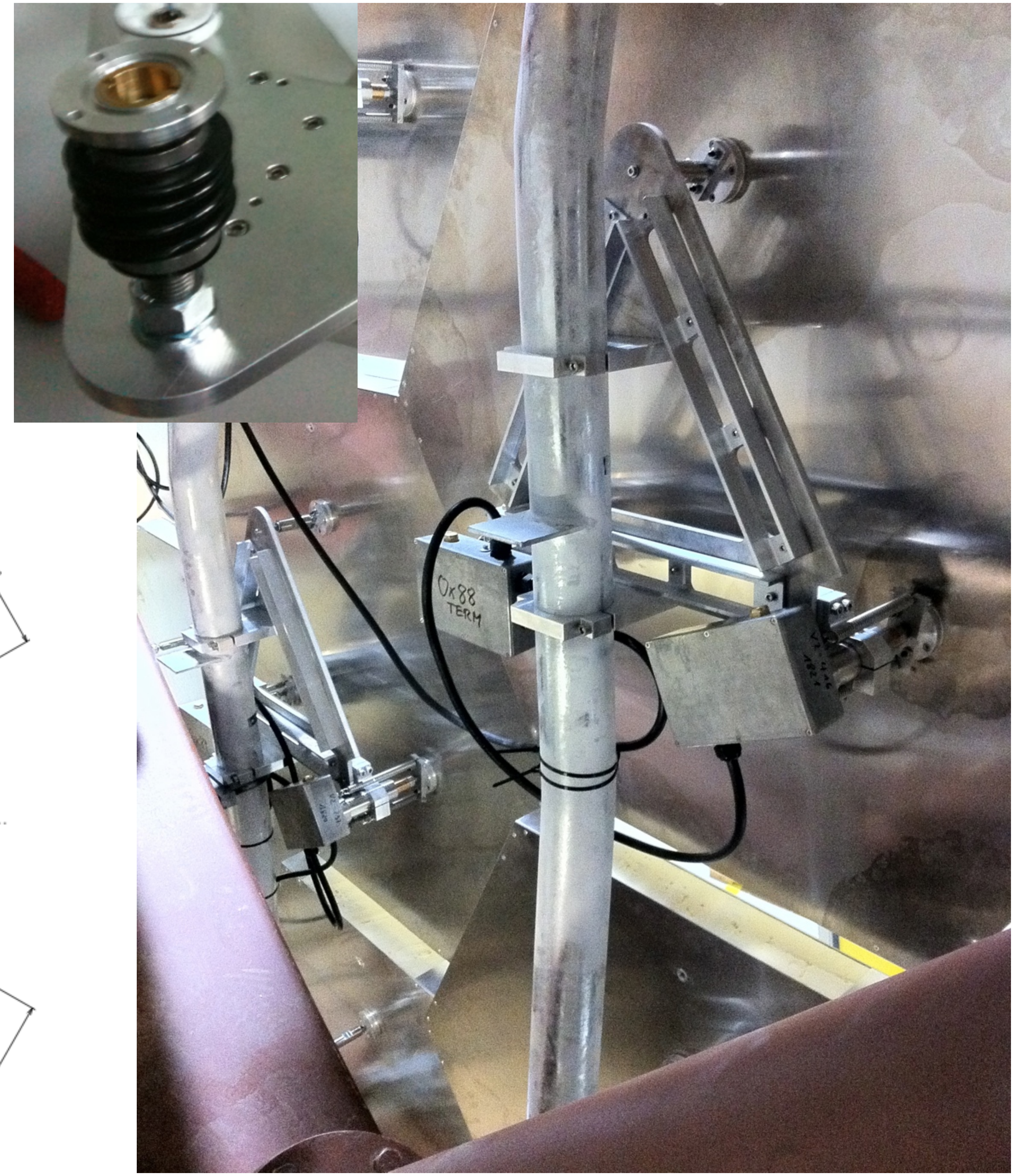
MST-MIR

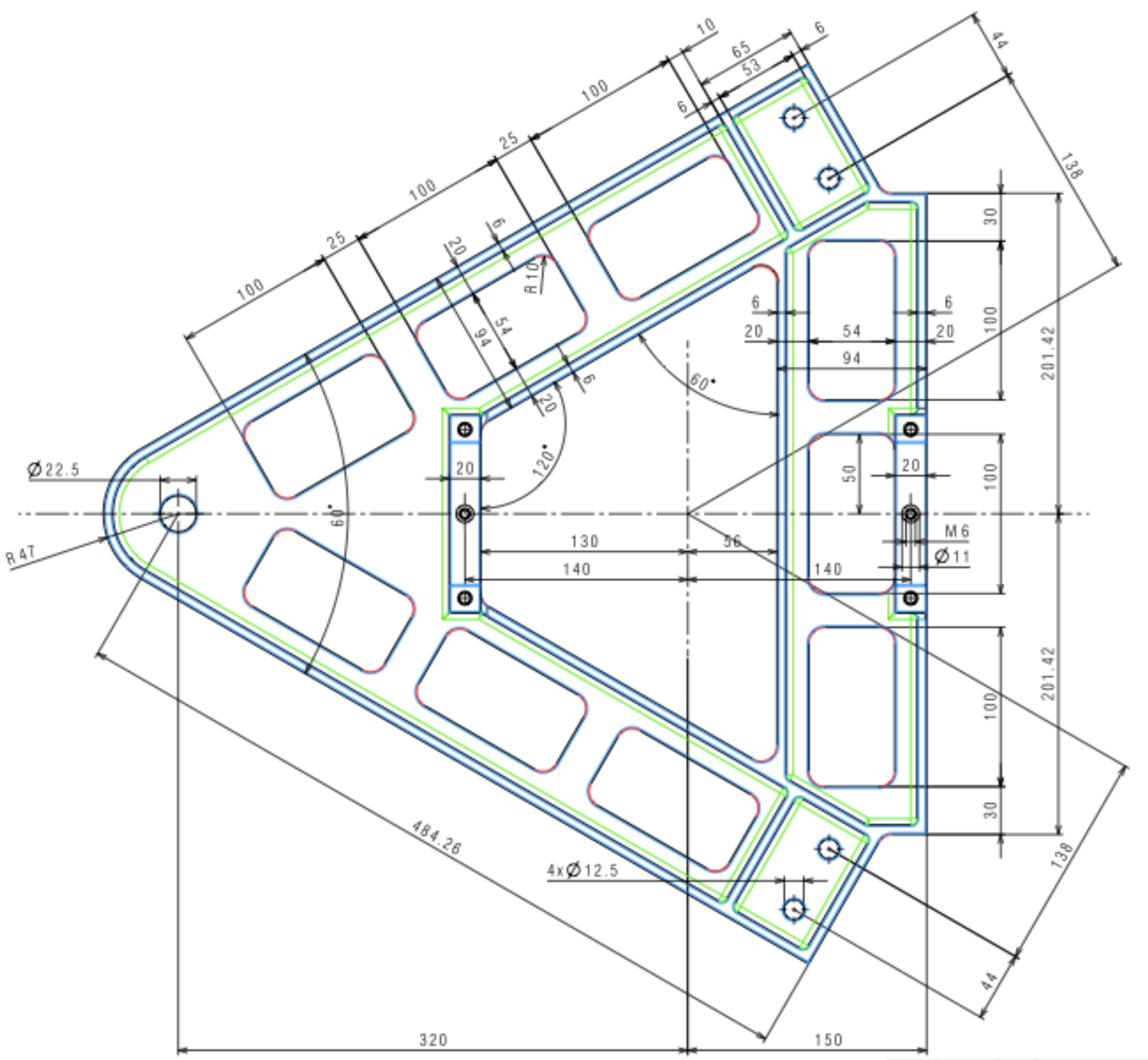
- Spherical mirrors F=16.07m
- Hexagon flat-to-flat 1.20m
- 84 mirrors
  - 84 dummy mirrors on prototype
  - 20+ prototype mirrors produced by CEA/ Kerdry, Brera/ Media Lario, ICRR/ Sanko
    - Brera: 1.13m, 2.5cm, 14.4kg
    - CEA: 1.20m, 8cm, 23kg
    - Sanco: 1.20m
  - Contacts with Galactica and EURO-COMPOSITES



MST-MIR Support

- Tübingen and Zürich AMCs
- Mirror triangles by Zürich



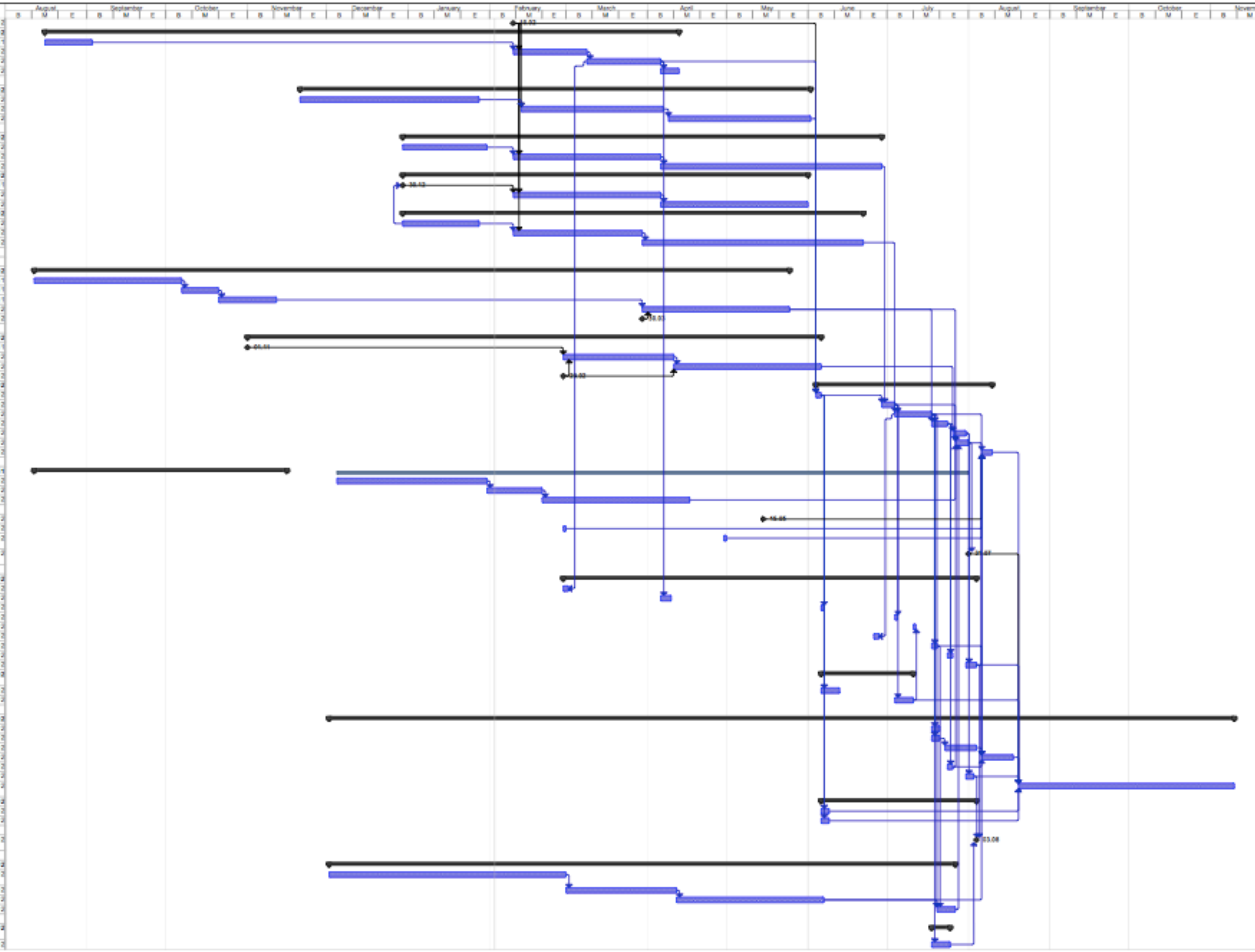


MST-STR: Procurement And Purchasing

- Buildings permit: all documents ready
- Site development prepared
- Bearings, drives and most PLCs in house
- Gears ready to order
- Purchase department informed and ready to go
- Foundation, dish+counterweight, yoke ready to tender
- Quadrupod tendered and ready to order
- Head and tower final touch on drawings and tender starts soon
- CCD-cameras in house
- Dummy camera tendered and partially ordered, final checks with quadrupod

MST Berlin Prototype

ID	Task Name	Duration	Start	Finish
1	Building permit	0 days	Fri 10.02.12	Fri 10.02.12
2	**Foundation**	**173 days?**	**Tue 16.08.11**	**Thu 12.04.12**
3	Drawings	14 days?	Tue 16.08.11	Fri 02.09.11
4	Bidding proc	20 days	Fri 10.02.12	Thu 08.03.12
5	Manufacture	20 days?	Fri 09.03.12	Thu 05.04.12
6	Lock	5 days?	Fri 06.04.12	Thu 12.04.12
7				
8	**Tower**	**140 days?**	**Mon 21.11.11**	**Fri 01.06.12**
9	Drawings	50 days	Mon 21.11.11	Fri 27.01.12
10	Bidding proc	40 days?	Mon 13.02.12	Fri 06.04.12
11	Manufacture	40 days?	Mon 09.04.12	Fri 01.06.12
12				
13	**Head**	**130 days?**	**Fri 30.12.11**	**Thu 28.06.12**
14	Drawings	22 days	Fri 30.12.11	Mon 30.01.12
15	Bidding proc	40 days?	Fri 10.02.12	Thu 05.04.12
16	Manufacture	60 days?	Fri 06.04.12	Thu 28.06.12
17	**YOKE**	**110 days?**	**Fri 30.12.11**	**Thu 31.05.12**
18	drawings	0 days	Fri 30.12.11	Fri 30.12.11
19	Bidding proc	40 days?	Fri 10.02.12	Thu 05.04.12
20	Manufacture	40 days?	Fri 06.04.12	Thu 31.05.12
21	**Dish and CW**	**125 days?**	**Fri 30.12.11**	**Thu 21.06.12**
22	Drawings	21 days	Fri 30.12.11	Fri 27.01.12
23	Bidding proc	35 days	Fri 10.02.12	Thu 29.03.12
24	Manufacture	60 days?	Fri 30.03.12	Thu 21.06.12
25				
26				
27	**Quadrupod**	**205 days?**	**Fri 12.08.11**	**Thu 24.05.12**
28	Design steel q.	40 days?	Fri 12.08.11	Thu 06.10.11
29	Drawings	10 days?	Fri 07.10.11	Thu 20.10.11
30	Bidding proc	16 days	Fri 21.10.11	Fri 11.11.11
31	Manufacture	40 days?	Fri 30.03.12	Thu 24.05.12
32	Money available	0 days	Fri 30.03.12	Fri 30.03.12
33				
34	**Camera dummy**	**136 days?**	**Tue 01.11.11**	**Tue 05.06.12**
35	Drawings	0 days	Tue 01.11.11	Tue 01.11.11
36	Bidding proc	30 days?	Wed 29.02.12	Tue 10.04.12
37	Manufacture	40 days	Wed 11.04.12	Tue 05.06.12
38	Money available	0 days	Wed 29.02.12	Wed 29.02.12
39	**Mounting**	**49 days**	**Mon 04.06.12**	**Thu 09.08.12**
40	Tower	2 days	Mon 04.06.12	Tue 05.06.12
41	Head	3 days	Fri 29.06.12	Tue 03.07.12
42	Dish and CW	10 days	Wed 04.07.12	Tue 17.07.12
43	quadrupod	4 days	Wed 18.07.12	Mon 23.07.12
44	Camera dummy	3 days	Thu 26.07.12	Mon 30.07.12
45	Tubes and clamps	3 days	Fri 27.07.12	Tue 31.07.12
46	Mirrors	4 days	Mon 06.08.12	Thu 09.08.12
47				
48	**Tubes and clamps**	**68 days**	**Fri 12.08.11**	**Tue 15.11.11**
49	Design and drawings	41 days	Mon 05.12.11	Mon 30.01.12
50	Bidding proc.	15 days	Tue 31.01.12	Mon 20.02.12
51	Manufacture	40 days?	Tue 21.02.12	Mon 16.04.12
52				
53	Mirrors available	0 days	Tue 15.05.12	Tue 15.05.12
54	Triangels avail.	1 day?	Wed 29.02.12	Wed 29.02.12
55	Mirror dummies available	1 day?	Mon 30.04.12	Mon 30.04.12
56	Finish mounting steel structure	0 days	Tue 31.07.12	Tue 31.07.12
57				
58	**Survey**	**113 days?**	**Wed 29.02.12**	**Fri 03.08.12**
59	S1	2 days	Wed 29.02.12	Fri 02.03.12
60	S2	2 days	Fri 06.04.12	Mon 09.04.12
61	s3	1 day?	Wed 06.06.12	Wed 06.06.12
62	S4	1 day?	Wed 04.07.12	Wed 04.07.12
63	S5	1 day?	Wed 11.07.12	Wed 11.07.12
64	S6	2 days	Tue 26.06.12	Thu 28.06.12
65	s7	2 days	Wed 18.07.12	Thu 19.07.12
66	s8	2 days	Tue 24.07.12	Wed 25.07.12
67	s9	4 days	Tue 31.07.12	Fri 03.08.12
68	**Mounting of and comm.drive system**	**25 days**	**Wed 06.06.12**	**Tue 10.07.12**
69	azimuth	5 days	Wed 06.06.12	Tue 12.06.12
70	elevation	5 days	Wed 04.07.12	Tue 10.07.12
71				
72	**Measurements**	**246 days?**	**Fri 02.12.11**	**Fri 09.11.12**
73	Installation	3 days	Wed 18.07.12	Fri 20.07.12
74	Cabelling	3 days	Wed 18.07.12	Fri 20.07.12
75	Commisioning	10 days	Mon 23.07.12	Fri 03.08.12
76	Calibration Point	10 days?	Mon 06.08.12	Fri 17.08.12
77	Estimate tel.axis	2 days	Tue 24.07.12	Wed 25.07.12
78	Instrun. Cam dumm.	3 days	Tue 31.07.12	Thu 02.08.12
79	Measurements and Monitoring	60 days?	Mon 20.08.12	Fri 09.11.12
80	**Electronics**	**43 days**	**Wed 06.06.12**	**Fri 03.08.12**
81	Installation	3 days	Wed 06.06.12	Fri 08.06.12
82	Cabelling	3 days	Wed 06.06.12	Fri 08.06.12
83				
84	Mounting and commiss. Fin.	0 days	Fri 03.08.12	Fri 03.08.12
85				
86	**Catwalks**	**170 days?**	**Fri 02.12.11**	**Thu 26.07.12**
87	Design and drawings	64 days	Fri 02.12.11	Wed 29.02.12
88	bidding	30 days	Thu 01.03.12	Wed 11.04.12
89	Manufacture	40 days?	Thu 12.04.12	Wed 06.06.12
90	Mounting	5 days	Fri 20.07.12	Thu 26.07.12
91				
92	**Lightening protection**	**5 days**	**Wed 18.07.12**	**Tue 24.07.12**
93	Mounting	5 days	Wed 18.07.12	Tue 24.07.12



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