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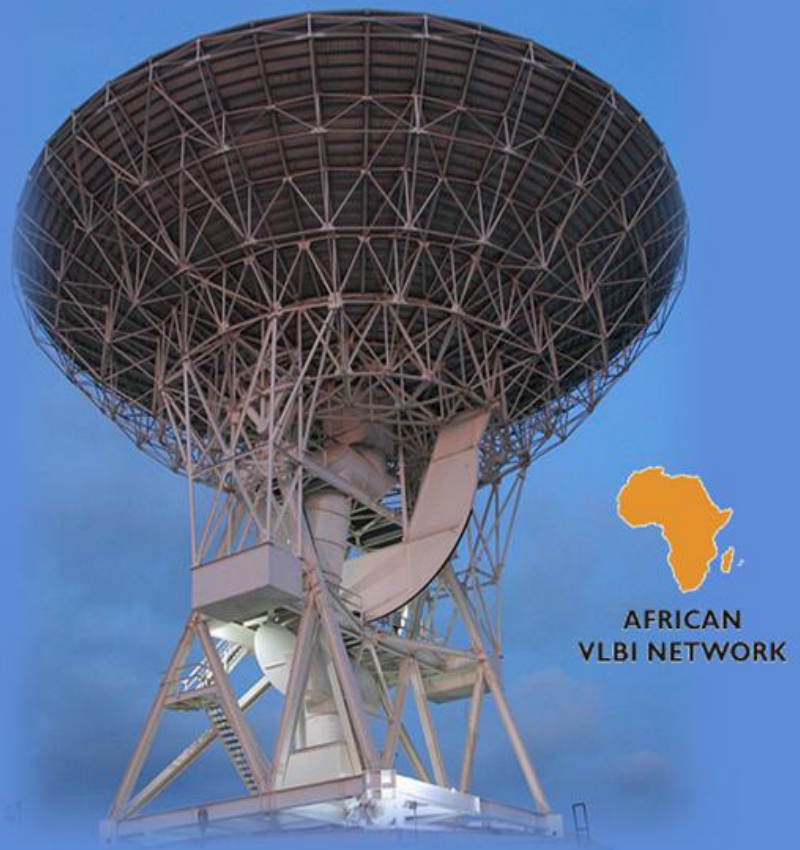
International Relations and Cooperation
REPUBLIC OF SOUTH AFRICA

CONVERSION OF A DISUSED EARTH SATELLITE STATION FOR RADIO ASTRONOMY : STRUCTURE AND CONTROL SYSTEM – KUNTUNSE STATION , GHANA

PRESENTER: Japie Ludick – May 2019, Hartebeesthoek



CONTENTS

- Background (History/Characteristics)
- Radio Astronomy versus Telecoms
- Conversion Process
- Major Modifications
- Performance Predictions
- Performance Checks
- Questions

BACKGROUND

History

- Kuntunse Antenna (25 km North West of Accra, Ghana)
- Built in 1979 – TIW Systems (Vertex – GDSatcom)
- One of 9 similar antennas around the world (INTELSAT)
- Out of service since 2009 (Vodafone)
- Identified as suitable conversion in 2012

BACKGROUND

BACKGROUND

Antenna Characteristics

- 220 Ton wheel and track, Beam Wave Guide
- 32m Diameter (F/D = 0.32)
- Elevation operational range 5 to 90 deg
- Azimuth (-8 to 327 deg wrt N)
- Dual drive on sector gear (elevation)
  - Elevation slew rate (0.27 deg/s @ motor rated speed)
- Dual drive on wheel/track (azimuth)
  - Azimuth slew rate (0.29 deg/s @ motor rated speed)
- Max operational wind speed (80mph)
- Survival at stow (120 mph)

RADIO ASTRONOMY vs. TELECOMS

Feature	Original Specification	Deterioration	AVN Specification at 6.7GHz	Modification(s)
Main reflector surface accuracy @ 60°	0.12 mm RMS	Damage/repairs/ removals	2.5mm RMS (η= 0.4)	Holography measurements + subreflector adjustments
Elevation slew rate	0.27°/s	N/A	0.27°/s	Servo motors (0.38°/s max)
Azimuth slew rate	0.29°/s	N/A	0.29°/s	Servo motors (0.41°/s max)
Lifetime	30 years	38 years (8 years non operational)	15 years since conversion	• Corrosion treatment • Repainting of entire structure • Pintle bearing pad upgrade/replacement • Updated maintenance schedule/training/reporting

RADIO ASTRONOMY vs. TELECOMS

	Original Specification	Deterioration	AVN Specification at 6.7 GHz	Modification(s)
Duty cycle	Geostationary satellite	Virtually stationary	Radio-astronomy – 500, 000 cycles (VLBI + Single dish HartRAO)	- Quad leg / subreflector support replacement - Azimuth pintle bearings – intermediate - Azimuth pintle bearings permanent
Azimuth Range	+/-170° from due South		-8° CCW / 327° CW from North	+/- 305° from West
Pointing accuracy	0.0025°	Track level?	0.0018°	Antenna Steering Control System (including track level compensation)
Tracking accuracy	N/A	Track level?	0.0048° RMS (Initial)	Antenna Steering Control System (including track level compensation)

CONVERSION PROCESS

\+

AVN Specifications

OEM Structural Assessment Report

As built datapack and ATP/R

Operation and Maintenance logs

Feasible to convert

Ready for science operations

Conversion complete

Costing	**Immediate mods (Conversion safety)**	Major mods (Safety / Performance)	Antenna level testing	Antenna characterisation	Performance/ Reliability mods	Handover period (2 – 3 years)	Upgrades

Analyses – compliance to requirements

Tests – compliance to requirements

+/- 4 years

Feasibility

Main Drivers

Antenna Safety

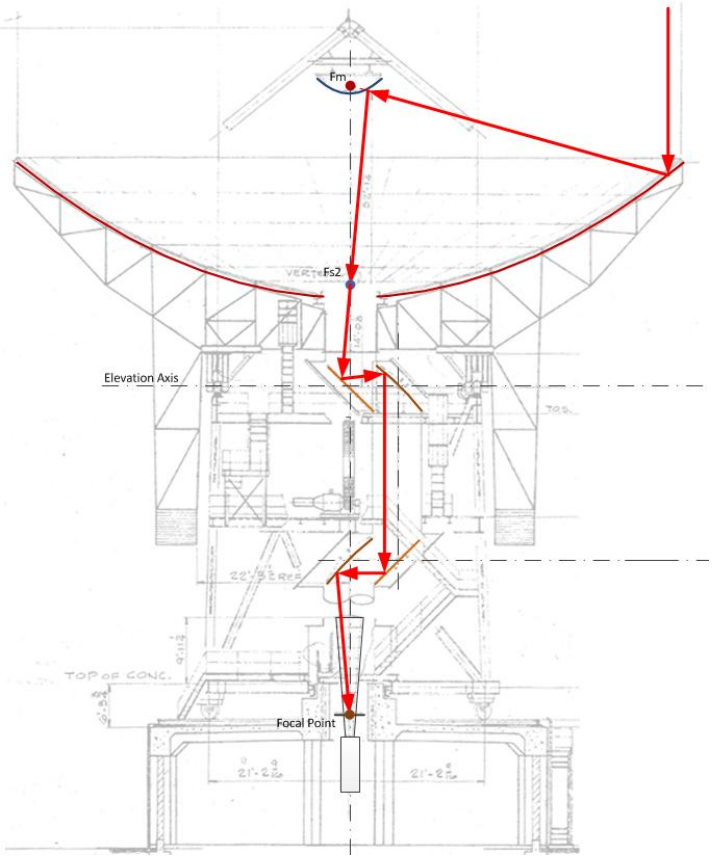
- Primary Structure / Reference
- Energy absorbing systems
- Control system

Antenna Performance

- Surface accuracy of reflector system (Main and subreflector)
- Optical alignment (Main/sub/BWG mirrors)
- Pointing performance
- Tracking performance

Antenna lifetime/reliability

- Maintenance / Spares /Support



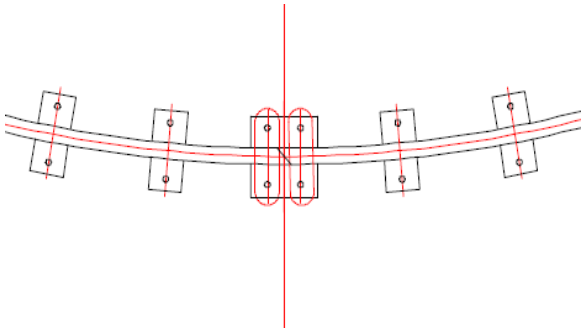
Feasibility

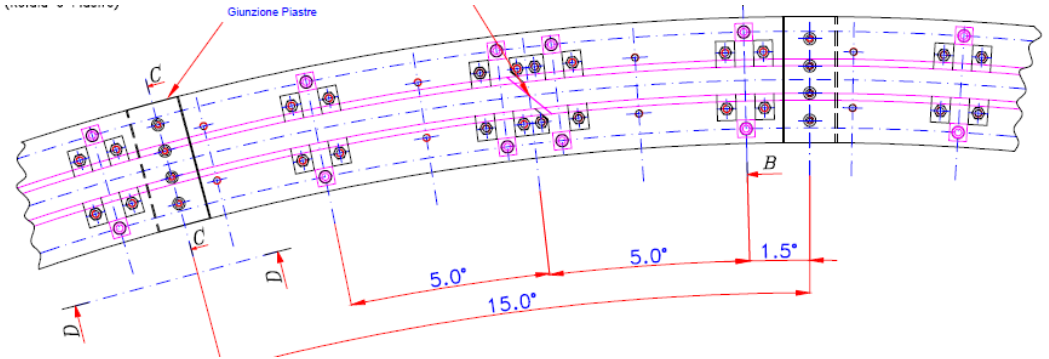
Main drivers – Condition of Track and Track Bed

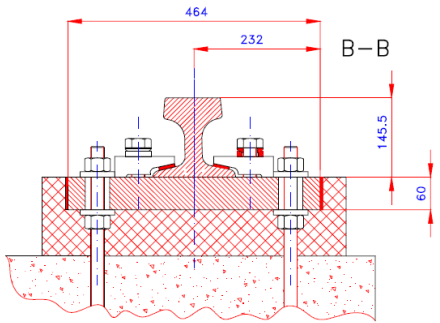
- Track segments – fatigue cracks (+/- 2 million wheel rotations – Medicina)
- Track bed configuration plays a major role

Feasibility

Main drivers – Condition of Track and Track Bed



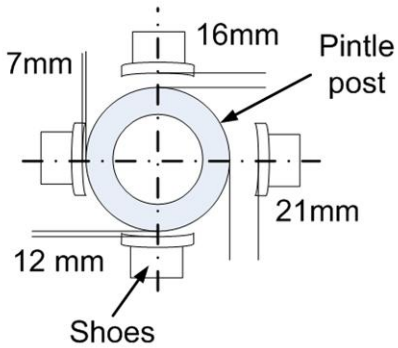


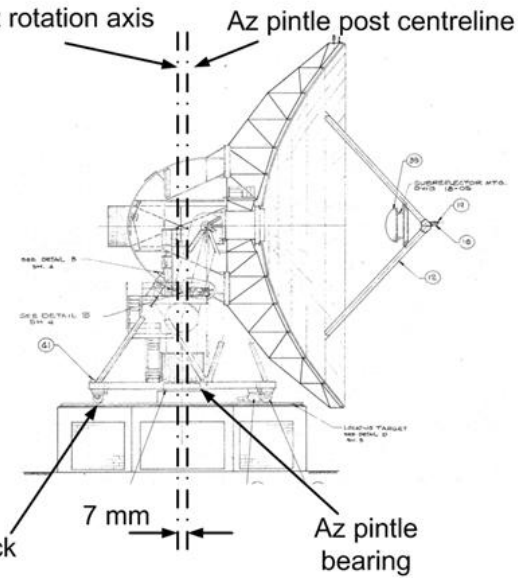


Feasibility

Main drivers – Azimuth Pintle Bearing

Unconventional pintle bearing – 4 pintle “shoes”





Feasibility

Main drivers – Corrosion of primary structure

- Long term structural integrity as well as integrity during conversion

Feasibility

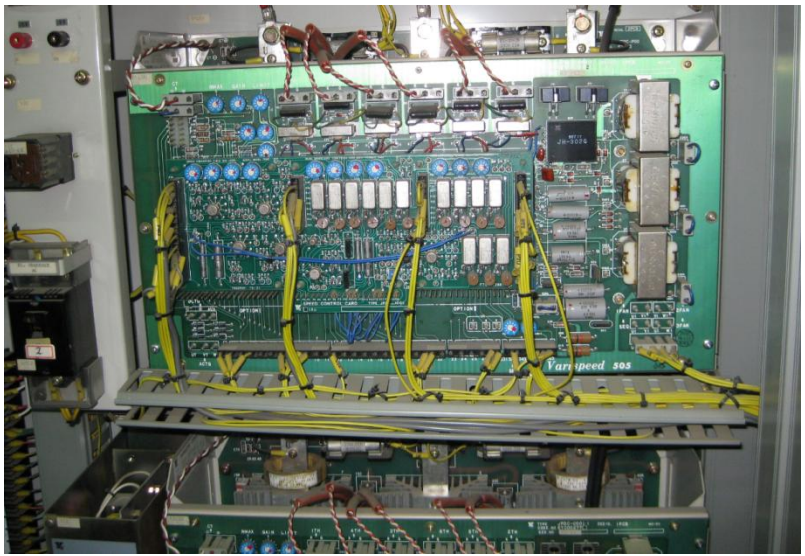
Main drivers – Condition of main reflector and subreflector surfaces

- Adjustment ?

Feasibility

Main drivers – Antenna Steering Control System

- Performance / Maintainability / Support ?



Performance predictions

Pointing / Tracking

- Two types of error sources
  - Correlated errors: Errors which can be predicted by analysis and which are repeatable
  - Random errors: Errors which we only know the range (min, max) of
- Compensation
  - Repeatable errors can be compensated for (pointing model)
  - Some random errors can be eliminated /minimised(e.g. drive train backlash)
- Pointing error budget – summation of correlated and random errors based on analyses/simulation to predict subsystem error.
- Tracking – ADAMS/Simulink co-simulation

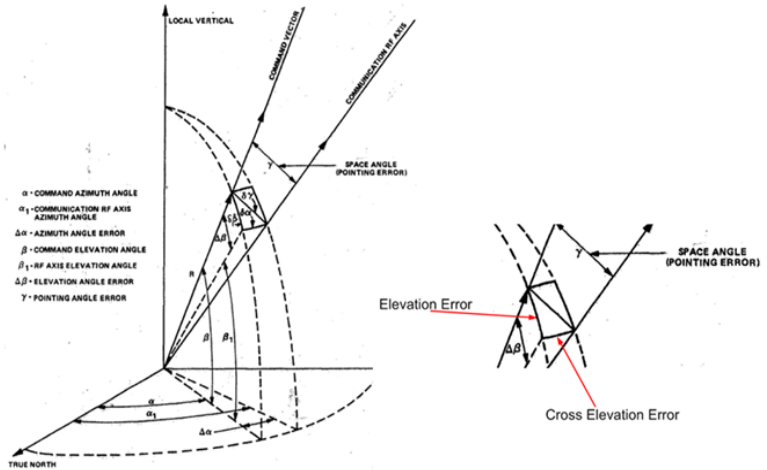
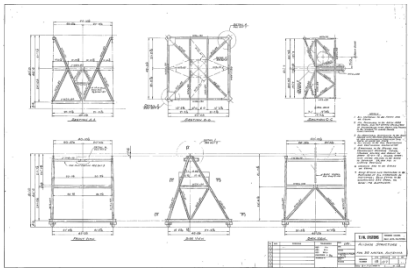
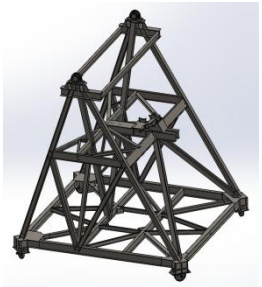


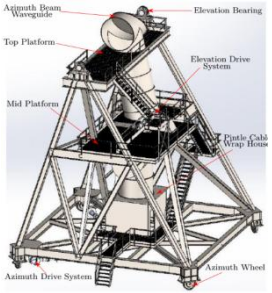
Figure 1: Pointing Error Definition

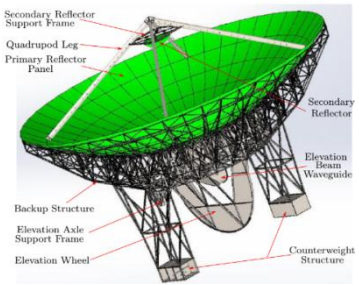
MAJOR MODIFICATIONS

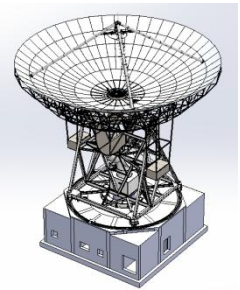
- Performance predictions (Pointing error)

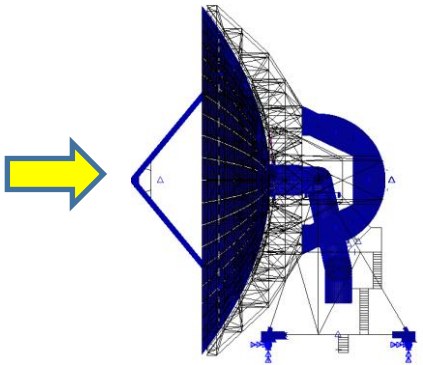


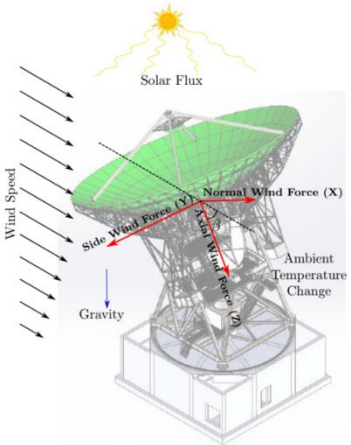


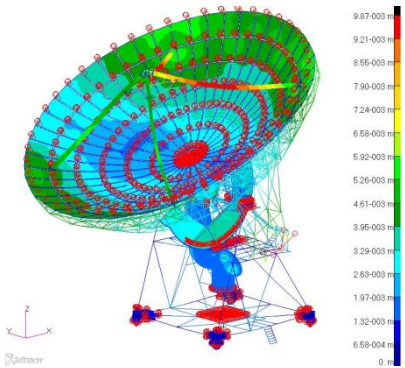


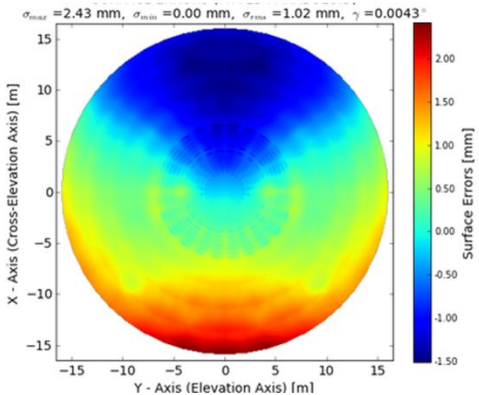








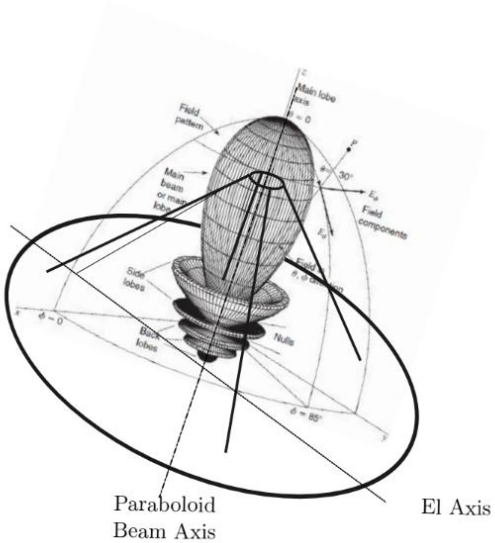




Performance predictions

Pointing error (Antenna Structure level)

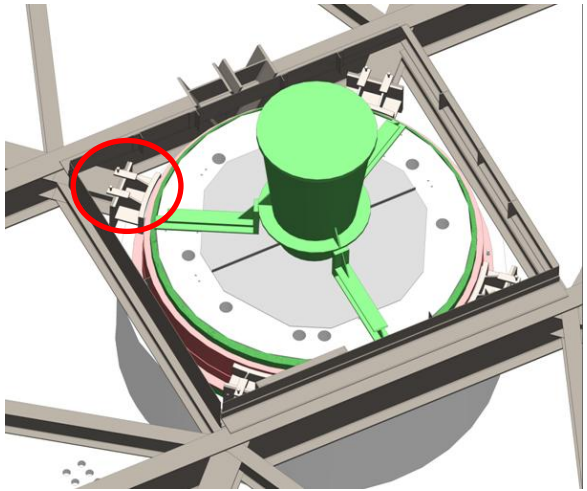
- Initial operations will be at 5.6 – 6.7 GHz (HPBW = 0.0096 deg)

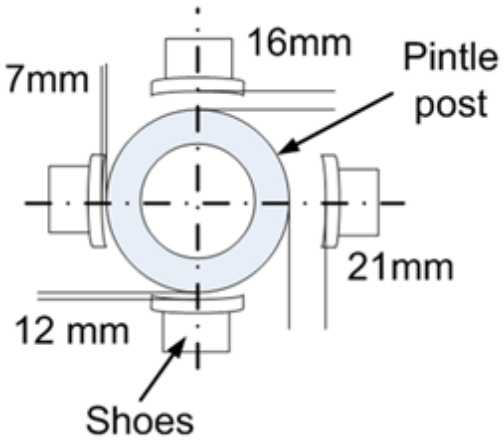


Pointing error budget				El = 0°, Az = 0°			
				Elevation Error		Cross Elevation Error	
Error definition	S	C	arcsec	deg		deg	
Correlated errors			W/O	W/O	W	W/O	W
RF axis collimation	RSS	C	14	0.0039	0.0004	0.0039	0.0004
Orthogonality refl/ EL axis	RSS	C	60			0.0167	0.0000
Orthogonality EL/AZ axis	RSS	C	10			0.0000	0.0000
Orthogonality AZ/track plane	RSS	C	7	0.002	0.001	0.002	0.001
Thermal (8K)	RSS		7.56	0.0021	0.0021	0.0021	0.0021
Gravity	A	C	5.76	0.0016	0.0002		
Wind deflection at 19 km/h (constant wind)	A		5.76	0.0016	0.0016		
Sum of Correlated errors/axis				0.0081	0.0041	0.0174	0.0024
Total correlated pointing error			Tot (W/O)	0.0191			
			Tot (W)	0.0047			
Random errors							
Drive train backlash	RMS	C	30	0.0083	0	0.0083	0
Encoder shaft deflection	RMS		1.1	0.00029	0.00029	0.0003	0.0003
Encoder accuracy	RMS		5	0.0014	0.0014	0.0014	0.0014
Azimuth Encoding Error (Wheelslip/Conc)	RMS	C	20*			0.0056	0.0044
Control loop	RMS		+/- 5	0.0010	0.0010	0.0014	0.0014
Sum of random errors				0.0043	0.0009	0.0046	0.0022
Total random pointing error			Tot (W/O)	0.0062			
			Tot (W)	0.0023			
Total Error (W/O)			91	0.0254			
Total Error (W)			25	0.0071			

MAJOR MODIFICATIONS

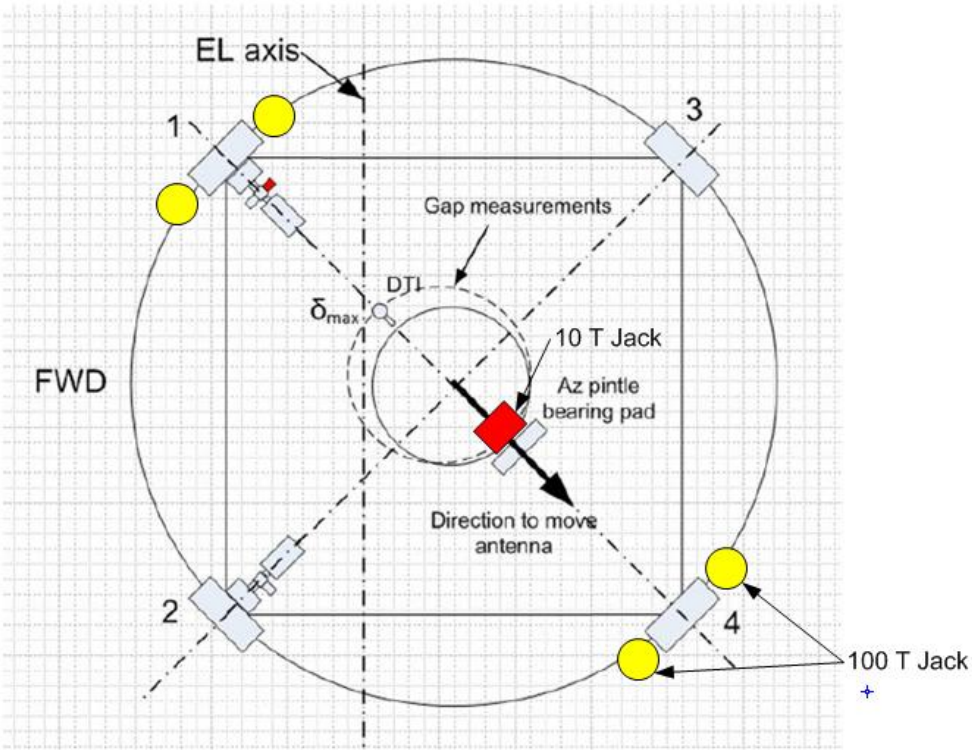
- Unconventional pintle bearing – 4 pintle “shoes”





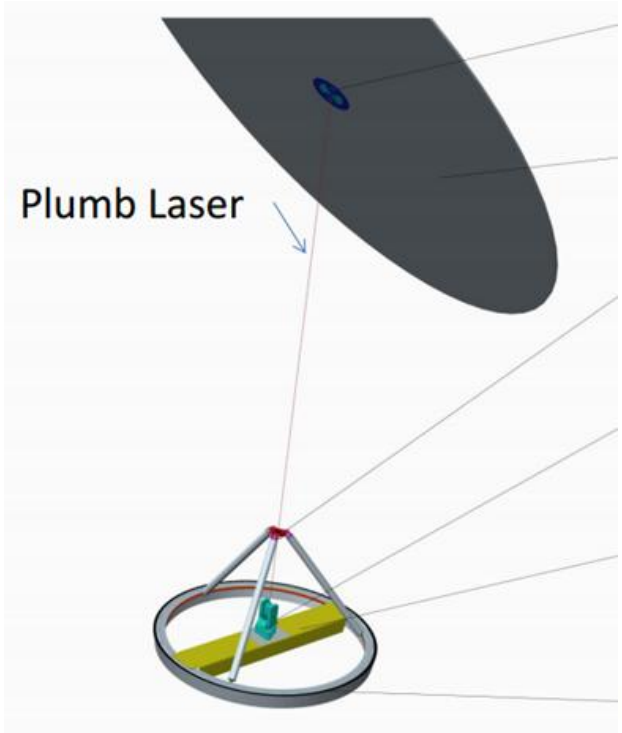
MAJOR MODIFICATIONS

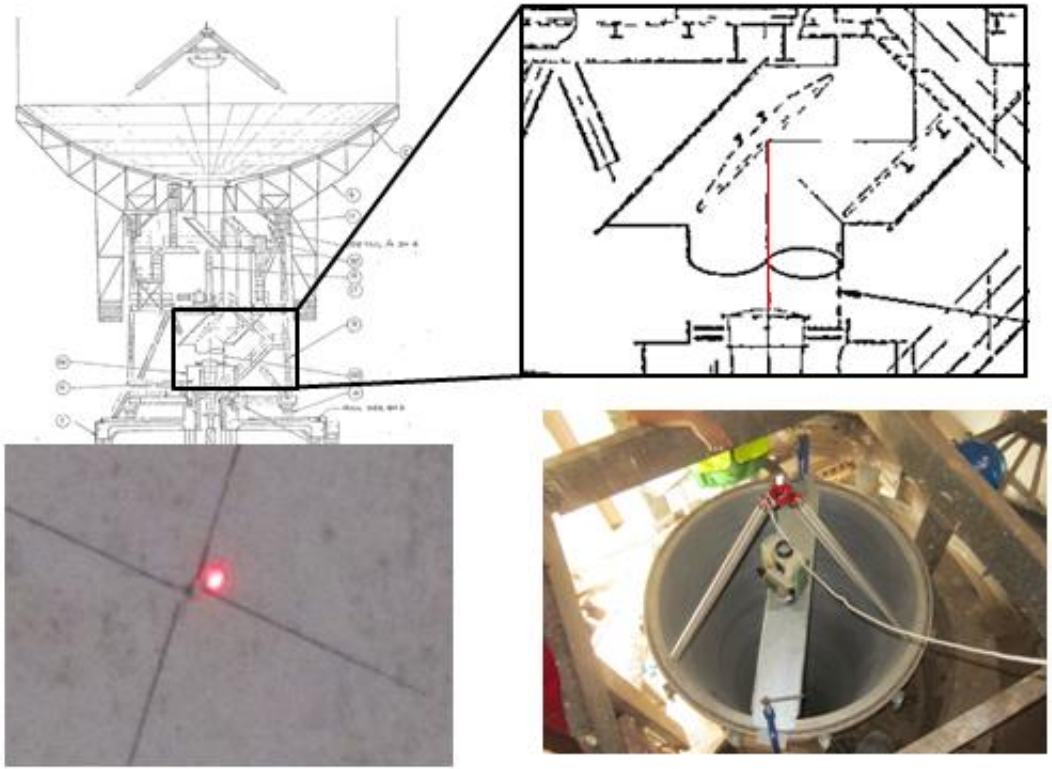
- Antenna Centring



MAJOR MODIFICATIONS

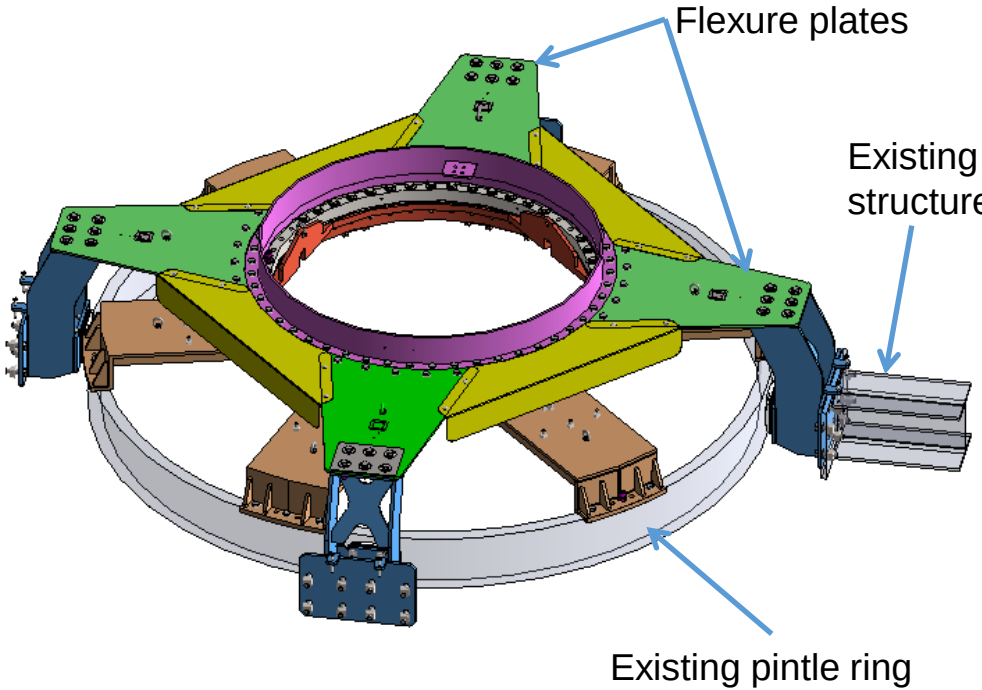
- Antenna Centring

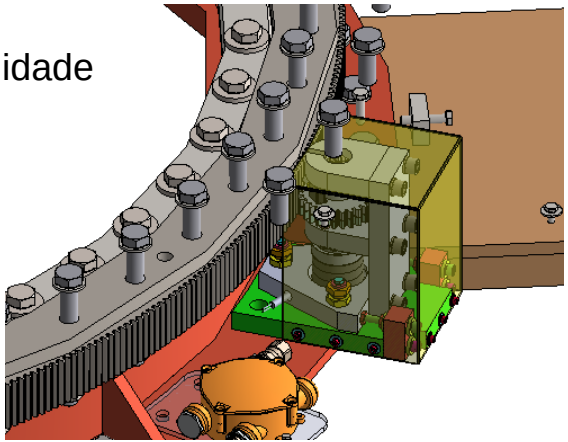




MAJOR MODIFICATIONS

- Long term – Azimuth Bearing/Encoder





Encoder – gear driven off main bearing outer race

MAJOR MODIFICATIONS

- Shock absorber / structure replacement

MAJOR MODIFICATIONS

- Corrosion treatment and re-painting

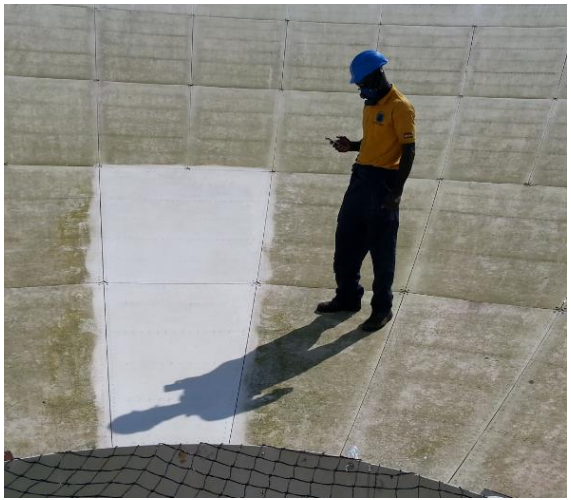
- Stripped down to bare metal at corroded areas
- Pre-primed (Al filled epoxy Interseal 670 HS) – bare metal areas
- Primed (Al filled epoxy paint – Interseal 670 HS) – everywhere
- Intermediate coat (Epoxy – Interseal 670 unfilled) – everywhere
- Top coat (Polyurethane Interthane 990)
- +/- 2400 Liters of paint (4 months – crew of 10 people)

MAJOR MODIFICATIONS

- Corrosion treatment and re-painting

MAJOR MODIFICATIONS

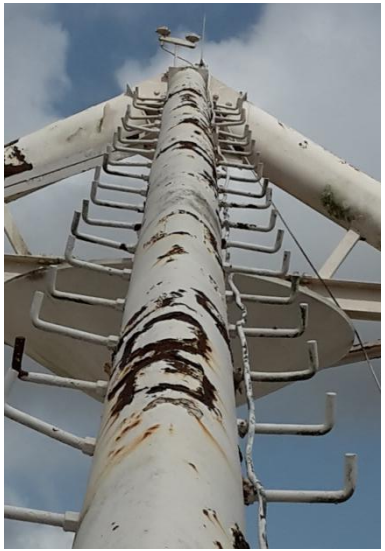
- Fungus growth



MAJOR MODIFICATIONS

- Quad leg structure / subreflector support frame



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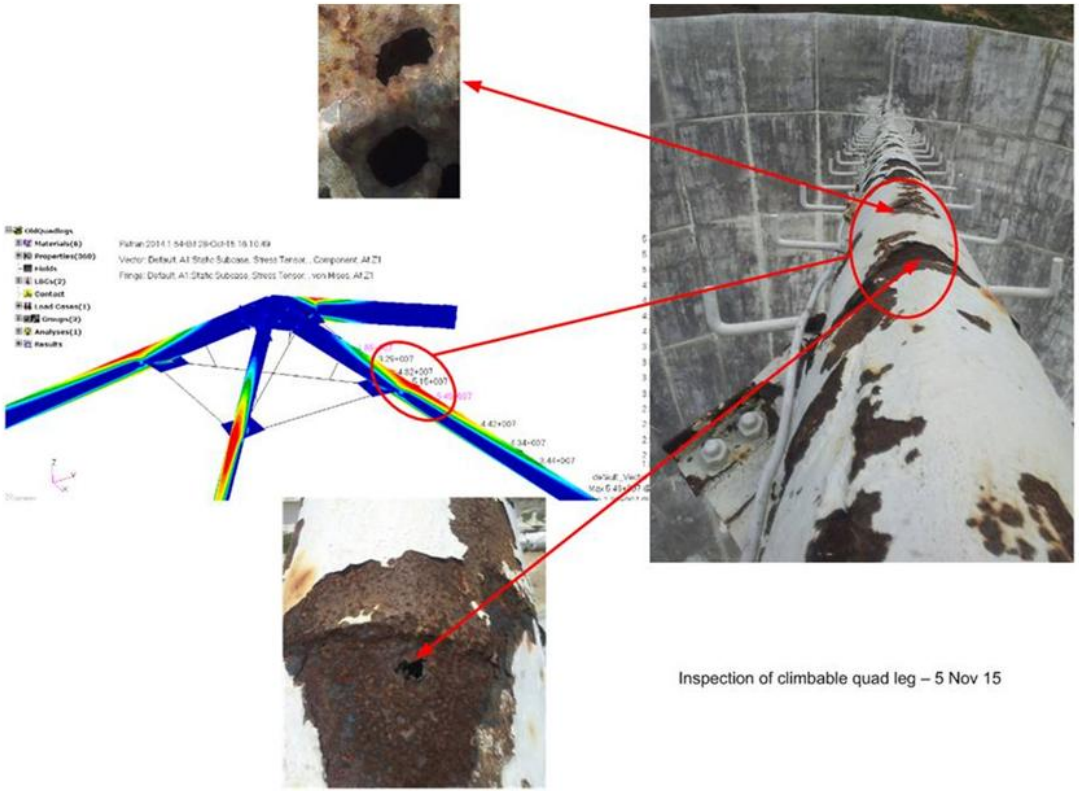
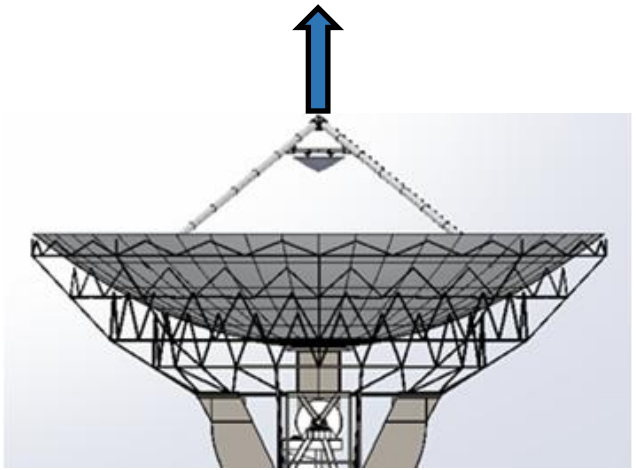
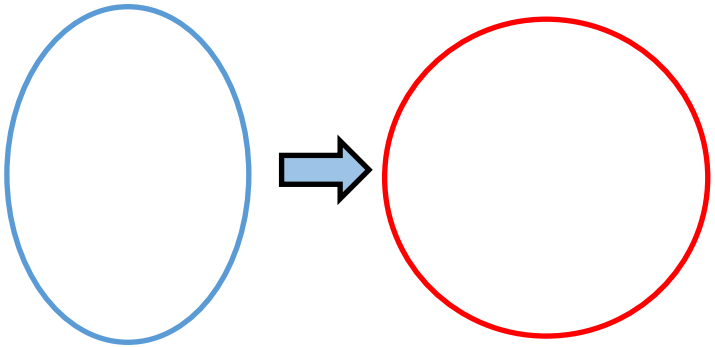


Inspection of climbable quad leg – 5 Nov 15



MAJOR MODIFICATIONS

Quad leg structure / subreflector support frame

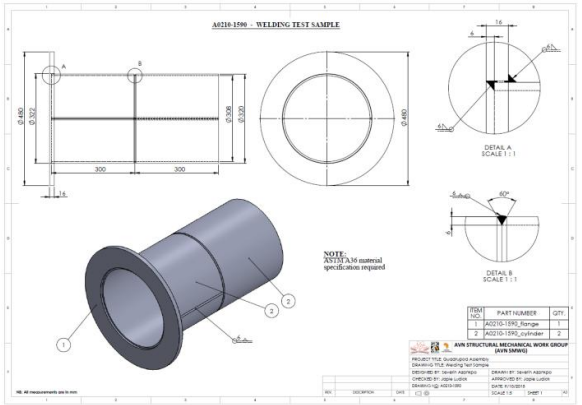


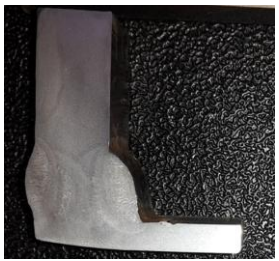
MAJOR MODIFICATIONS

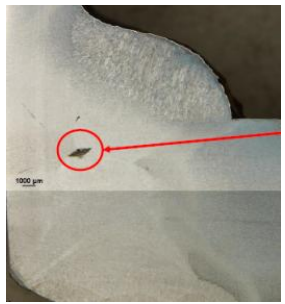
Quad leg structure / subreflector support frame

<u>Quality Measures</u>

- Material Certification (South Africa)
- On site - weld process recording
- Welder certification to AWS D1.1
- 100% X-ray inspection (circular welds)
- 10% X-ray inspection (longitudinal welds)
- 100% dye penetrant (pipe to flange / gussets) – AWS certificated weld visual inspection
- +/- 400m of welding

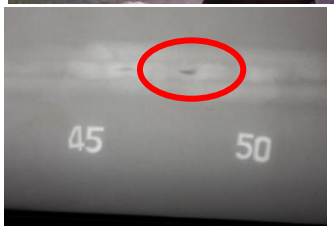


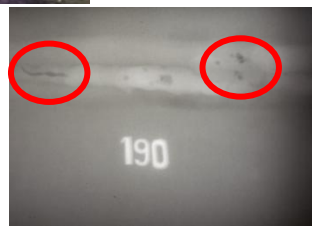


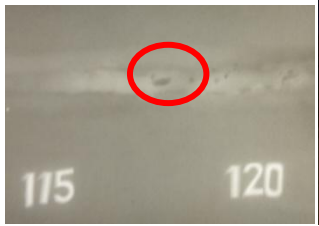


MAJOR MODIFICATIONS

- Welder training intervention







MAJOR MODIFICATIONS

- Quad leg structure / subreflector support frame

WELDER PERFORMANCE QUALIFICATION

SKA AFRICA

P.O. No.: Item:
Ref.: Item No.:

General

Employer	: *Square Kilometre Array (SKA Africa)*	Welder	: S. Saad
Designation	: Welder	Identity No.	: G1155703
Identification Method	: Passport	Stamp Number	: SS
Date Of Birth	: 29-Nov-79	Certification No.	: 16/01/8730
Place of Birth	: Accra		
Job Knowledge	: Not tested		
Code / Testing Standard	: AWS D1.1 - 2015		

WELDING DETAILS

Welding Process	: SMAW
Process Type	: Manual
WPS Followed	: WPS SKA001/W Rev. 0
Material 1	: ASTM A36
Thickness	: 5.0 mm
Material 2	: ASTM A36
Thickness	: 5.0 mm

VARIABLES	*ACTUAL VALUE*	*QUALIFICATION RANGE*
Backing	: SMAW-None	SMAW-With or without backing only
Material Group-No.	: Group I	Determine a welders ability to produce sound welds
Material Group-No.	: Group I	Determine a welders ability to produce sound welds
Diameter	: None-Plate material	Plate and pipe 600 mm O/D & above
Filler SFA & AWS No.	: SFA A5.1 & AWS E7018-1	SFA A5.1 & SFA A5.5
Filler Composition	: C/Mn/Si	C/Mn/Si only
Consumable Insert	: None	With or without inserts
Deposit Thick./Process	: 5.0 mm	3.0 to 10.0 mm CJP & PJP groove welds
Weld Position	: Flat	Flat only CJP & PJP
Weld Progression	: N/A	N/A
Backing Gas	: N/A	N/A
Transfer Mode	: N/A	N/A
Current Type GTAW	: N/A	N/A
Polarity GTAW	: N/A	N/A
Control Method	: N/A	N/A
Joint Tracking	: N/A	N/A
Filler added	: N/A	N/A
Filler Metal Product Form	: N/A	N/A
Remarks	: Visual inspection found to be acceptable & welder qualified with radiography examination	

TEST DETAILS

Bend test: None ***Bend Angle:*** N/A ***Former Size:*** N/A

Type	Result	Type	Results
-			

RADIOGRAPHY TEST	: Par. 4.9.2.2	REPORT NUMBER:	NDIS RT/SKA/16/008
Result	: Acceptable		
FILLET WELD TEST	: N/A		
Fracture Test (1)	: N/A		
Fracture Test (2)	: N/A		
Defect Length (mm)	: N/A		
Defect %	: N/A		
Macro Test Fusion	: N/A		
Appearance Test Fusion	: N/A		
Appearance Fillet Size	: N/A		
Appearance Fillet Size	: N/A		
Convexity (mm)	: N/A		
Concavity (mm)	: N/A		

CERTIFICATION

WE CERTIFY THAT THE WELDS WERE PREPARED, WELDED AND TESTED SATISFACTORILY IN ACCORDANCE WITH THE REQUIREMENTS OF THE CODE / TESTING STANDARD INDICATED ABOVE, TO THE BEST OF OUR KNOWLEDGE.

MANUFACTURER		CERTIFIED BY		
Signature	Date	Signature	2016-03-24 Date	LVUP068

RBI-Tech Job No.: GR/8318 Certificate No.: 16/01/8730

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MAJOR MODIFICATIONS

- Quad leg structure - manufacturing

MAJOR MODIFICATIONS

- Quad leg structure – manufacturing and QA






Major Modifications

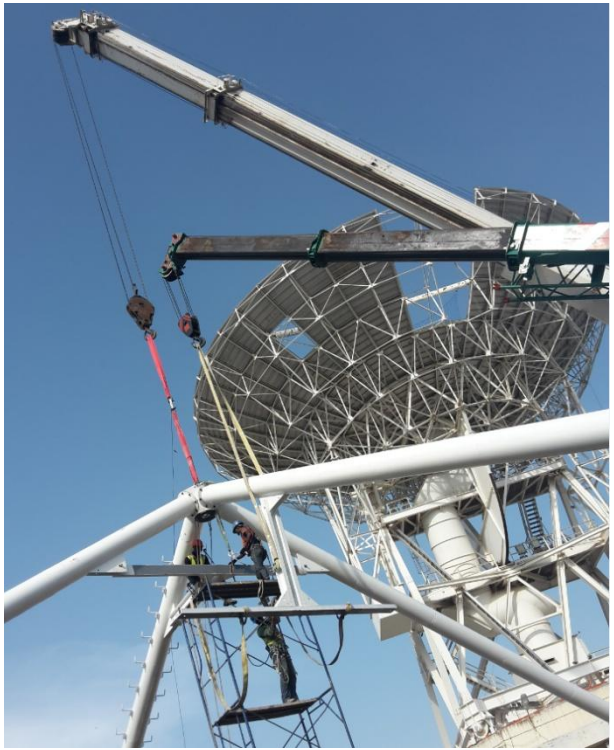
Quad leg structure - manufacturing





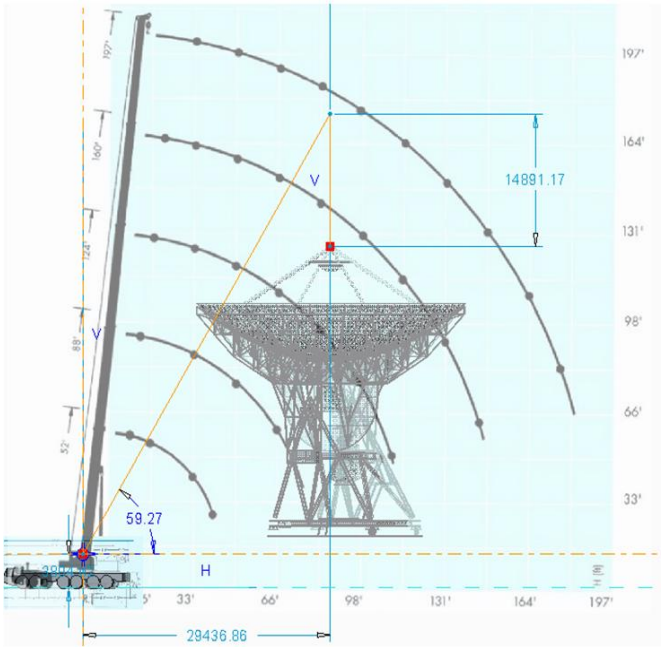

Major Modifications

Quad legs - installation



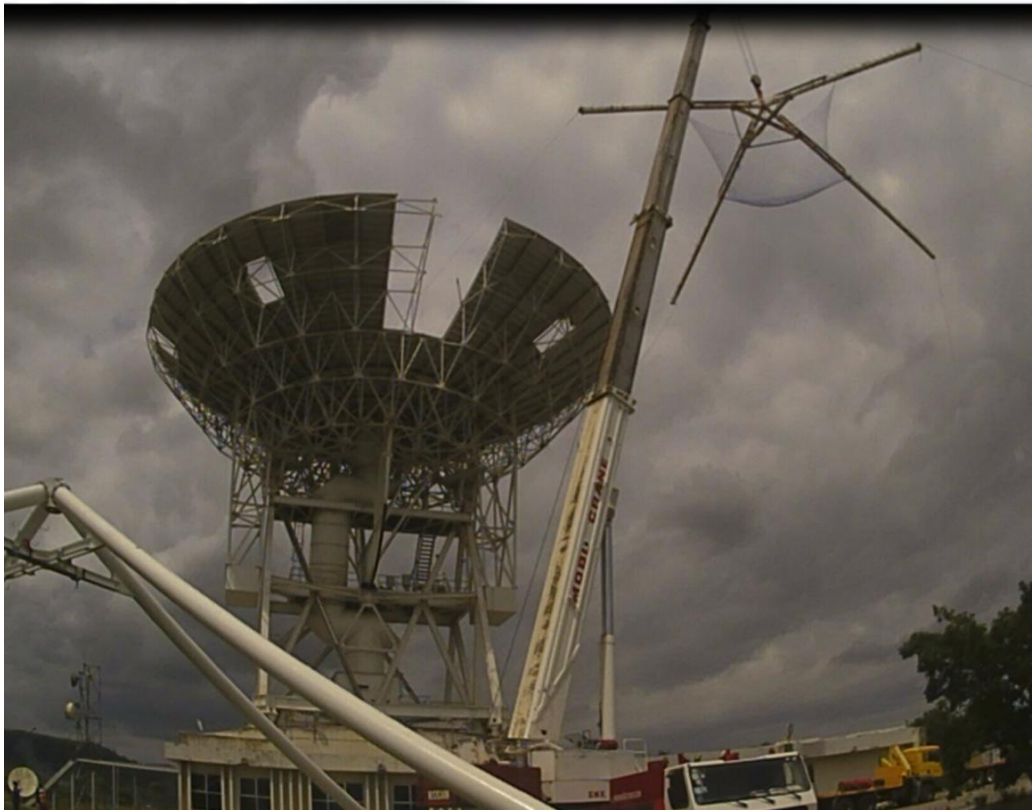
MAJOR MODIFICATIONS

Quad leg structure - replacement



MAJOR MODIFICATIONS

Quad legs - installation

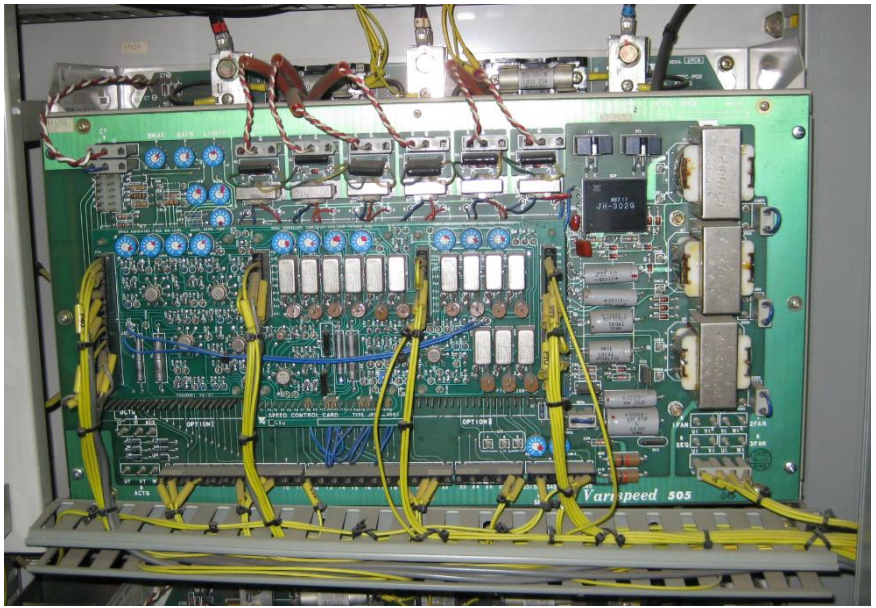


Major Modifications

Quad legs - installation

MAJOR MODIFICATIONS

Antenna Steering Controller System (ASCS) - Development

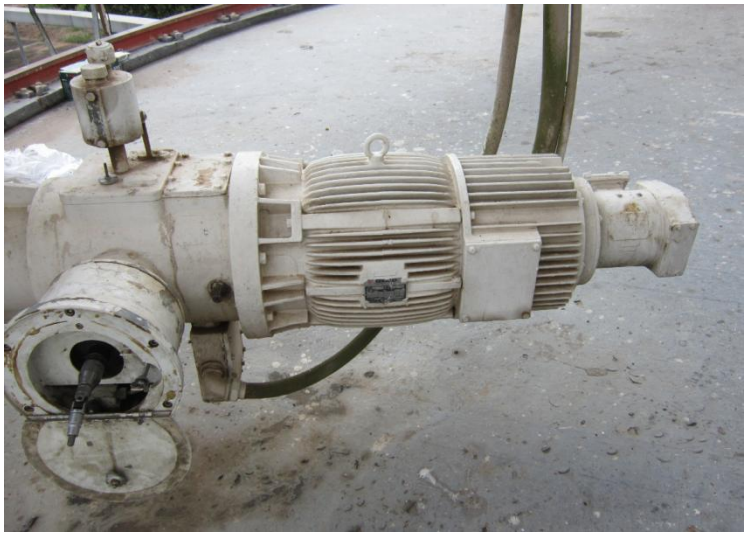


MAJOR MODIFICATIONS

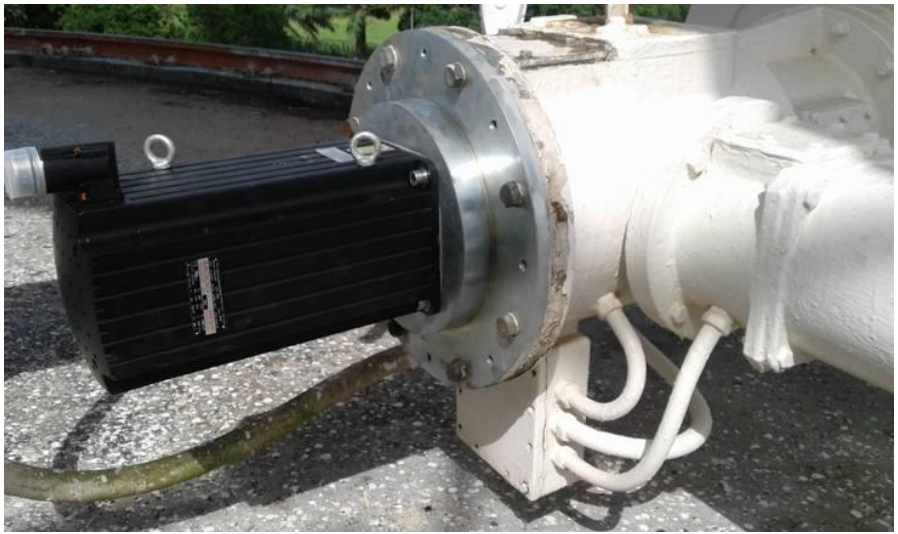
ASCS Test rig commissioning and qualification (Cape Town)

MAJOR MODIFICATIONS

ASCS On site integration



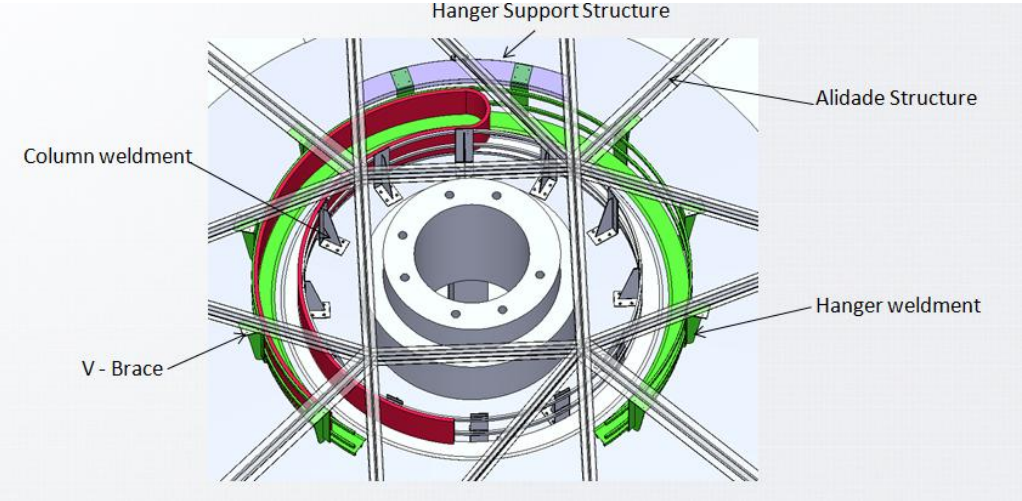
Original DC motor – 450 kg



Servo motor – 50 kg

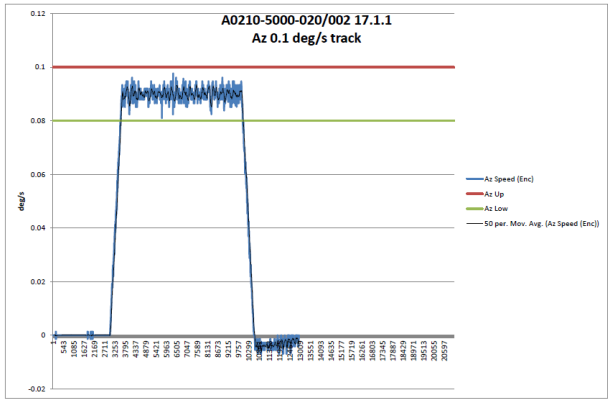
MAJOR MODIFICATIONS

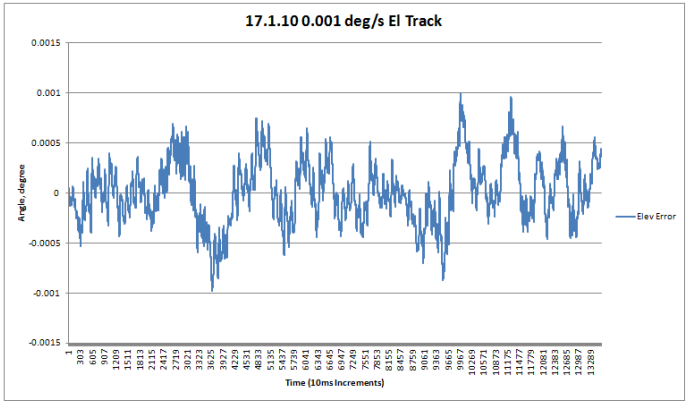
+/- 305° Azimuth Cable Wrap

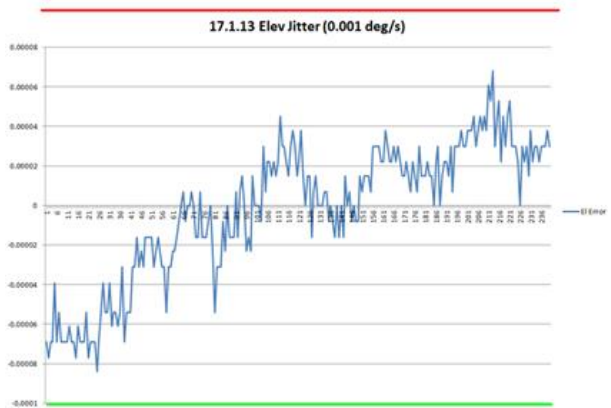


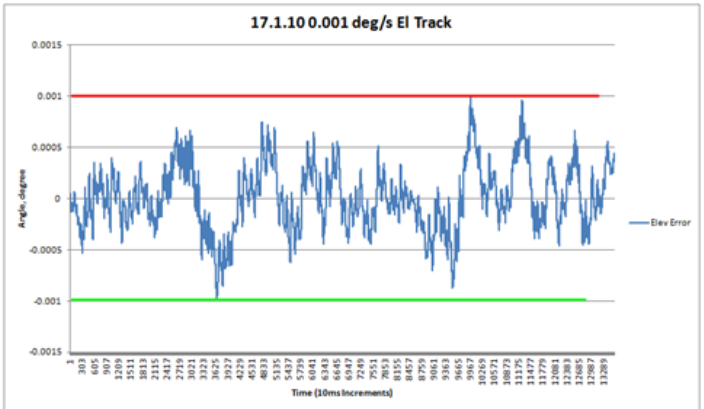
PERFORMANCE CHECKS

Tracking – Elevation (Control System Performance)



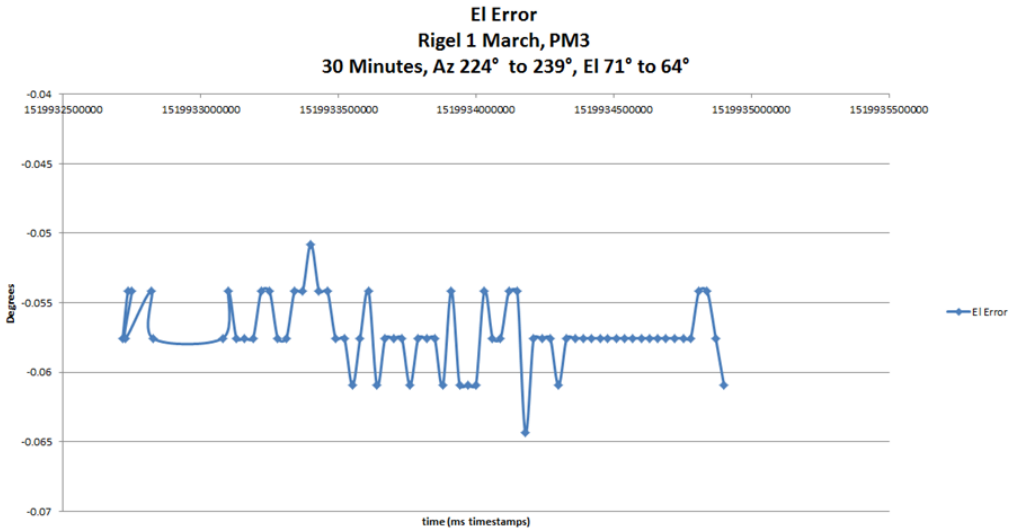


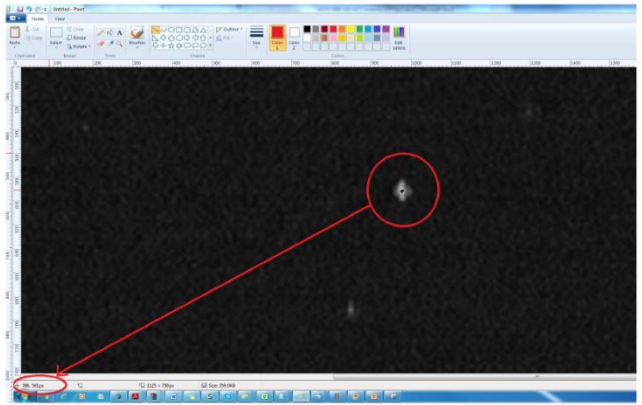




PERFORMANCE CHECKS

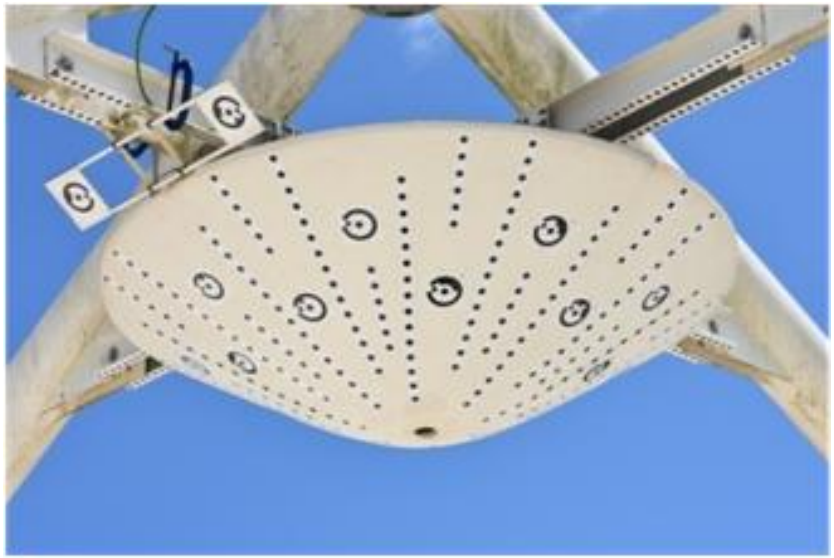
Tracking – Elevation (Control System Performance – including structure deflection)



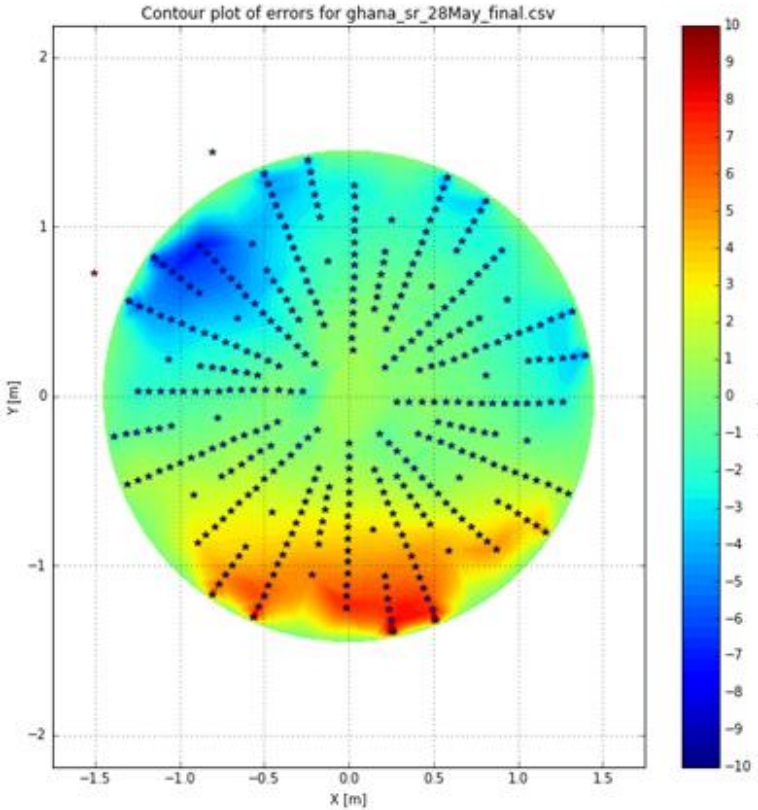


PERFORMANCE CHECKS

Photogrammetry

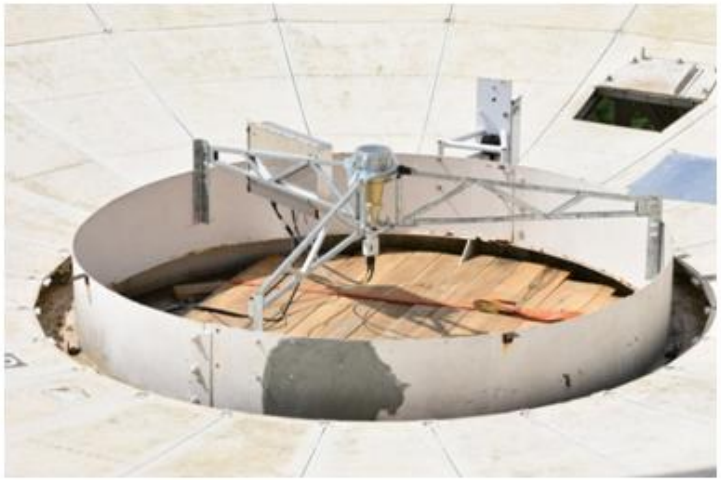


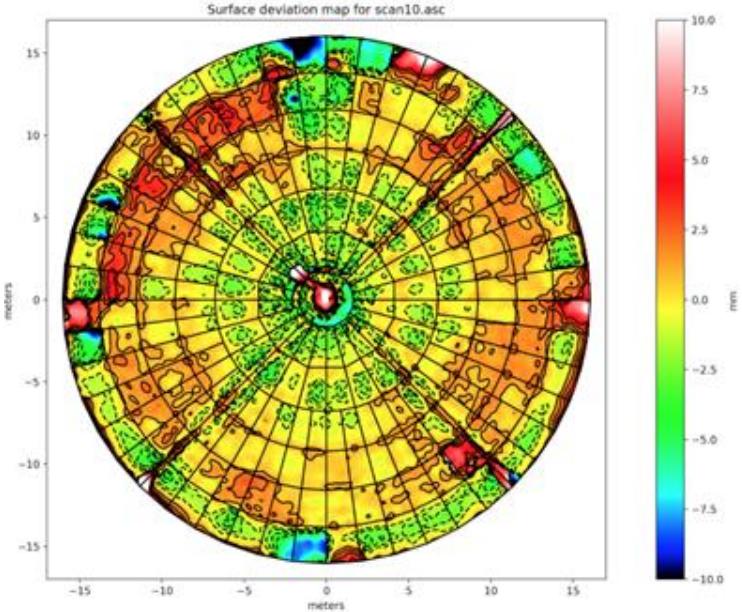
RMS = 2.7mm



PERFORMANCE CHECKS

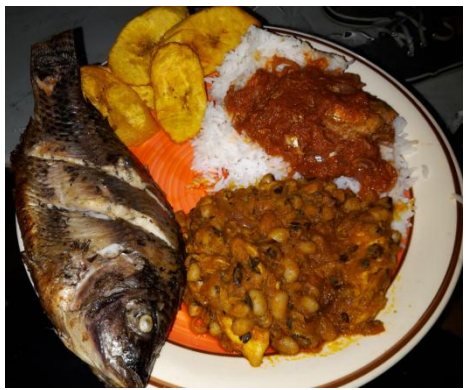
Microwave Holography





- RMS = 1.88mm (Main and subreflector), EL = 80 deg
- Subreflector axial position low by 48mm

Questions?



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