Discussion of Various Mounts for Array Antennas Related to ngVLA Designs

NGVLA Science Workshop, Socorro NM

June 26, 2017

Matt Fleming, presenter.

U C Berkeley , Retired | Minex Engineering, Owner

Representing work by:

Matt Fleming, Roger Schultz, Dave Enterline

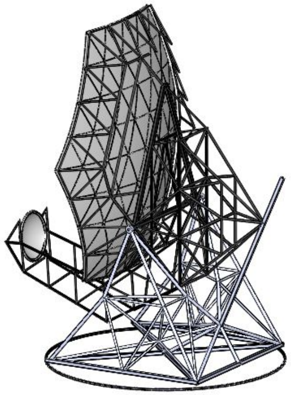
MINEX
ENGINEERING CORP.

Trying to get the Right Specifications for an Array

Searching for the right compromise.

I always like to show this slide.

Strawman Design
(farmer near Manchester)



NRAO Community Study
Mounts for the ngVLA

Matt Fleming, Roger Schultz and Dave Enterline, wanted to take our considerable experience in antenna mechanical and structural design and give guidance to the ngVLA project.

We wanted to explore what sort of antenna mount might be most practical for this application. We will submit a paper in Late August with our results and recommendations.

This presentation will discuss the status of our work exploring the performance and cost of 3 mount concepts. This presentation will be missing actual numbers and final conclusions.

Mount Study Design Team and Relevant Expertise

Matt Fleming: 25 + years Antenna Mechanical Design.
UCBerkeley BIMA Array, SETI ATA Array,
US SKA TDP.

Roger Schultz: 40+ years Antenna Mechanical Design.
Many commercial antennas, and radio telescopes
Early SKA proposals.

David Enterline: 40+ years Antenna Structural Design.
Licensed structural, Many antennas and foundations
lead analyst on GBT Structural.

Specifications that Drive Mount Design

Sources of Error Catagories that control performance

- Size of the aperture. (drives pointing error)
- Optical arrangement & feed angle. (cass or gregorian)
- Optical configuration. (symmetric or offset, high or low)
- Lowest elevation pointing angle.
- Frequency, Low & spillover. (drives secondary size)
- Frequency, high. (drives surface Accuracy & pointing)
- Pointing Error. some from ERS & some from ARS
- Path Length Error.
- Stability over some period of time.
- Maintenance.

Surface Accuracy

Surface Accuracy

It is not within the scope of our efforts to provide designs for reflector surfaces or support structures. We did have to pick some sort of design in order to move forward.

Pointing Error (PE)

We have identified the “Referenced Pointing Requirement” as the most difficult criteria for the mount.

3 arc-sec rms during a 4 deg movement over a 15 min period with 7m/s winds & gusts.

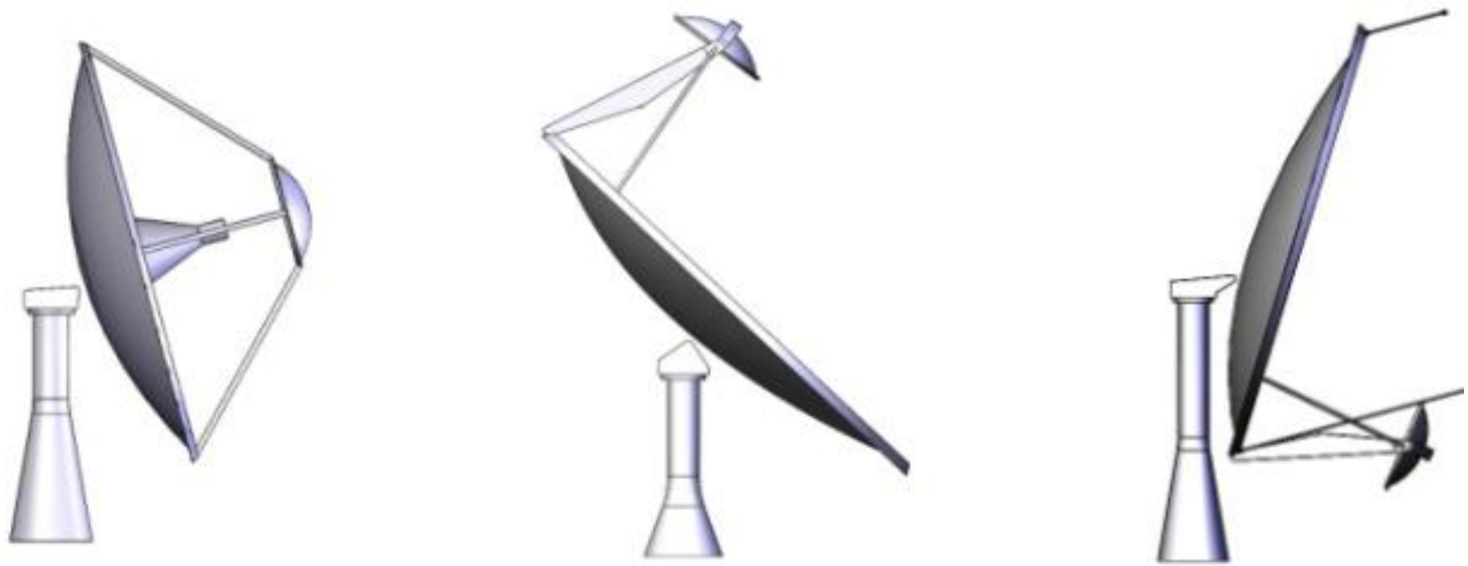
In most telescopes 50% to 67% of the pointing error is taken by the ERS leaving 33% to 50% for the mount.

Active Secondary support can help, but adds cost.

Reference structures in the ARS can help, but adds cost.

ERS = Elevation Rotating Structure.
ARS = Azimuth Rotating Structure.

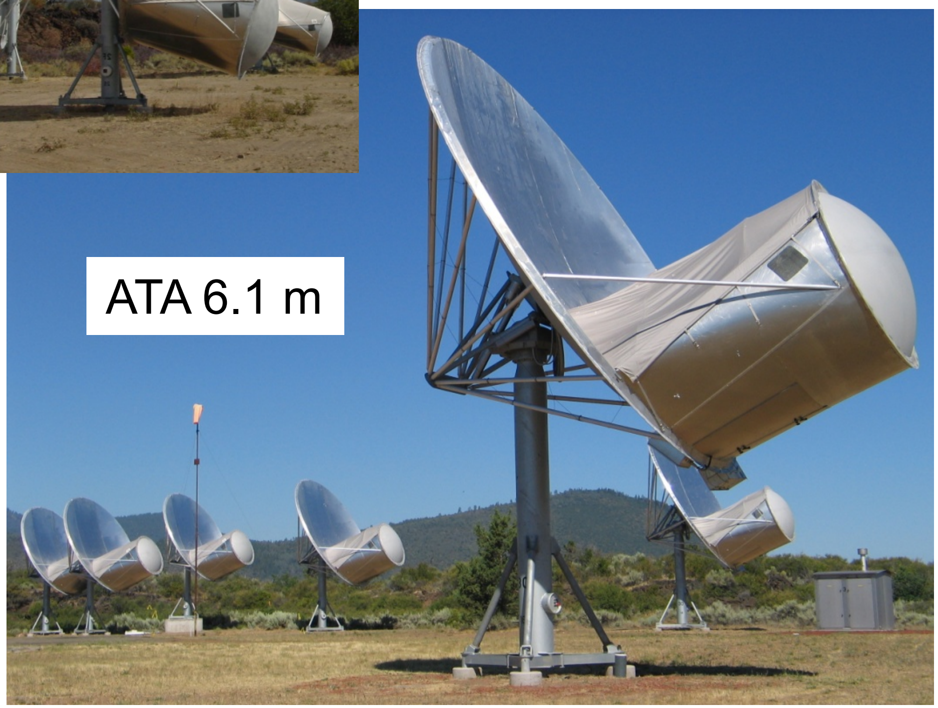
Configuration Choices



Symmetric Offset High Offset Low

Existing Offset Low

Elevation lower
limit ≈ 15°

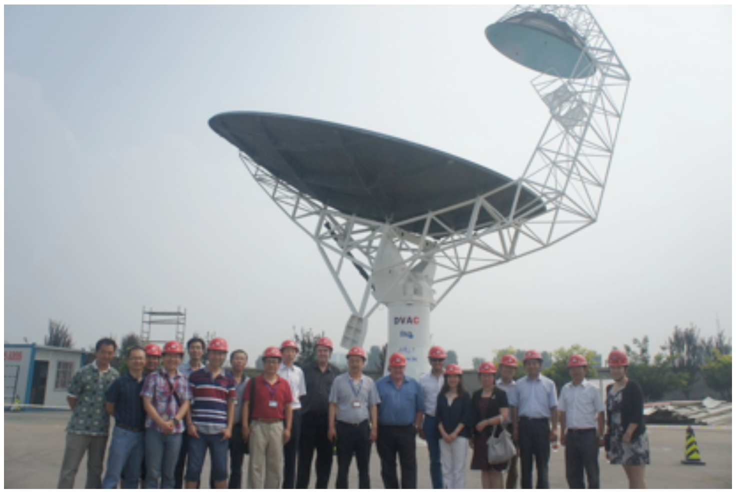


ATA 6.1 m

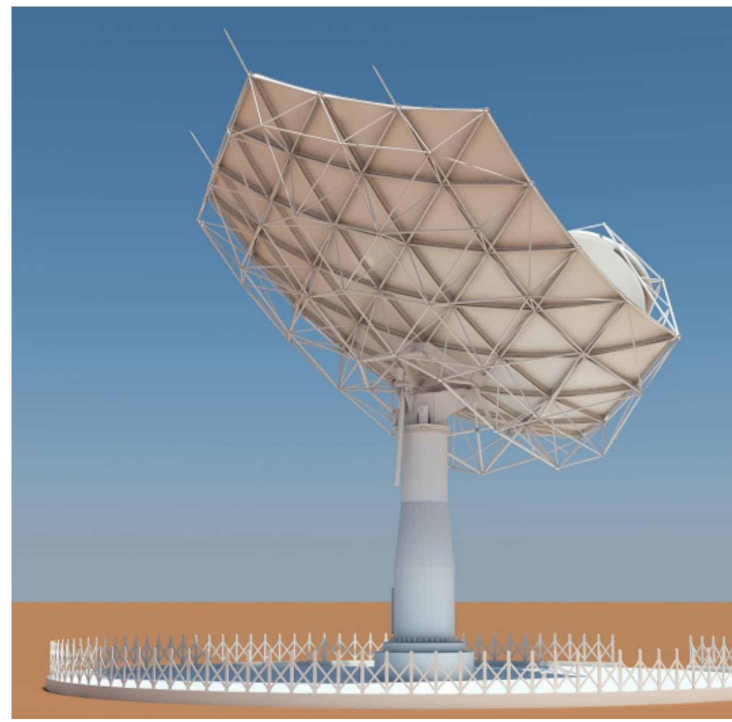
MeerKAT 13.5 m

SKA Proposed Offset Low

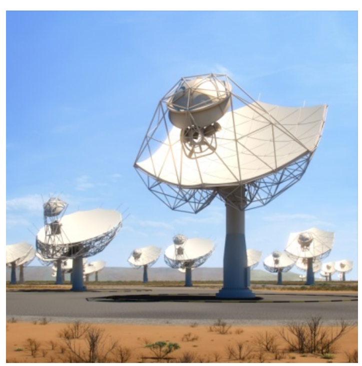
SKA DVA-C



SKA DVA-P
CETC 54 & MT Mechatronics



15 m



Existing Offset High

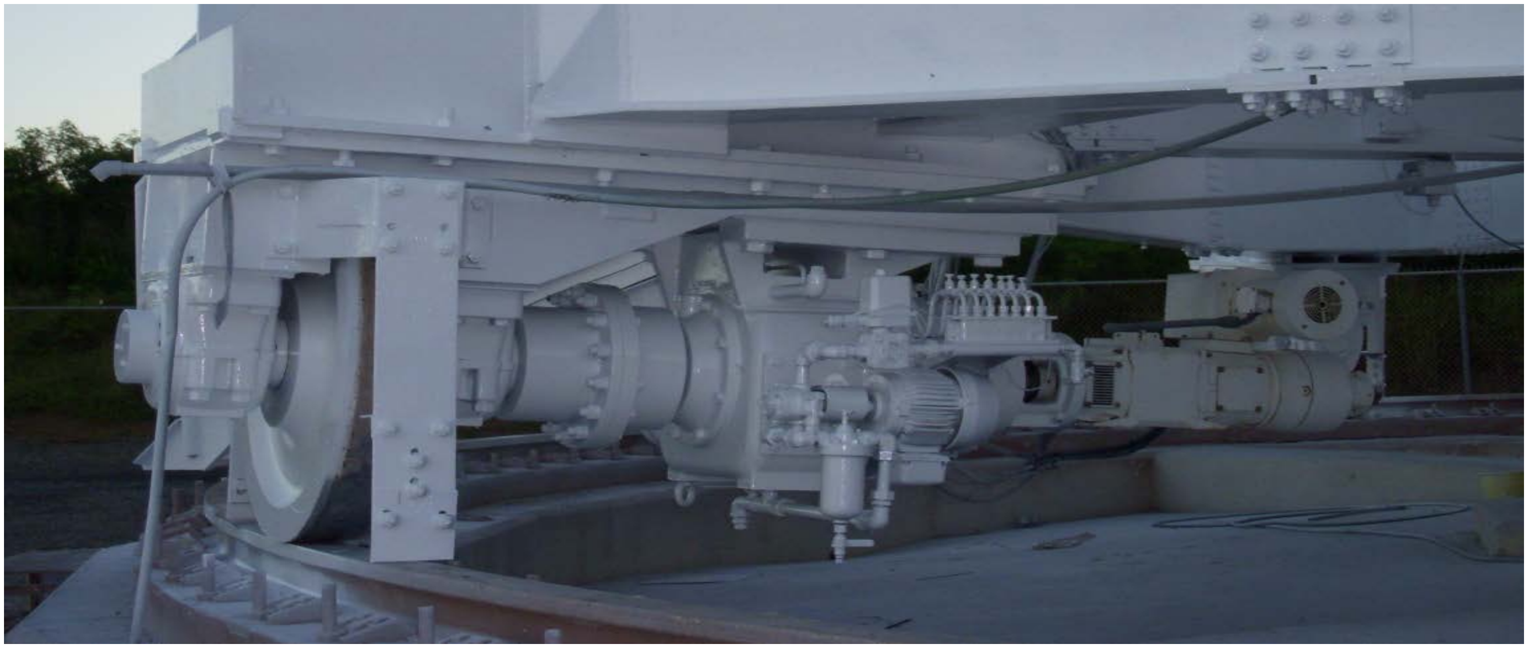
SKA Dish Verification Antenna 1
DVA-1 15 m

Wheel & Track not New

3 wheel Woodbury

4 wheel VLBA 25m

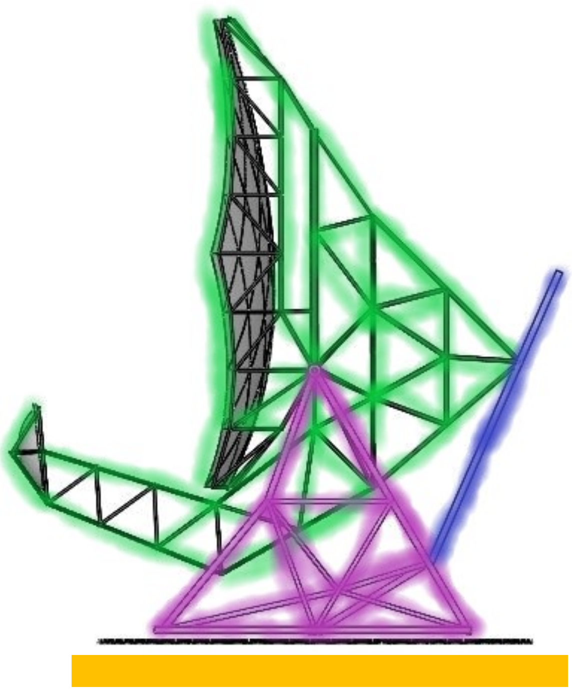
History of Antenna Wheel & Track



It can work well, but proper design is critical.
VLBA has had fixes, GBT not relevant.

NRAO has good Memos via Jon Thunborg & Bob Broilo

Antenna Components



- ERS Elevation Rotating Structure.
- ARS Azimuth Rotating Structure.
- Elevation Drive Beam.
- Foundation.

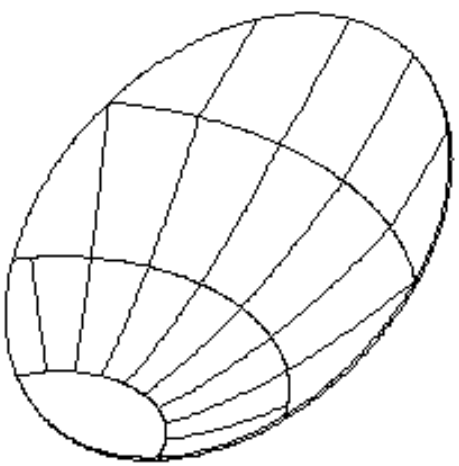
We are not attempting analysis of the ERS
All other components will be analyzed for deflection.

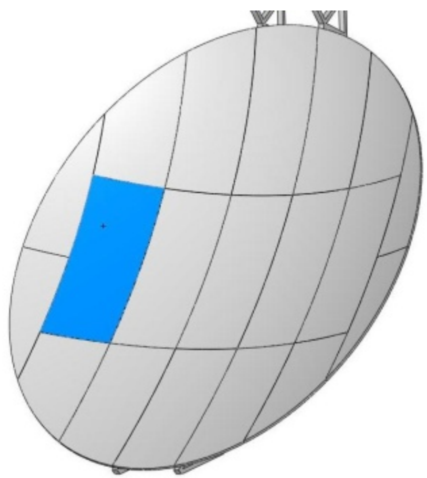
We do need some sort of ERS to share in each design.

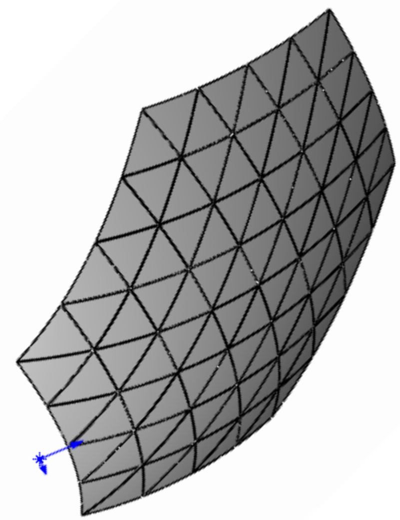
ERS Reflector Surface

There are lots of ways to generate a reflector surface.
We would love to work on this. but it is outside the scope of our study.
Metal & composite have different capabilities.

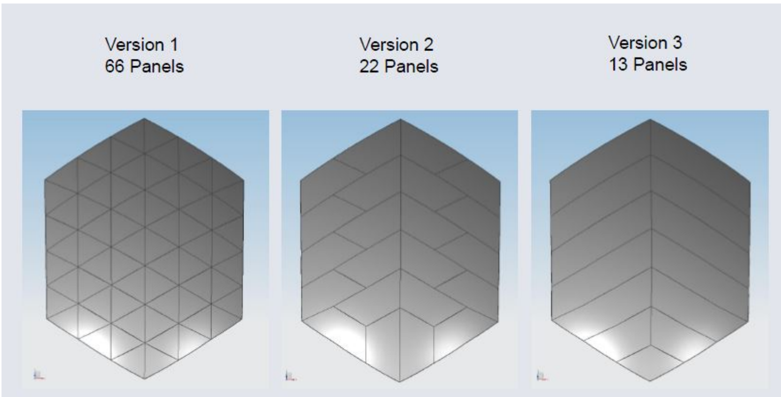
We believe a metal panel ,no mater what the panel shape, will most likely need a support structure with hard points at 1.2 to 2.4 m separations. Composite panels might be different.

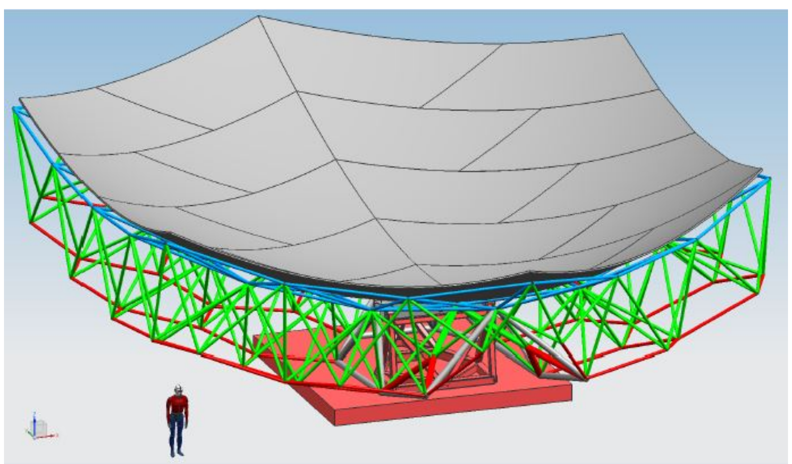






ERS Reflector & Support Concept M T Mechatronics





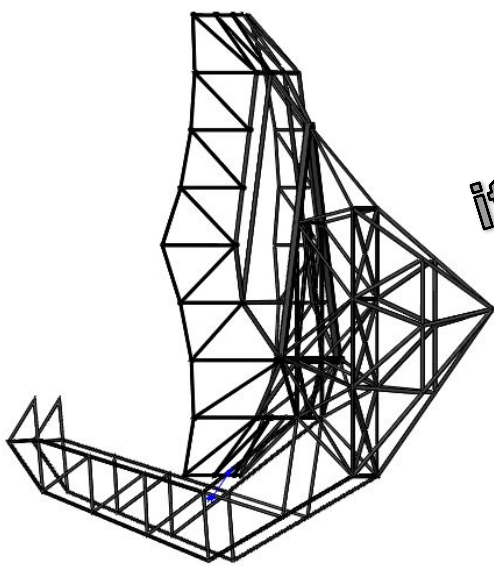
M T Mechatronics
proposes panels to fit containers
and a tetrahedral space frame.

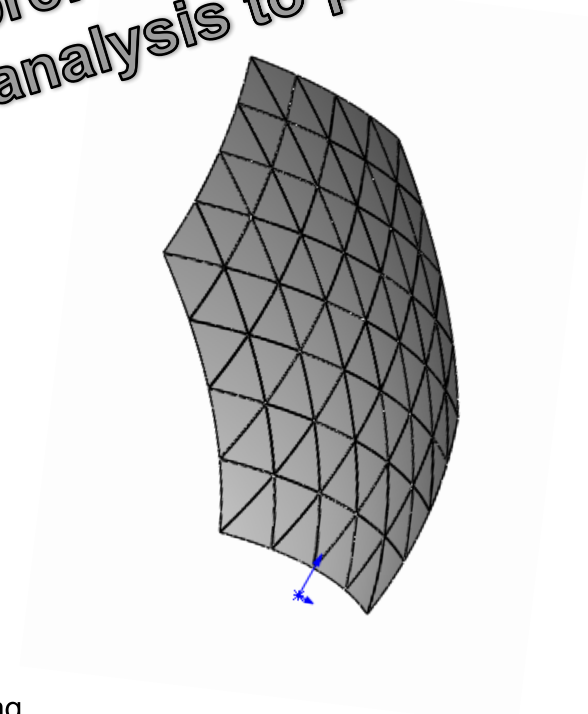
Images from presentation at
meeting Caltech 04/08/2015

ERS We Have Chosen

Based on previous experience, we chose to create an 18 m Elevation Rotating Structure with metal panels and a steel support system made from 3" and 6" members. We decided on a total weight of 80,000 lbs and elevation bearings spaced at about 11.5 m.

This is not a preferred design
it allows mount analysis to proceed





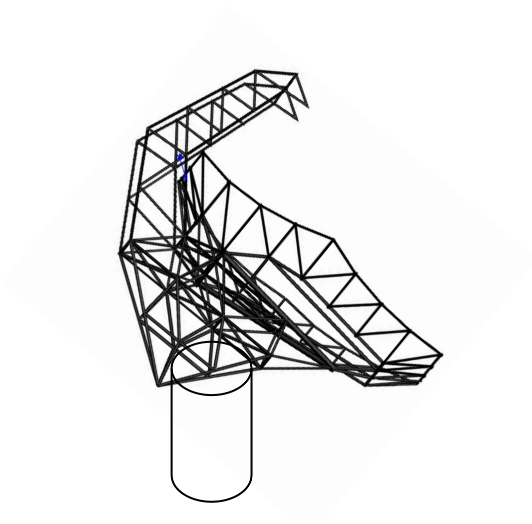
Analyze 3 ARS Designs

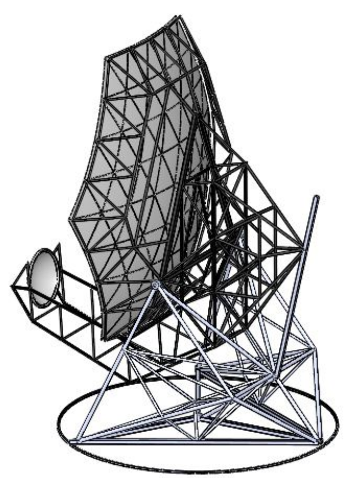
Offset High, Pedestal Az EL (violates preference for Low)

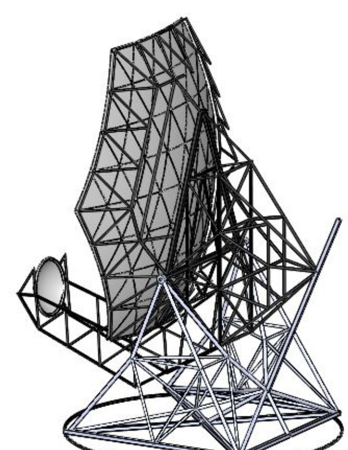
Offset Low, Wheel & Track, 3 points of Rail

Offset Low, Wheel & Track, 4 points of Rail

20 m dia track







18m Analysis
Worst Wind Load Conditions

Wind pressure for precision 7 m/s (15.7 mi/h) wind load.

We assume that, using wind speed and direction data, a Pointing Error (PE) correction for average wind forces can be made. Some residual error will remain.

Use 90% calibration correction for average wind.

Wind gusts speeds are 0.4 Vave.

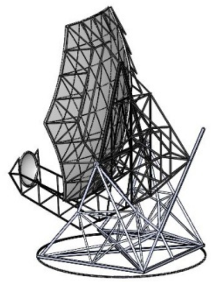
Wind forces for precision operating PE are the result of 10% of the average wind speed plus the wind gust speed.

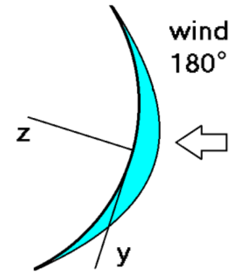
VPE = 0.1 Vave + 0.4 Vave = 0.5 Vave = 3.5 m/s (7.83 mi/h)

q = wind pressure = (256E-5)V2 = (256E-5)(7.83)2 = 0.157 lb/ft2 (7.52 Pa)

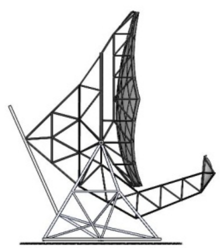
(Ref. ASCE 7-10, Eq 27.3-1)

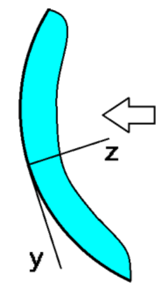
Wind Load Case Positions



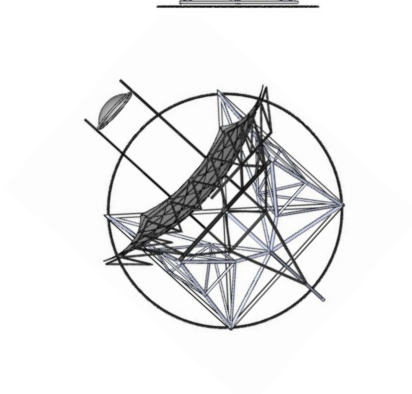


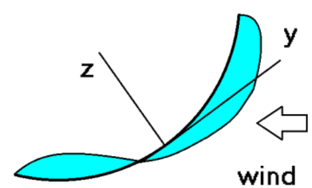
El 90° wind on rear.





El 35° wind on front.





El 35° wind at 120°.

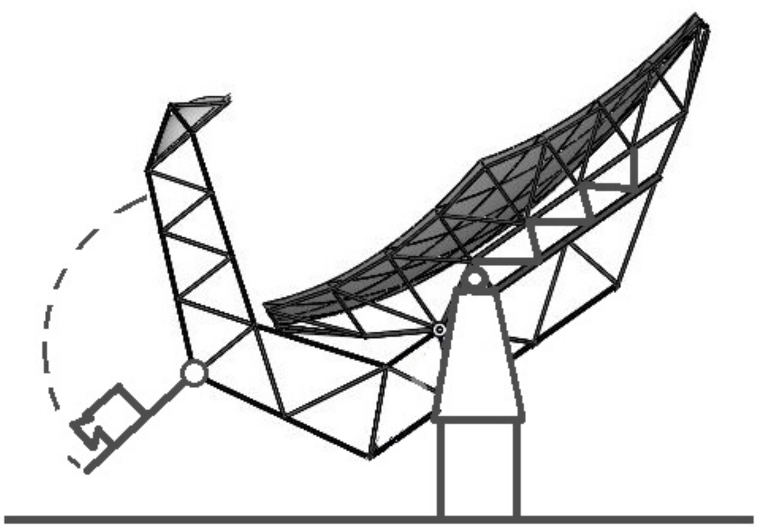
Pedestal, Offset High

Pedestal type mount, high or low, does not seem likely to meet the pointing requirements at low cost. (probably needs reference structure)

Offset High is the most likely to meet spec and can reach 5° elevation.

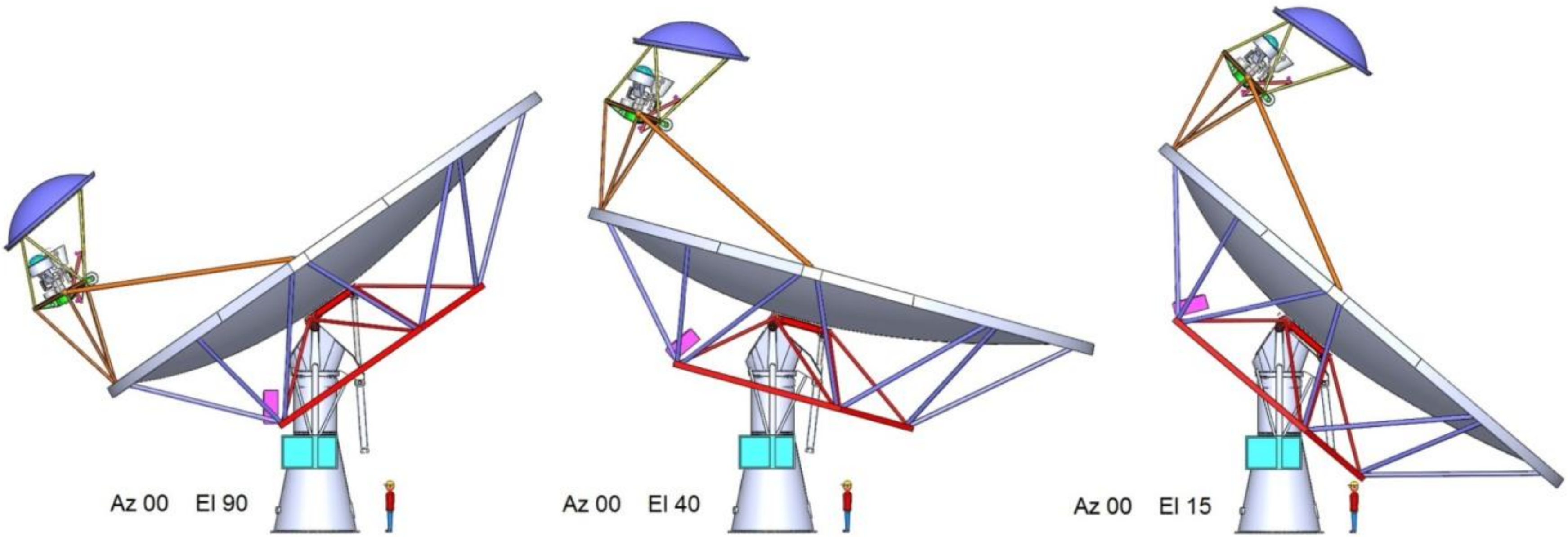
Offset high may be slightly worse for spillover, but TDP team decided this is feed dependant and a very small effect. (ask Lynn Baker)

A transportable version may be possible.



Maintenance of feeds may be more difficult, but in reality feeds are heavy and out of reach for all mount types. A device that lowers the entire feed package out for service or replacement is a possible solution. (ask Sandy Weinreb)

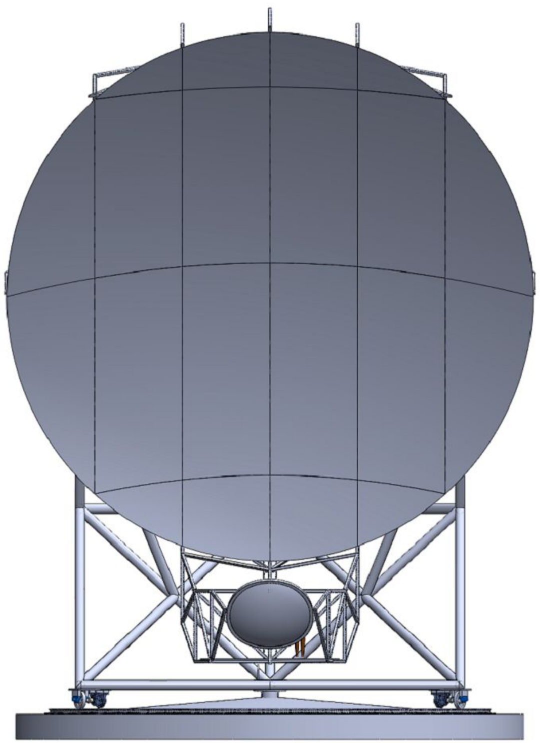
Pedestal, Offset High DVA-1

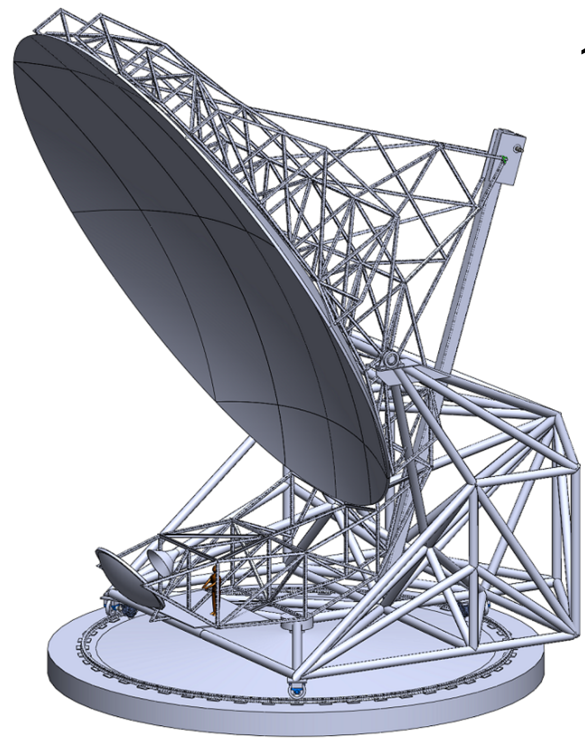


Zenith position Stow Position Low Position

3 Point ARS, Offset Low

Design proposed by Roger Schultz some time ago demonstrating good Offset Low Positioning.



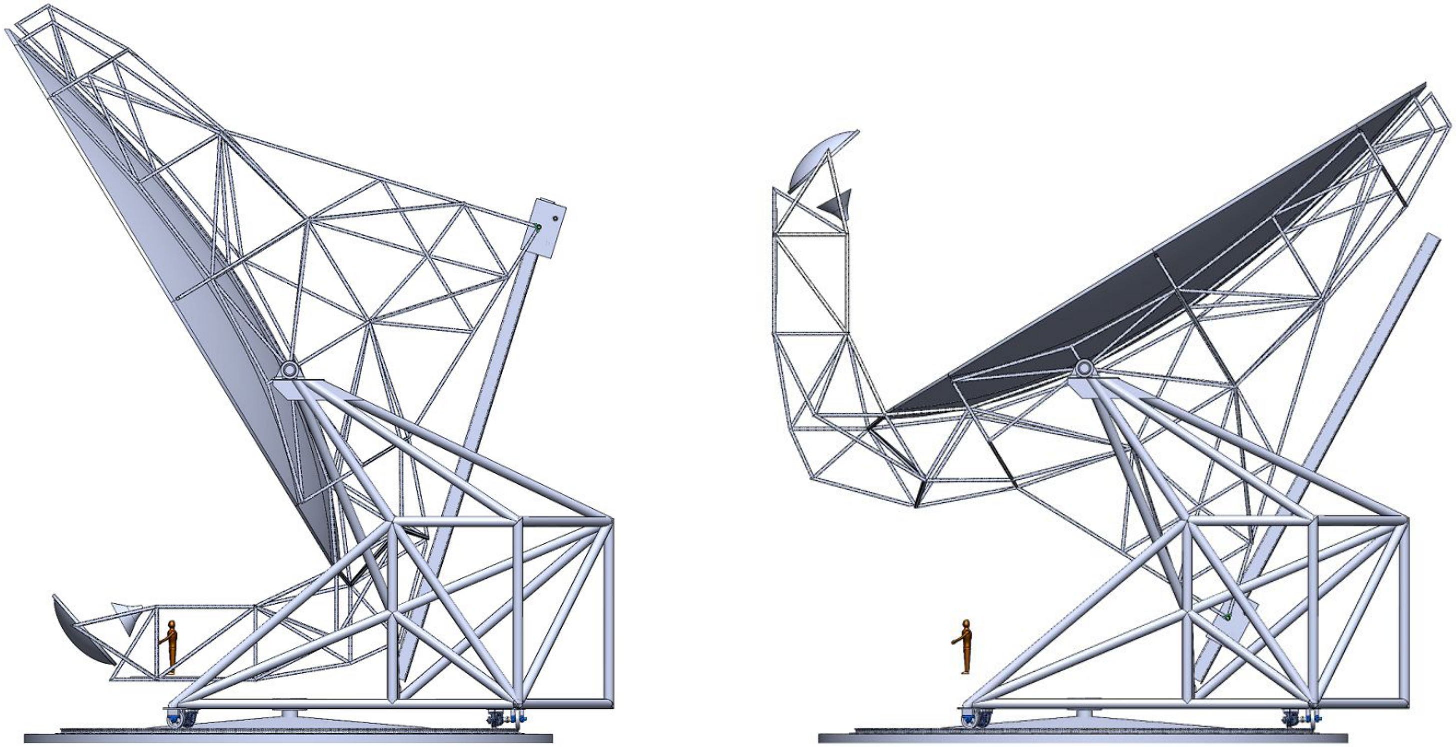


18 m Aperture

El drive
gear beam

Welded track ground in place.

3 Point ARS, Offset Low

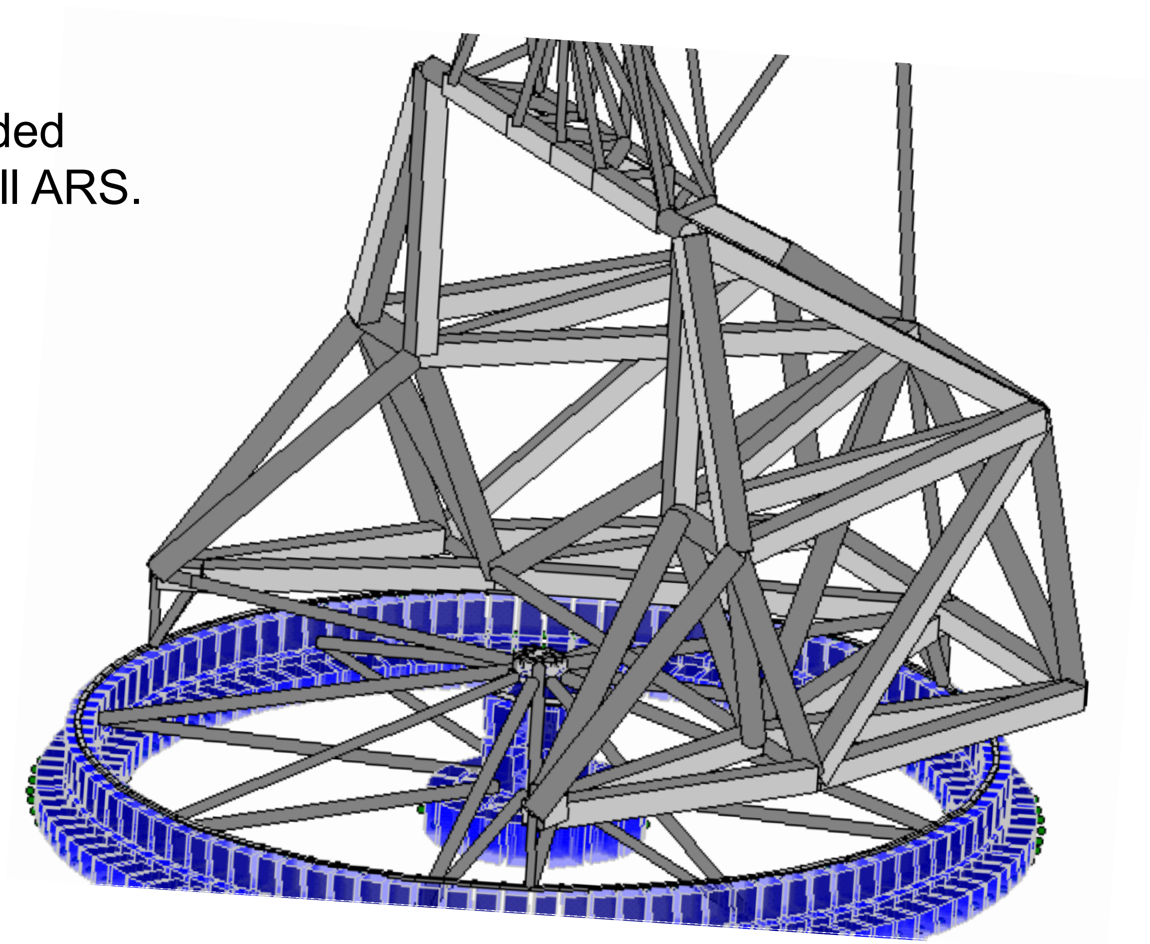


welded crane rail.
ground top local machine.
more discussion later.

3 Point ARS

Foundation is included
in the analysis for all ARS.

Dave Enterline



3 Point ARS (heavy)

Foundation is included
in the analysis for all ARS.

Dave Enterline

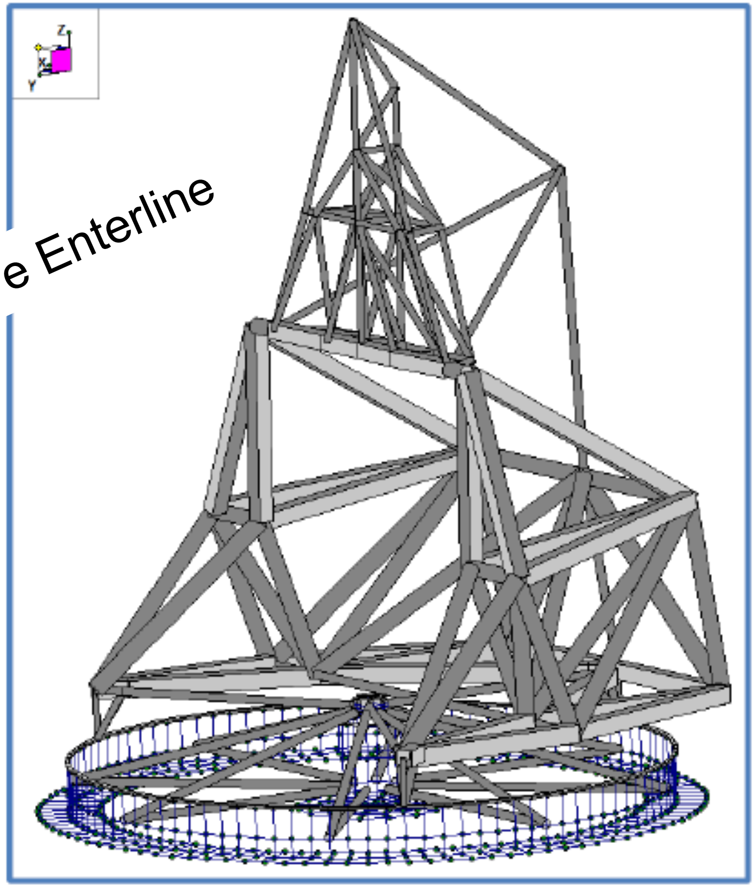


Figure 7.1-18: 3-Wheel 3.3 EL35 FEM

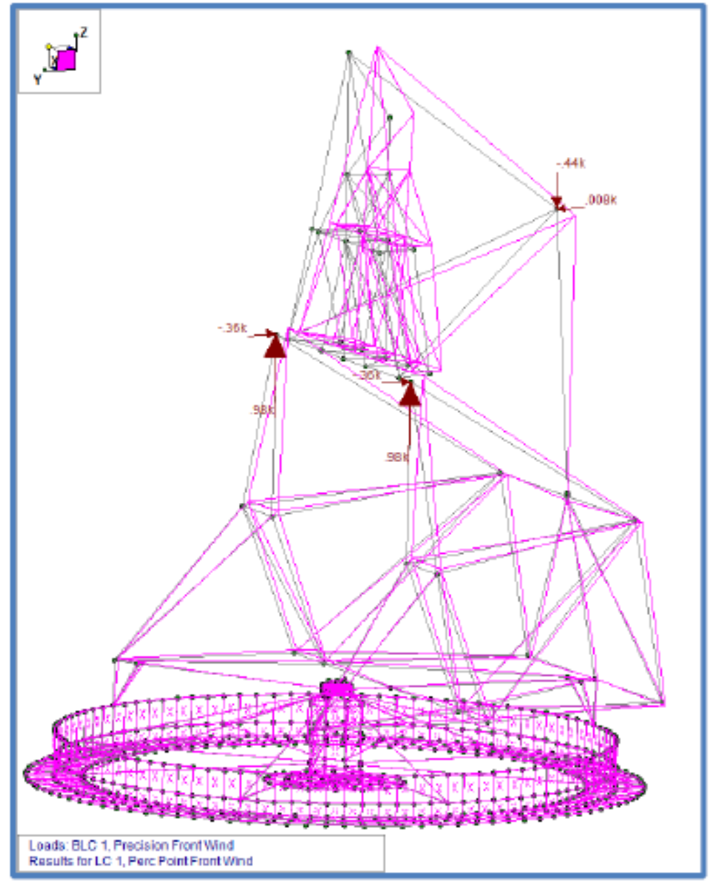
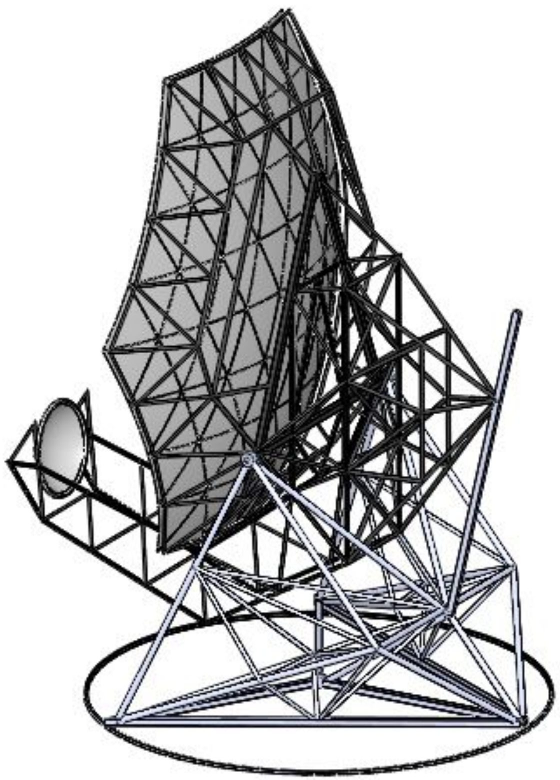
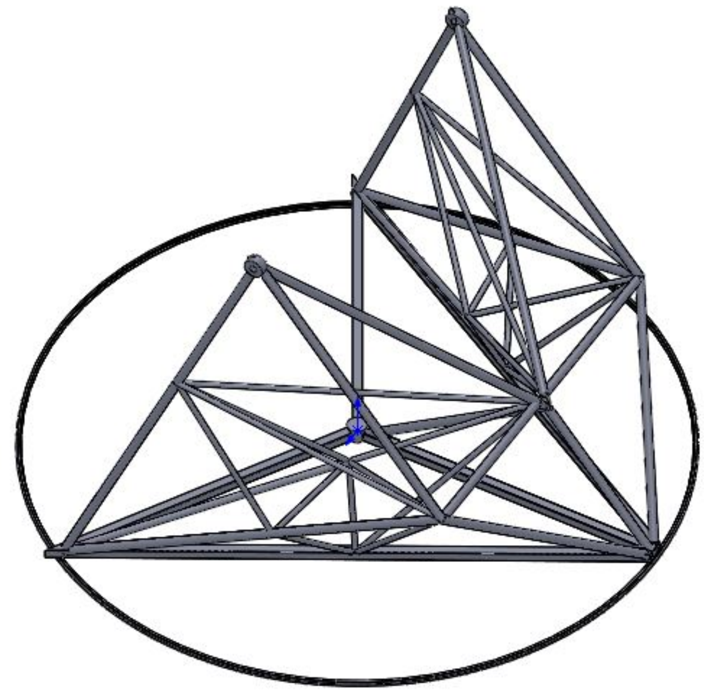


Figure 7.1-19: Front Wind Deflected
Structure PE = 1.04 arc-sec

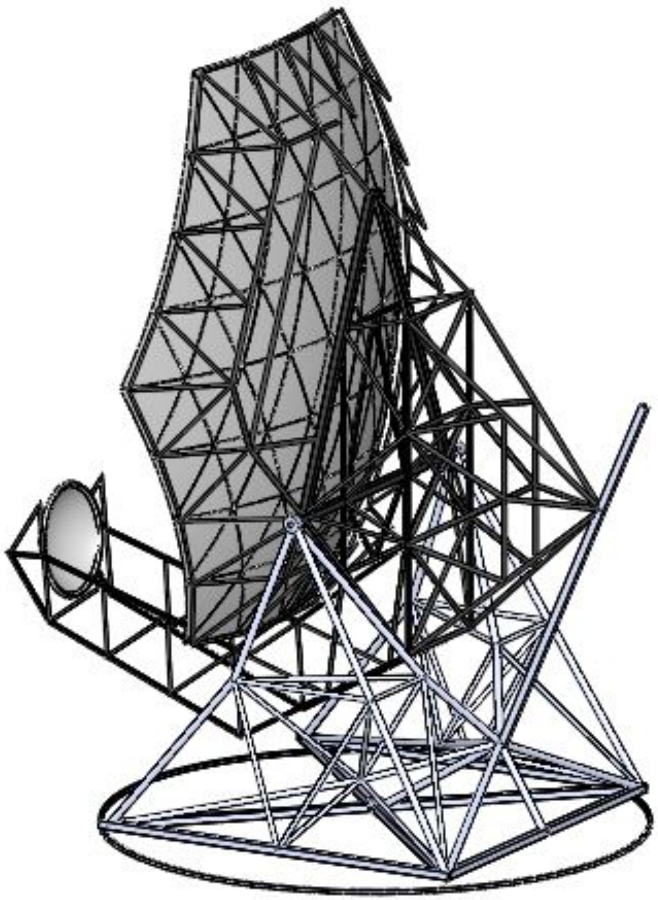
3 Point ARS
(light weight)

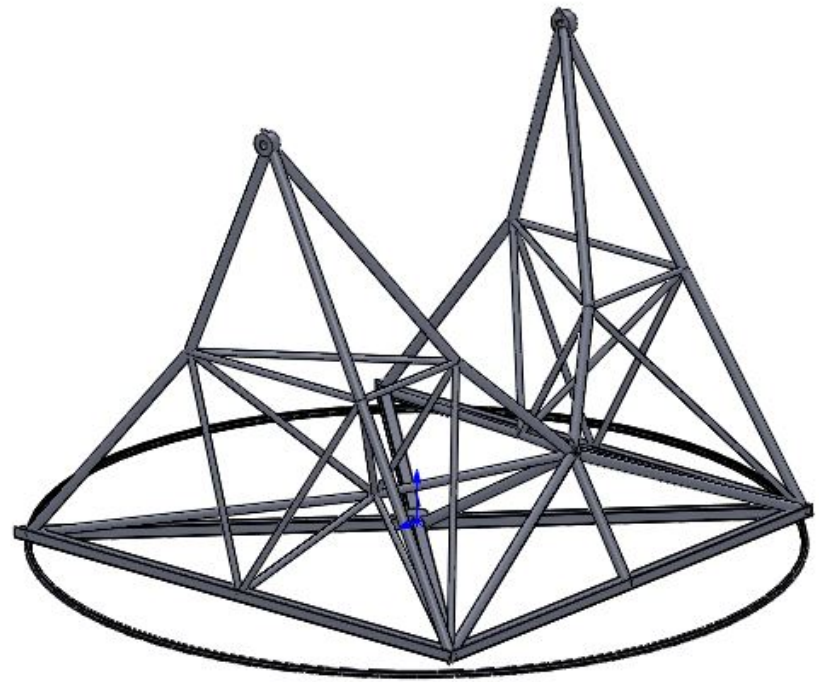




Not analyzed yet.

4 Point ARS





4 Wheel FEA Deflections

Dave Enterline

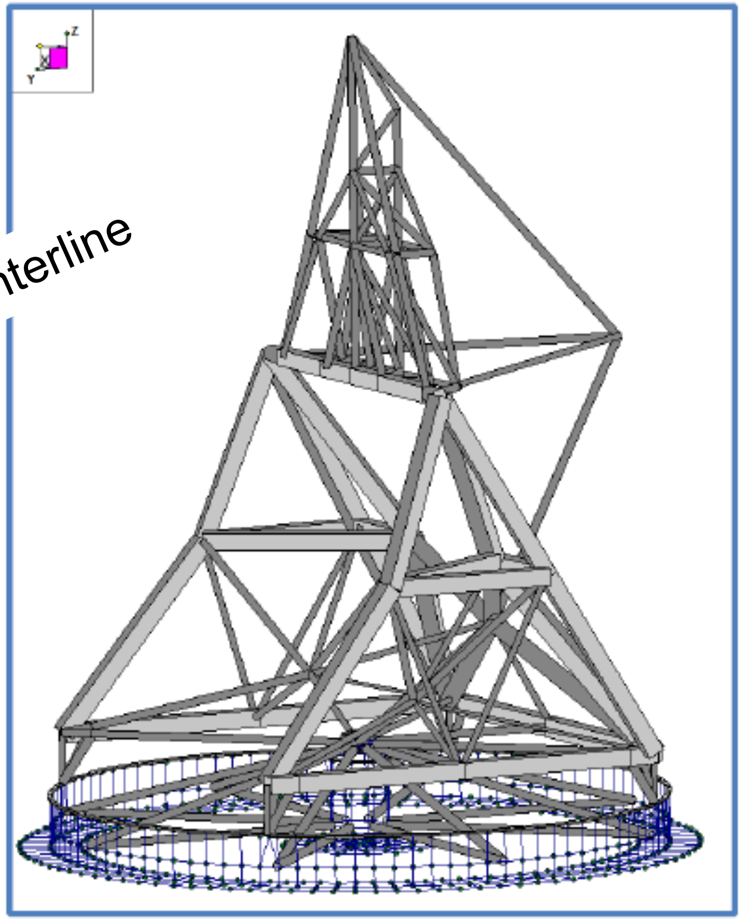


Figure 7.1-23: 4-Wheel 4.1 EL35 FEM

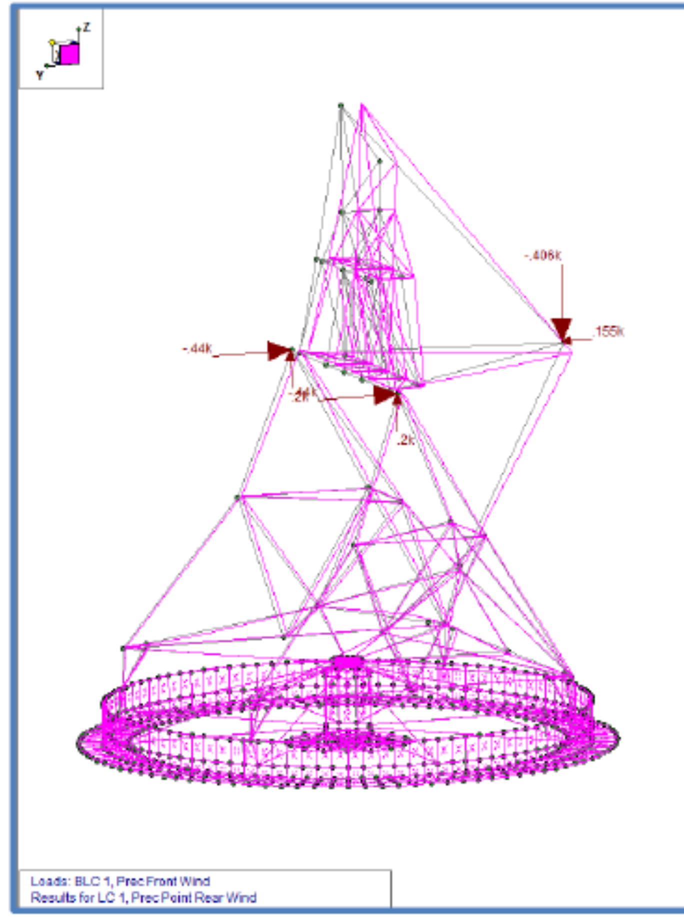
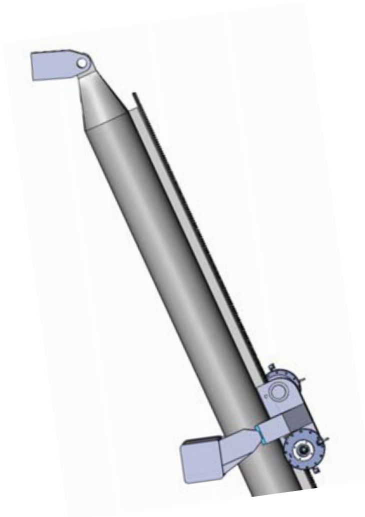


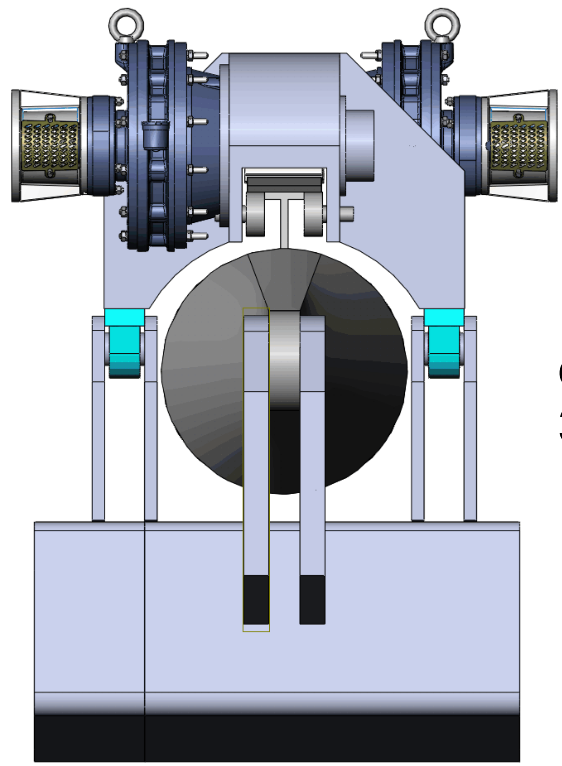
Figure 7.1-24: Front Wind Deflected Structure PE = 1.58 arc-sec

Elevation Drive
(gear beam preliminary concept)

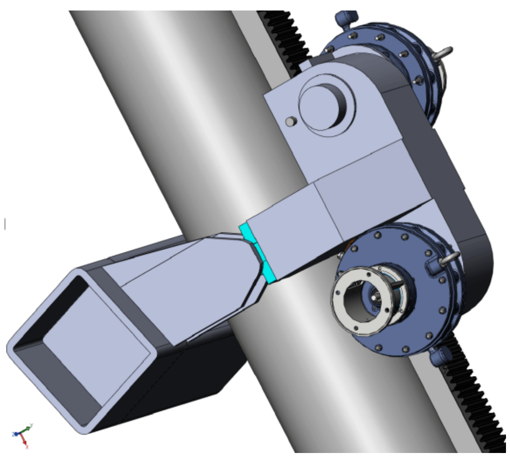


Roger Schultz

Wind load deflection
on various parts of drive

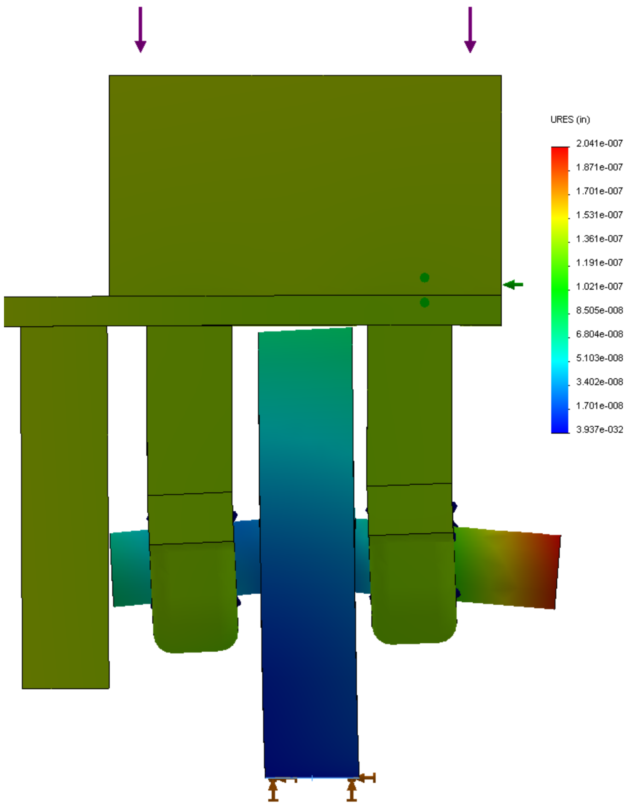


can be near
35% of total

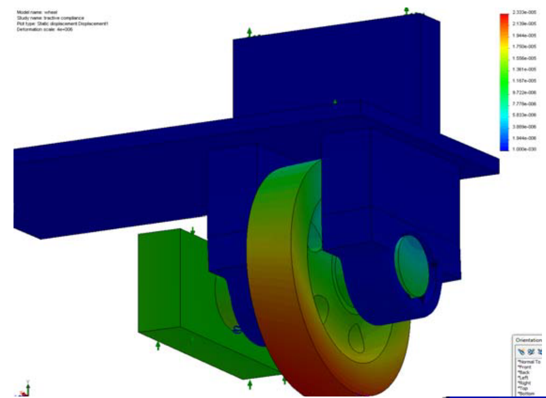


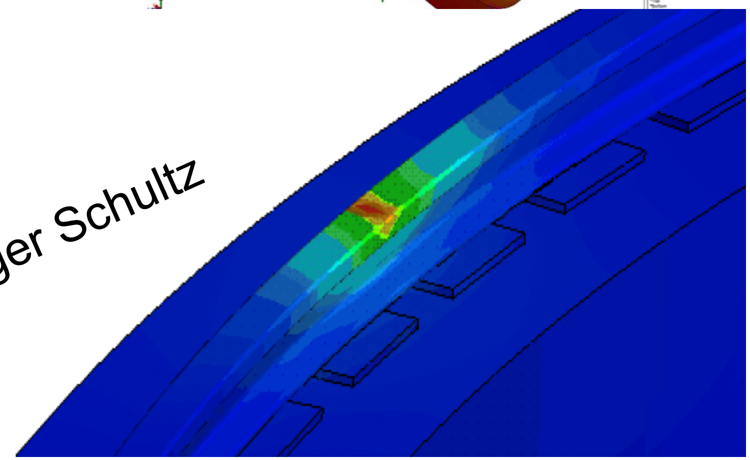
Wheel to Track Deflection

Wind load deflection
wheel & axle



3 or 4% of total





Roger Schultz

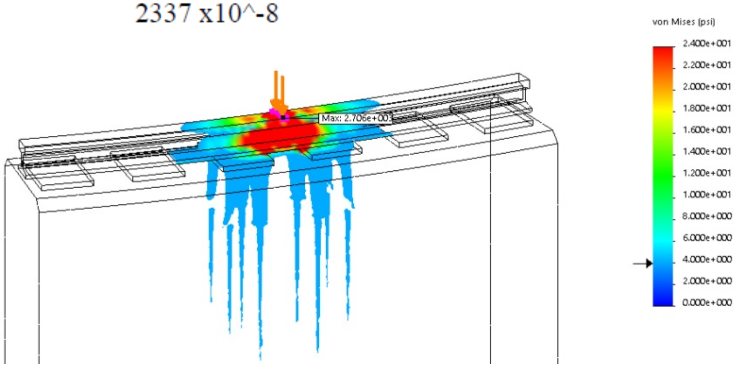
Track Deflection

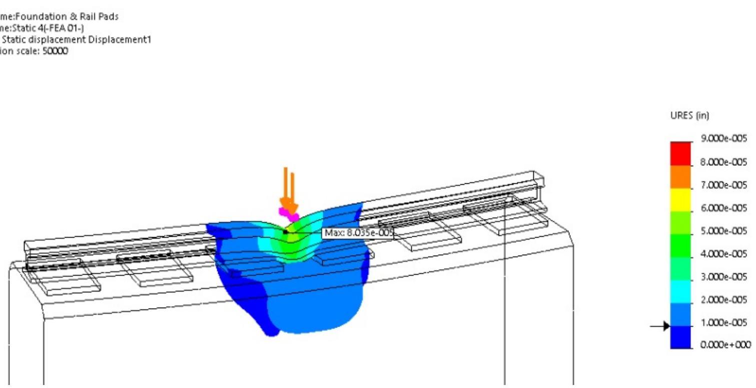
vertical

	rail & up	14 x10^-8
	rail & down	6.25 x10^-8
	sum	20.3 x10^-8

horizontal (tractive AZ driving shear)

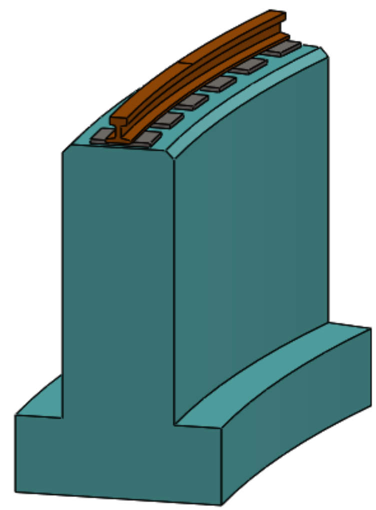
	rail & up	2333 x10^-8
	rail & down	3.51 x10^-8
	sum	2337 x10^-8





Wind load deflection local on track quite low

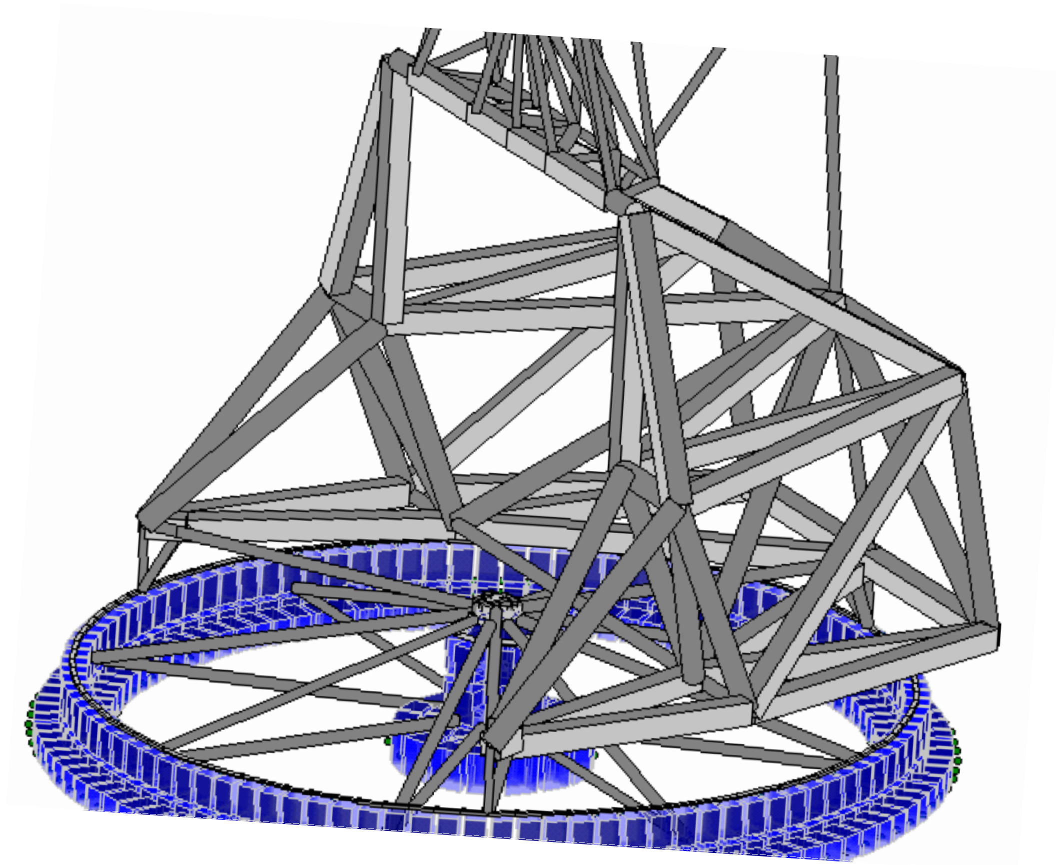
1 or 2% of total



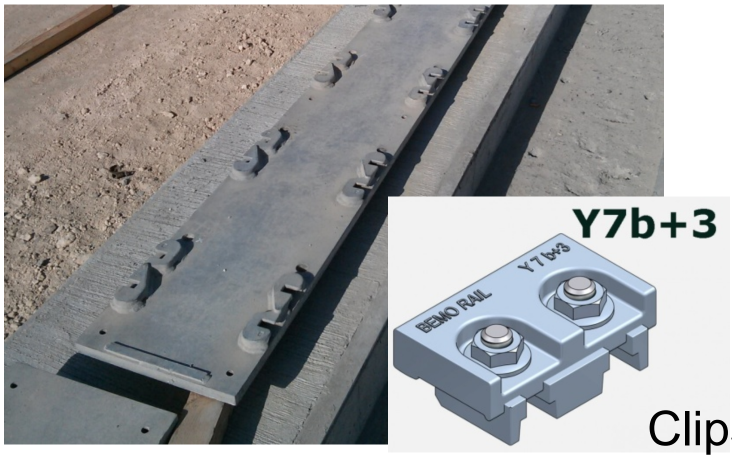
Foundation

Wind load deflection on the circular foundation is quite low

10 or 15% of total



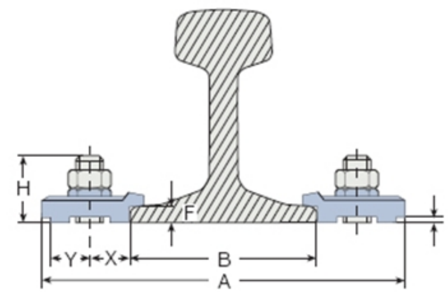
Modern Rail Welding & Sole Plates



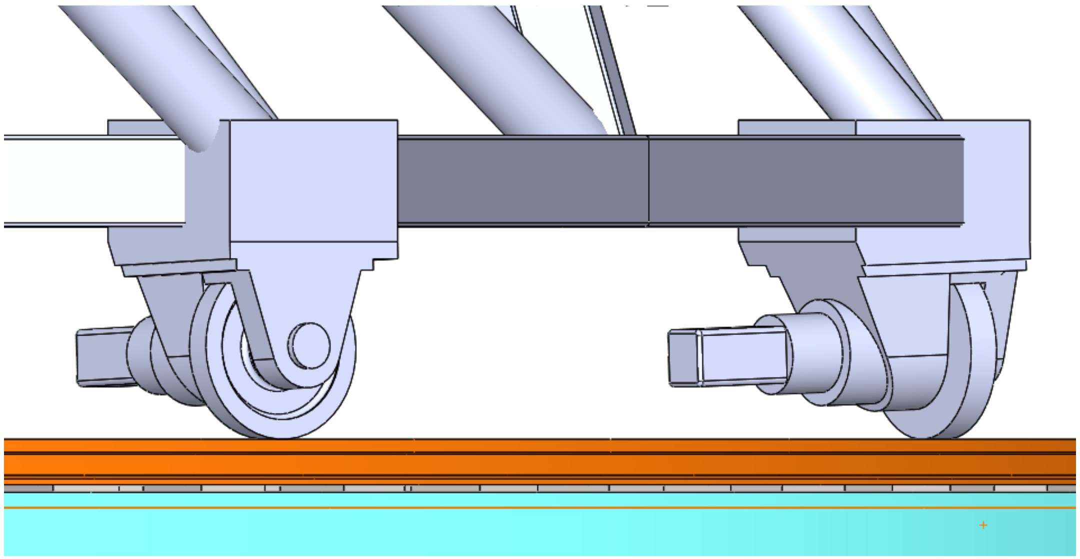
Clips

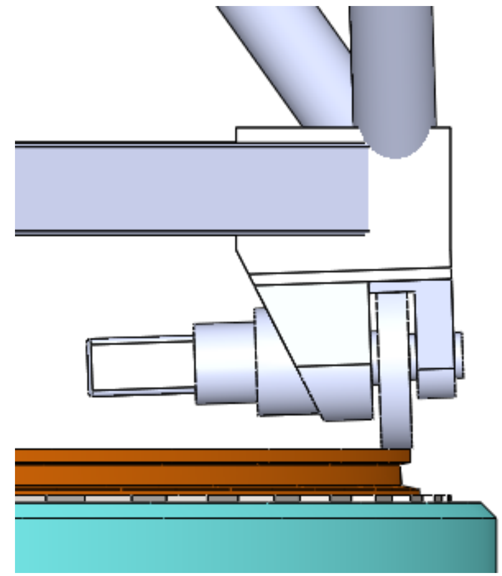
Sole plate

Welded rail joints is mature technology



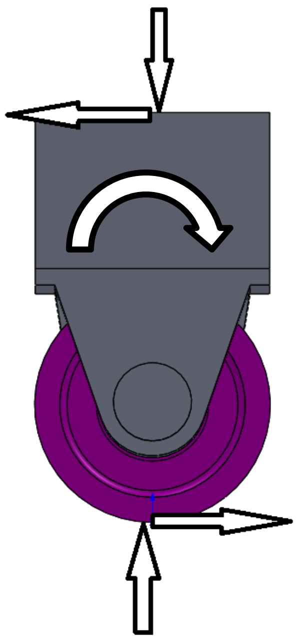
One Wheel at Each Corner



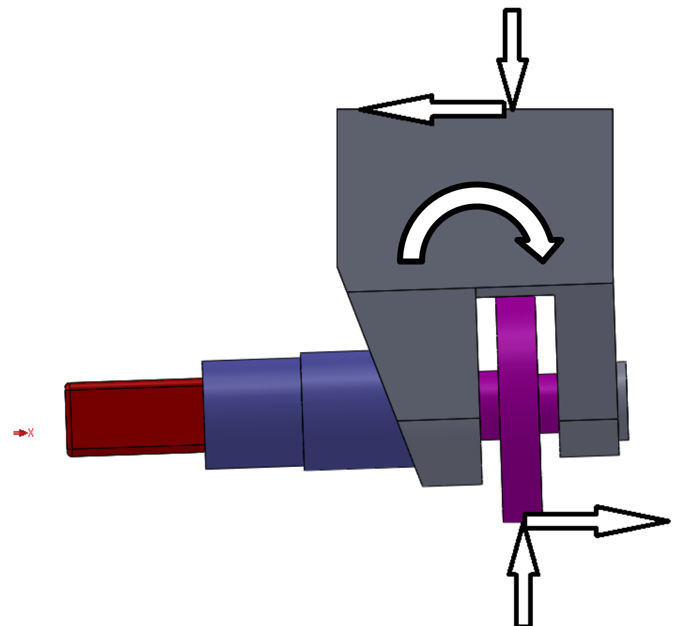


One Wheel Corner

These axial and moment loads are not repeatable and can cause pointing trouble. So far our structures seem to be able to handle the loads

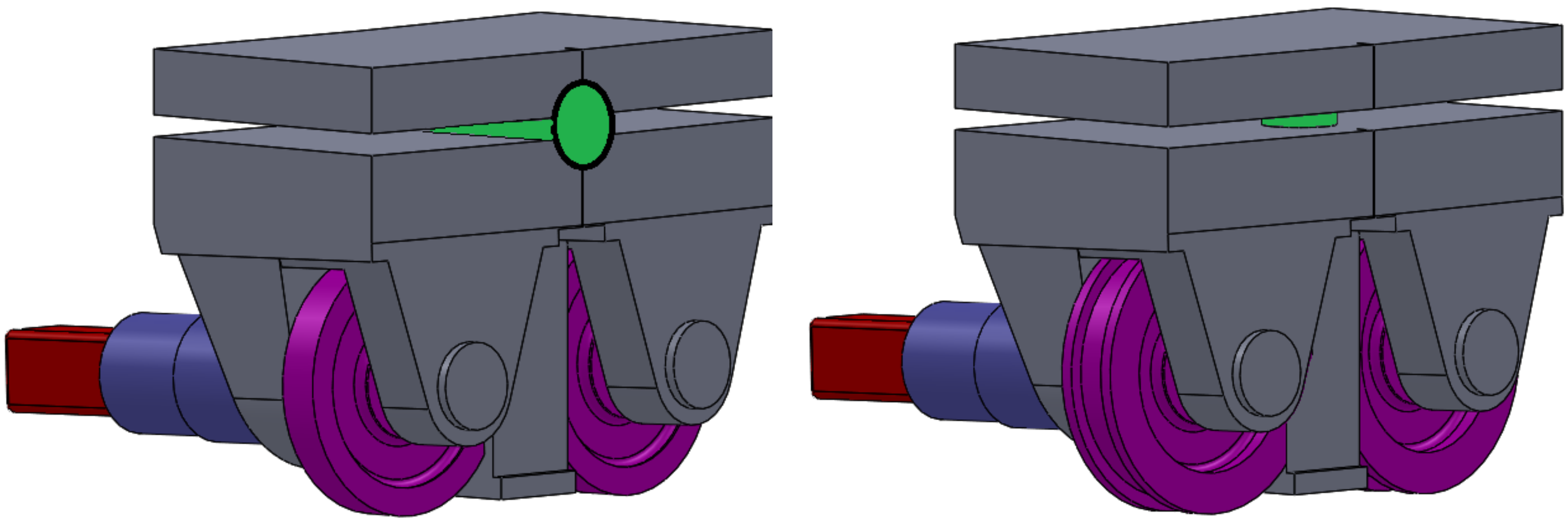


Axial load and moment load delivered into structure



Axial load up to 0.3 x normal load up to 30,000 lbs

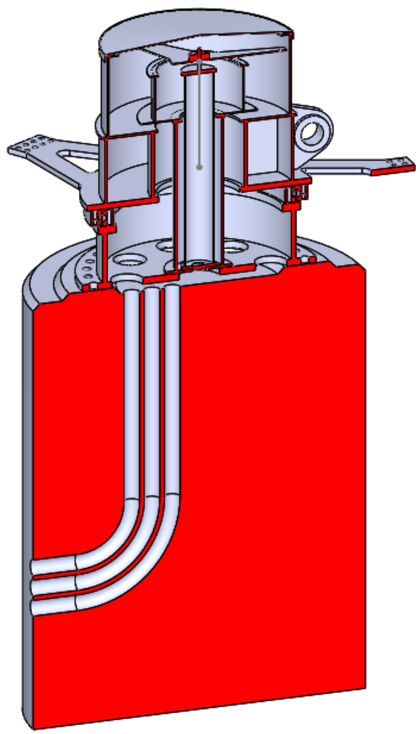
Two Wheel Bogie May Be Worthwhile



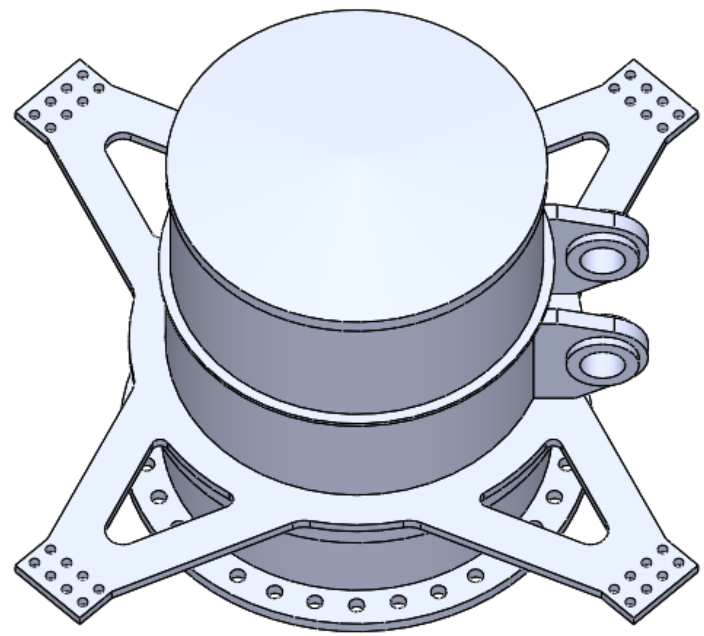
Wheel and track issues are being discussed with the following:
Molyneux Industries, Coraoplis, PA
(experts in rail and rail tie down products)
Moran Engineering Systems, Alliance, OH
(experts large track mounted structures)

Pintle Concepts

Above bearing
drum cable warp



Below bearing
maypole cable wrap



Preliminary ARS Pointing Comparison

The pedestal mount does not have complete analysis yet. However a 66ft antenna mount that we had stiffness data for did not do well for precision pointing error (PE). 40

The 3 point ARS did well in all cases except wind at 120° giving about 4.0 arc-sec PE.

The 4 point ARS was best with the worst case being wind into the face of the dish causing 1.6 arc-sec PE.

Preliminary Cost Comparison

The 3 point and 4 point are not that different in cost.

The 4 point performs better.

The Pedestal mount seems to be cheaper at the moment, but we will have to beef it up quite a bit get closer to spec which will increase the cost.

Preliminary Comments

ERS will most likely need active secondary.

Problems with wheel & track in the past can be solved.

Maintenance is related to N antennas but reliability is more important.