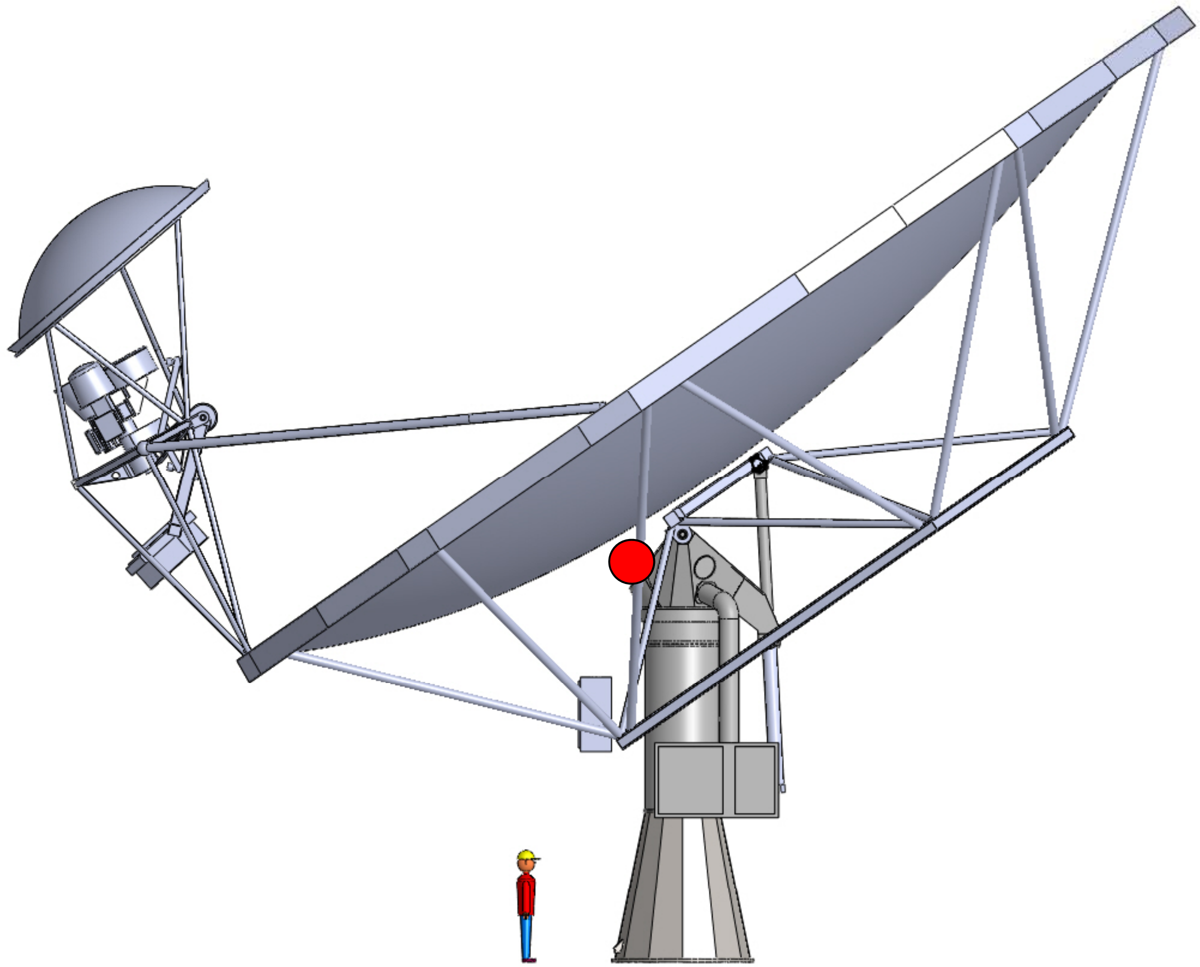
SKA Dish CoDR
US SKA TDP & DRAO NRC

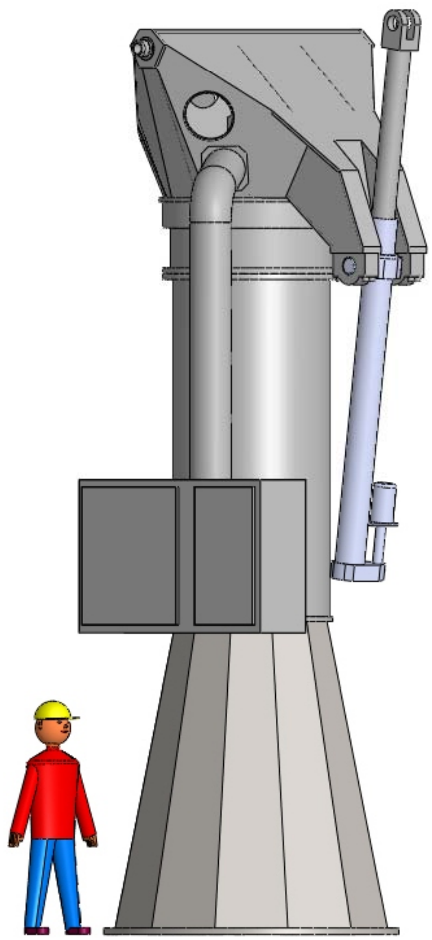
Mount Design (section 4.8)

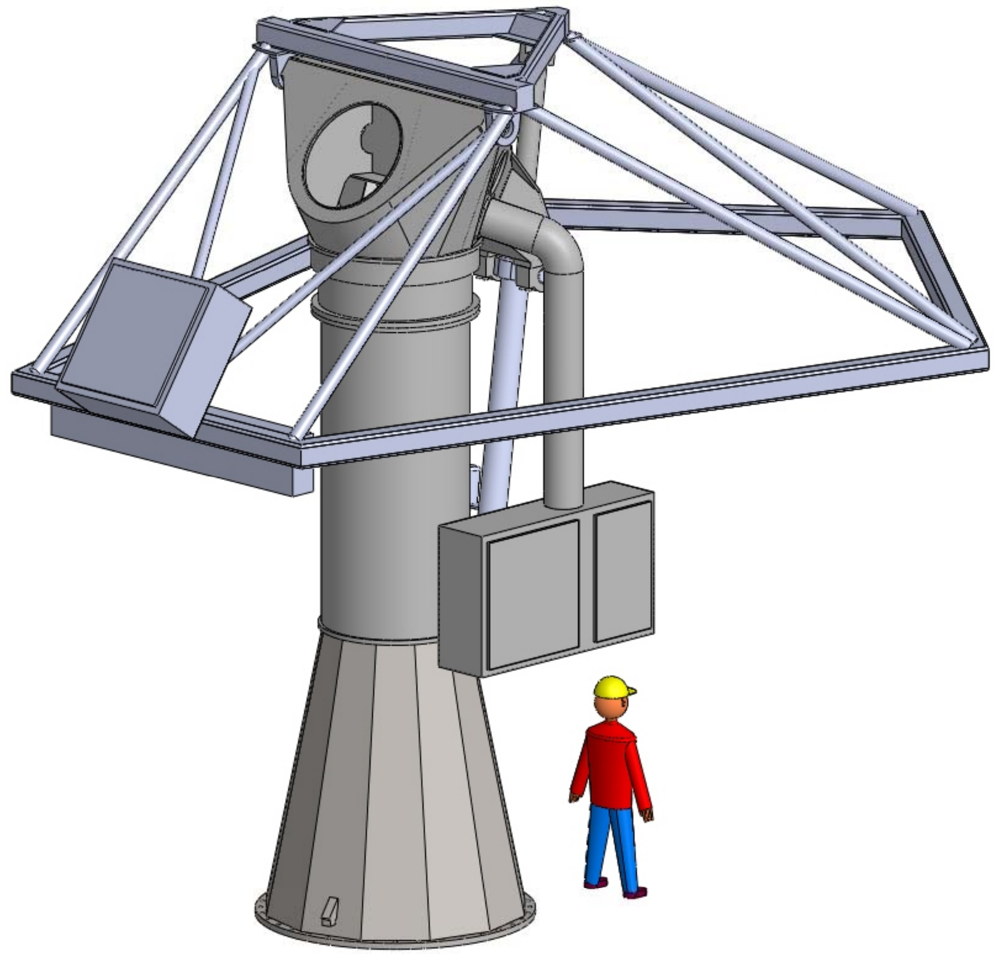
Matt Fleming U. C. Berkeley / Minex Engineering

Full Antenna Side View



Mount Assembly





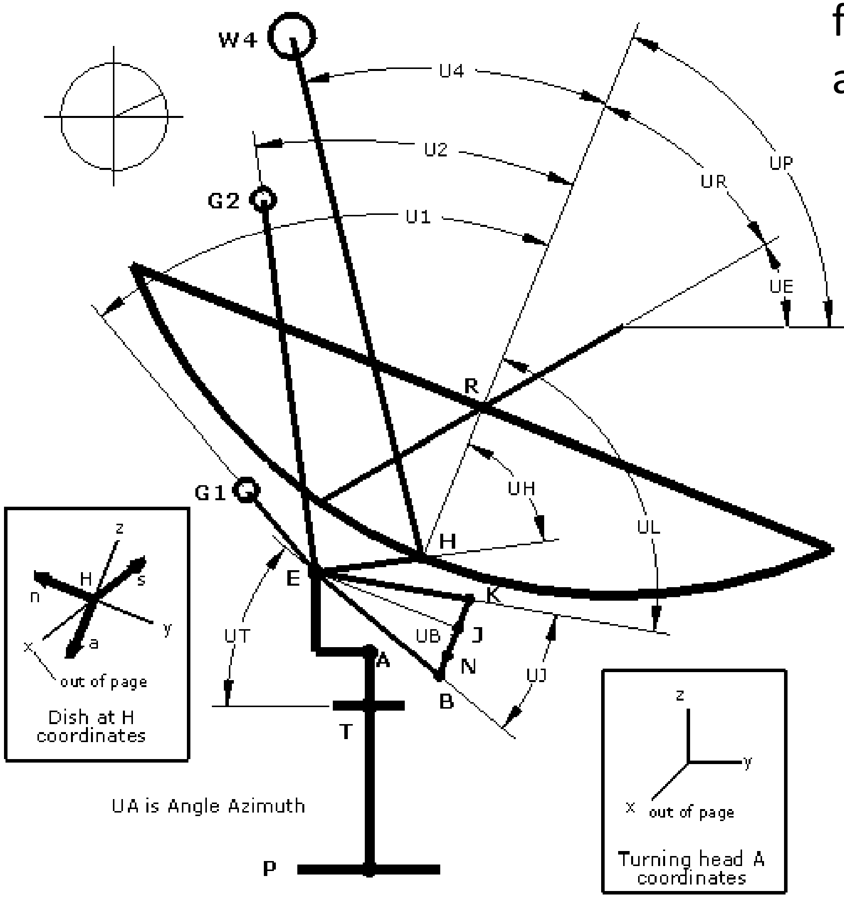
Gravitational Loading

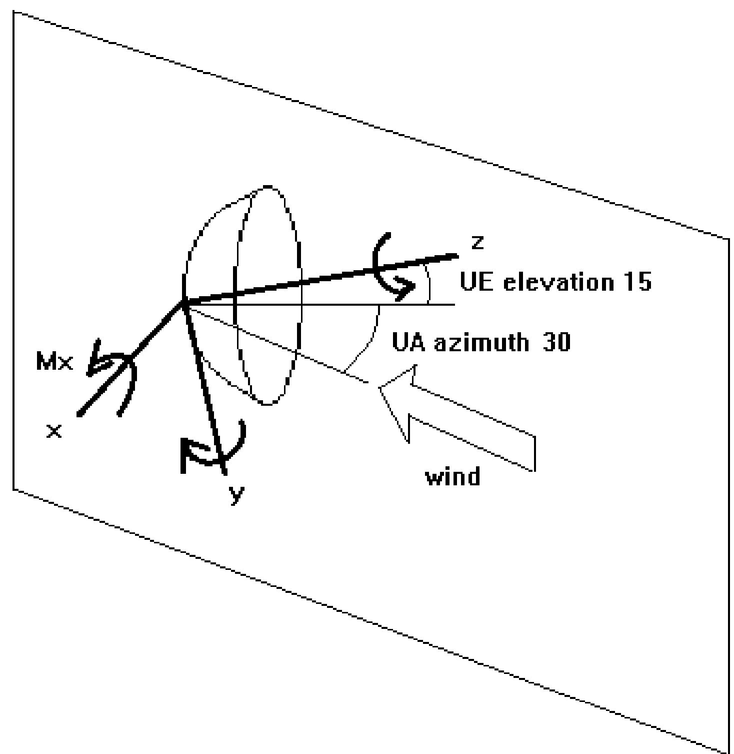
Table	Estimated Mass	Design 15m D1-03	(Eng 10 Masses)	
Item name	**(kg)**		**Item name**	**(kg)**
Secondary & Flanges	175		Turning Head	2,000
Secondary Support	170		El Drive Actuator	200
Feed Center Frame	256		Az Drives & Ring Gear	700
Feed Support Tubes	238		Az Bearing & Support Hub	870
Indexer & SPFs	216		Electronics 2 on Head	100
SPFs	150		Pedestal	4,000
PAF & Swing	547		Electronics 1 on Pedestal	20
Electronics 4	50			
Primary Flanges & Spring	2,400		Total Secondary Assy	1,802
Frame	4,028		Total Primary Assy no CW	8,434
spars	1,956		Total Turning Head Assy	3,870
Electronics 3 on Primary	50		Total on El Bearings with CW	12,868
CW	2,632		Total on Az bearing	16,738
			Total on Pedestal	20,758
			Total on Foundation	20,583

Total on El Bearings 28,369 lbs   Total on Foundation 45,379 lbs

Wind Load calculation
Variable Names & Coordinates

A program was developed to calculate loads from wind tunnel coefficients generated from a symmetric dish.

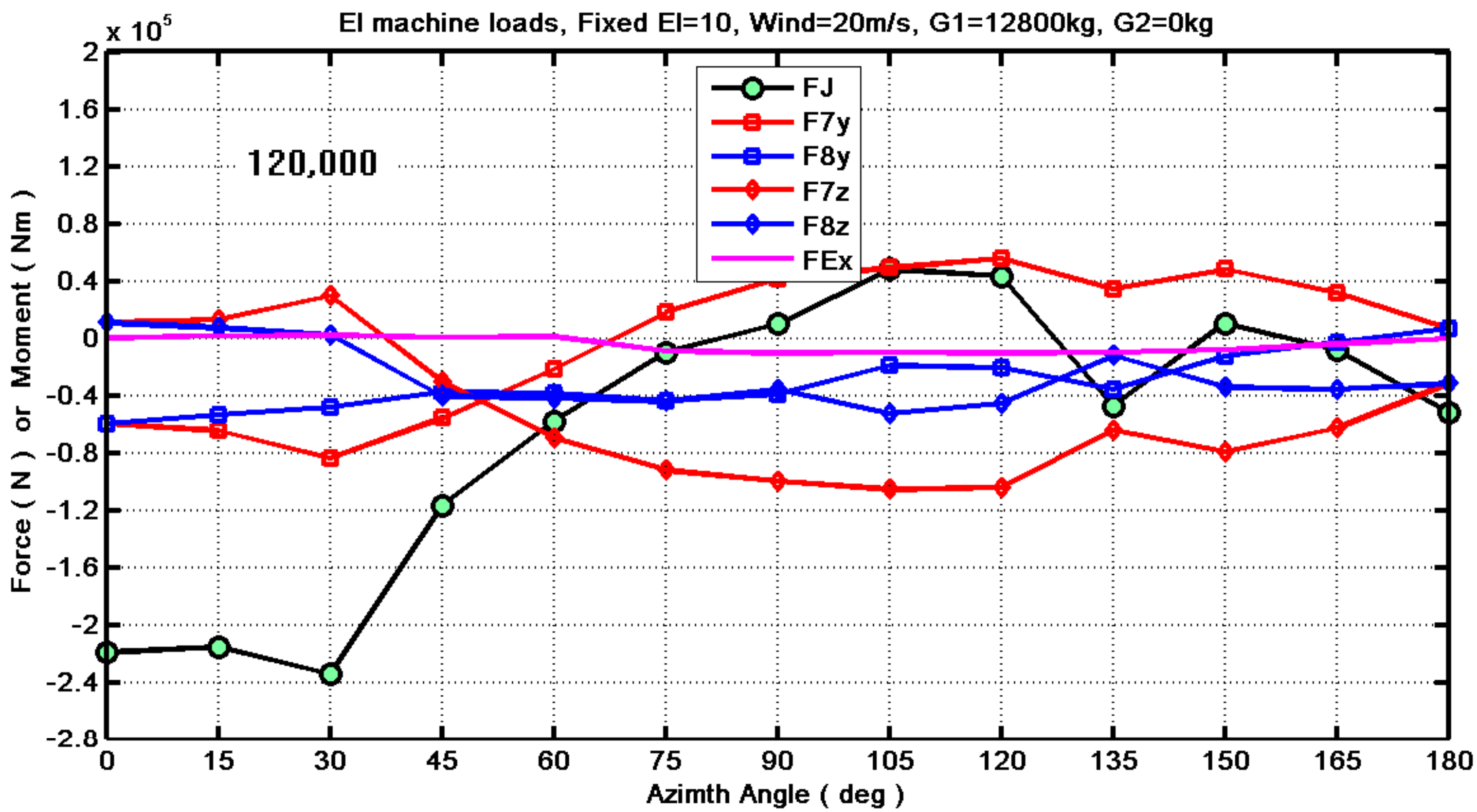




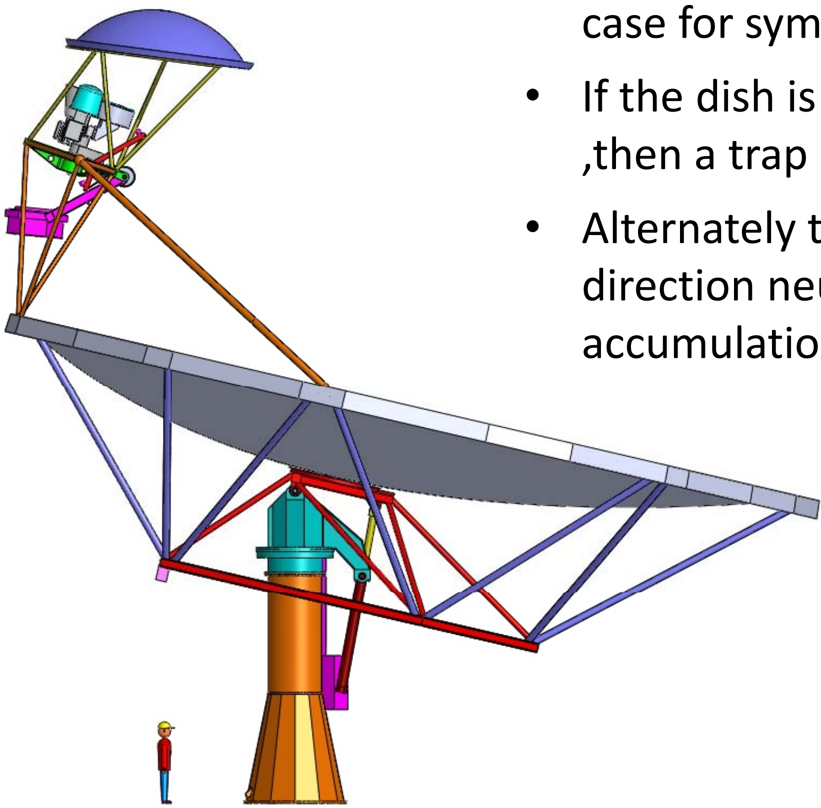
Typical Program Output
Loads on Elevation Machinery

Load curves are adapted from CP3 coefficients from work by Roy Levy JPL

Adaptation of symmetric to offset is not ideal and loads may be +/- 20%



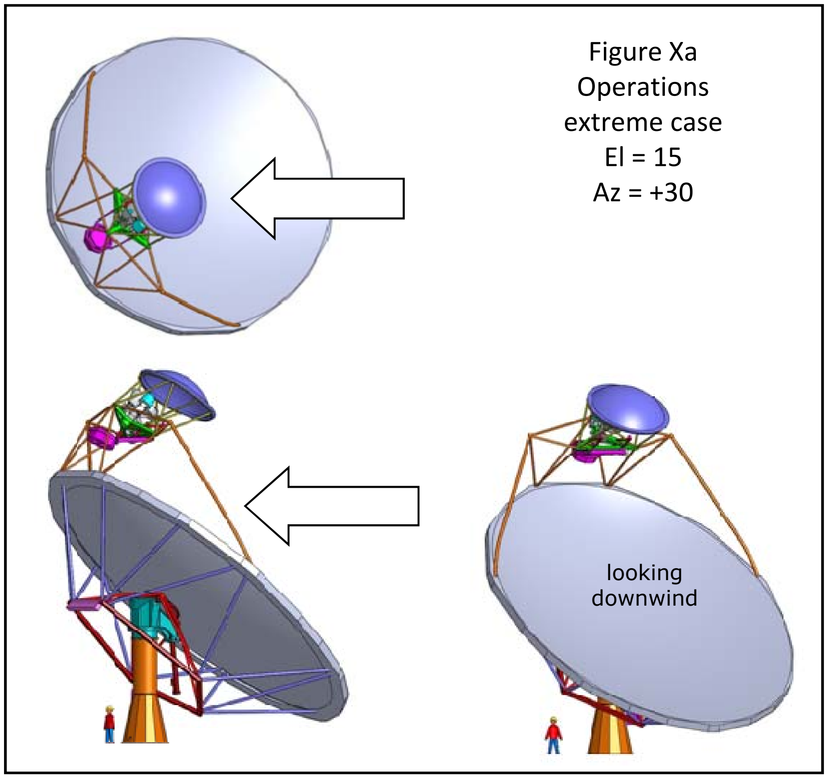
Survival Position
Consider 40° Elevation

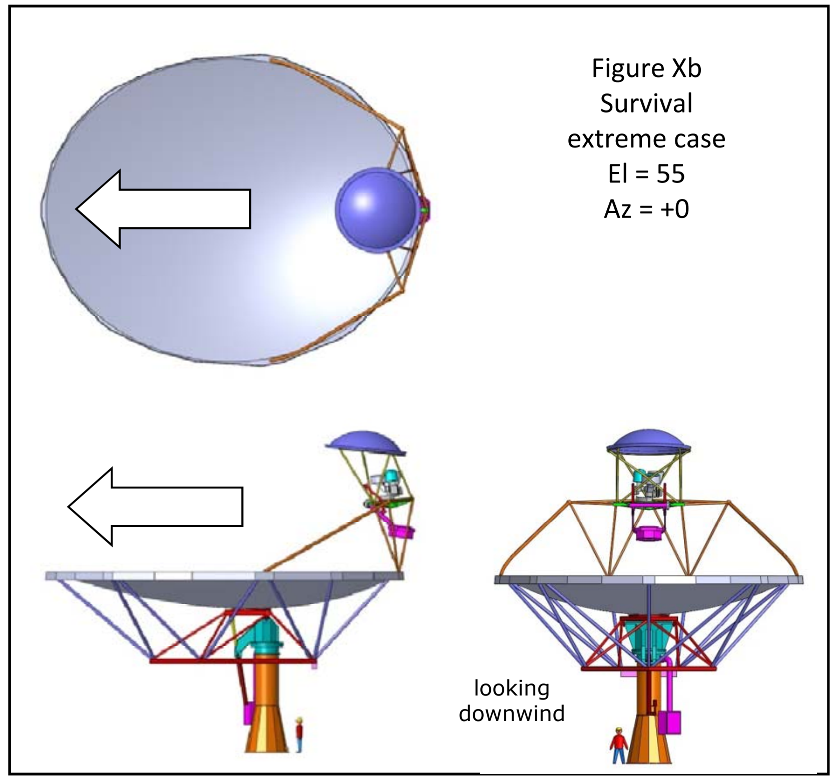


- Rain water accumulation is an issue.
- Center area of dish is not available for drain as is the case for symmetric designs.
- If the dish is to be placed at rim level, “birdbath” ,then a trap door drain may have to be installed.
- Alternately the 40°elevation position is fairly wind direction neutral while still minimizing water accumulations.

Extreme Load Positions

Load curves are adapted from CP3 coefficients shown in work by Roy Levy

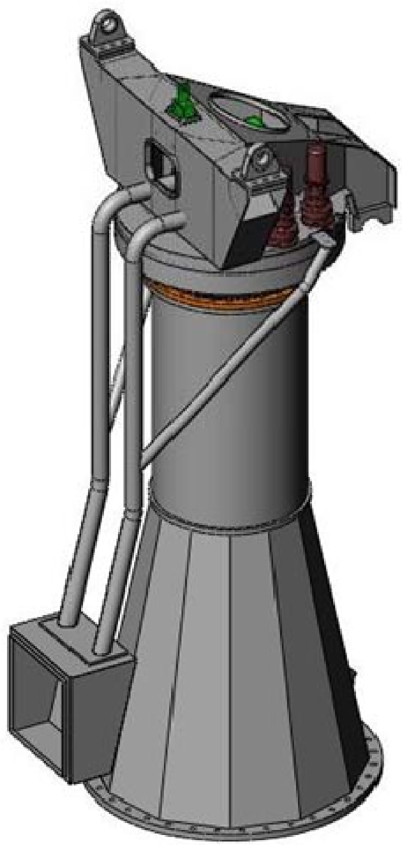


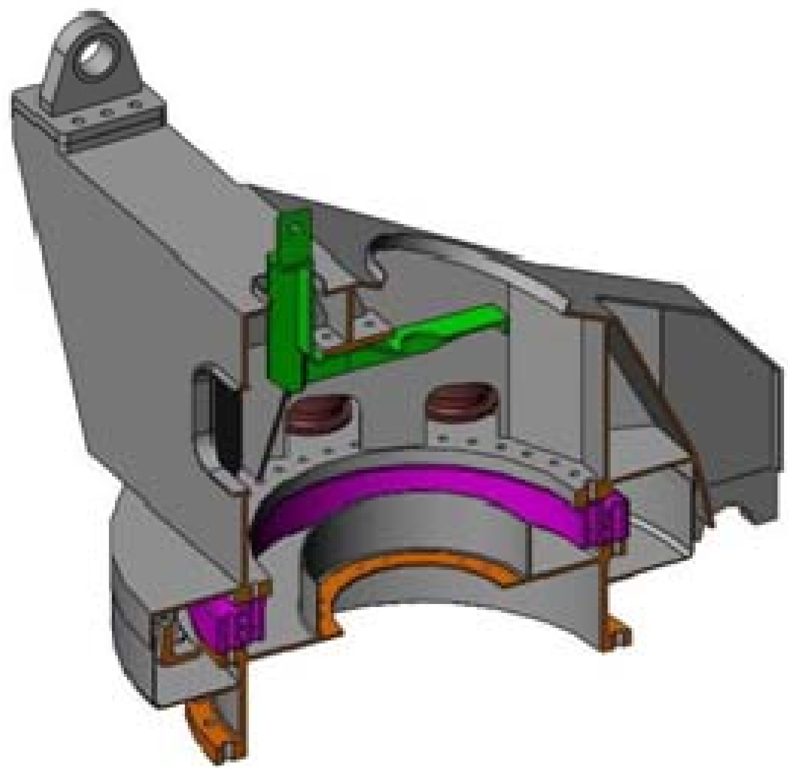


Extreme Load Orientations

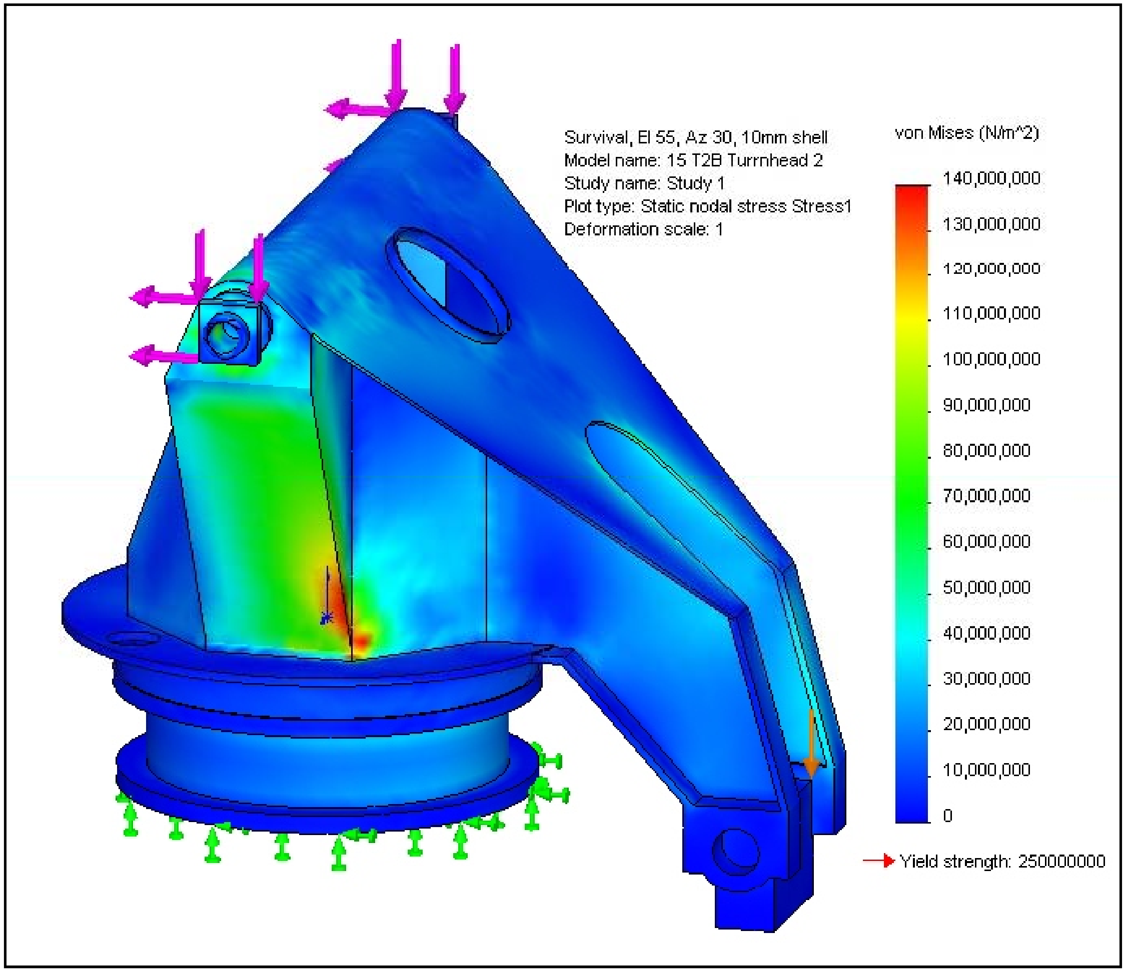
Table X Some Extreme Loads		Operation 20 m/s		Survival 42 m/s		Units
Elevation ang		15	85	55	55	deg
Wind azimuth ang		30	30	30	135	deg
Actuator tension.	FJ	-240	160	340	-240	kN
El bearing y force.	F7y	-80	-30	-20	50	kN
El bearing y force.	F8y	-50	0	-50	20	kN
El bearing z force.	F7z	30	-160	-320	-100	kN
El bearing z force.	F8z	0	-90	-100	180	kN
El bearings axial.	FEx	-10	-10	-20	-30	kN
Az Drive Torque. *	MAz	84	-40	-40	0	kNm
Az Bearing axial force.	FAz	-190	-84	-140	-140	kN
Az Bearing radial force.	FA	62	30	40	40	kN
Az Bearing overturn.	MA	130	300	720	500	kNm
Pedestal axial.	FPz	-191	-85	-141	-141	kN
Pedestal overturn. 0.55m	MP	164	317	742	522	kNm
Foundation axial.	FAz	-195	-89	-145	-145	kN
Foundation overturn.5.70m	M	483	471	948	728	kNm

Pedestal & Turning Head



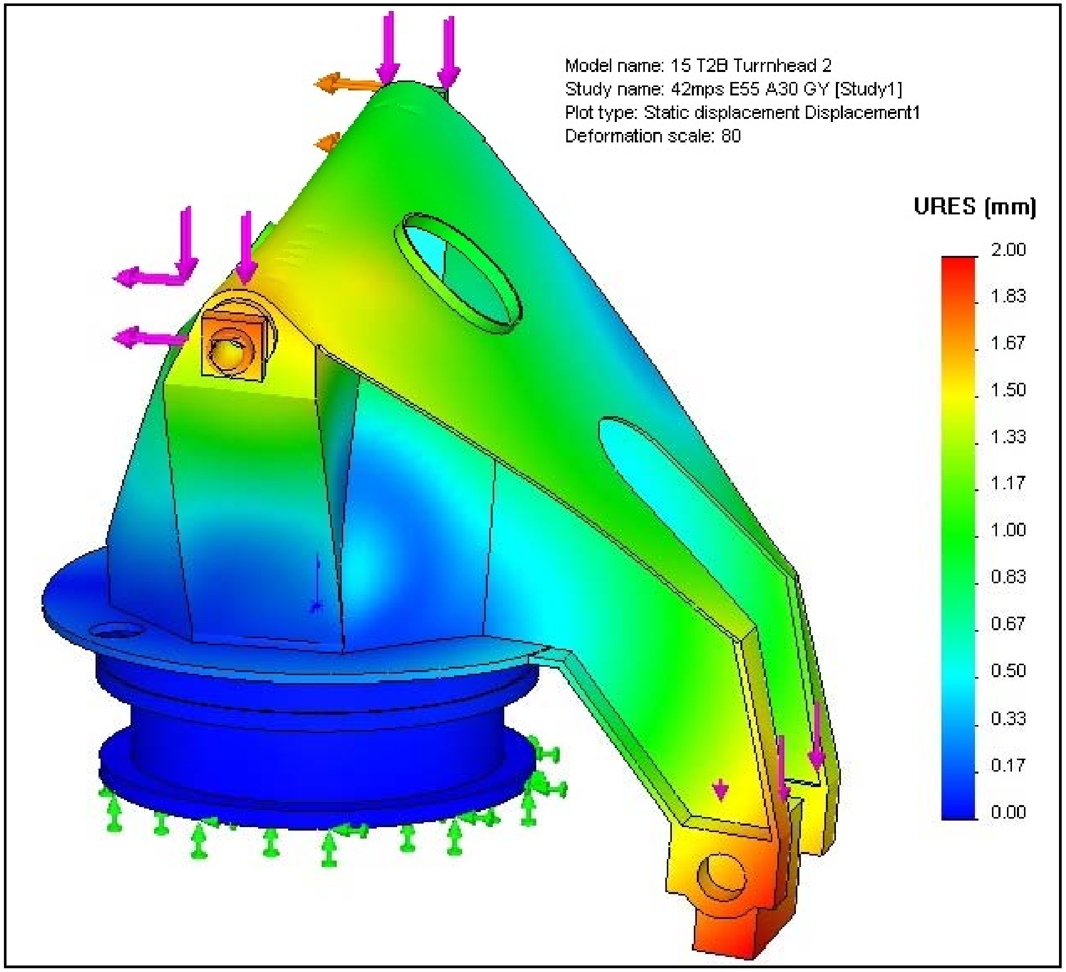


Turnhead
Stress During Survival



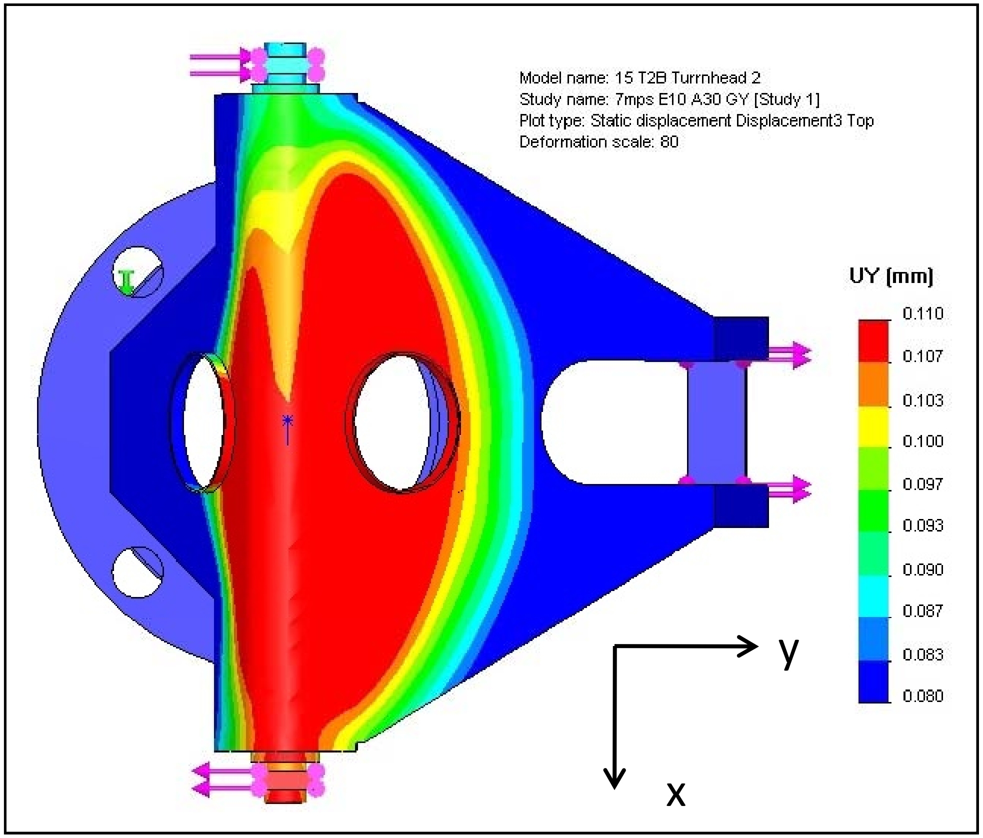
- Survival 45m/s
- El 55°(birdbath)
- 10mm thick plate.
- Max stress 1.6 Yield.
- Optimization will improve this.

Turnhead Deflection During 42m/s



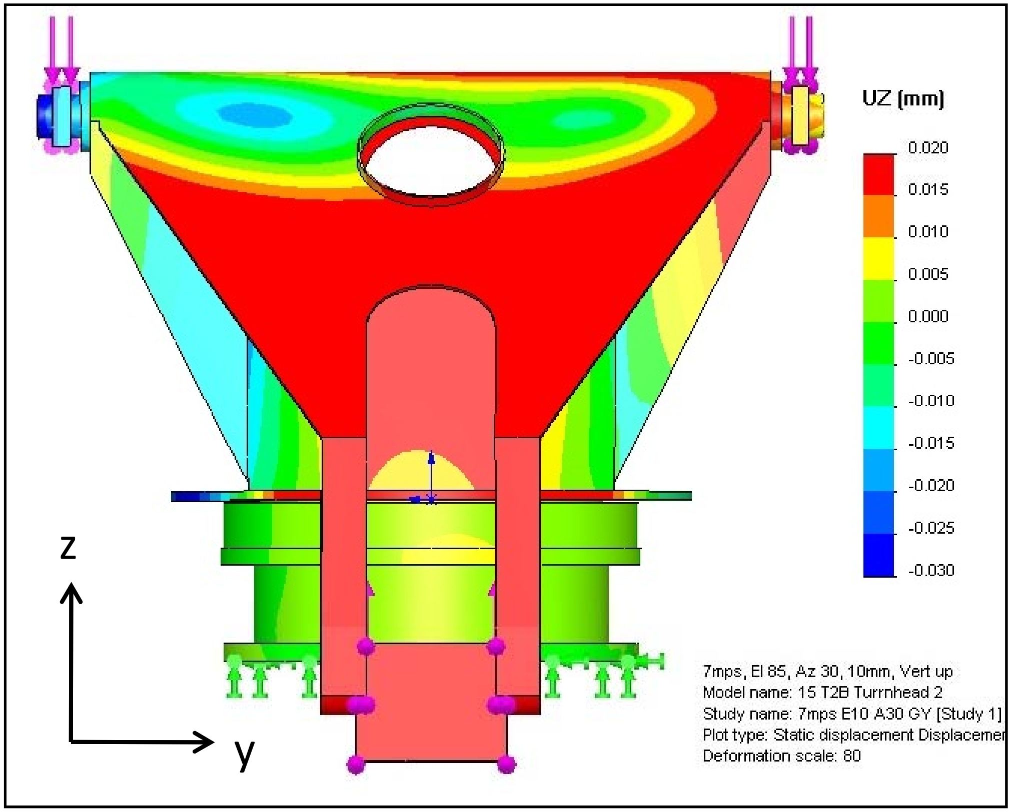
- Survival 42m/s.
- El 55°(birdbath)
- Az +30°wind direction.
- 10mm thick plate.
- Maximum 2.00 mm.

Turning Head Deflections
Y direction



- Precision, 7m/s, x-y plane
- El 15°
- Az +30°wind direction
- Δy = -0.095 mm center
- Δ 0.15 / 2500 brg separation
- 0.12 arc-sec Az error..

Turning Head Deflections
Z Direction

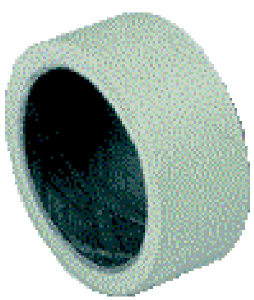


- Precision, 7m/s, x-z plane
- Elevation 15°
- Az +30°wind direction
- Δz = -0.005 mm center
- Δ 0.05 / 2500 brg separation
- 0.41 arc-sec ⊥ El error.

Elevation Bearing Component Choice

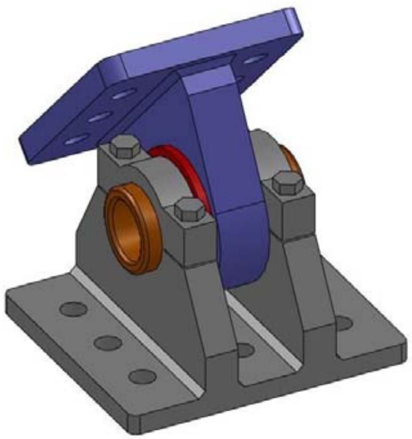
A20000

Spherical Roller Bearing:
- Traditional spherical double row roller bearing.
- Outer ring pair allows clearance adjustment.
- Requires lubrication.
- Only moves through 75 deg.
- Conservative best choice.



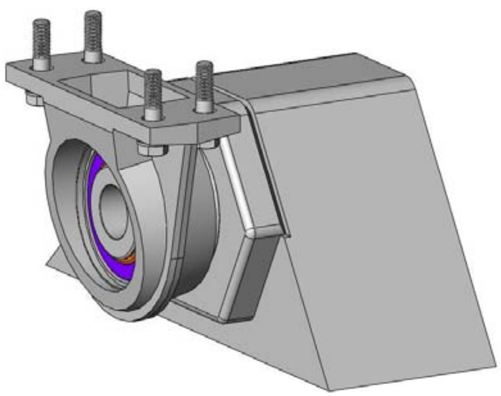
Filament wound dry lubricant bearings:
- Eliminates need for lubrication maintenance.
- High static load capacity.
- Good tolerance to misalignment
- Inexpensive and easy to install.
- Unknown lifetime and performance.
- Currently used on the ATA.

Elevation Bearing
Two Concepts of Interest



Clamped Shaft:

- Stiffer than cantilevered shafts.
- Clamped hollow shaft is inexpensive.
- Easy to control radial clearance.
- Used on ATA and other designs.
- Roller bearing or dry composite bearing.

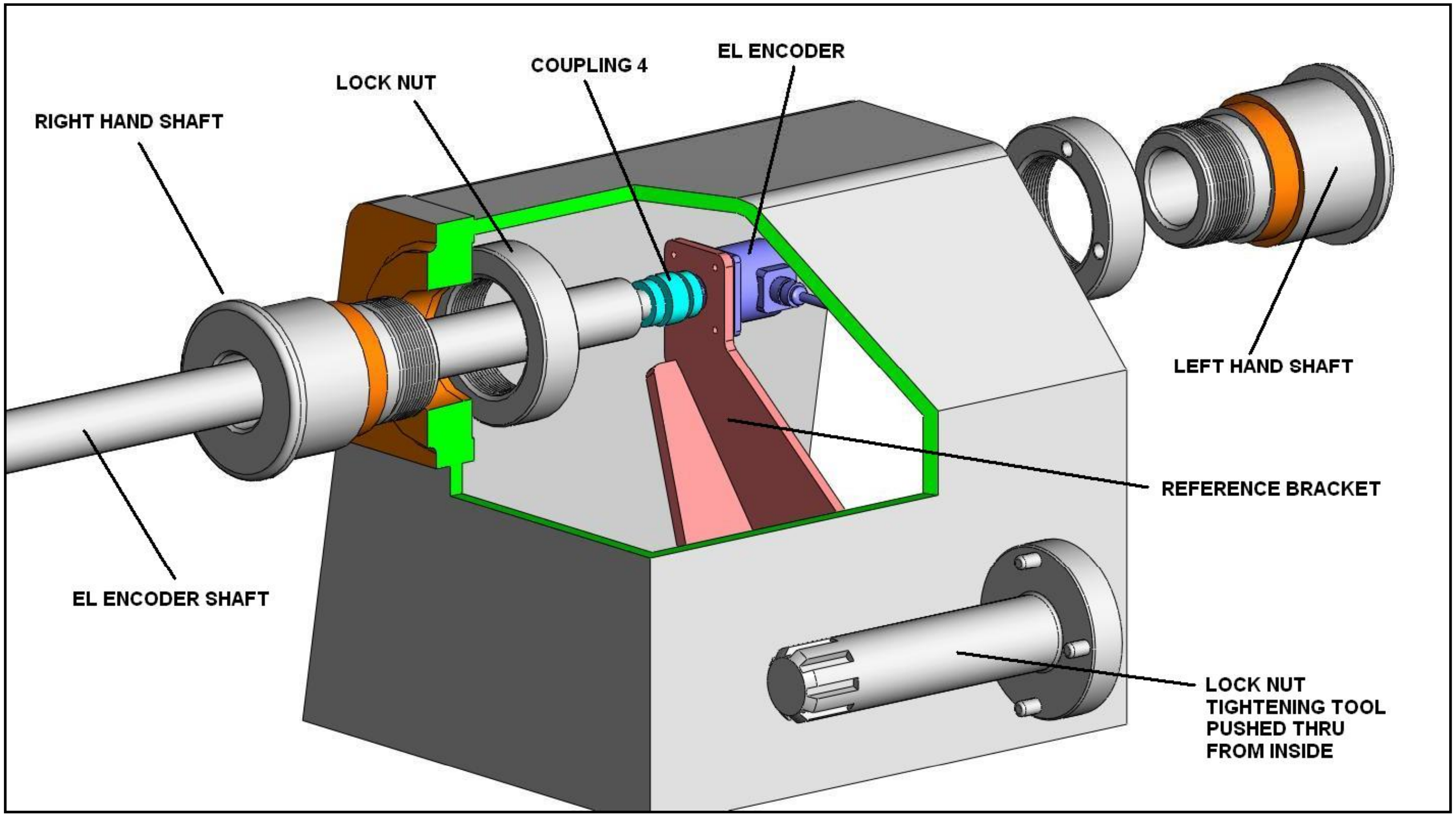


Cantilever Shaft:

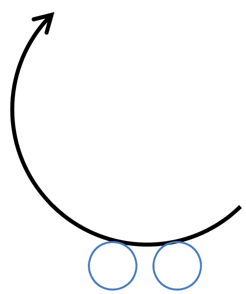
- Allows encoder shaft to enter turnhead.
- Large diameter hole is possible.
- Radial clearance can be adjusted in place
- CNC machine shaft bore in turnhead.
- Roller bearing or dry composite bearing.

Elevation Bearing
Cantilever Shaft Concept

Best for integrated and protected elevation encoder.



Elevation Drive Discussion
Sector Gear Advantages

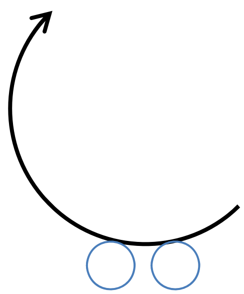


General notes:
Target slew is 1.0 to 1.5 deg/sec slew using a 1200 rpm motor gives ratios of 4,800:1 to 6,800:1

Advantages:

- Dual drives allow full backlash removal on all gearing and bearings.
- Can be adjusted to match wind conditions.
- Each drive unit can be smaller in size than a single unit.
- Sector drives can be replaced one at a time with little effect.
- Can accommodate an elevation range up to 180 degrees.

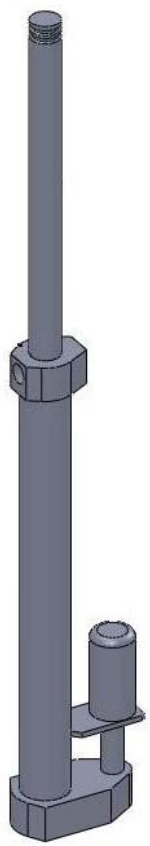
Elevation Drive Discussion
Sector Gear Drawbacks



Drawbacks:

- The Az bearing is forced away from El axis by the sector gear radius.
- Pinion shaft, final stage, torsional stiffness can be hard to achieve.
- Final stage reduction is near 15 so 3 or 4 more reduction stages needed. (5000:1)
- Sector gear is on center, splitting the turnhead into a yoke with arms, less stiff.
- Sector gear is open and needs some sort of protection scheme.
- Axis intersection area may not be available to metrology system.

Elevation Drive Discussion
Linear Actuator Advantages



Advantages:

a) Final stage reduction ratio. 400 to 600. (4,800:1 needed)

b) High efficiency parallel shaft gearing with high reliability.

c) Ball nut is available with anti-backlash. (limited value)

d) A 4” screw size is readily available, 3” might work

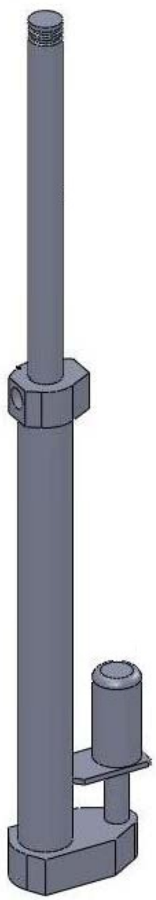
e) Rod & cylinder design increases screw buckling limit.

f) Sealed system with no open gearing or bellows.

g) Oil bath lubrication of all components is possible.

h) Full repair with one replacement, but heavy.

Elevation Drive Discussion
Linear Actuator Drawbacks



Drawbacks:

a) Limited range of motion generally less than 100 degrees.

b) Anti-backlash magnitude from gravity is not adjustable.

c) Anti-backlash nuts do not solve pivot & gearing backlash.

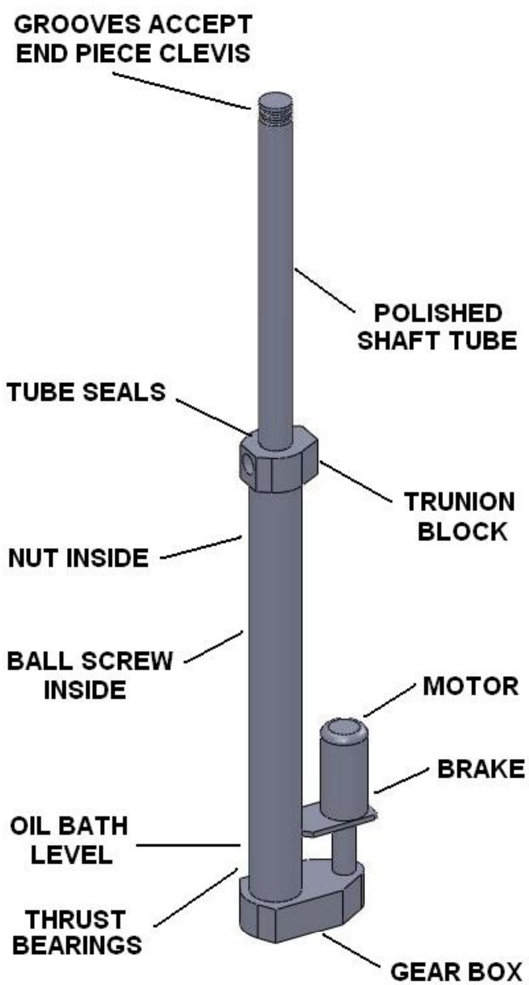
d) A brace must be installed for unit replacement.

e) Unit is heavy.

f) Compression buckling is often the limiting failure mode.

g) Power used to raise mass of telescope should be recovered.

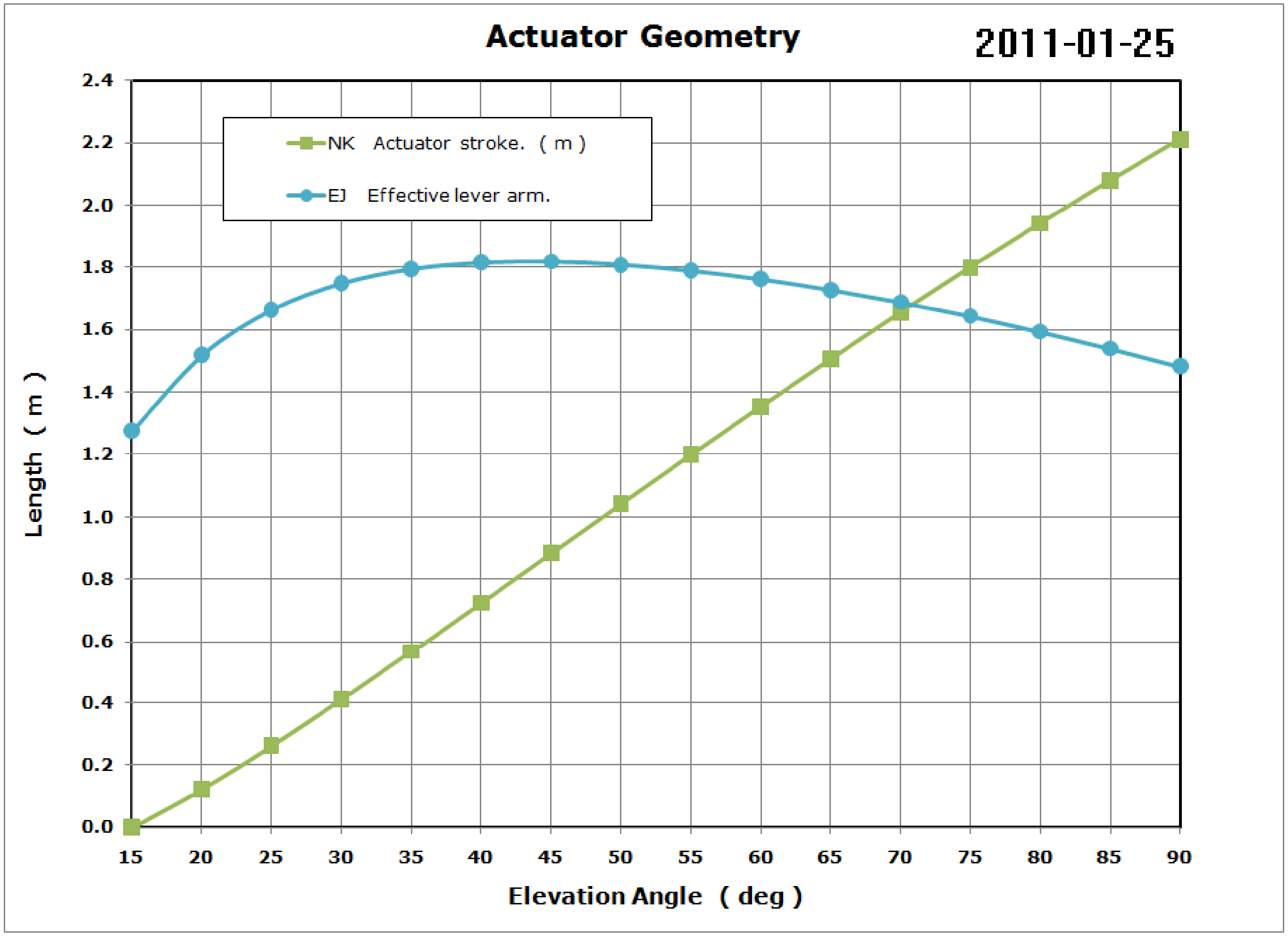
Actuator Key Components



Also needs: oil pump, oil level sensor, spring brake, effective seals.

Limits may be part of the actuator or at internal elevation encoder

Actuator Geometry

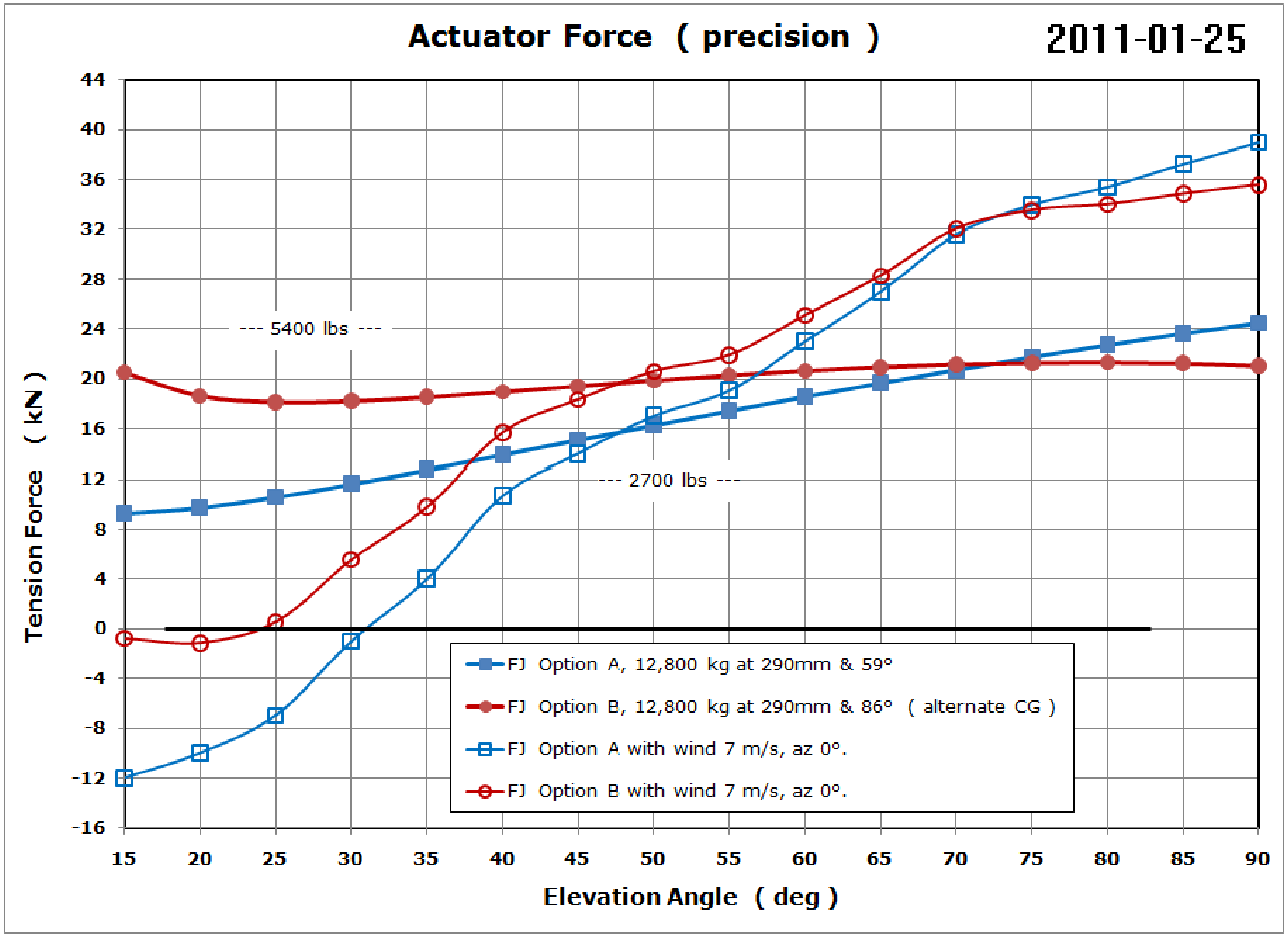


Max stroke
2.20 m

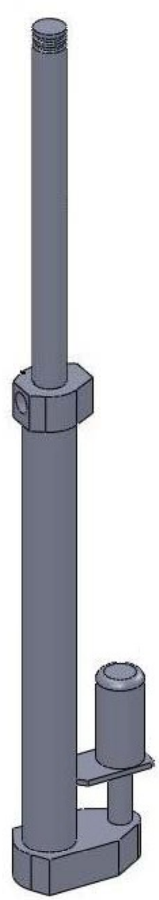
Max lever
1.82 m

Min lever
1.26 m

Actuator Load
Precision 7 m/s



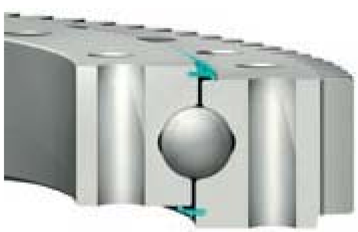
Actuator Power Consumption

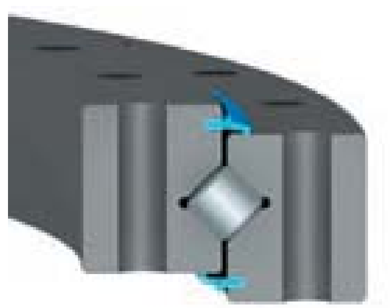


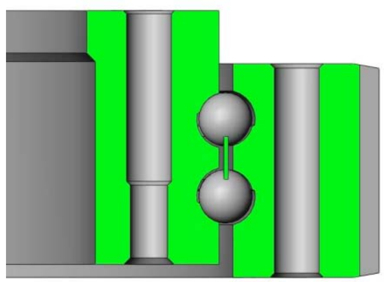
- Assuming 200 cycles / day of 4 deg track 1 degree slew.
- Give 500 deg lifting 125 kN on a 0.29 m radius
- Gives 36.4 kw-hrs / year
- Gives $ 5.46 $ / yr at 0.15 $ / kw-hr   USD

Azimuth Bearing
General Requirements

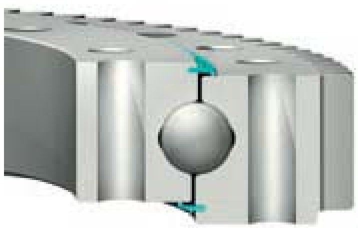
a) Still consulting with the manufacturers about properties and costs.
b) Must be lightly preloaded to eliminate clearance.
c) High overturning moment stiffness is important.
d) Low tuning torque is important, but conflicts with stiffness.
e) External or internal gear teeth available with high quality steel.
f) Survival static overturning moment is a one time event, some damage tolerable.
g) Long lifetime with low wear is important, replacement is not an option.



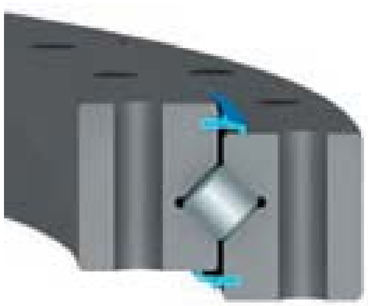




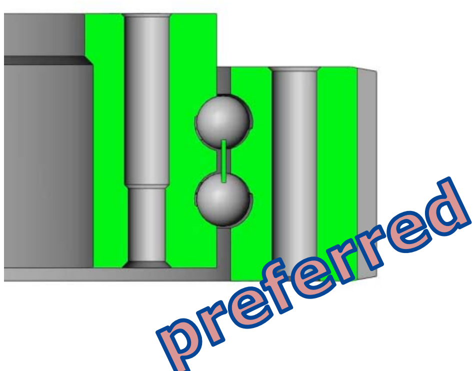
Azimuth Bearing Candidates



- Single row four point contact bearing.
- Lowest cost option, 1.00, common choice.
- Medium stiffness, 1.00, low turning torque, 1.00.
- Medium tolerance on mount flatness, perhaps 0.005”.
- Wear rate suspected to be medium.

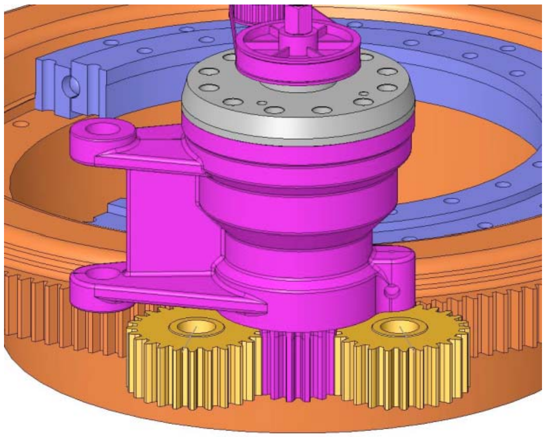


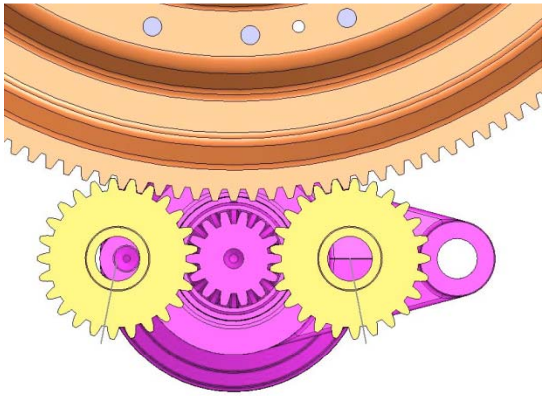
- Single row crossed roller bearing.
- Medium cost, 1.25x?, also common choice.
- High stiffness, 2.00x, medium turning torque, 2.20x.
- Tight tolerance on mount flatness, perhaps 0.003”.
- Wear suspected to be higher.



- Double row, angular contact bearing.
- Medium cost, 1.30x?, not common.
- Medium stiffness, 1.00x, Lowest turning torque, 0.90x.
- Medium low mount flatness, perhaps 0.008”.
- Wear rate suspected to be lowest.

Azimuth Drive
Pinion Support Concept

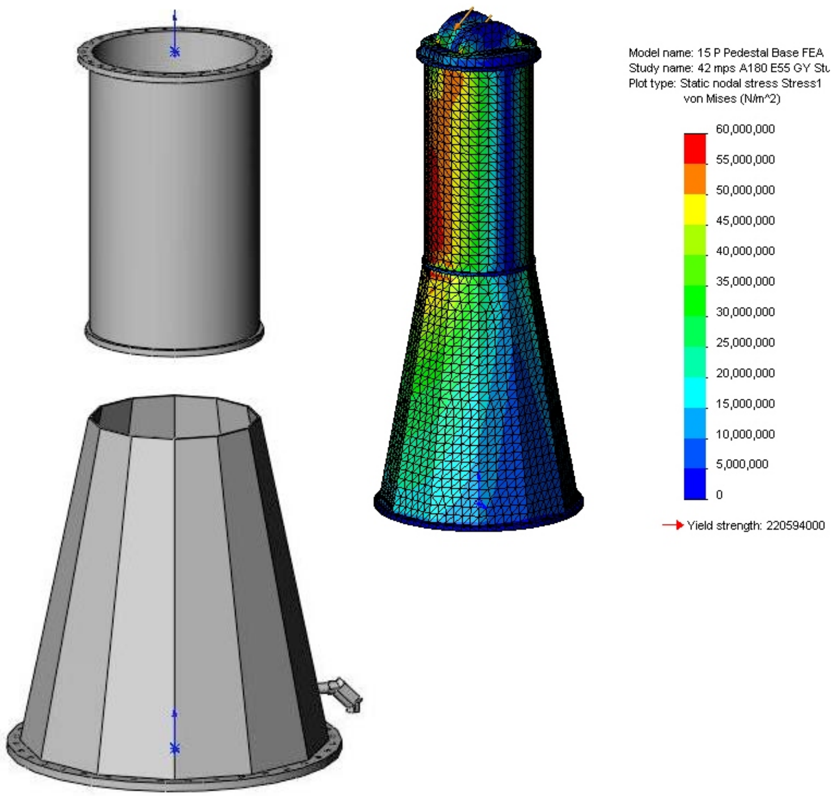




General Notes:
With a slew of 3.0 deg /sec
using a 1200 rpm motor gives
a ratio of 2,400:1

- This concept is employed on the ATA.
- Drive modules are easily removed.
- Two idler gears deliver 1.80 X torque capacity.
- Pinion has balanced opposing loads.
- Pinion is protected from cantilever bending.
- Allows for a smaller gear tooth size.
- Allows higher final ratio near 15.
- Currently concept uses two drive modules.
- Only special tooth ratios give proper geometry.
- Detail design is still underway.

Pedestal Stress Analysis



- Total pedestal height is 5.7 m with top diameter of 1.2 m and a bottom diameter of 2.3m.
- Upper tube section is 2.4 m tall.
- Top flange is welded to the tube and then turned to maintain flatness.
- Upper section is 15mm rolled plate.
- Lower section is 15mm plate and is made using step bending or bump bending rather than the more expensive cone rolling.
- Bolt patterns are not highly stressed.
- Max stress is 60 MPa 4.2 SF yeild.

This pedestal is well suited to the ALMA test site. However alternate designs should still be considered for the SKA as new foundation concepts are considered.

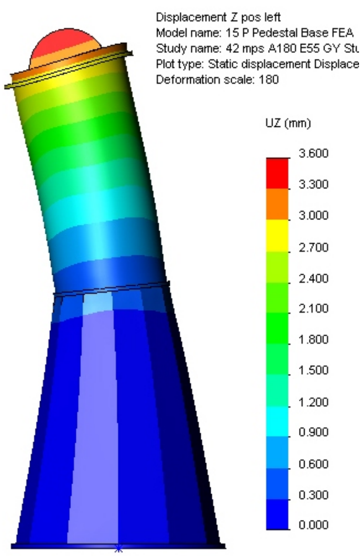
Pedestal Deflection

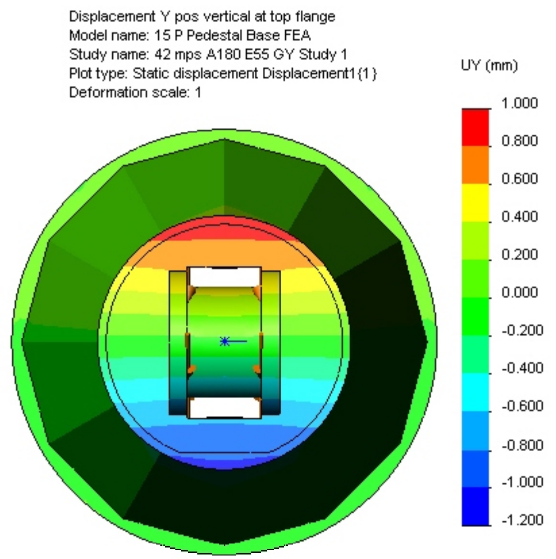
Elevation 15°Wind +30°

Wind 7 m/s, Δy = 0.068 mm, y-z tilt 0.044 / 1200 = 7.6 arcsec

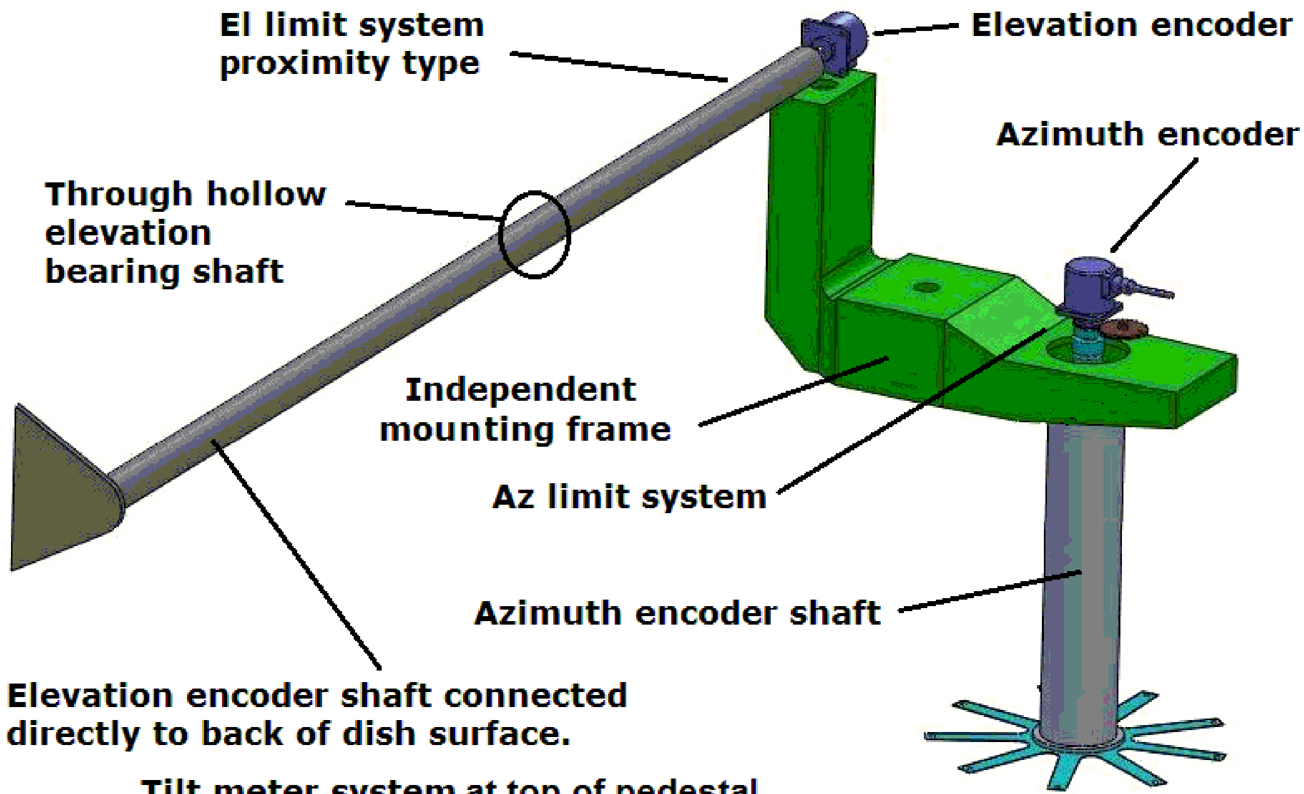
Wind 20 m/s, Δy = 0.55 mm, y-z tilt 0.40 / 1200 = 61.1 arcsec

Wind 45 m/s, Δy = 2.80 mm, y-z tilt 1.80 / 1200 = 5.16 arcmin





Metrology System



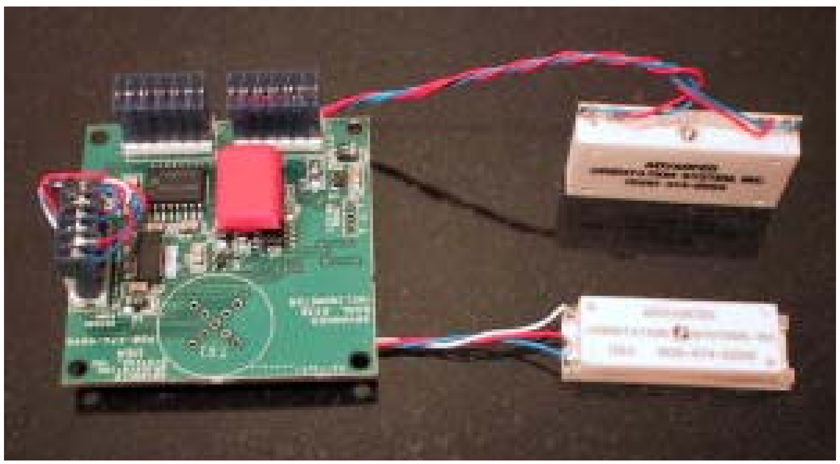
Tilt meter system at top of pedestal

All encoders, tiltmeters and limits internal to the turnhead.

Metrology System
Possible Components

A tiltmeter system is needed to track pedestal tilting.

Dual axis tiltmeter sys, AOSI 3000 shown below.

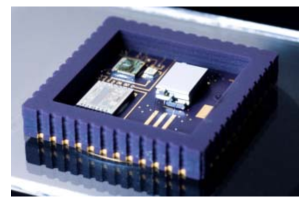


Very high quality tiltmeters are also available from Applied Geomechanics.

Heidenhain

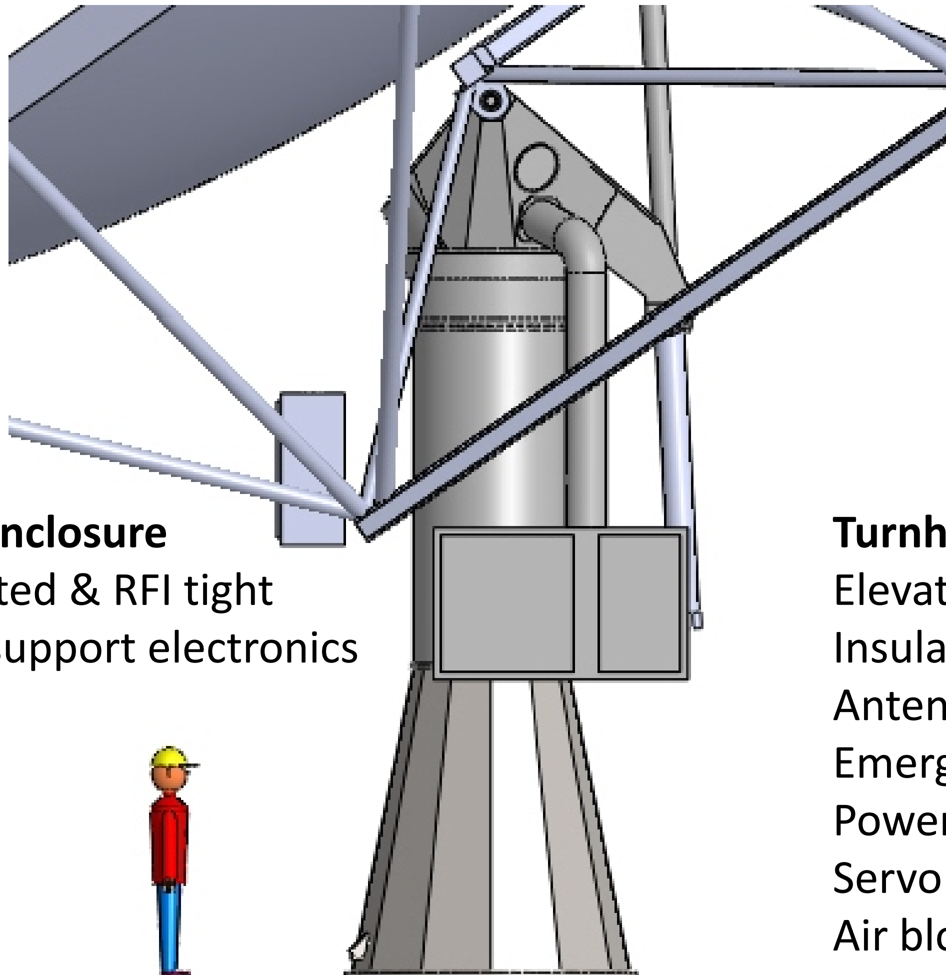
ROD 780 +/- 2 arcsec

ROD 260 is also good



MEM accelerometer

Electronics Enclosures & Access



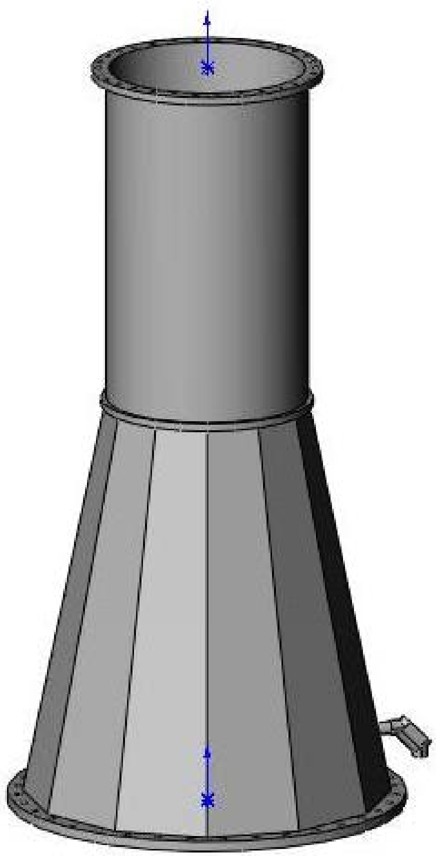
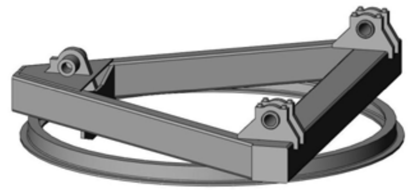
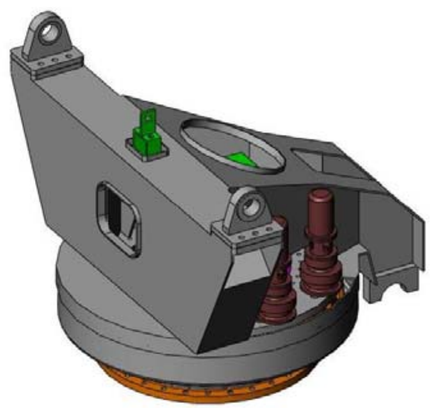
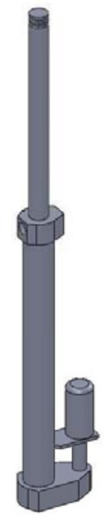
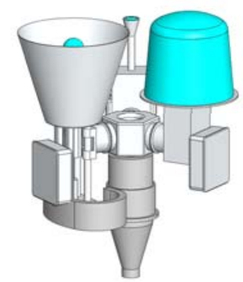
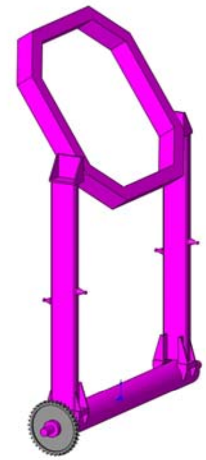
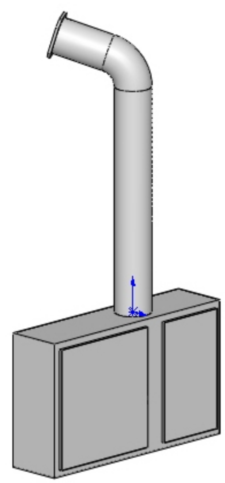
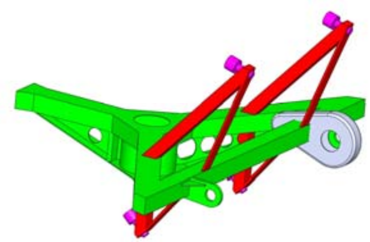
Turnhead interior space
RFI tight
Encoders inside
Limits inside
Az wrap inside
Az reducers & motors inside
El drive motors near

Dish Enclosure
Insulated & RFI tight
Feed support electronics

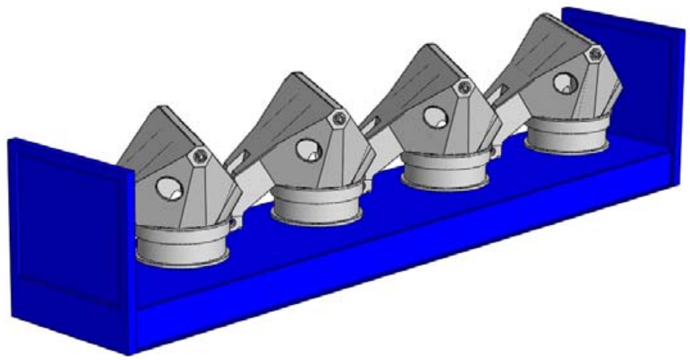
Turnhead Pendent enclosure.
Elevated for security
Insulated & RFI tight
Antenna control
Emergency stop
Power supplies
Servo Amplifiers
Air blower & filter
Water chiller

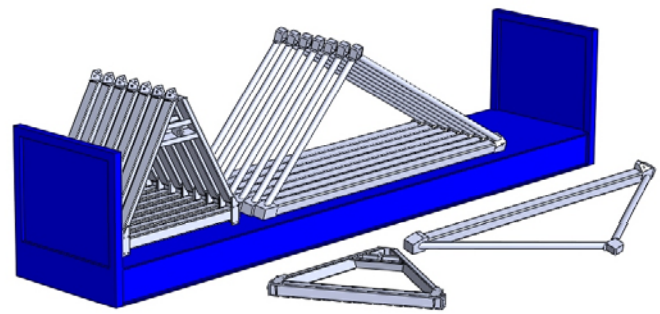
Access Vehicles

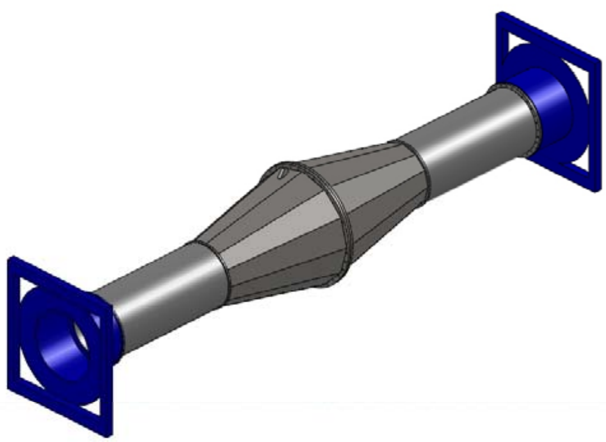
Deliverables

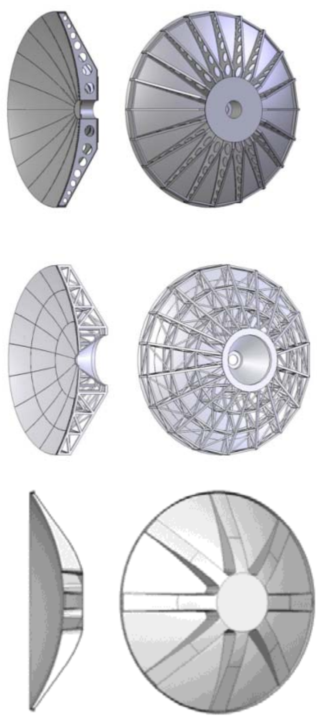
Shipments

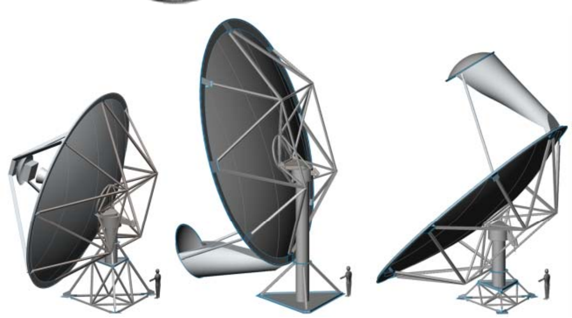


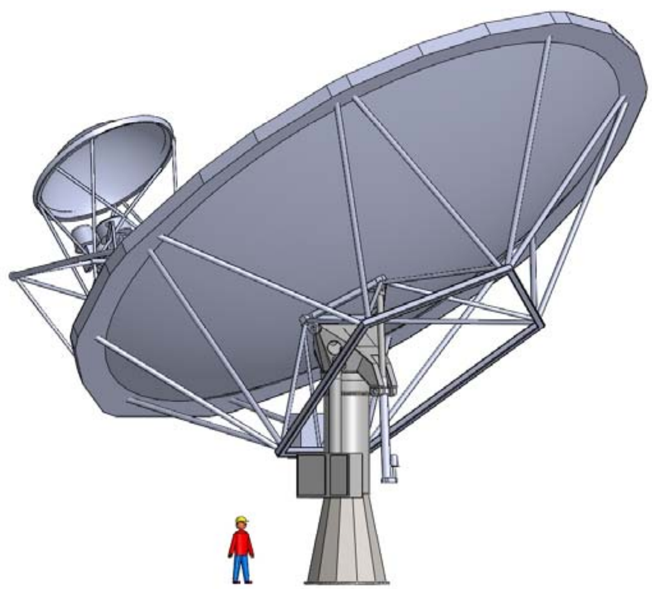


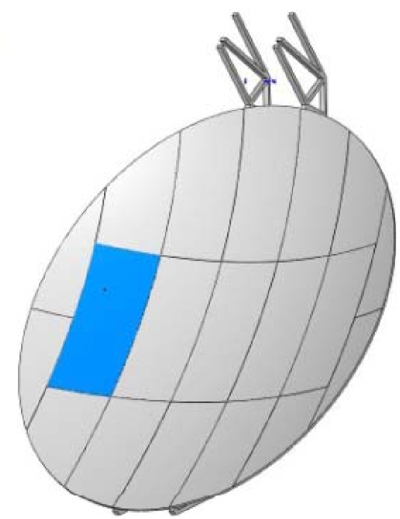


End









Specs (mechanical 1a)

DBA-1 15m Antenna Specifications			Rev B Part 1
Optics	**Values**	**Units**	**Comment**
Optics type	Offset Gregorian high		
Primary diameter	15.00 x 18.26	m	(15.0m = 49.2ft)(176.7m²)
Secondary diameter	4.00 x 3.97	m	set 4λ for min freq. (4 x 1.0 = 4.0 m for 300 MHz)
Primary illumination ang	102.20	deg	
Secondary illumination ang	110.0	deg	Total ang focal pt to edge of secondary (84 on ATA)
Primary focal length	6.028	m	
Offset ratio	0.5575	ratio	offset primary beam center to parabolic axis
Beam clearance	> 0.500	m	

Specs (mechanical 1b)

DBA-1 15m Antenna Specifications			Rev B Part 1
Mechanical	**Values**	**Units**	**Comment**
Mount type	Az - El		Azimuth-Elevation
Azimuth range	-270 to +270	deg	0 at south, +90 East. Hemisphere?
Elevation range	+15 to +85	deg	zero at horizon
Ambient Temp range	-10 to +55	°C	(+14°F to +131°F)
Solar exposure range	30 13	MJ/m^2	mean daily, summer, winter.
Stow wind speed	20m/s, 45mph	m/s	1%, 88 hours / year 72kph
Survival wind speed	45m/s, 101mph	m/s	clean wind. spectrum? 162kph
Operation	Continuous		use 24 hours / 7 days a week.
Az drive cycle	2,400	deg/day	200 cyc, 6 deg slew, 6 deg track.
El drive cycle	1,000	deg/day	200 cyc, 4 deg slew, 1 deg track.
Maintenance lubrication	60	months	for drive & bearing lubrication.
Maintenance filters	12	months	air, lube, filters, battery, coolant.
Maintenance paint covers	144	months	
Power range	1000 to 3000	watts	Includes 200w for 1/10 zone node.
SPFs + indexer sec focus	300	Kg	
PAF at prime focus	300	Kg	Includes swing arm.

Specs (mechanical 2a)

DVA-1 15m Antenna Specifications (environment dependent performance)						Rev B Part 2
Name		**Precision**	**Standard**	**Degraded**	**Unit**	**Comment**
Environment		night low wind	day * low wind	strong wind		* day, dead calm, may = degraded
Availability 98%		48%	48%	3%	time	observing time.
Wind speed max		7	7	20	m/s	(7 m/s, 25 Km/hr, 16 mph)
Design Frequency	F =	10	6.0	1.4	GHz	(20 m/s, 72 Km/hr, 45 mph)
Wavelength	W =	3.00	5.00	21.43	cm	W = C / F = 30 / F (in GHz)
Primary Surface, rms	S =	0.7	2.50	4.29	mm	S = ratio x W (rms)
Frequency (GHz)	10.0	3.3%	8.3%	14.3%	% λ	10% = 1/10 is okay 5% = 1/20 is good 3% = 1/30 is better
	6.0	2.0%	5.0%	8.6%		
	1.4	0.5%	1.2%	2.0%		
	0.5	0.2%	0.4%	0.7%		

Item of interest

Items subject to change

Specs (mechanical 2a)

DVA-1	15m Antenna Specifications (environment dependent performance)					Rev B Part 2
Name		**Precision**	**Standard**	**Degraded**	**Unit**	**Comment**
Environment		night low wind	day * low wind	strong wind		* day, dead calm, may = degraded
Availability 98%		48%	48%	3%	time	observing time.
Wind speed max		7	7	20	m/s	(7 m/s, 25.2 Km/hr, 15.6 mph)
Design Frequency	F =	10	6.0	1.4	GHz	(20 m/s, 72 Km/hr, 44.7 mph)
Wavelength	W =	3.00	5.00	21.43	cm	W = C / F = 30 / F (in GHz)
Secondary Surf, rms	S =	0.30	1.00	2.14	mm	S = ratio x W (rms)
Frequency (GHz)	10.0	1.0%	3.3%	7.1%	% λ	10% = 1/10 is okay 5% = 1/20 is good 3% = 1/30 is better
	6.0	0.6%	2.0%	4.3%		
	1.5	0.2%	0.5%	1.1%		
	0.5	0.1%	0.2%	0.4%		

Specs (mechanical 2c)

DVA-1 15m Antenna Specifications (environment dependent performance)						Rev B Part 2
Name		**Precision**	**Standard**	**Degraded**	**Unit**	**Comment**
Environment		night low wind	day * low wind	strong wind		* day, dead calm, may = degraded
Wind speed max		7	7	20	m/s	(7 m/s, 25.2 Km/hr, 15.6 mph)
Design Frequency	F =	10	6.0	1.4	GHz	(20 m/s, 72 Km/hr, 44.7 mph)
Wavelength	W =	3.00	5.00	21.43	cm	W = C / F = 30 / F (in GHz)
Beam size	B =	0.14	0.23	1.00	deg	B = 70 (W / D) for offset FWHM
Pointing, peak		30 sec	0.84	9.00	arc-min	10.0% = 1/10 is okay 5.0% = 1/20 3.3% = 1/30 is okay for survey 2.0% = 1/50 1.0% = 1/100 good image & survey P = ratio x B x 60 (rms)
Pointing, rms	P =	10 sec	0.28	3.00	arc-min	
Frequency (GHz)	10.0	2.0%	3.3%	35.7%	% λ	
	6.0	1.2%	2.0%	21.4%		
	1.5	0.3%	0.5%	5.4%		
	0.5	0.1%	0.2%	1.8%		

Spec (mechanical 2d)

DVA-1 15m Antenna Specifications (environment dependent performance)						Rev B Part 2
Name		**Precision**	**Standard**	**Degraded**	**Unit**	**Comment**
Environment		night low wind	day * low wind	strong wind		* day, dead calm, may = degraded
Availability 98%		48%	48%	3%	% time	observing time. < 1% maintenance
Wind speed max		7	7	20	m/s	(7 m/s, 25.2 Km/hr, 15.6 mph)
Design Frequency	F =	10	6.0	1.4	GHz	(20 m/s, 72 Km/hr, 44.7 mph)
Optical Alignment		2.00			mm	All axis, all alignments
Az slew rate		3.0	3.0	1.0	deg/sec	
El slew rate		1.0	1.0	1.0	deg/sec	
Slew Time		1.08	1.08	3.08	min.	to anywhere on sky, Az 180°, El 78°