SIGMA3D
FLEXIBLE 3D MESSTECHNIK

3rd RadioNet3 European Radio Astronomy Technical Forum Workshop
Metrologies at Radio Astronomy Antennas, September 1-2, 2014,
At the Department of Earth and Space Sciences, Chalmers University of Technology in Gothenburg, Sweden

Antenna Alignment with Theodolite, Lasers and Photogrammetry

Date: 02.09.2014

Table of Content

Company information

Foundation:

2001

Employee (in Europe):

3 Management

30 Technicians & Engineers

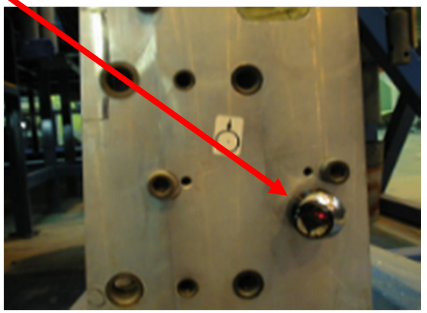
2 Administration

Departments:

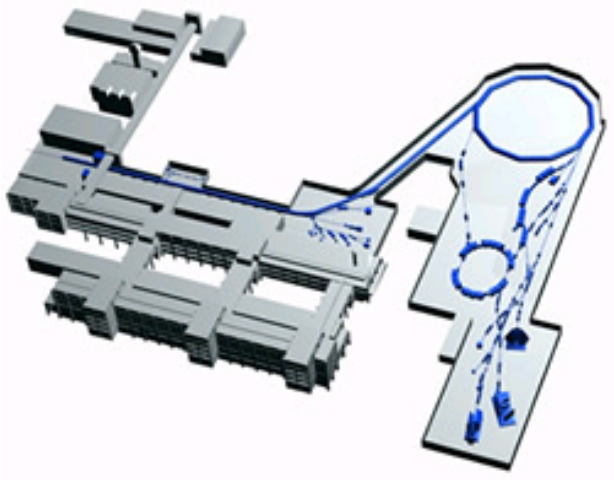
- ✓ M3DMT – Mobile 3D on-site Measurements
- ✓ ScauD - Scanning and Digitizing
- ✓ PuK – Calibration Service for Machine Tools and CMM

M3DMT – Aerospace Industrie

- Build Yigs and Tools
- Periodic inspection
- 100% Part inspection
- New measurement concepts

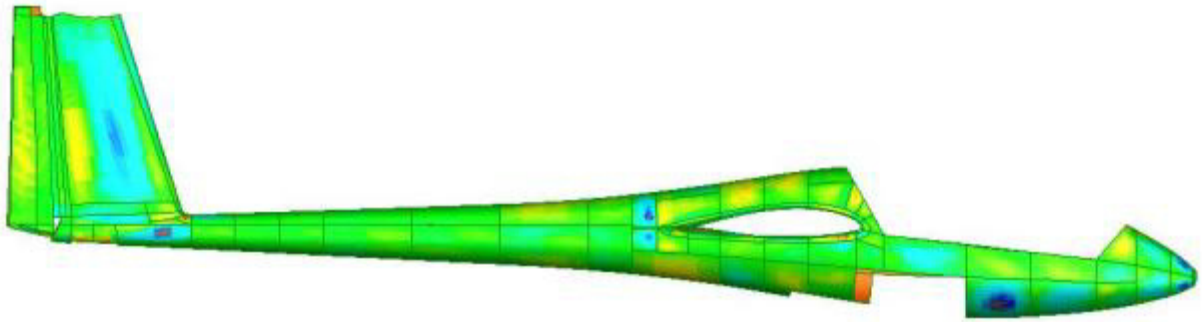


M3DMT – Particle Accelerator

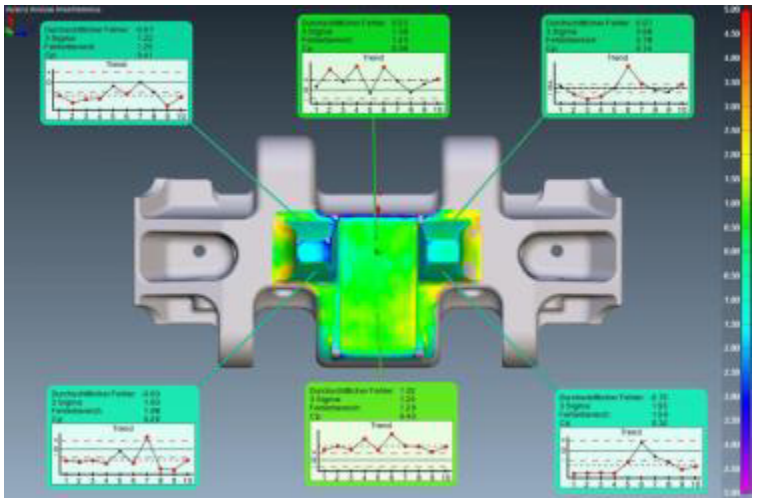


- Setup Magnets
- 3D Network measurement
- Adjust special components
- Support new ideas/experiments

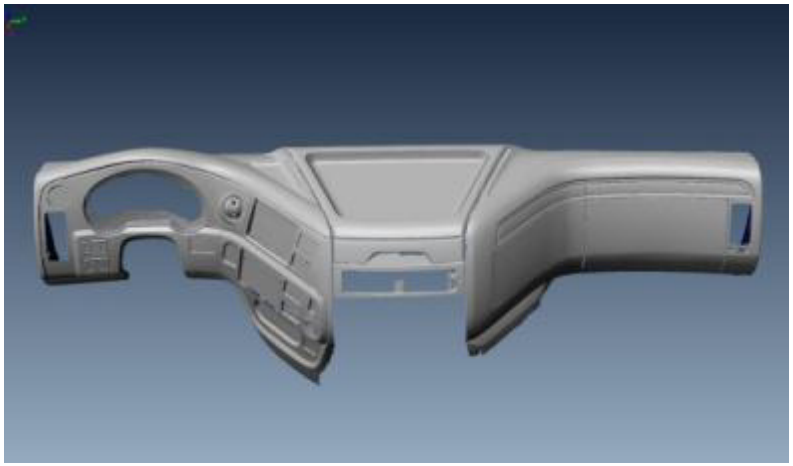
ScauD – 3D Quality control

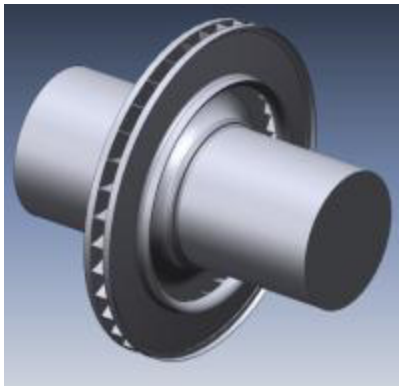


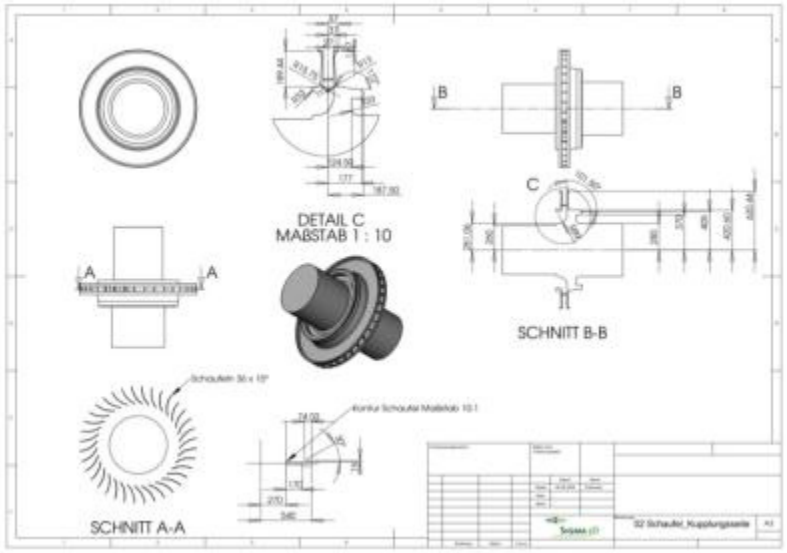
- Data comparison with point clouds
- Actual to CAD data
- Initial sampling
- Prozess control / Variance analysis



ScauD – Reverse Engineering





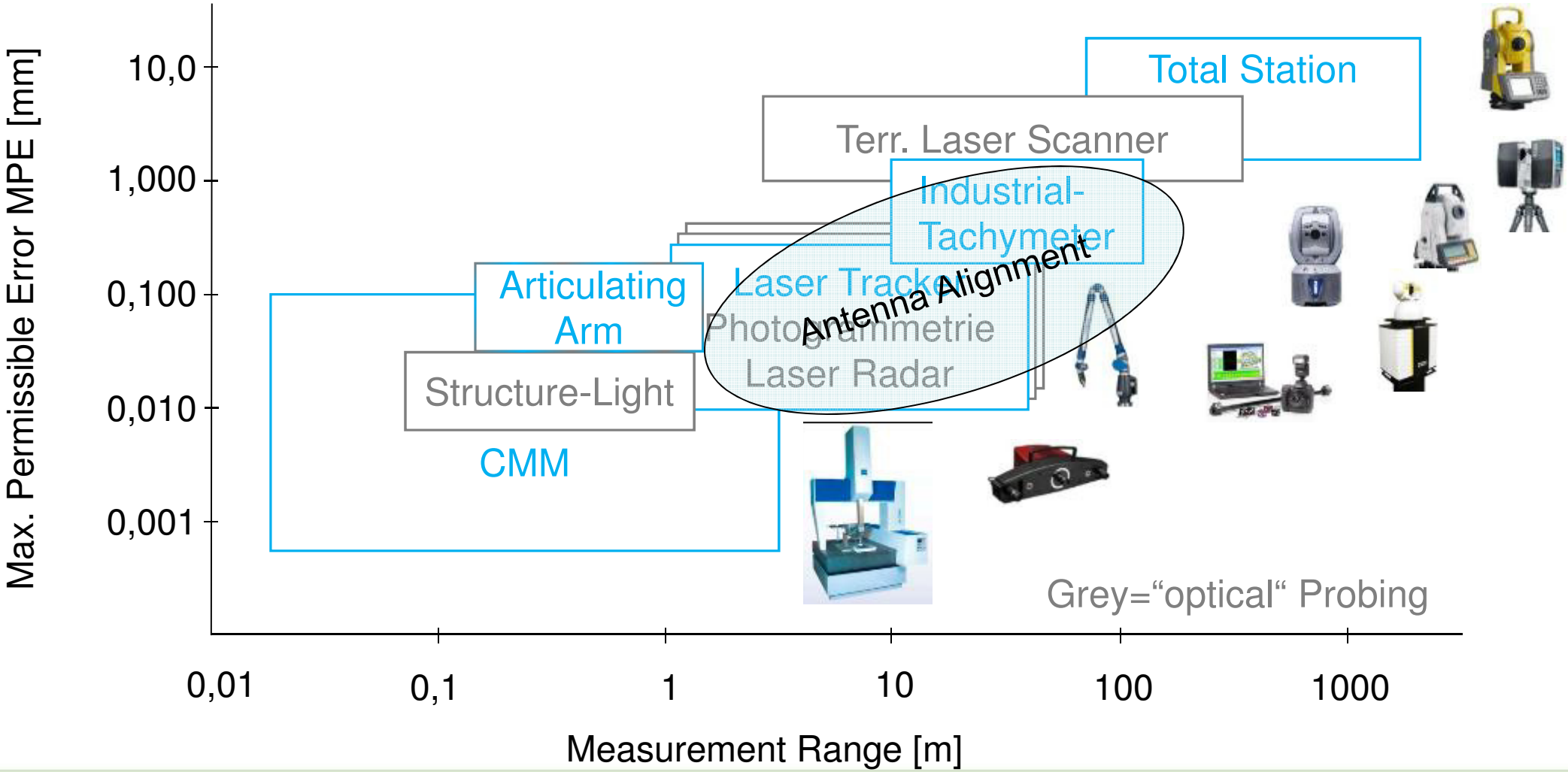


- Draw up 3D CAD data
- Parametric CAD construction
- Build free-form surfaces
- CAE -Computer Aided Engineering

Mobile 3D Measurement Systems

Using different mobile 3D measurement technologies.

Industrial 3D Measurement Systems



Industrial-Tachymeter / Total Station

Physical principle	Optical angle measurement + Speed of light (distance)
Advantage	Long range
	Different Target types
Disadvantage	Highest accuracy only with CCR
Trigger Mode	Single points
Range	2 to 120m
Accuracy (MPE)	±0,3mm + 13µm/m
Typical Application	Shipbuilding / Railway
Traceability	ISO 17123-5, DIN 18723-6
Price	45.000 to 80.000 €
Target	Retroreflector / Reflective tape

Manufacturer:

- Leica
- Sokkia

Total Station – Application in Antenna Alignment

Application:
- Steel Structure (Alidade / BUS)
- Setting Reference Points
- Single Part positioning
- (Refector Alignment)

Accuracy:
- 0,5mm to 3mm

Targets:
- Reflective tape
- CCR (Corner Cube Reflector)

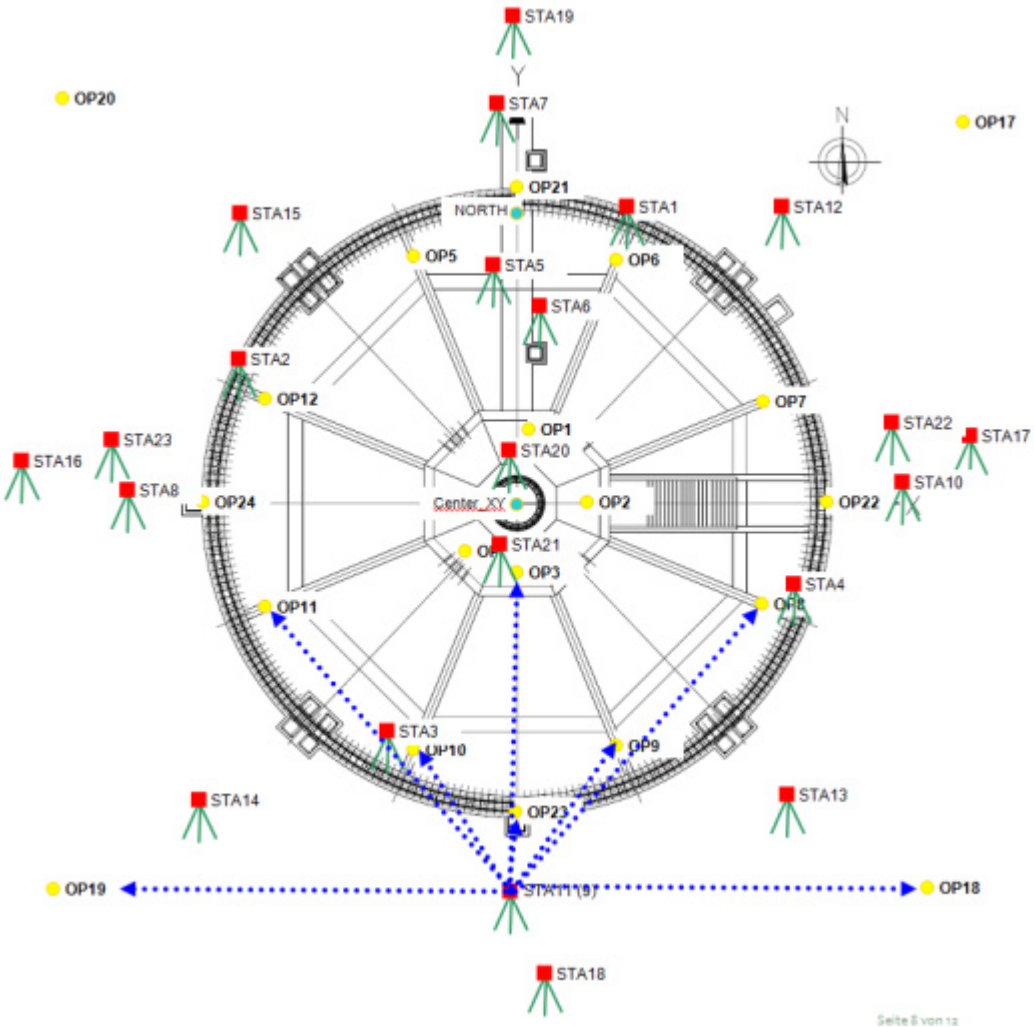
Total Station – Application: Steel Structure Alignment (SRT, 2010)

Application:

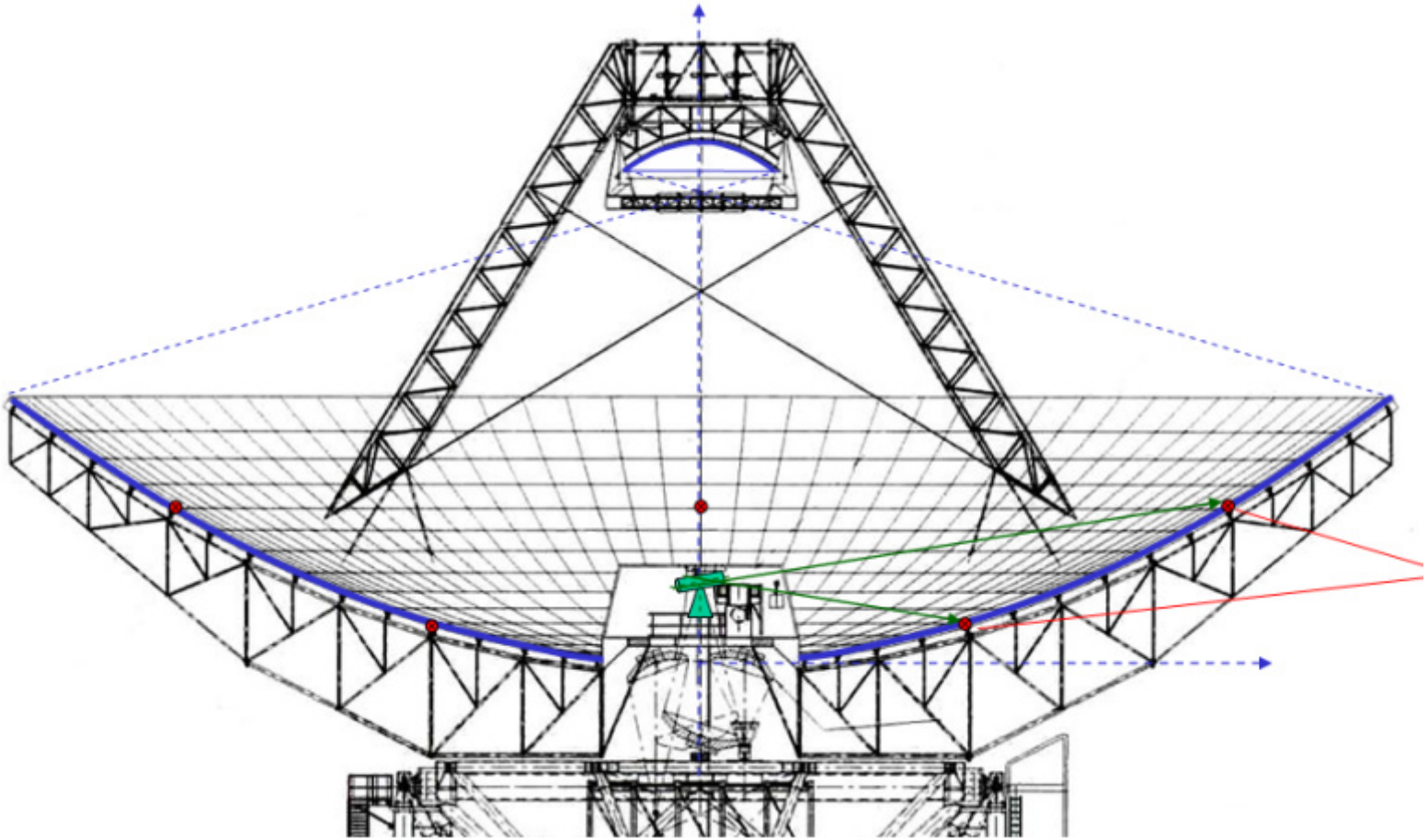
- BUS Alignment
- Panel supports

Total Station – Application: Setting Reference Points (SRT 2009)

POINT ID	X [mm]	Y [mm]	Z [mm]	RMS X [mm]	RMS Y [mm]	RMS Z [mm]	Total RMS [mm]
Center_XY0	0.00	0.00	5520.54	0.80	0.45	0.31	0.97
NORTH_Pilar	-3.33	52568.17	258.73	0.00	0.00	0.00	0.00
NORTH	0.00	19710.33	-154.02	0.00	0.00	0.00	0.00
OP1	-231.05	5868.97	1599.21	0.52	0.06	0.11	0.54
OP2	5899.67	272.51	1584.79	0.16	0.02	0.17	0.23
OP3	249.06	-5826.97	1589.88	0.28	0.13	0.30	0.43
OP5	-6720.02	16227.87	3.43	0.46	0.06	0.12	0.48
OP6	6604.84	15966.18	43.97	0.32	0.03	0.17	0.36
OP7	16127.74	6664.51	13.08	0.23	0.04	0.23	0.33
OP8	16158.69	-6668.14	12.11	0.26	0.03	0.27	0.37
OP9	6645.24	-16029.62	29.05	0.28	0.04	0.16	0.32
OP10	-6633.03	-15931.09	49.34	0.33	0.08	0.35	0.49
OP11	-16171.64	-6681.69	6.53	0.39	0.13	0.19	0.46
OP12	-16127.46	6711.41	10.18	0.50	0.12	0.12	0.52
OP16	-4213.14	-4056.56	1577.02	0.72	0.14	0.05	0.74
OP17	13004.28	43400.97	-209.22	0.47	0.21	0.38	0.64
OP18	42150.58	-26163.23	-333.90	0.72	0.11	0.74	1.04
OP19	-46375.51	-30656.09	-1643.93	0.78	0.02	0.56	0.96
OP20	-44629.83	24765.52	-1733.67	0.81	0.24	0.58	1.02
OP21	11.90	20293.94	-4.14	0.24	0.05	0.12	0.27
OP22	20283.89	1.92	-8.61	0.40	0.26	0.13	0.49
OP23	-504.45	-20286.39	-0.09	0.41	0.22	0.09	0.48
OP24	-20279.27	513.92	-3.53	0.45	0.01	0.47	0.65
max	42150.58	52568.17	5520.54	0.81	0.45	0.74	1.04
min	-46375.51	-30656.09	-1733.67				
Range	88526.09	83224.26	7254.21				



Total Station – Application: Reflector (Pre-Alignment)



Disadvantages:
- Only in 90° Elevation
- Changing conditions (temperature)

Accuracy:
- 0,5mm to 1mm

Targets:
- Reflective tape
- Retroreflector

Critical
- Intersection angle
- Structure movement during measurement

Laser Scanner

Manufacturer :

- Faro
- Leica Geosystems
- Riegl

Physical principle	Optical angle mearsurement + Speed of light / Phase-shift
Advantage	Fast data acquisition
	“Optical“ probing (no targets)
	Option: with targets
Disadvantage	Hugh data volume
	Distance not accurate
Trigger Mode	Scanning
Range	0,6 to 120m
Accuracy (MPE)	±2 to 5mm
Typical Application	As-built documentation
	Building reconstruction
Traceability	ISO 17123-9
Price	30.000 bis 80.000 €
Target	Non or paper targets

Laser Scanner – Application in Antenna Alignment

Application:
- As-built documerntation
- Completeness check
- (Panel Surface RMS > 1000µm)

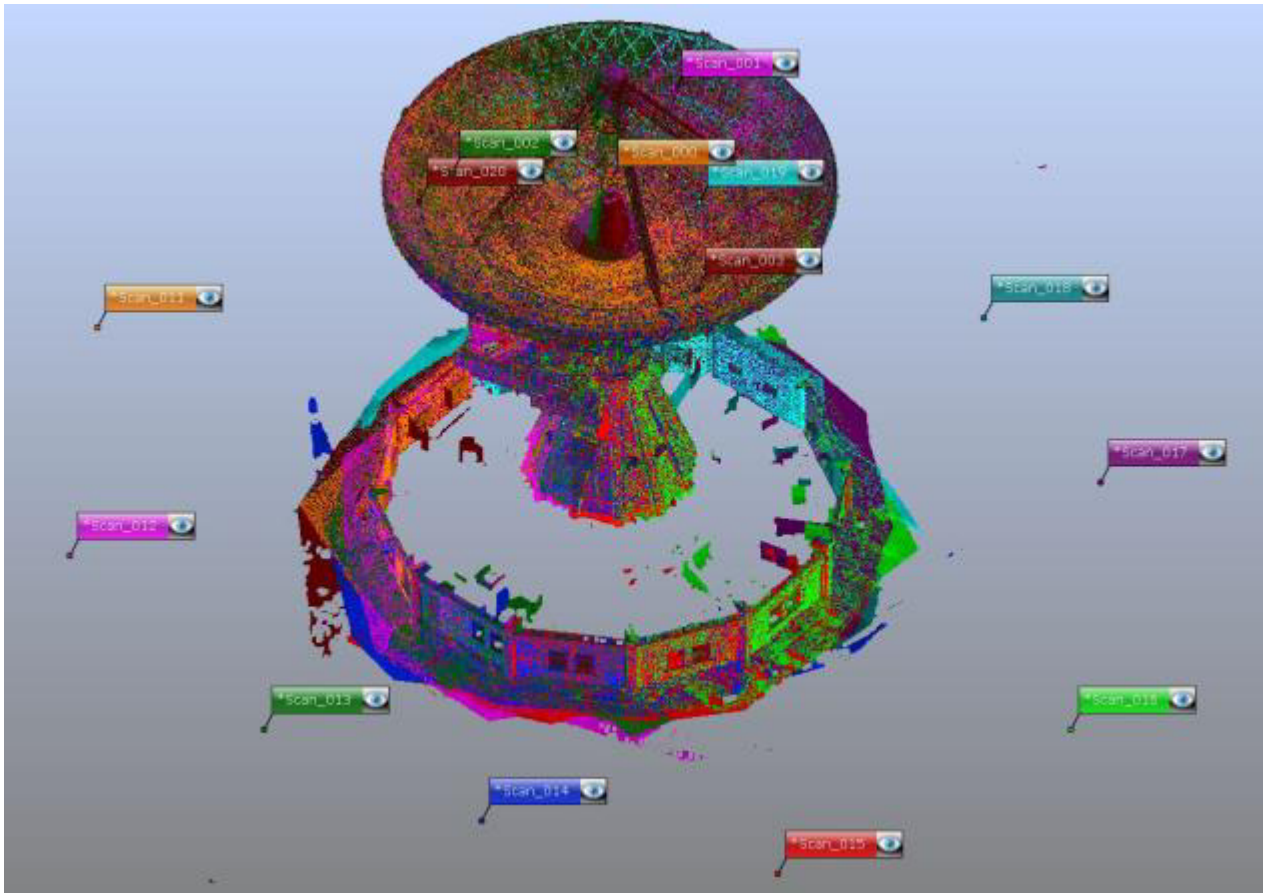
Accuracy:
- 2mm to 5mm

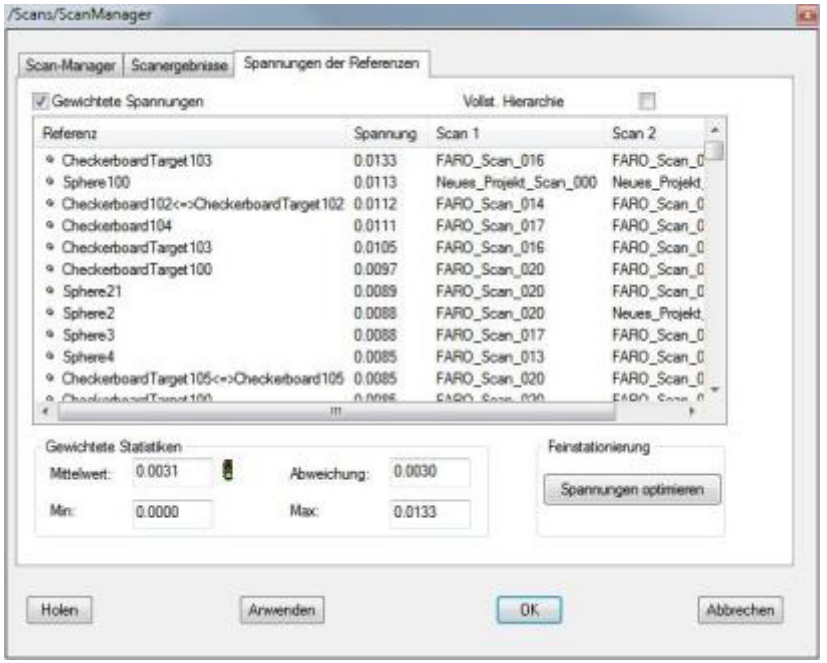
Targets:
- non
- Paper targets
- Sphere targets

Laser Scanner – Application: As-built documentation

10 positions on the ground, 4 positions in the main reflector, one of them on the feed cone.

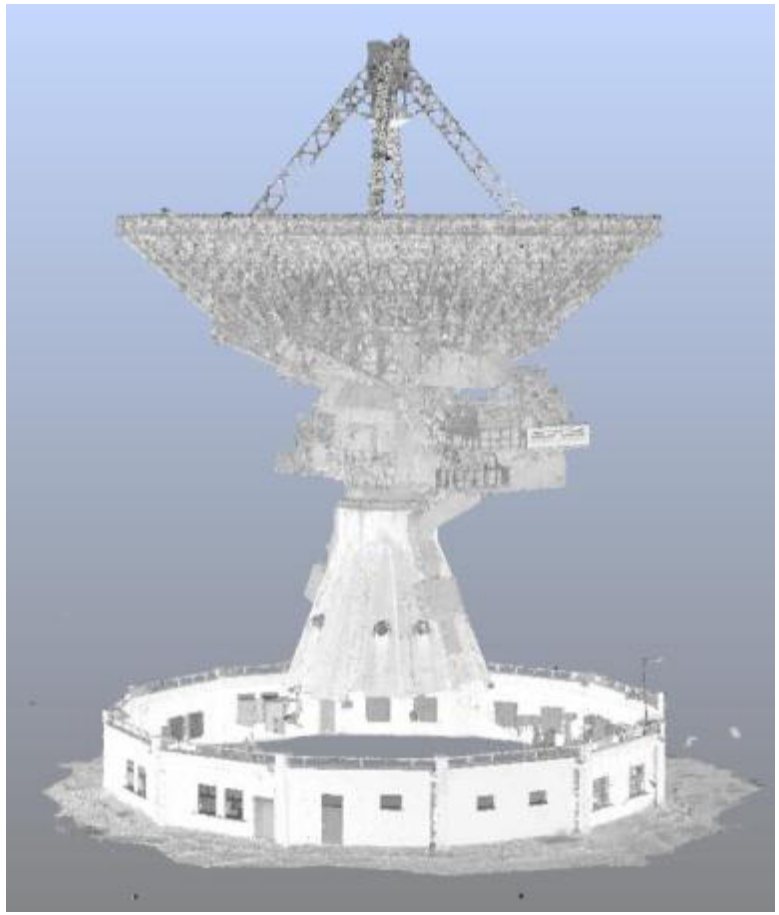
Laser Scanner – Application: As-built documentation

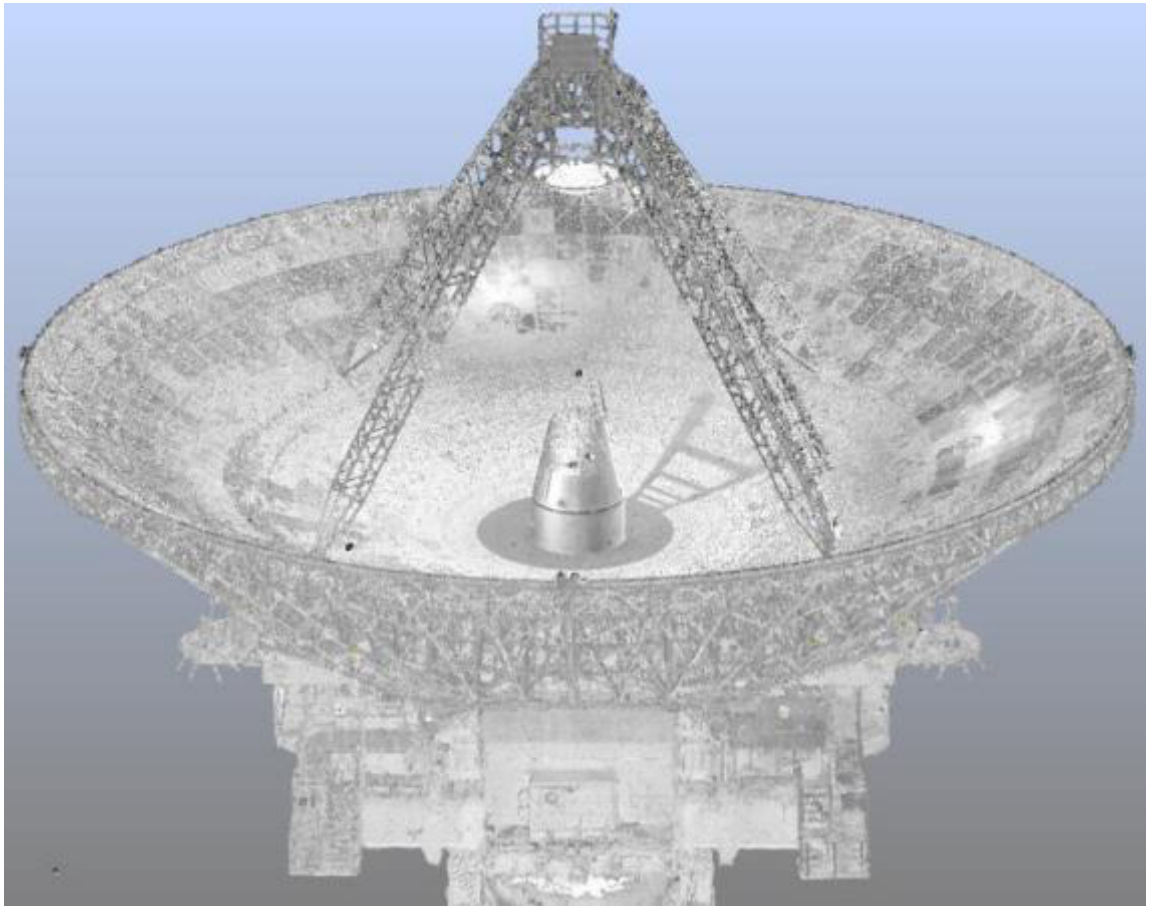




The Measurement was done with a resolution of 3mm at 10m distance.

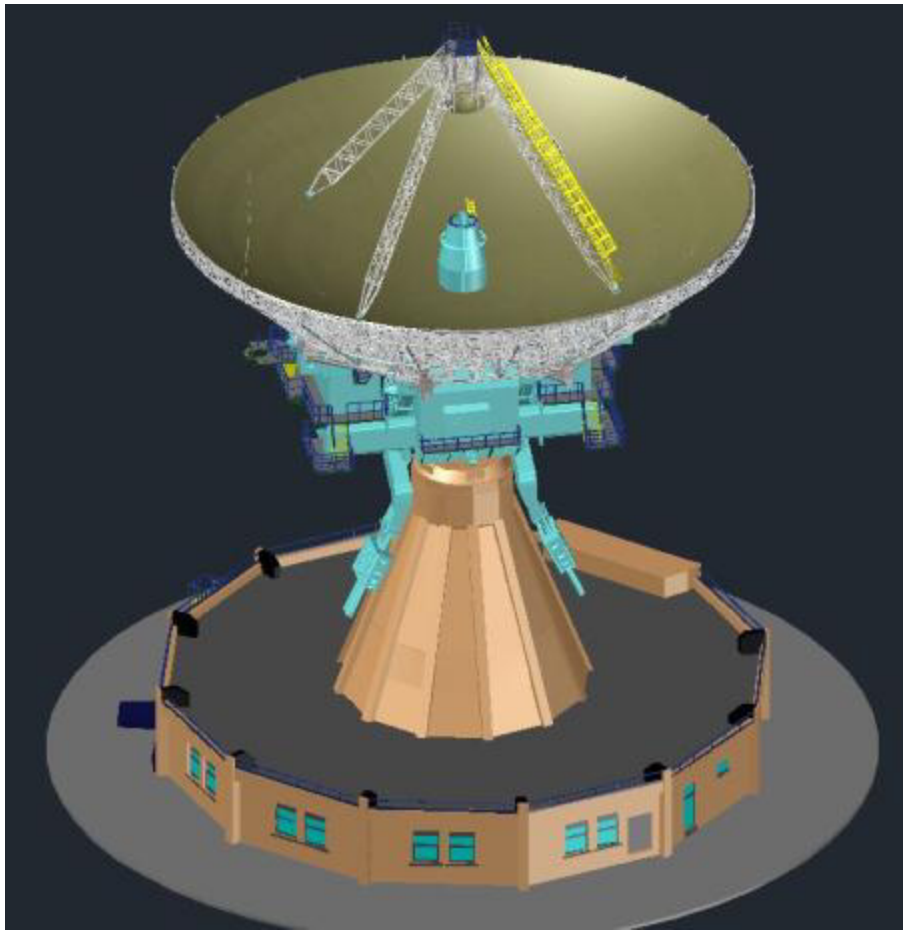
Laser Scanner – Application: As-built documentation

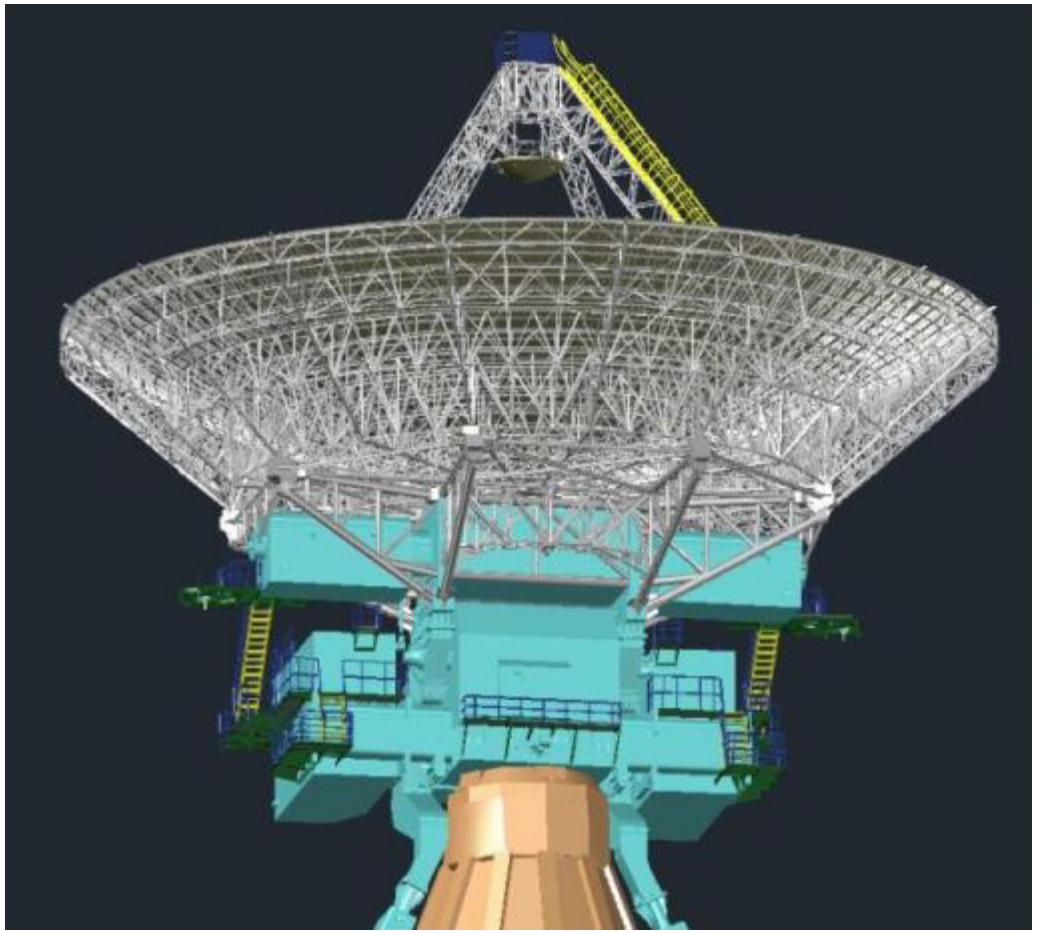




The 14 individual scans have been connected and deployed to a single point cloud.

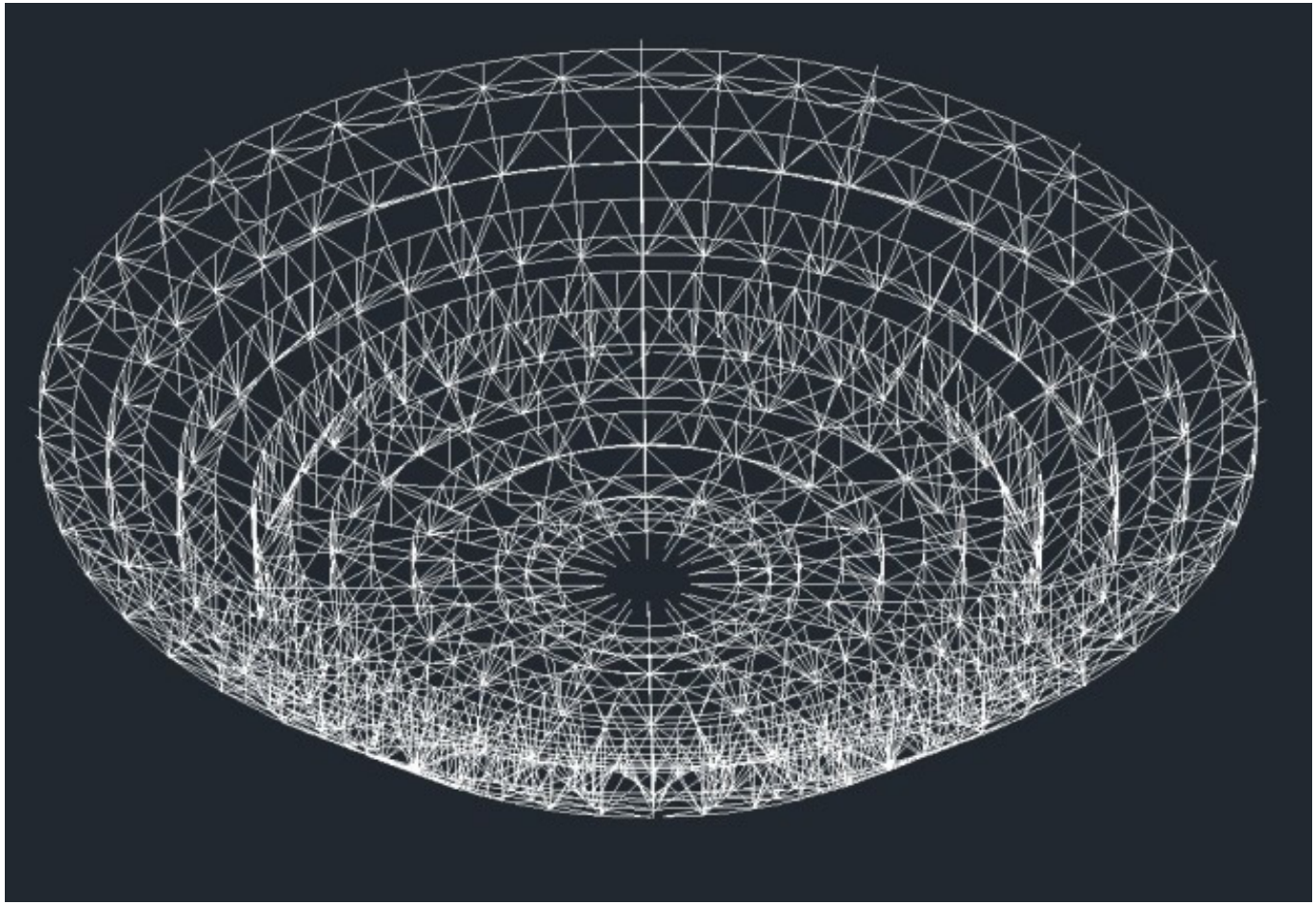
Laser Scanner – Application: As-built documentation





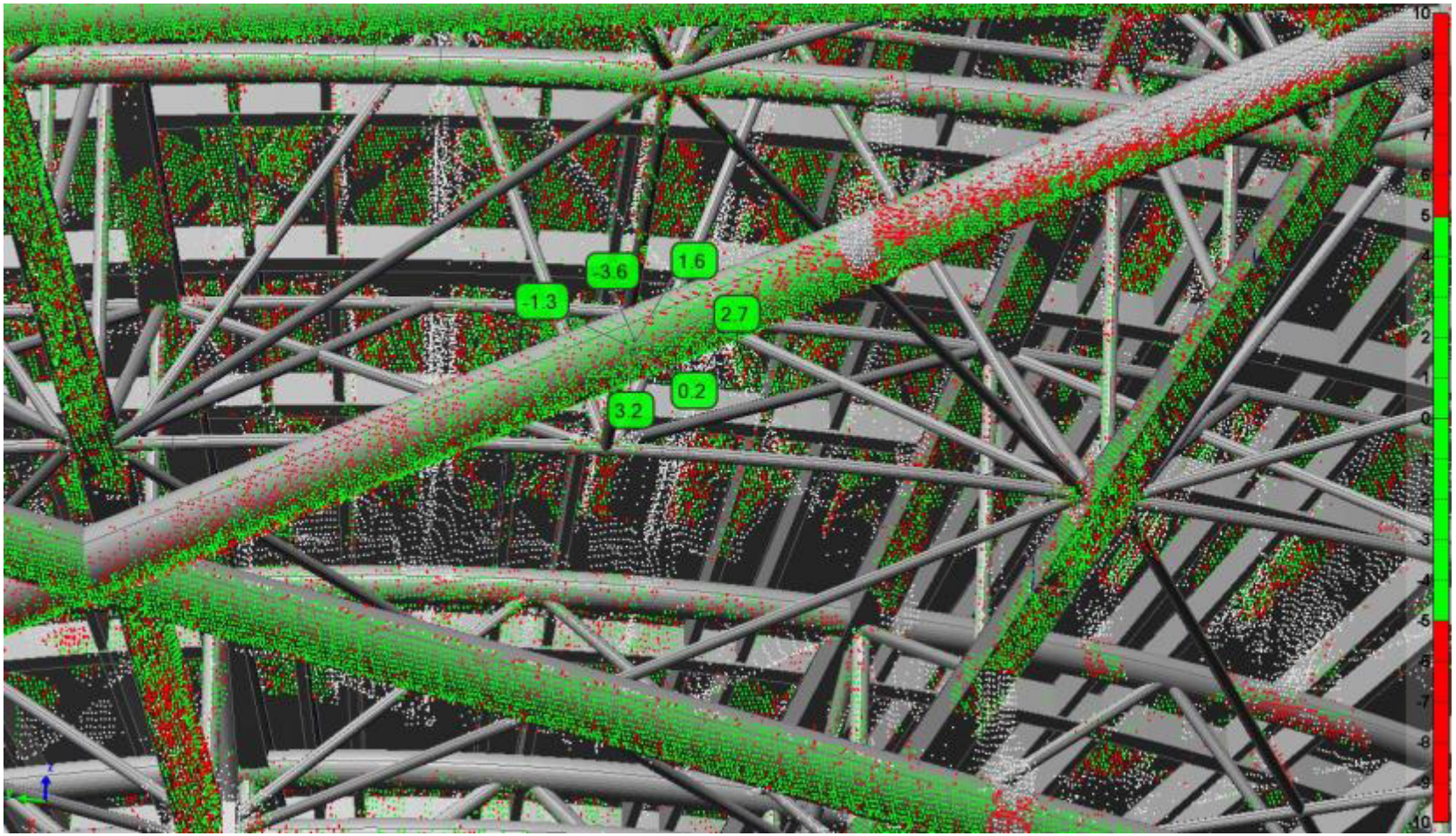
3D point cloud is modeled to a CAD model in step- and dwg-format

Laser Scanner – Application: As-built documentation



Center-axis model of steel structure for FEM Analysis

Laser Scanner – Application: As-built documentation



Quality check: CAD model to measured points

Laser Tracker

Manufacturer:

- Faro
- Hexagon
- API

Physical principle	Optical angle measurement + Interferometry / Phase-shift & SoL
Advantage	Accurate distance measurement
	“Online“ measurements possible
Disadvantage	Target (Retroreflector) needed
Trigger Mode	Single-points, Scanning
Range	0 to 80m
Accuracy (MPE)	20µm to 400µm
Typical Application	3D / 6D Online-Adjustment,
	Tool & Yig verification
Traceability	ISO 10360-10, VDI 2617-10, ASME B89.4.19
Price	60.000 to 250.000 €
Target	Retroreflector (CCR, SMR, BMR)

Comparison: Laser Tracker from FARO vs. Leica

	Faro		Leica	
	ION	Vantage	AT401	AT901
ADM-Accuracy *(MPE)*	16µm+0,8µm/m	16µm+0,8µm/m	±10µm	±10µm
IFM-Accuracy *(MPE)*	4µm+0,8µm/m	-	-	±0.4µm+0,3µm/m
R0 Parameter *(MPE)*	16µm	16µm	-	5µm
Encoder Accuracy *(MPE)*	20µm+5µm/m	20µm+5µm/m	15µm+6µm/m	±15µm+6µm/m
XYZ-Coordinate *(typical v.)*	15µm+6µm/m	15µm+6µm/m	15µm+6µm/m	±7,5µm+3µm/m
Level *(MPE)*	±2“	±2“	±1“ (2σ)	±1“+0,5%
Range (distance)	55m	80m	320m	160m
Range (horizontal)	±270°	±360°	±360°	±360°
Range (vertikal)	75° bis -50°	77,9° bis -52,1°	±145°	±45°
Sample Rate	10.000/sec	10.000/sec	2/sec	3000/sec

Quellen
ION: FARO ION - Features, Benefits & Technical Specifications (01.2013)
Vantage: FARO Laser Tracker Vantage - Features, Benefits & Technical Specifications (07.2012)
AT401: Leica Absolut Tracker AT401 – Absolut portable (April 2010)
AT901: PCMM System Specifications - Leica Absolute Tracker and Leica T-Products (02.2008)

Laser Tracker – Application in Antenna Alignment

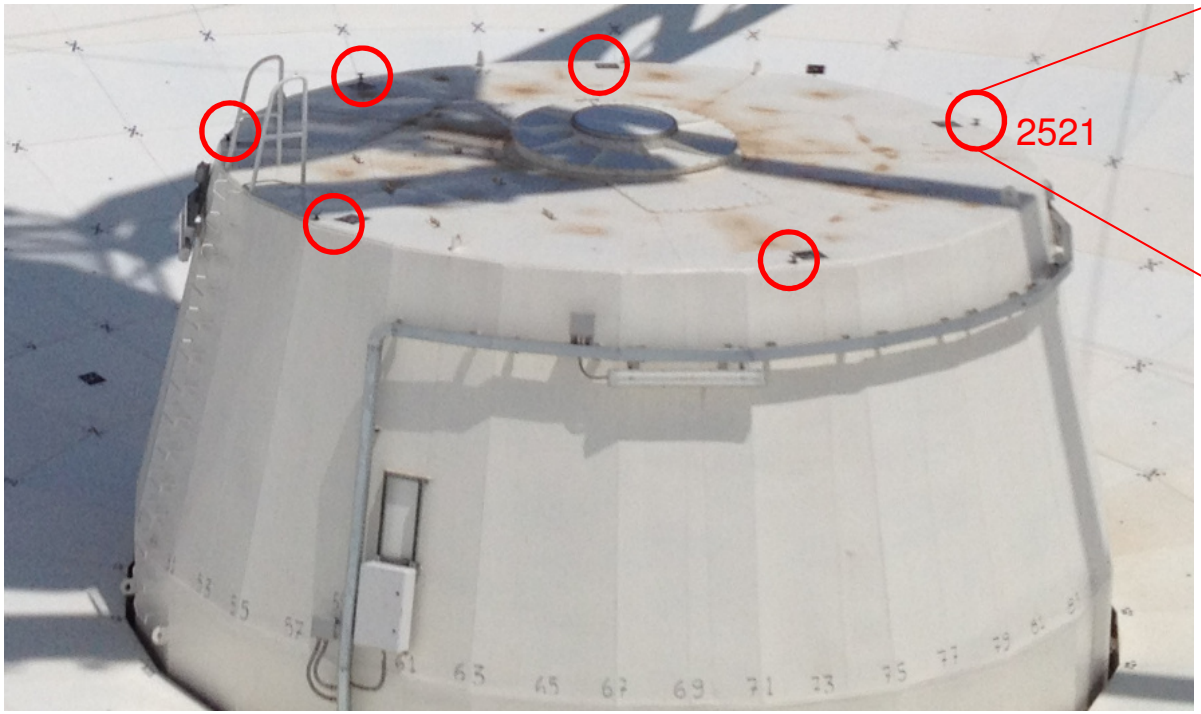
Application:
- Setting Reference Points
- 6 DOF single-part positioning
- Movement Sub-Refector

Accuracy:
- 0,05mm to 0,15mm

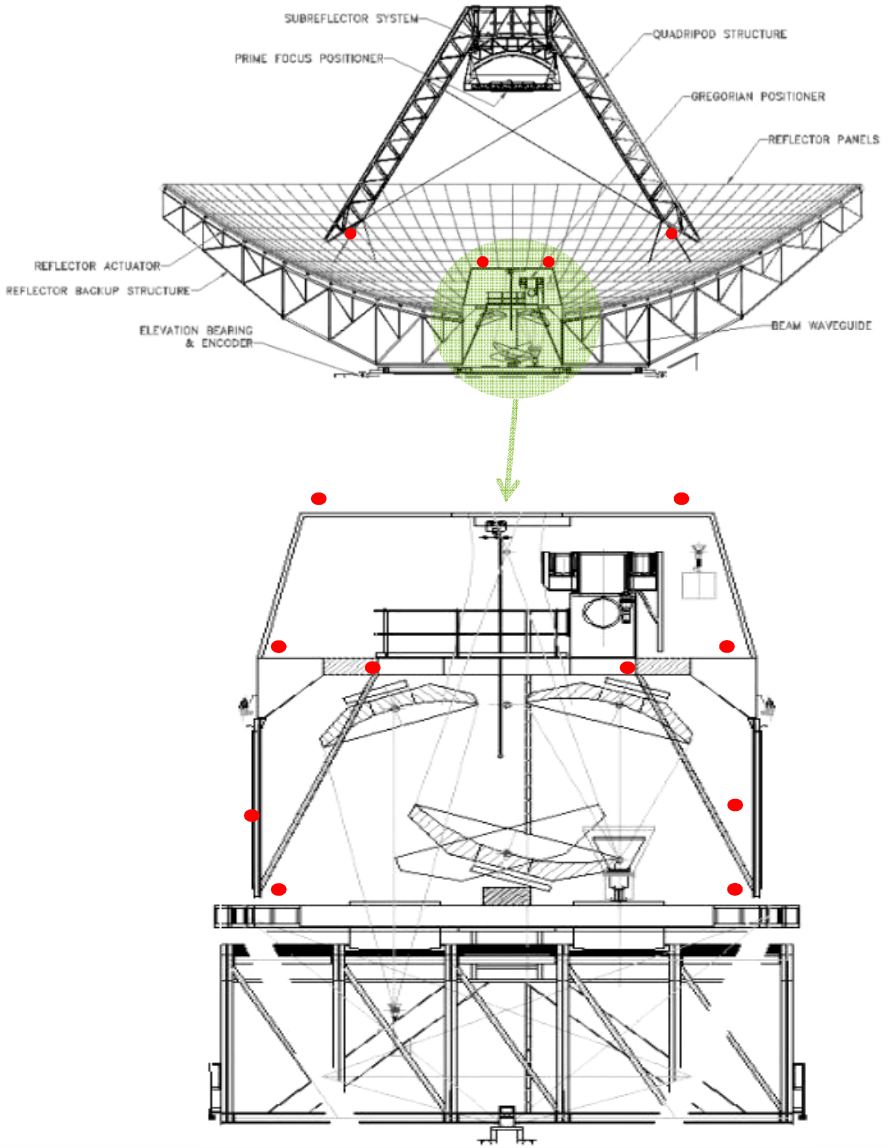
Targets:
- Retrorefl. (> 750 US$/each)
- CCR (Corner Cube Reflector)
- SMR (Spherical Mounted R.)
- BMR (Ball Mounted R.)

Laser Tracker – Application: Set Reference points

Set reference points for Photogrammetry setup



Reference points

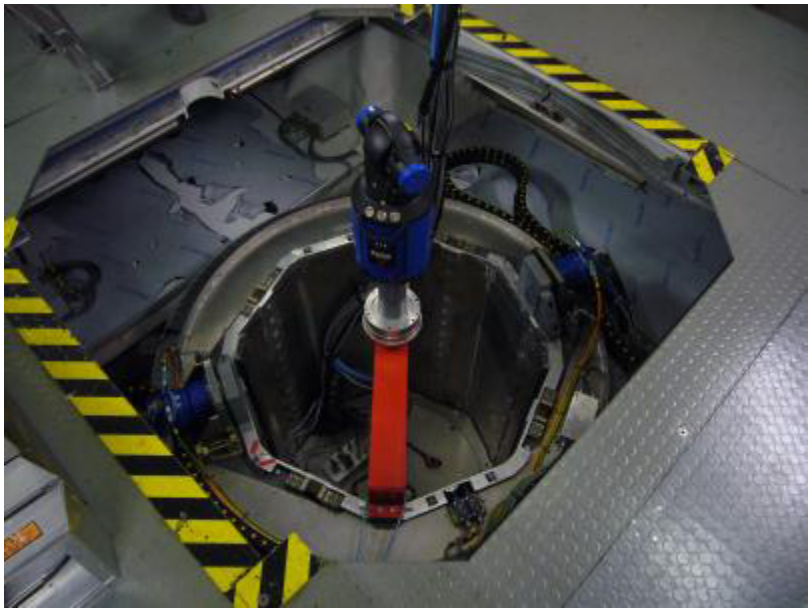


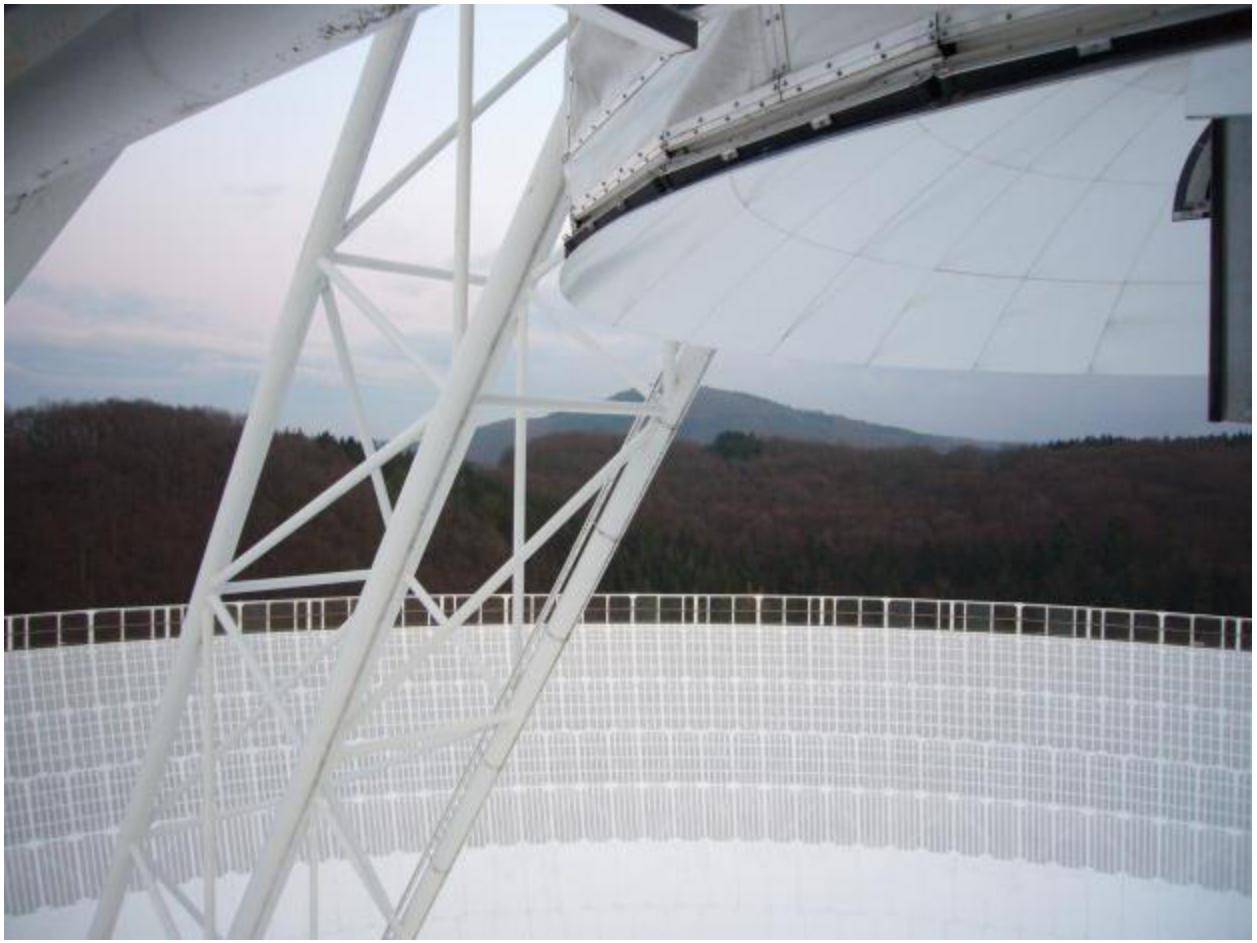
Laser Tracker – Application: 6 DOF positioning mirrors

Application:

- Solid-mirror Alignment
- Online-Adjustment

Laser Tracker – Application: Movement Sub-Reflector





Application:

- Check the movement of the Sub-Refector transit system from inside the SR-cabin

Laser Tracker – Application: Sub-Reflector different elevation angle

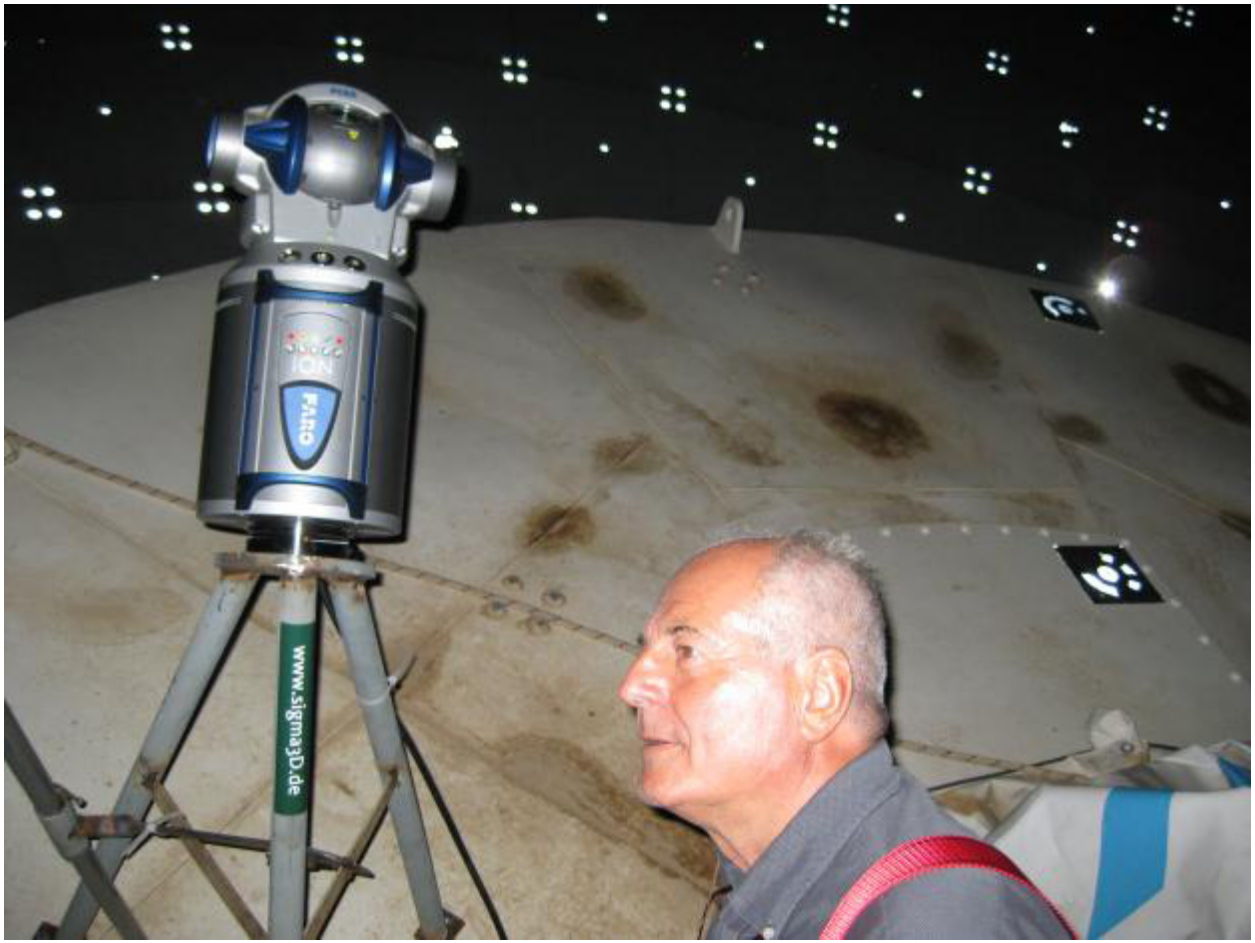




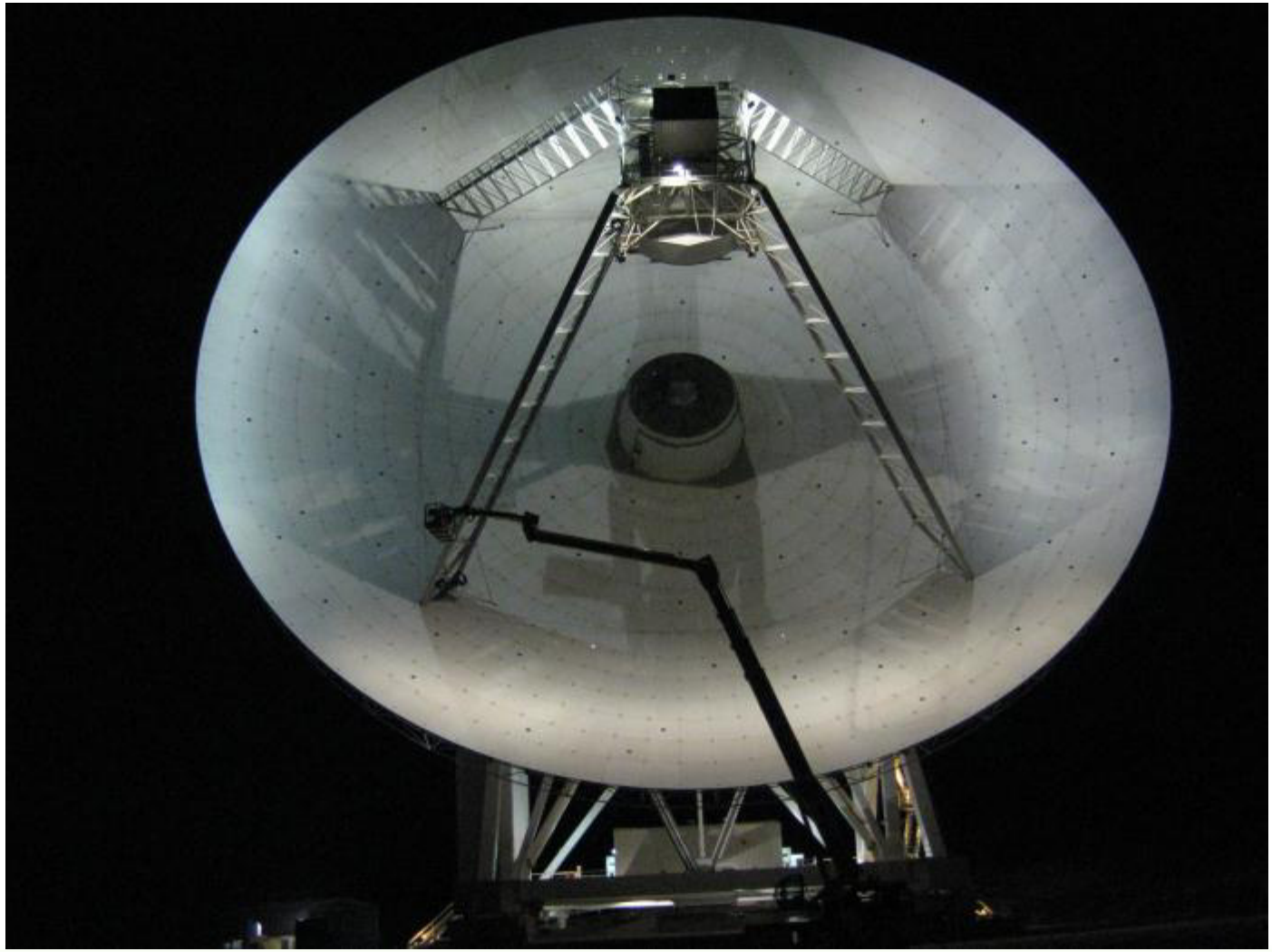

Laser Tracker – Application: Sub-Reflector different elevation angle

Application:

- Movement of the Sub-Refector in different elevation angle (calibration hexapod)



Laser Tracker – Application: Sub-Reflector different elevation angle



Laser Tracker – Application: Sub-Reflector different elevation angle

Project	M2-Alignment	
Measurement place	SRT, San Basilio, Sardinia	
Date	15.08.2011, 21:10 - 21:25 Uhr	
Measurement object	SRT - M2 (Subreflector)	
Customer	MT Mechatronics	
Contact person on site	Mr. S. Doth	sigma3D GmbH
Measurement system	Laser Tracker Faro SN 3301	Max-Hufschmidt-Str.4a
Inspector	H. Paluszek, sigma3D GmbH	D-55130 Mainz
Air temperature	21°C - 20°C	Tel. +49 (0) 61 31 - 96 257 - 0
Material temperature	17°C - 18°C (Material-kompensation on 20° C)	Fax +49 (0) 61 31 - 96 257 - 20
Coordinate System	M1 Mirror after Best-Fit calculation	www.sigma3D.de
(karthesian)	Best-Fit with 6 Parameter	info@sigma3D.de
Remark	Measurement in 90° Position (1st)	

Point ID	Measured (act.)			M1 Best-Fit (nominal)			deviation (actual - nominal)			Remark
RHR	x [mm]	y [mm]	z [mm]	x [mm]	y [mm]	z [mm]	Δx [mm]	Δy [mm]	Δz [mm]	
Mirror Reference points in M1 coordinate system										
2521	3660.96	22.26	4521.45	3661.02	22.22	4521.30	-0.06	0.04	0.15	
2522	-37.03	-3692.51	4517.86	-36.94	-3692.64	4517.99	-0.09	0.13	-0.13	
2523				-3439.50	-1431.09	4523.18				not visible from LT Stand
2524	-3419.27	1414.60	4513.91	-3419.18	1414.72	4513.73	-0.09	-0.12	0.18	
2525	-1451.13	3408.54	4511.66	-1451.23	3408.72	4511.78	0.10	-0.18	-0.12	
2526	1447.95	3402.79	4504.34	1447.82	3402.65	4504.43	0.13	0.14	-0.09	
M2_Ref1	-1.63	39.98	23739.96	0.21	-0.51	23742.94	-1.84	40.49	-2.98	Mid-point
M2_Ref2	77.51	-412.41	23738.70	80.07	-452.69	23743.10	-2.56	40.28	-4.40	
M2_Ref3	351.10	336.51	23740.79	352.49	296.57	23743.06	-1.39	39.94	-2.27	
M2_Ref4	-433.69	199.27	23740.80	-431.99	158.14	23743.03	-1.70	41.13	-2.23	
21300	13158.87	15329.01	6690.88	13155.12	15323.13	6697.80	3.75	5.88	-6.92	
23700	-15379.33	13143.68	6585.24	-15373.88	13139.43	6589.49	-5.45	4.25	-4.25	
26100				-13174.43	-15333.90	6705.44				not measured
28500	15433.71	-13104.74	6543.72	15436.33	-13109.61	6541.50	-2.62	4.87	2.22	

Laser Tracker – Application: Sub-Reflector different elevation angle

Tra x	1.931	mm							
Tra y	-40.446	mm							
Tra z	3.095	mm							
Rotx	0.1752	DEG	=	631	arcsec				
Roty	0.0333	DEG	=	120	arcsec				
Rotz	-0.0873	DEG	=	-314	arcsec				
Scale x	1								
Scale y	1								
Scale z	1								
xy	0								
Azimuth	0								
ZtoXY	0								
R_Dist	0								
s0	0.033								
sx	0.049	max x	0.037	min x	-0.07	max x - min x	0.107		
sy	0.041	max y	0.03	min y	-0.06	max y - min y	0.09		
sz	0.007	max z	0.004	min z	-0.011	max z - min z	0.014		
PktNr.	MCS.x	MCS.y	MCS.z	OCS.x	OCS.y	OCS.z	dev.x	dev.y	dev.z
M2_Ref1	0.242	-0.478	-0.068	0.205	-0.508	-0.057	0.037	0.03	-0.011
M2_Ref2	80.071	-452.749	0.102	80.067	-452.689	0.098	0.004	-0.06	0.004
M2_Ref3	352.52	296.59	0.061	352.49	296.572	0.057	0.03	0.018	0.004
M2_Ref4	-432.06	158.155	0.034	-431.99	158.142	0.03	-0.07	0.013	0.004

Laser Tracker – Application: Sub-Reflector different elevation angle

Project	M2-Alignment	
Measurement place	SRT, San Basilio, Sardinia	
Date	15.08.2011, 23:52 - 23:59 Uhr	
Measurement object	SRT - M2 (Subreflector)	
Customer	MT Mechatronics	
Contact person on site	Mr. S. Doth	sigma3D GmbH
Measurement system	Laser Tracker Faro SN 3301	Max-Hufschmidt-Str.4a
Inspector	H. Paluszek, sigma3D GmbH	D-55130 Mainz
Air temperature	21°C - 20°C	Tel. +49 (0) 61 31 - 96 257 - 0
Material temperature	17°C - 18°C (Material-kompensation on 20° C)	Fax +49 (0) 61 31 - 96 257 - 20
Coordinate System	M1 Mirror after Best-Fit calculation	www.sigma3D.de
(karthesian)	Best-Fit with 6 Parameter	info@sigma3D.de
Remark	Measurement in 5° Position	

Point ID	Measured (act.)			M1 Best-Fit (nominal)			deviation (actual - nominal)			Remark
RHR	x [mm]	y [mm]	z [mm]	x [mm]	y [mm]	z [mm]	Δx [mm]	Δy [mm]	Δz [mm]	
Mirror Reference points in M1 coordinate system										
2521	3661.02	22.26	4521.53	3661.02	22.22	4521.30	0.00	0.04	0.23	
2522	-37.05	-3692.55	4517.81	-36.94	-3692.64	4517.99	-0.11	0.09	-0.18	
2523				-3439.50	-1431.09	4523.18				not visible from LT Stand
2524	-3419.29	1414.60	4513.98	-3419.18	1414.72	4513.73	-0.11	-0.12	0.25	
2525	-1451.12	3408.55	4511.63	-1451.23	3408.72	4511.78	0.11	-0.17	-0.15	
2526	1447.93	3402.81	4504.28	1447.82	3402.65	4504.43	0.11	0.16	-0.15	
M2_Ref1	-1.29	-17.11	23748.79	0.21	-0.51	23742.94	-1.50	-16.60	5.85	Mid-point
M2_Ref2	78.02	-469.48	23749.20	80.07	-452.69	23743.10	-2.05	-16.79	6.10	
M2_Ref3	351.35	279.59	23748.53	352.49	296.57	23743.06	-1.14	-16.98	5.47	
M2_Ref4	-433.37	142.07	23749.09	-431.99	158.14	23743.03	-1.38	-16.07	6.06	
21300	13152.44	15321.90	6701.69	13155.12	15323.13	6697.80	-2.68	-1.23	3.89	
23700	-15370.47	13136.12	6592.10	-15373.88	13139.43	6589.49	3.41	-3.31	2.61	
26100				-13174.43	-15333.90	6705.44				not measured
28500	15437.13	-13111.07	6542.32	15436.33	-13109.61	6541.50	0.80	-1.46	0.82	

Laser Tracker – Application: Sub-Reflector different elevation angle

Tra x	1.5	mm							
Tra y	16.617	mm							
Tra z	-5.86	mm							
Rotx	-0.0347	DEG	=	-125	arcsec				
Roty	0.0368	DEG	=	132	arcsec				
Rotz	-0.0678	DEG	=	-244	arcsec				
Scale x	1								
Scale y	1								
Scale z	1								
xy	0								
Azimuth	0								
ZtoXY	0								
R_Dist	0								
s0	0.037								
sx	0.036	max x	0.025	min x	-0.052	max x - min x	0.077		
sy	0.059	max y	0.047	min y	-0.085	max y - min y	0.132		
sz	0.016	max z	0.008	min z	-0.024	max z - min z	0.032		
PktNr.	MCS.x	MCS.y	MCS.z	OCS.x	OCS.y	OCS.z	dev.x	dev.y	dev.z
M2_Ref1	0.227	-0.498	-0.081	0.205	-0.508	-0.057	0.022	0.01	-0.024
M2_Ref2	80.071	-452.774	0.106	80.067	-452.689	0.098	0.004	-0.085	0.008
M2_Ref3	352.515	296.619	0.065	352.49	296.572	0.057	0.025	0.047	0.008
M2_Ref4	-432.042	158.171	0.038	-431.99	158.142	0.03	-0.052	0.029	0.008

Laser Radar

Manufacturer:
- Nikon (MetricVision)

Physical principle	Optical angle measurement + Radar
Advantage	High accuracy (like Laser Tracker)
	Without Target
Disadvantage	No industrial standard / Price
Trigger Mode	Single-points, Scanning
Range	1 to 50m
Accuracy (MPE)	24 to 300µm
Typical Application	Large Surface Scanning
Traceability	? (non)
Price	180.000 to 280.000 €
Target	Non or Retroreflector

Laser Radar – Application in Antenna Alignment

Application:
- Panel Inspection
- Panel Alignment
- Deformation Verifiation
- Movement Sub-Refector

Accuracy:
- 0,05mm to 0,15mm

Targets:
- Scanning without Targets possibel!

Digital Photogrammetry

Manufacturer:
- Aicon3D
- GOM
- GSI

Physical principle	Multiangulation + Scale
Advantage	Flexible
	(Range / Accuracy)
Disadvantage	Target (tape or paper) needed
	Offline method
Trigger mode	Single-points
Range	0 to 100m
Accuracy (MPE)	2µm + 5µm/m (RMS)
Typical Application	Deformation analysis
	Surface measurements
Traceability	VDI 2634-2
Price	10.000 to 40.000 €
Targets	Reflective Tape Paper targets

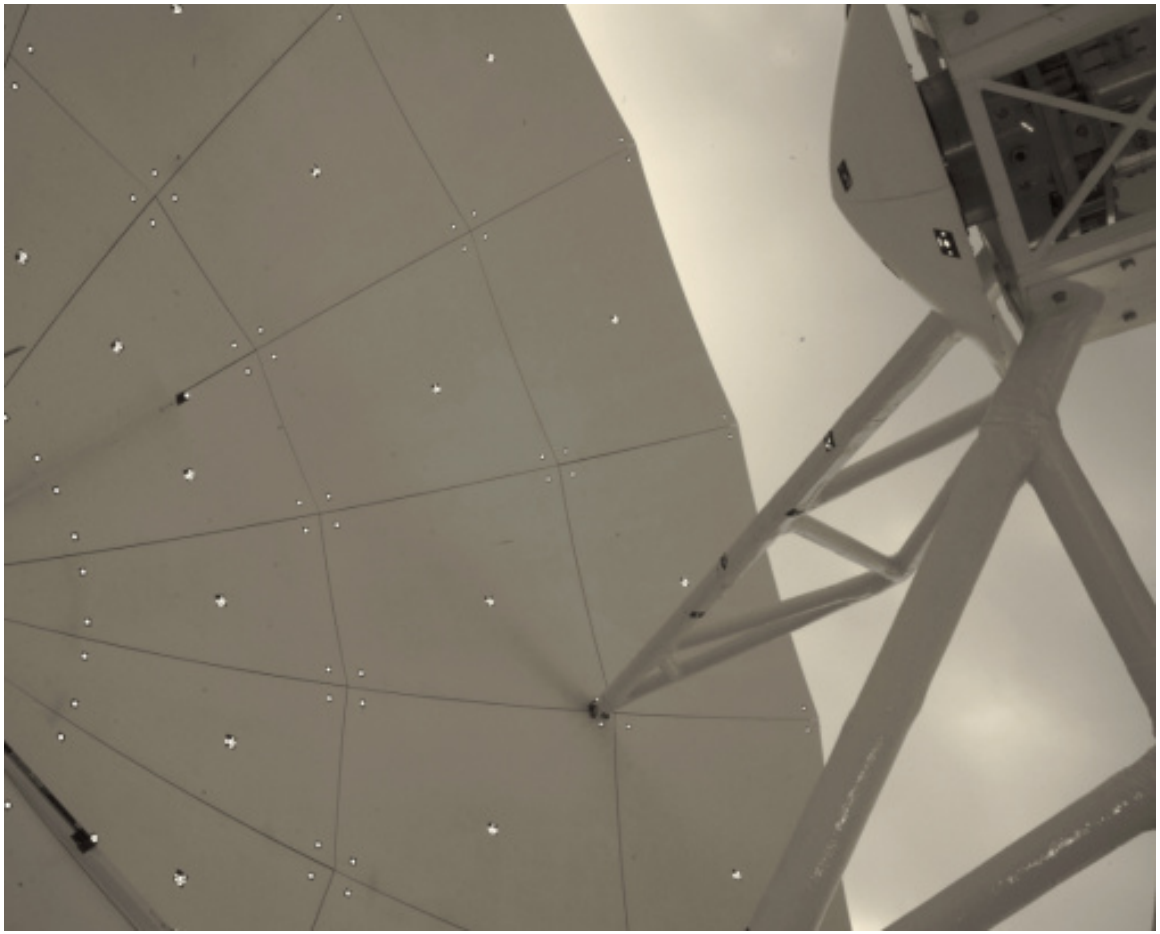
Photogrammetry – Application in Antenna Alignment

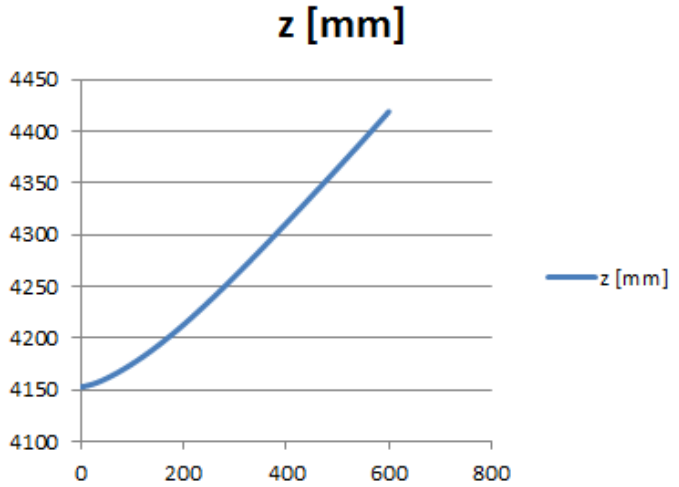
Application:
- Panel / SR Alignment
- Deformation Verification

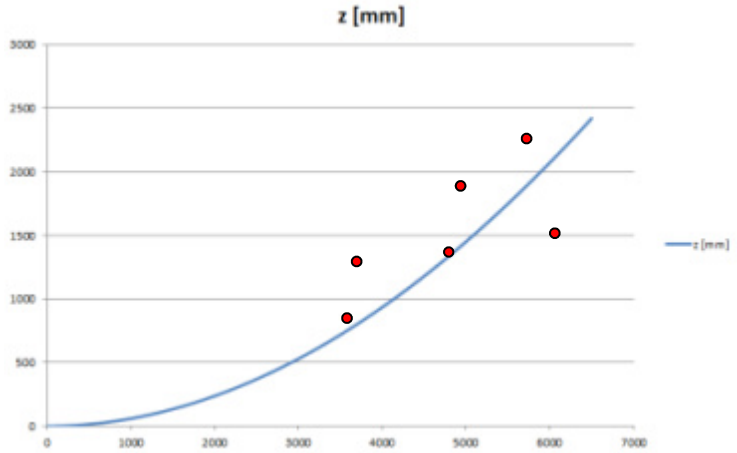
Accuracy:
- 0,03mm to 0,2mm

Targets:
- Paper targets (up to d=15m)
- Reflective tape

Photogrammetry – Application: Panel / SR Alignment

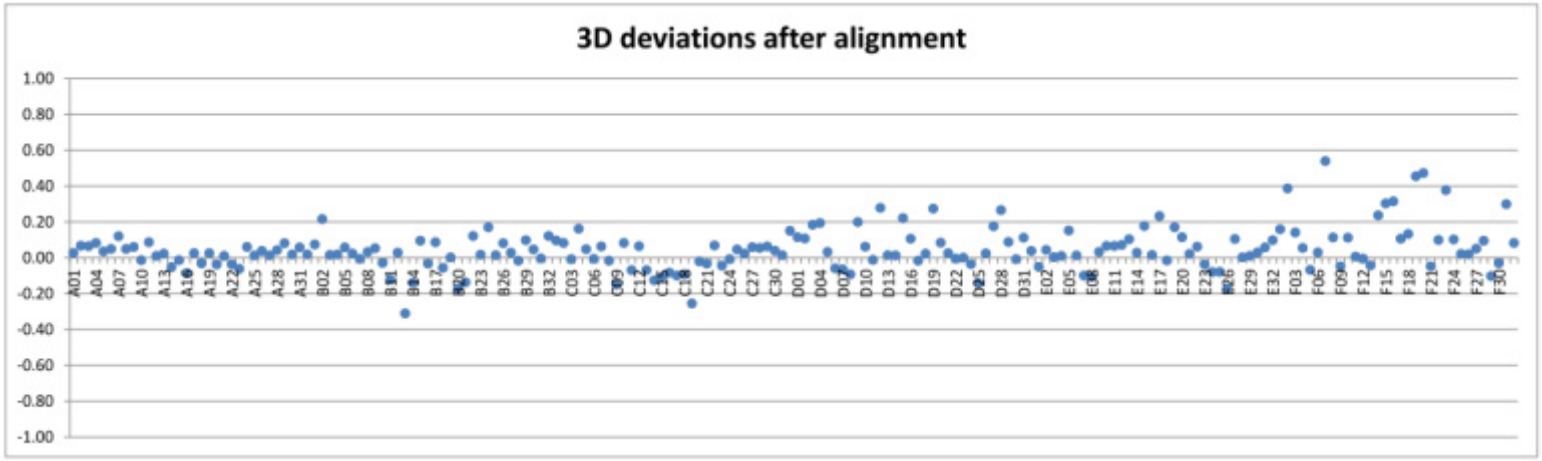


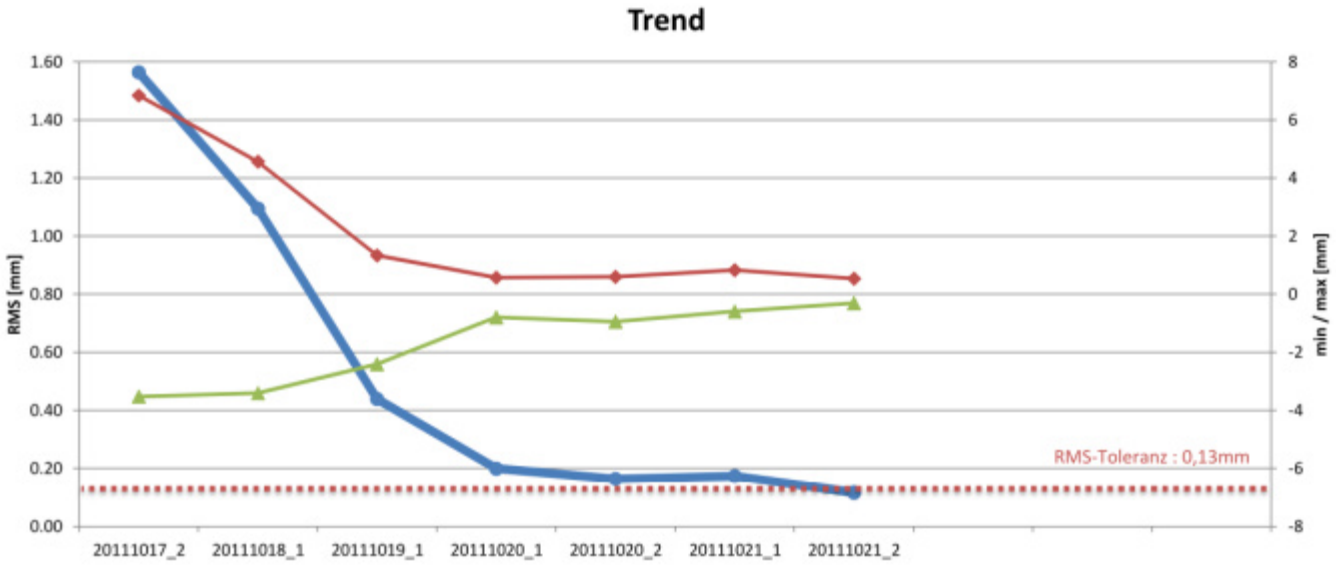




Photogrammetry – Application: Panel / SR Alignment

Punkt-ID (point-ID) ↑ - ↓ +	Abweichung (deviation) 3D [mm]	Screw M16 [faces]
A01	-0.10	-0.3
A02	-0.01	0.0
A03	-0.18	-0.5
A04	-0.01	0.0
A05	-0.07	-0.2
A06	-0.16	-0.5
A07	-0.19	-0.6
A08	-0.17	-0.5
A09	-0.02	-0.1
A10	-0.10	-0.3
A11	-0.10	-0.3
A12	-0.09	-0.3





Photogrammetry – Application: Deformation Verification (SRT)

Deformation of the Main-Reflector in various Elevation (90/75/60/45/30/15).

Photogrammetry – Application: Deformation Verification (SRT)

Elevation-Position	15°	30°	45° Panel Corner	45°	60°	75°	90°
Origin task	Various Elev.	Various Elev.	Global	Various Elev.	Various Elev.	Various Elev.	Various Elev.
ID	3D Dev. [mm]	3D Dev. [mm]	3D Dev. [mm]	3D Dev. [mm]	3D Dev. [mm]	3D Dev. [mm]	3D Dev. [mm]
R01_01_P5	-2.26	-0.74		-0.35	0.10	0.35	0.44
R01_02_P5	-2.27	-0.54		-0.41	0.37	0.85	1.26
R01_03_P5	-2.36	-0.45		-0.51	0.41	1.22	1.95
R01_04_P5	-2.24	-0.42		-0.02	0.86	1.92	2.47
R01_05_P5	-2.19	-0.22		0.07	1.04	2.53	3.16
R01_06_P5	-1.97	-0.25		0.17	1.19	2.64	3.45
R01_07_P5	-1.82	-0.54		0.07	1.26	2.68	3.69
R01_08_P5	-1.82	-0.48		0.24	1.66	2.75	3.63
R01_09_P5	-1.77	-0.34		0.02	1.43	2.25	3.33
R01_10_P5	-1.55	-0.11		0.02	1.36	1.78	2.88
R01_11_P5	-1.37	-0.33		0.12	0.99	1.30	2.36
R01_12_P5	-1.34	-0.29		0.16	0.68	1.13	1.71
R01_13_P5	-1.22	-0.08		0.06	0.40	0.61	0.99
R01_14_P5	-0.89	-0.06		0.10	0.30	0.14	0.21
R01_15_P5	-1.02	0.23		-0.16	0.13	-0.39	-0.51
R01_16_P5	-0.92	0.41		0.03	-0.03	-0.90	-1.06
R01_17_P5	-0.85	0.51		0.08	0.00	-1.04	-1.37
R01_18_P5	-0.77	0.62		0.08	-0.12	-0.72	-1.82
R01_19_P5	-0.52	1.10		0.29	0.07	-0.54	-1.73
R01_20_P5	-0.90	0.85		-0.26	-0.17	-0.64	-1.87
R01_21_P5	-0.89	0.59		-0.75	-0.39	-0.86	-2.30
R01_22_P5	-0.50	0.69		-0.10	-0.19	-0.33	-1.05
R01_23_P5	-0.77	0.61		0.18	-0.32	-0.37	-0.56
R01_24_P5	-0.77	0.36		0.35	0.28	0.22	0.20

Accuracy Photogrammetry

In general, the following approach applies to the measurement accuracy (Sxyz):

Sxyz = q * m * Sx‘y‘

q = Quality factor for the geometry of the recordings
0.4 to 0.8 with a good configuration, 2 for bad configuration
m = Image scale
Sx‘y‘ = Image measurement accuracy

For panel measurements following theoretical uncertainty estimated:

- **Reflector diameter 13 m**: Sxyz = 0,7 * 700 * 0,07 µm -> **34 µm -> RMS 70 µm (VLBI 2014)**
- Reflector diameter 15 m: Sxyz = 0,8 * 800 * 0,07 µm -> 45 µm -> RMS 90 µm
- Reflector diameter 40 m: Sxyz = 0,8 * 1400 * 0,07 µm -> 78 µm -> RMS 180 µm
- **Reflector diameter 64 m**: Sxyz = 0,8 * 1900 * 0,07 µm -> **106 µm -> RMS 290 µm (SRT 2012)**
- Reflector diameter 100 m: Sxyz = 0,8 * 2200 * 0,08 µm -> 140 µm -> RMS 350 µm

Reachable: Only with stable measurement conditions, good panels and the right strategy!

Conclusion: Antenna Alignment with mobile 3D Systems

Antenna Part	Alignment task	Accuracy	3D Systems
Steel construction	Aligment of steel construction	1 - 5 mm	Total Station / (Laser Tracker)
Single-Component Tests	Roundness, centering, ... of single-parts	0,04 – 0,2 mm	Laser Tracker
Secundary Mirrors	6 DOF-Alignment	0,05 - 0,15 mm	Laser Tracker / (Total Station)
M1 Surface	Panel Alignment	0,03 - 0,1 mm	Photogrammetry / Laser Radar
M1 Surface	Deformation measurement in various elevation angles	0,05 - 0,15 mm	Photogrammetry / (Laser Radar)
Sub-Reflector	Displacement verification in various elevation angles	0,1 - 0,2 mm	Photogrammetry / Laser Tracker Laser Radar / (Total Station)
Complete Antenna	As-built documentation	2 - 5 mm	Terrestical Laser Scanner (TLS)

Thank you for your attention!

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Visit also:

- VDI FA Large Volume Metrology - Symposium, 18th Sept. 2014, Magdeburg
- IWAA – International Workshop for Accelerator Alignm., Oct. 2014, Beijing
- LVMC - Large Volume Metrology Conference, Nov. 2014, Manchester
- CMSC – Coordinate Measurement System Conference, July 2015, USA