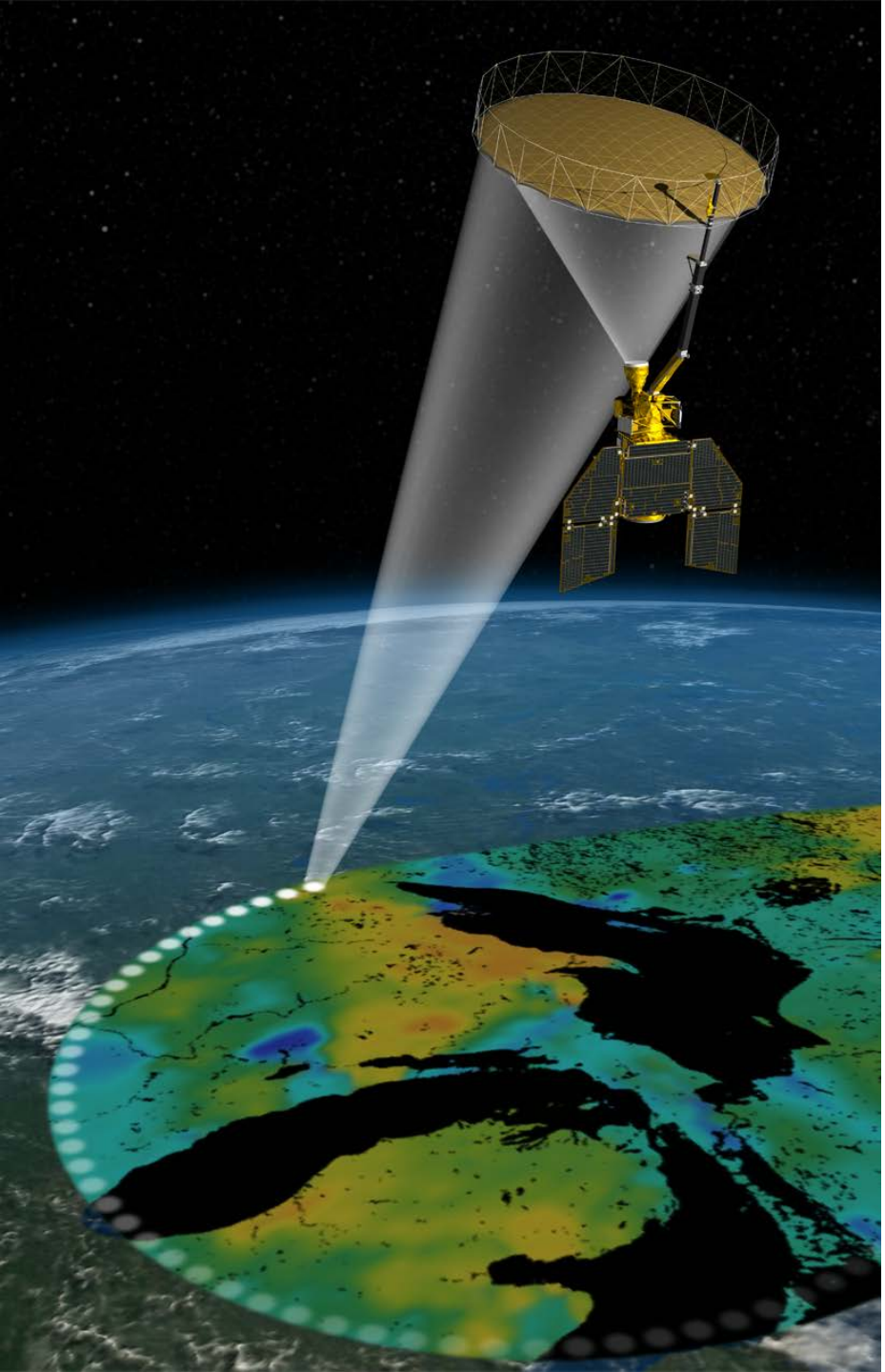

A 6-m Mesh Reflector Antenna for SMAP: Modeling the RF Performance of a Challenging Earth-orbiting Instrument

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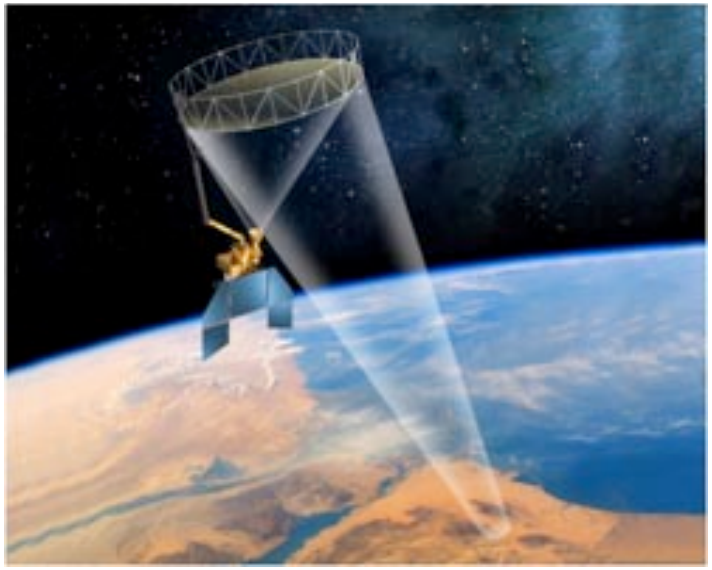
The SMAP mission has not been formally approved by NASA. The decision to proceed with the mission will not occur until the completion of the National Environmental Policy Act (NEPA) process. Material in this document related to SMAP is for information purposes only. (c) 2011. All rights reserved.

Outline

- This presentation addresses:
  - Soil Moisture Active and Passive (SMAP) mission and instrument overview
  - Implementation strategy
  - Major antenna design drivers
  - Basic antenna configuration
  - Pattern calculations
  - Thermal and dynamic distortions
  - Conclusions

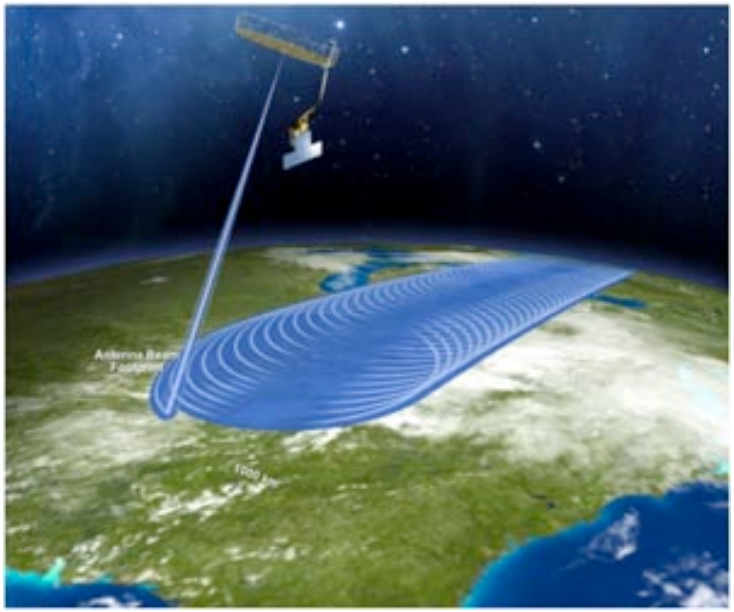
Mission Overview

- NASA's Soil Moisture Active and Passive (SMAP) mission objective is to measure Earth's soil moisture and its freeze/thaw state over a 3 year period
- Applications:
  - More accurate and longer-term weather and climate predictions
  - Earlier drought warnings
  - Improved flood and landslide predictions
  - Improved agricultural production predictions
  - Better understanding of the global carbon cycle



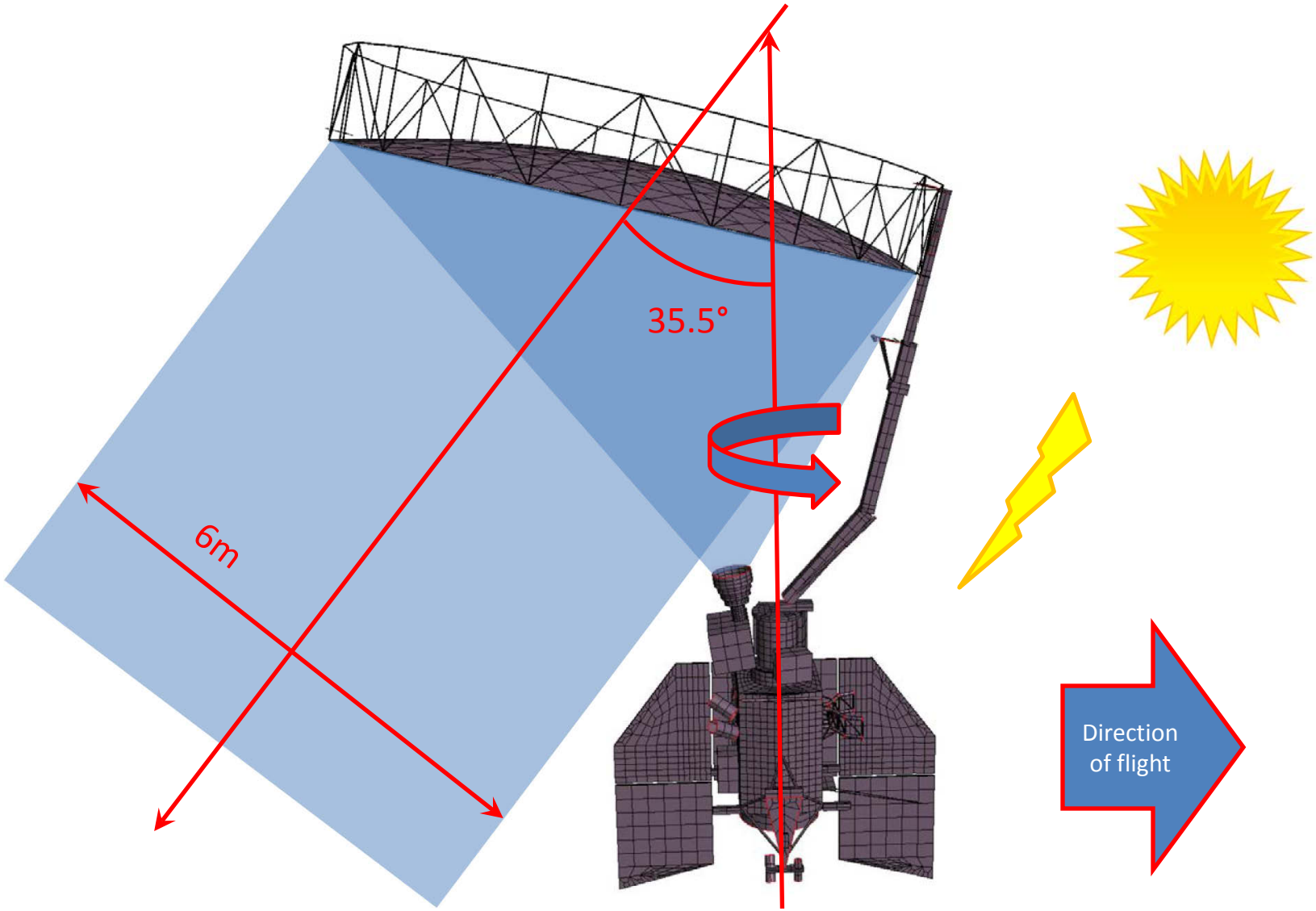
- Near-polar, sun-synchronous orbit of 680 km
- Planned launch date of November 2014

Instrument Overview



- An L-band Synthetic Aperture Radar (SAR) and L-band radiometer share an offset 6-m deployable mesh reflector and feed
- The antenna boresight beam is pointed 35.5° off nadir
- The instrument spins at approximately 14.6 RPM around the nadir axis
- The result is a 1000-km swath on the ground
- The radiometer data is more accurate than the SAR data, but has a spatial resolution of about 40-km; the SAR spatial resolution is 1 – 3 km

Basic Observatory Configuration



Implementation Strategy

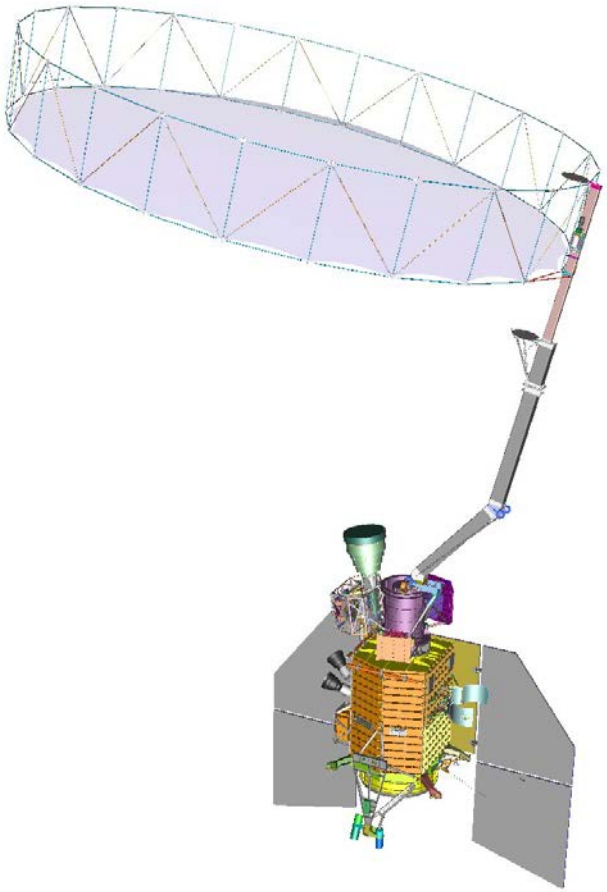
- The 6-m offset reflector is an AstroMesh™ antenna from Northrup Grumman, Astro Aerospace
- The feed assembly is a JPL in-house design
- Antenna pattern measurements will be done on the feed assembly, but not the reflector
- The radiometer performance calibrations require accurate predictions of the antenna radiation patterns
- A tenth scale model of the antenna and spacecraft will be built to verify the RF performance model
- Requirements verification will be done with a combination of the feed assembly measurements, the scale model data, and analysis

Major Design Drivers

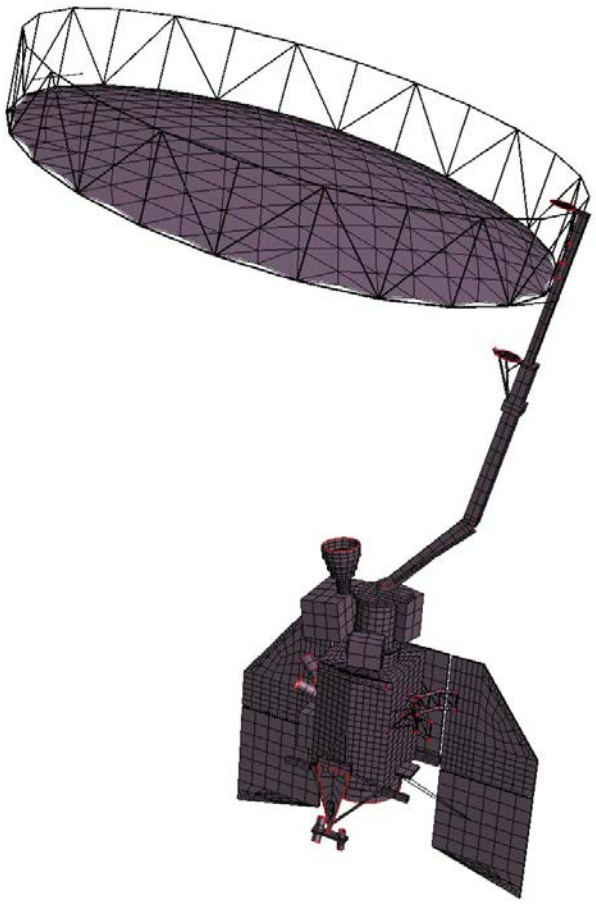
- Optical design
  - The reflector focal length and edge offset were a compromise between the RF performance and the spin dynamics
  - The focal length was shortened and the edge offset was increased to improve spin stability
- Combined SAR & radiometer RF bandwidth of 16%
- Radiometer beamwidth & main beam efficiency
- Radiometer antenna pattern stability requirements
- SAR gain
- SAR pointing stability requirements

Mechanical vs. RF Model

- Mechanical Model

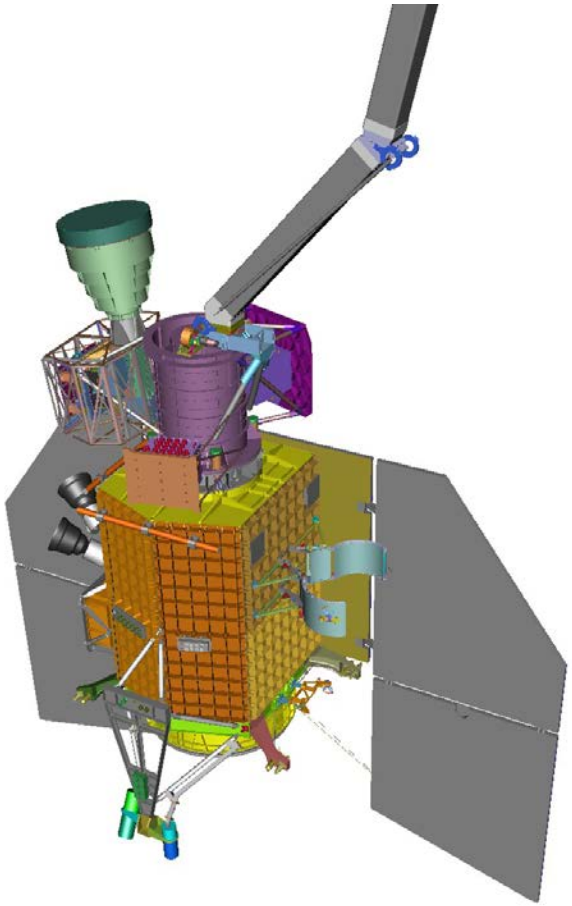


- RF Model

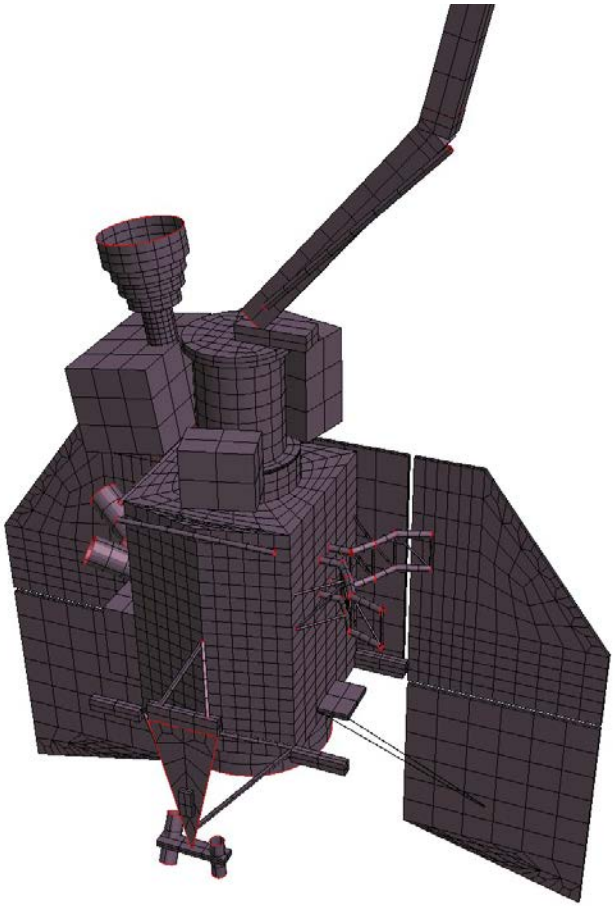


Mechanical vs. RF Model

- Mechanical Model

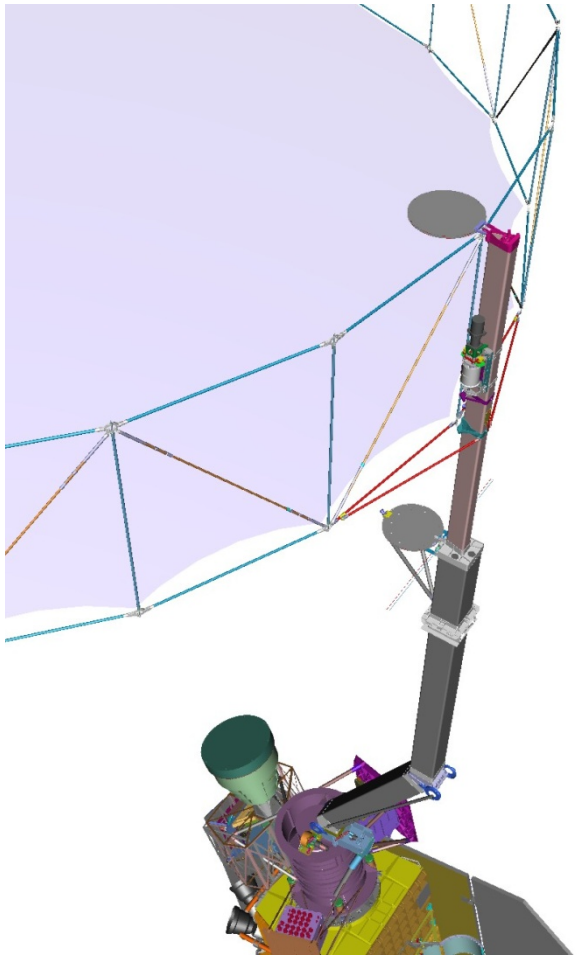


- RF Model

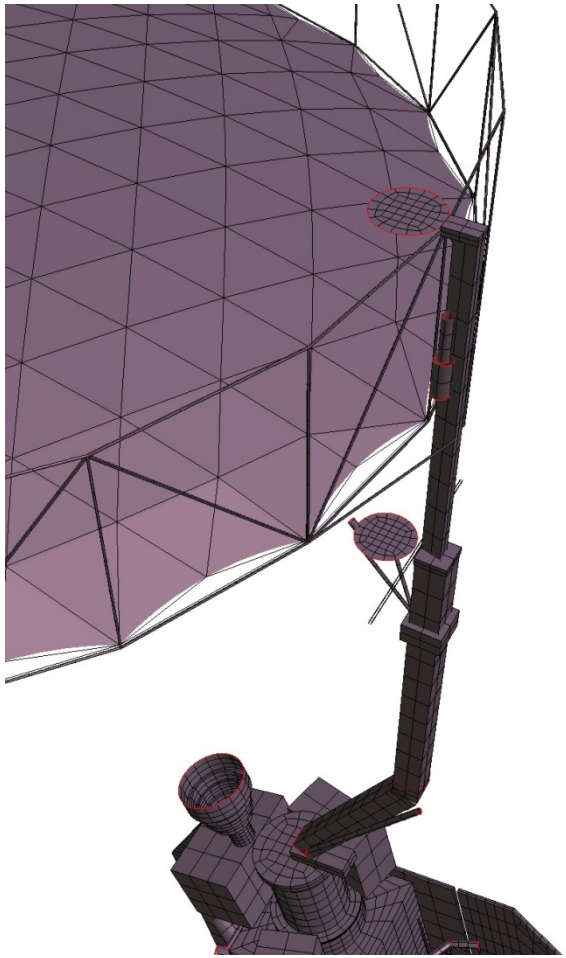


Mechanical vs. RF Model

- Mechanical Model

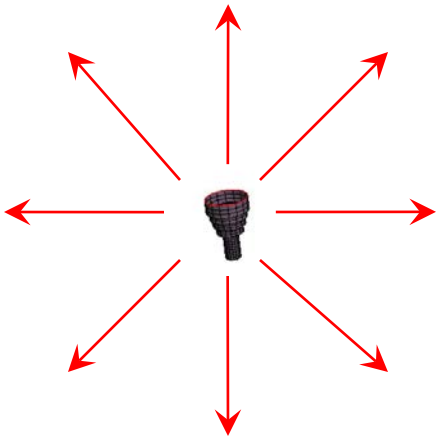


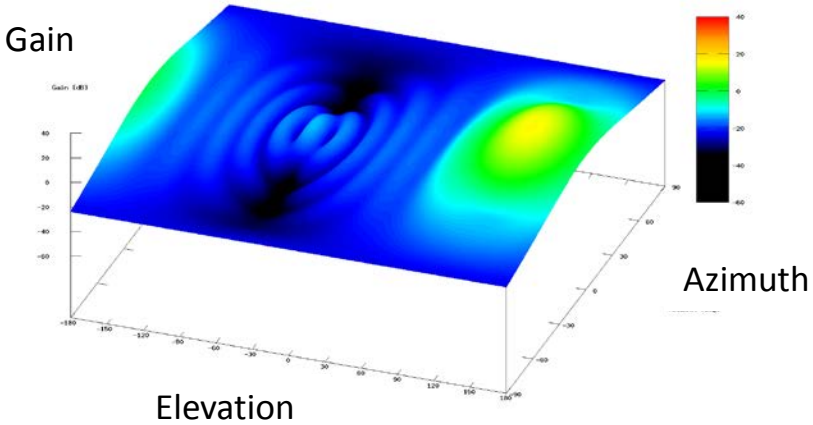
- RF Model



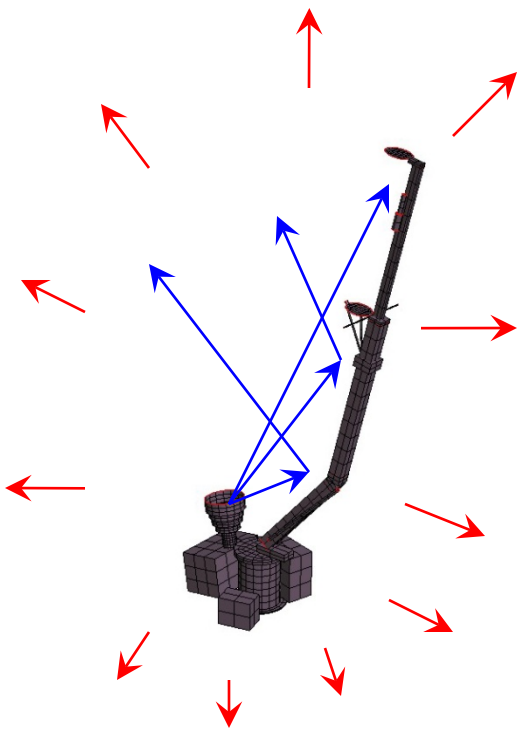
Radiation Pattern Calculation: Step 1

- Horn radiation pattern in free space
- Method: SWE + IE

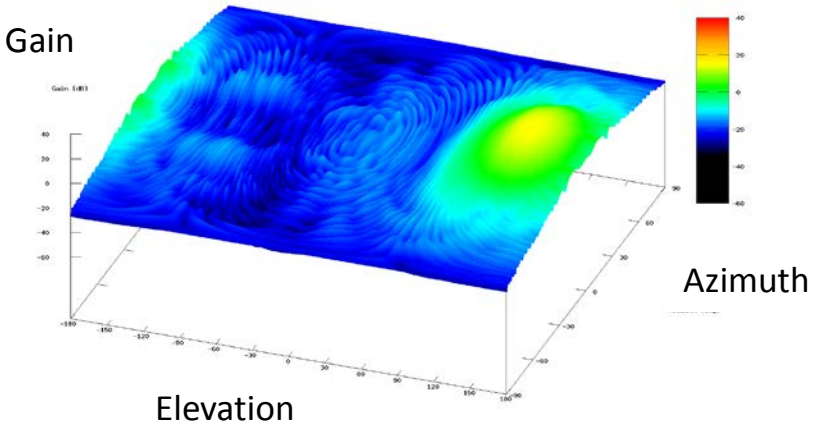




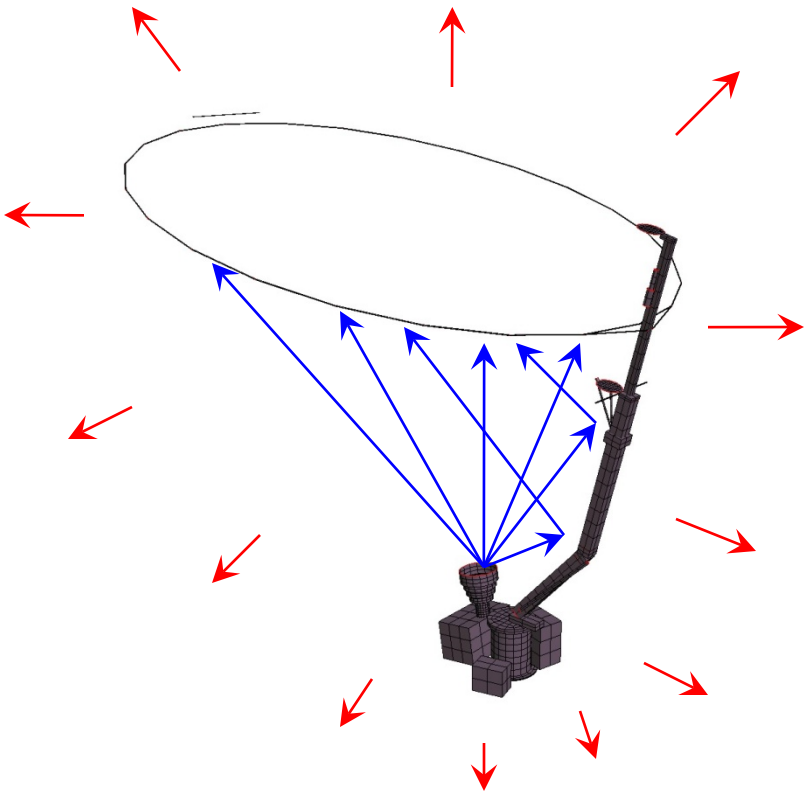
Radiation Pattern Calculation: Step 2



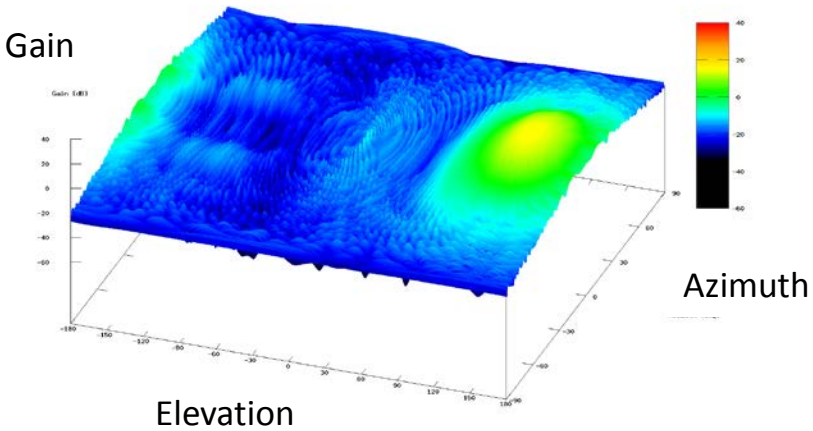
- Scattering from the spinning platform assembly + reflector boom
- Method: MoM



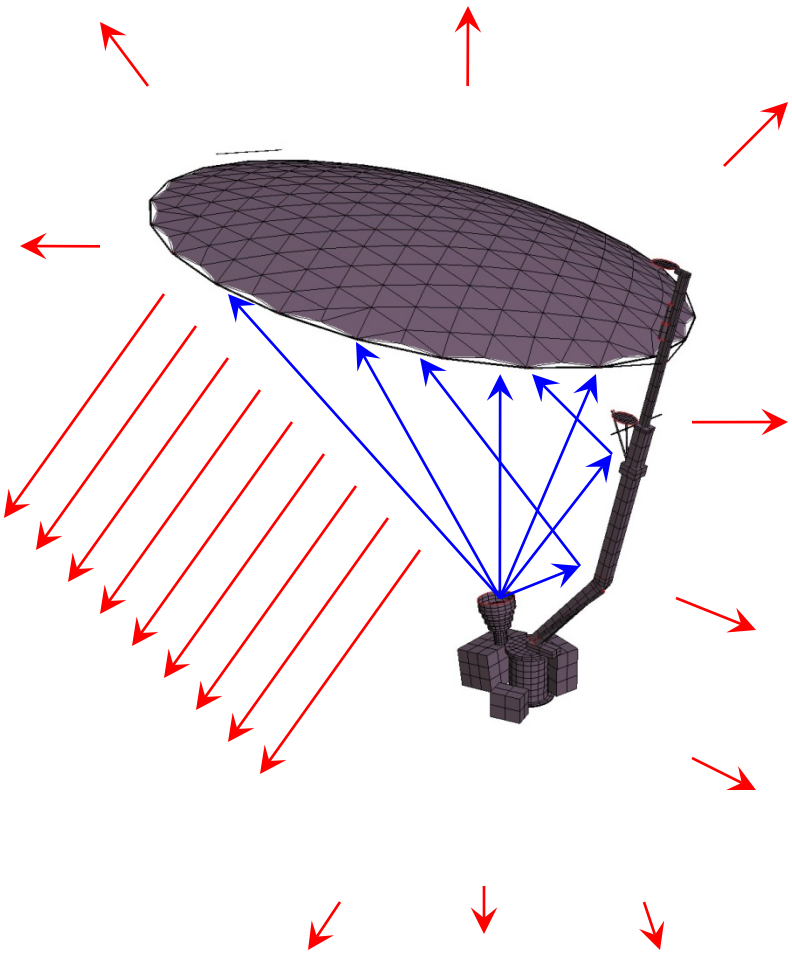
Radiation Pattern Calculation: Step 3



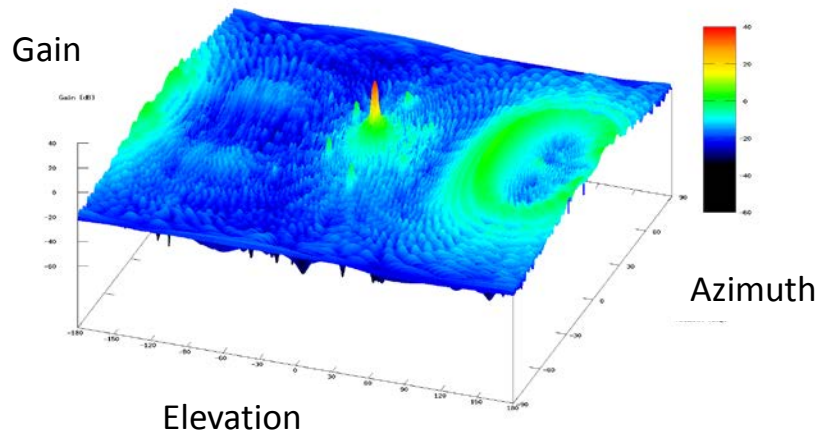
- Scattering from the lower ring of the truss
- Method: MoM



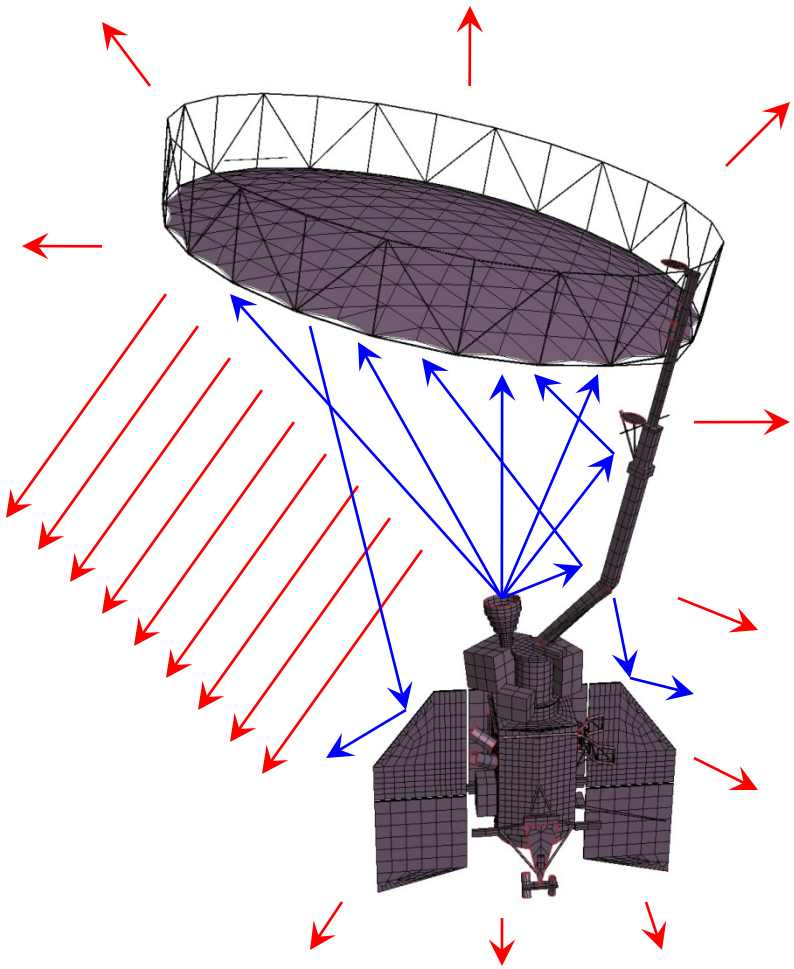
Radiation Pattern Calculation: Step 4



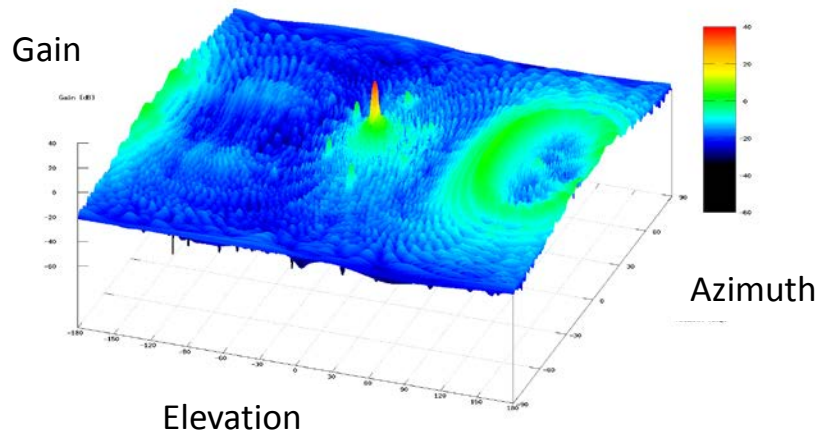
- Reflector radiation + scattering from the spinning platform assembly
- Method: PO + MoM



Radiation Pattern Calculation: Step 5



- Reflector radiation + scattering from the entire spacecraft
- Method: PO + MoM



Final antenna radiation pattern includes a very high fidelity model of the entire observatory

Field-of-View (FOV) Study

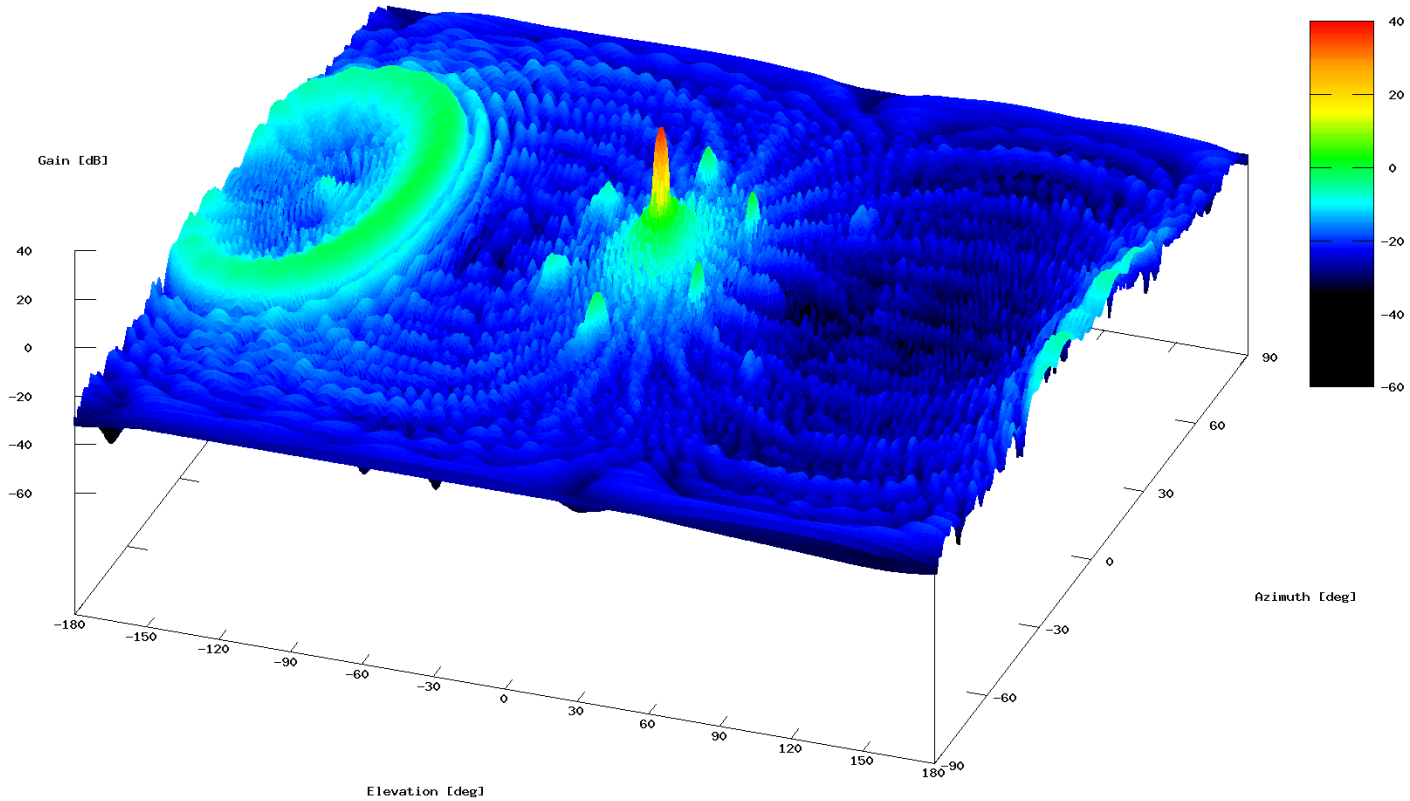
- A series of simulations with the spacecraft spinning under the instrument platform was carried out to verify that the antenna pattern stability requirement were met.
- While the effect of the moving parts of the observatory is clearly visible in the radiation pattern, the stability requirements are met.
- 4200mm focal length/394.7 edge offset optical design
- Catenary rim
- Complete loop around the spacecraft at 15° steps
- Both V- & H-Pol
- SAR @ 1.2172, 1.2572 & 1.2972 GHz
- RAD @ 1.4000, 1.4135 & 1.4270 GHz

Animation of the Entire Observatory

A9

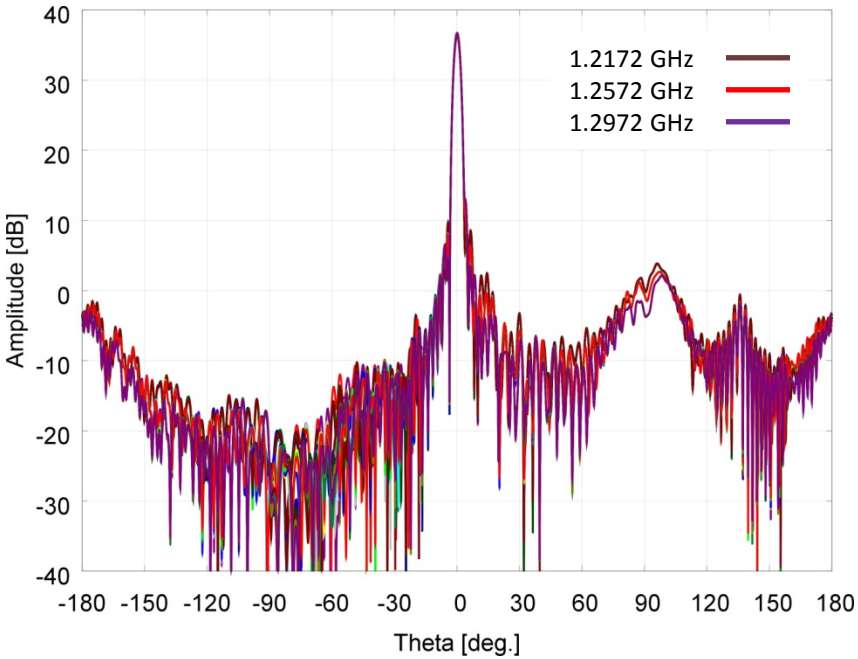
Rotation: mouse - Size: Shift+mouse - Translation: Ctrl+mouse - Bgcolor: b - Toggle info: Esc

Pattern Animation for RAD V-Pol

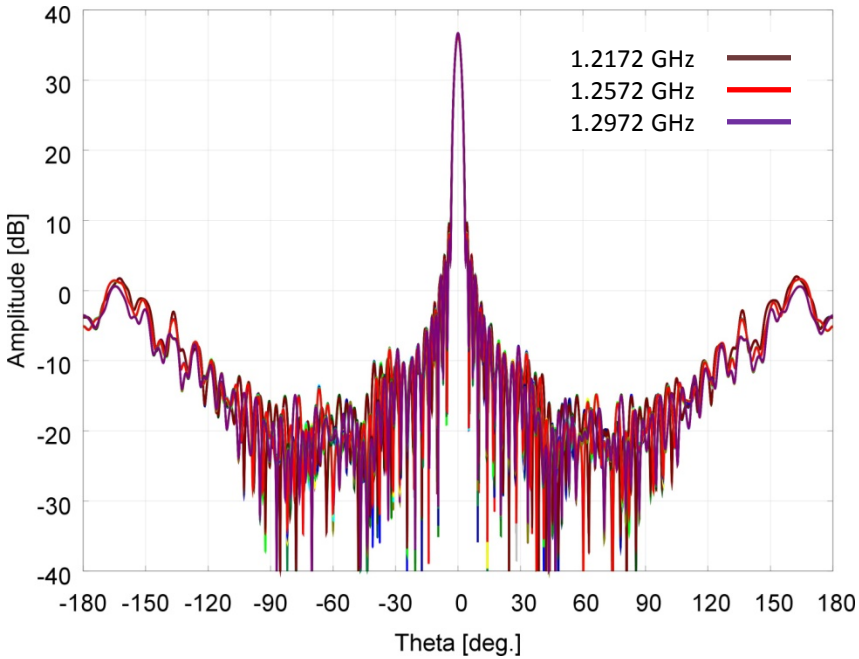


Radiation Patterns – SAR V-Pol

Elevation Cuts

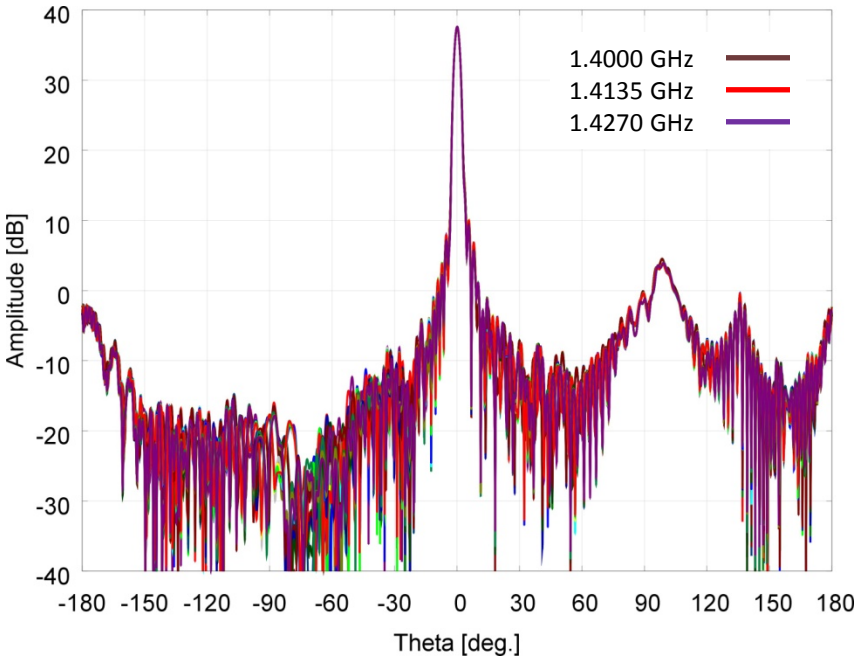


Azimuth Cuts

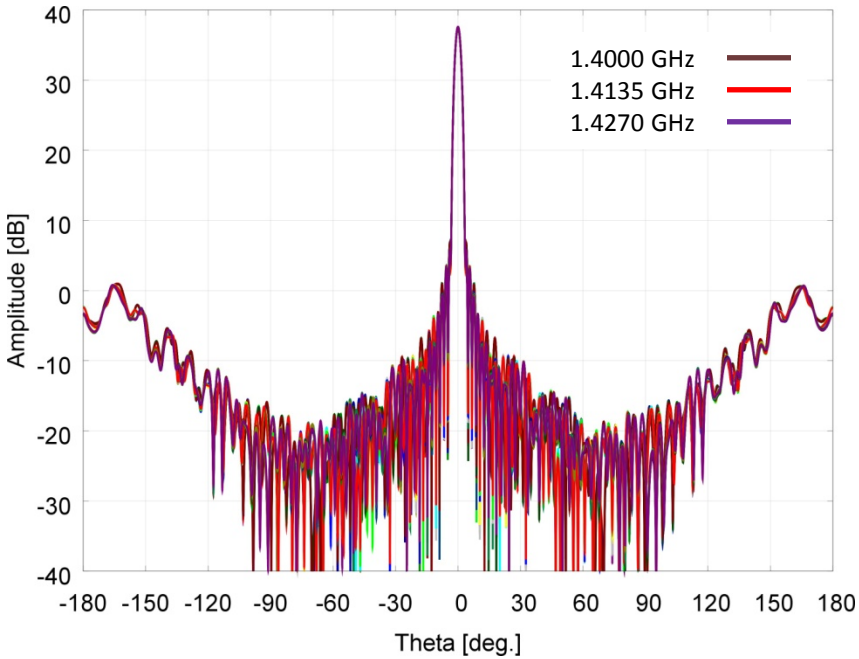


Radiation Patterns – RAD V-Pol

Elevation Cuts



Azimuth Cuts



Pointing Effect of the Spacecraft Scattering

SAR V-Pol	Pointing [deg.]
No Scattering	0.042°
000°	0.050°
045°	0.051°
090°	0.051°
135°	0.051°
180°	0.049°

RF to Mech. Boresight Bias	= +0.050°
Scattering Bias	= +0.008°
Stability	= ±0.001°

- Very small contribution to pointing error
- Calculation performed at 1.2572 GHz, SAR center frequency

Thermal Distortions

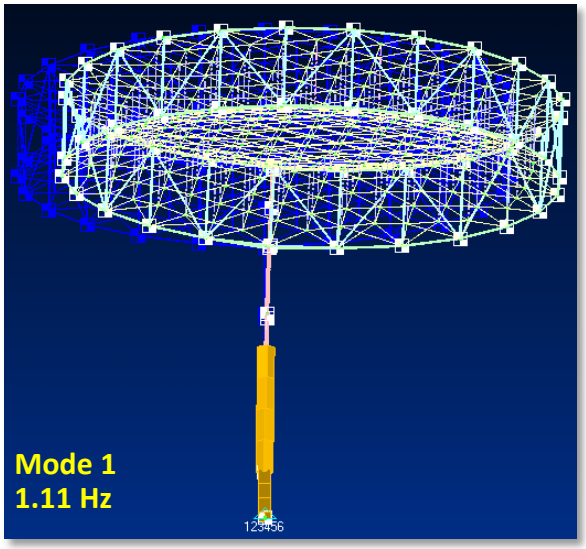
- Thermal distortions of the reflector and boom, over an orbit including eclipse, have been predicted and analyzed
- Reflector performance and pointing errors have been calculated
- The mechanical rigid body model and the RF PO/MoM analysis are in close agreement

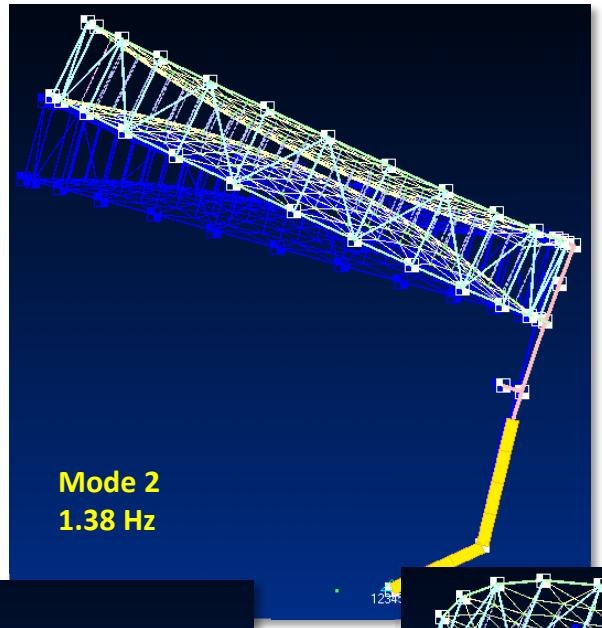
Dynamics Studies

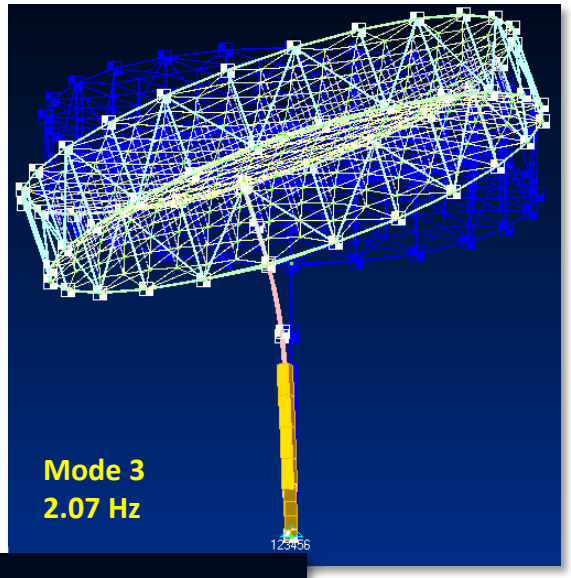
- Several mechanical disturbances map into pointing errors
  - Effect of spinning-up the reflector up to nominal speed
  - Spin torque effect induced by the spin motor once at the nominal rotation rate
  - Mass imbalance distortions
  - Reflector surface modal oscillations

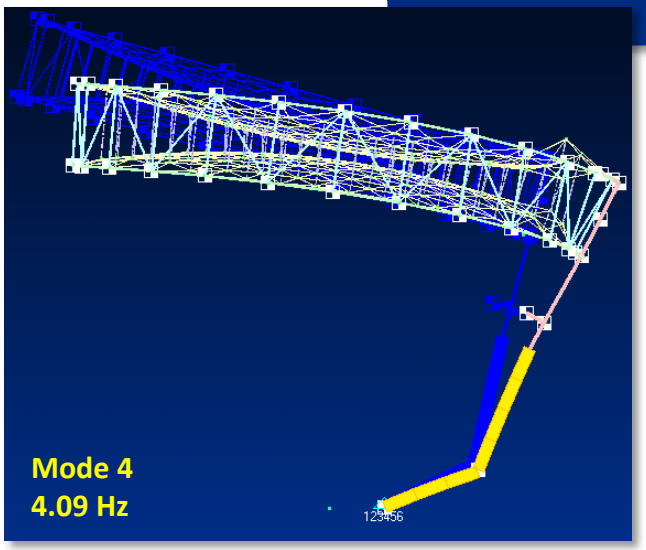
- Calculations performed with RF Model
  - Rigid body motions analysis using 6 degrees of freedom for the horn and 6 degrees of freedom for the reflector
  - Dynamic modes RF analysis using higher order modal variations of the reflector surface
  - RF vs. mechanical boresight bias and stability

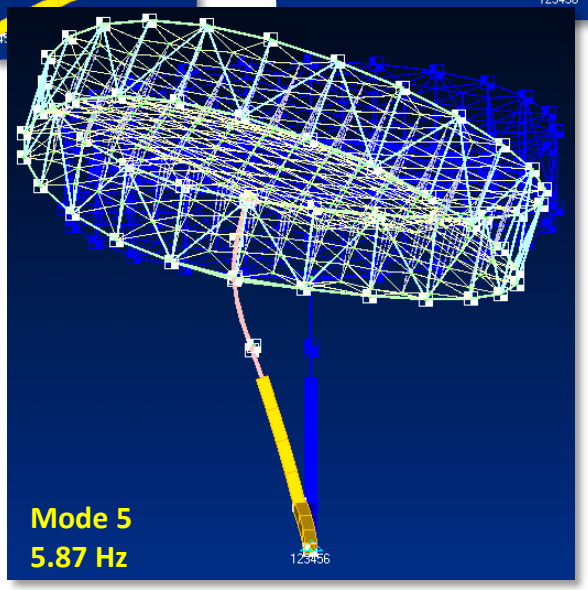
RBA Modes 1-5


Mode 1
1.11 Hz

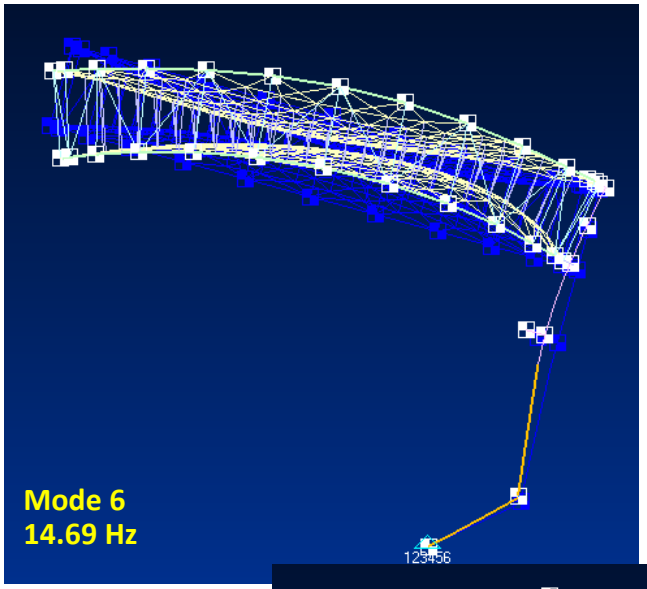

Mode 2
1.38 Hz

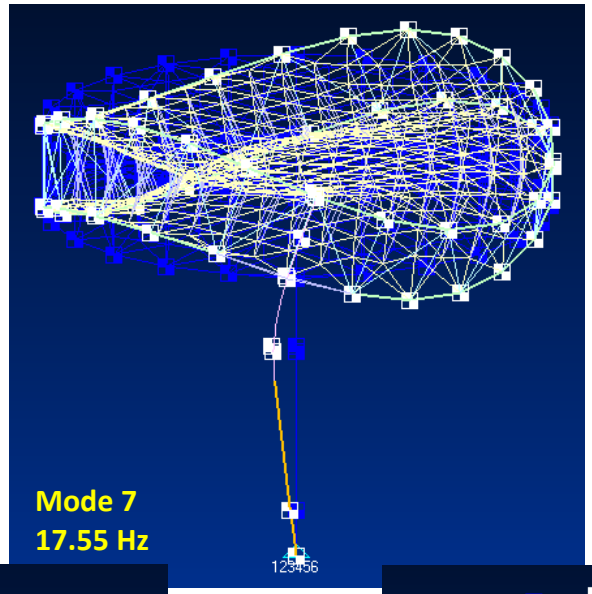

Mode 3
2.07 Hz

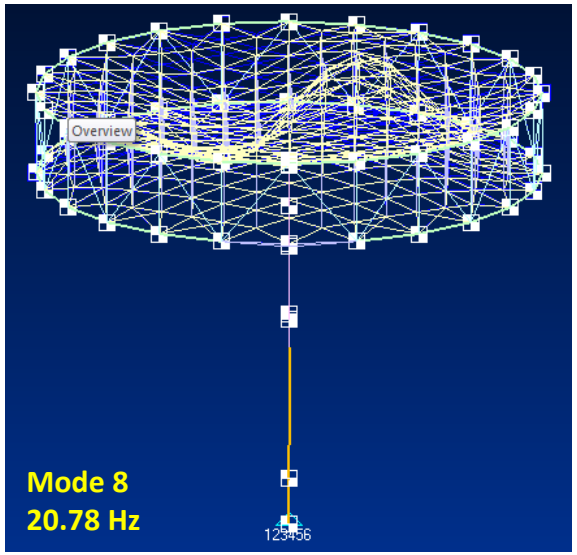

Mode 4
4.09 Hz

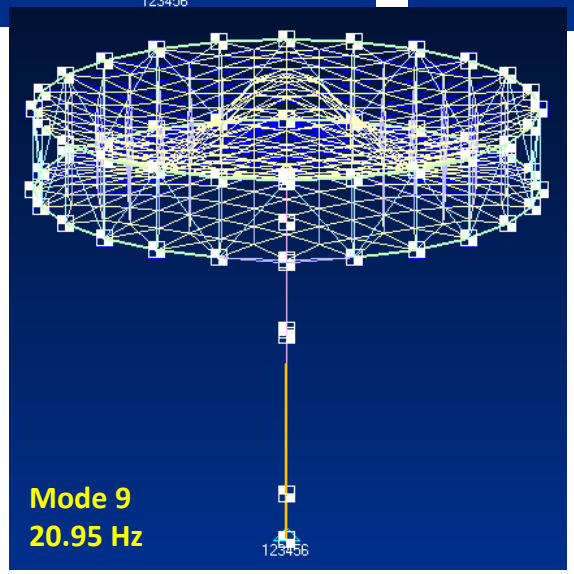

Mode 5
5.87 Hz

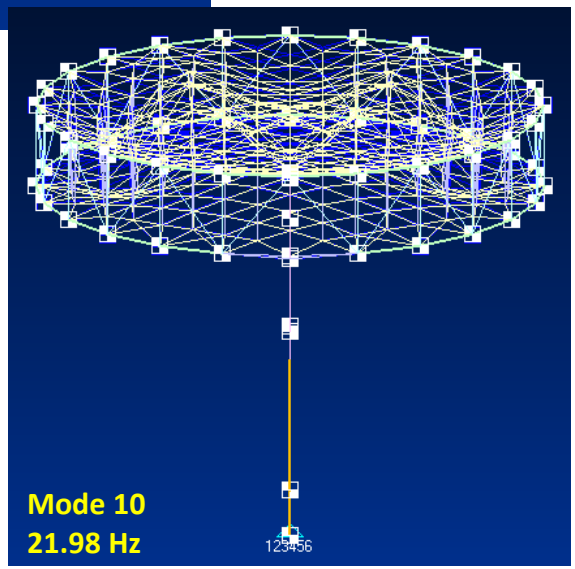
RBA Modes 6-10











Conclusions

- An detailed RF model of the entire SMAP observatory has been created
- Multiple configurations of the observatory have been analyzed, including the impact of the spacecraft as the instrument rotates, thermal distortions, and dynamic distortions
- Radiation pattern measurements of the flight assembly will not be feasible
- Much of the requirements verification will be based on the RF model performance