



On Orbit Performance Validation & Verification of the SMAP Instrument Antenna

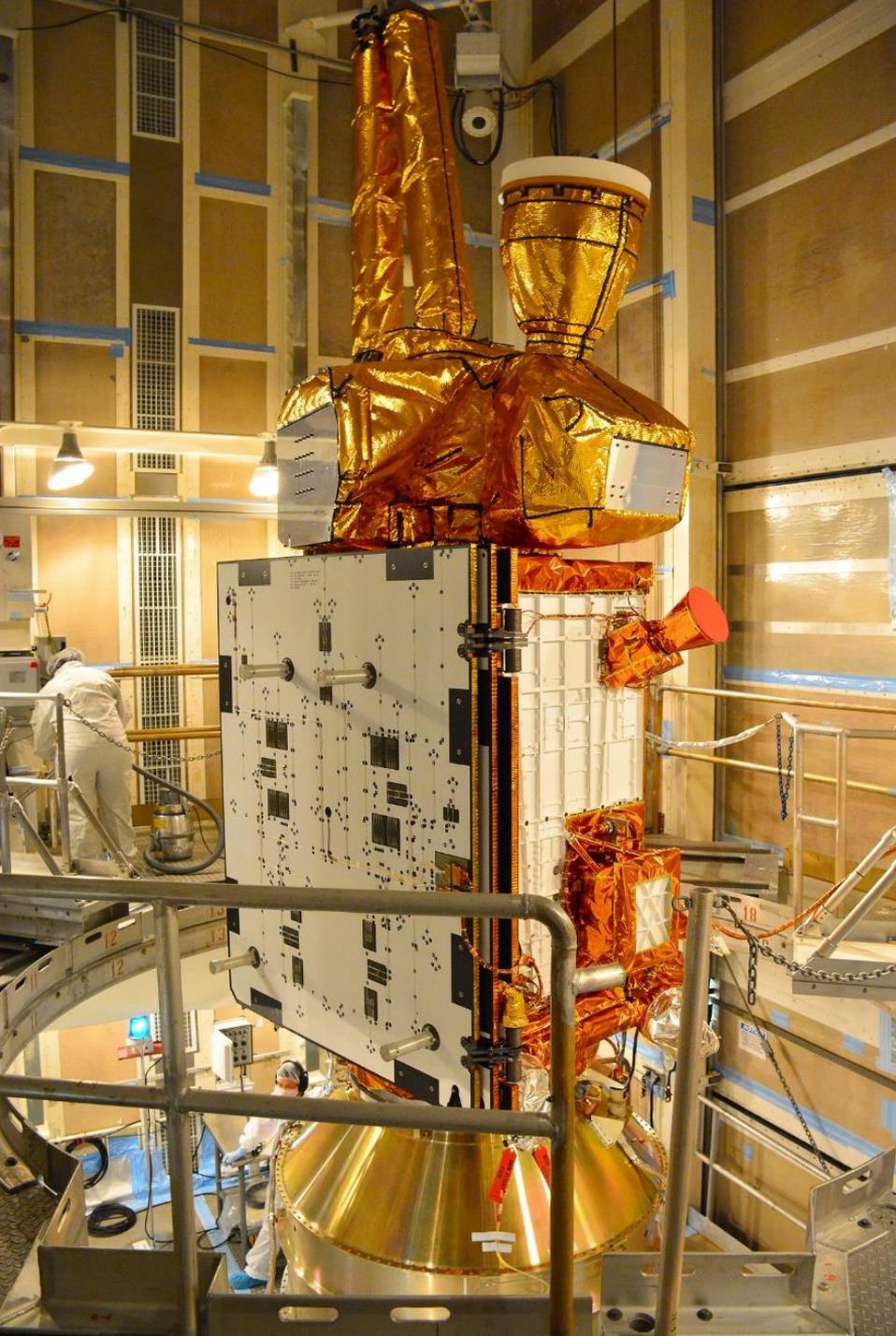
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California Institute of Technology &*

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EuCAP '17
Paris, France

<http://smap.jpl.nasa.gov>





Agenda

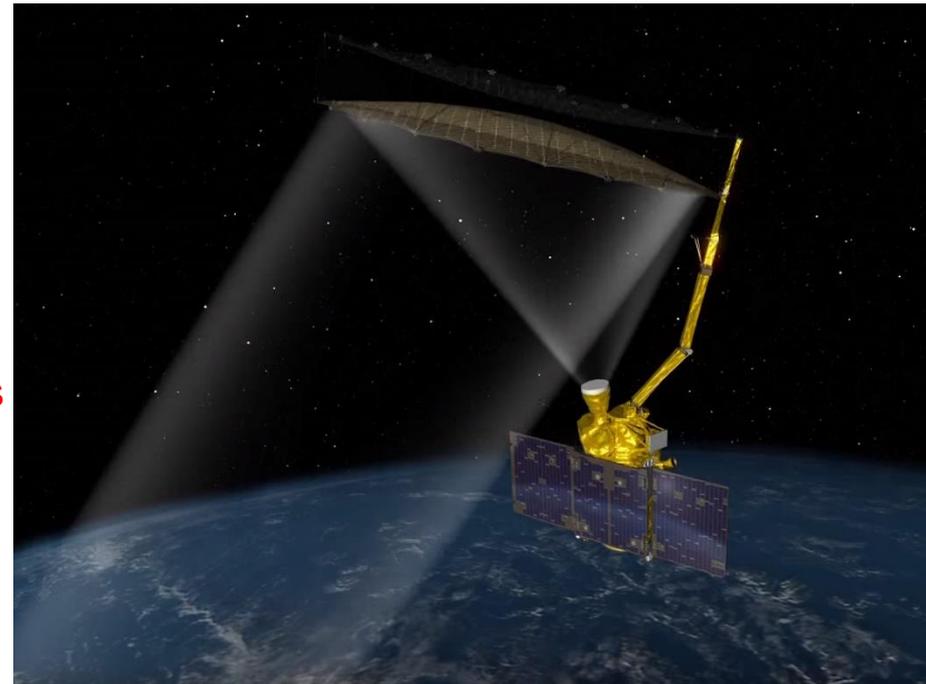
- Mission & Instrument Overview
- Latest Events
- Mission Timeline
- Instrument Implementation Strategy
- RF Model of SMAP Flight System
- 1/10th Scale Model
- Scale Model Measurements
- Flight System Data
- Conclusions





Mission Overview

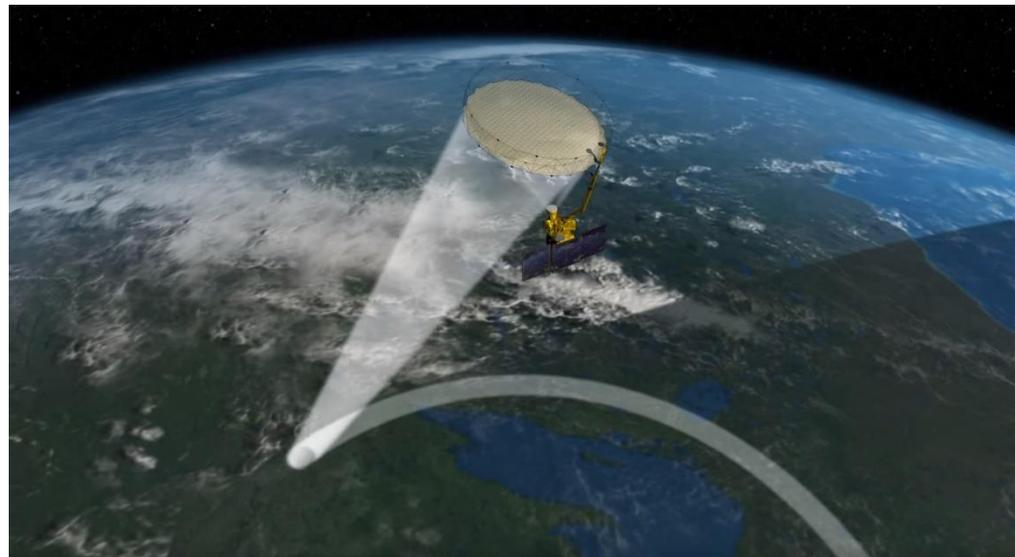
- NASA's **Soil Moisture Active and Passive (SMAP)** mission is measuring Earth's soil moisture and its freeze/thaw state over a 3 year period
- Applications:
 - More accurate and longer-term **weather and climate predictions**
 - Earlier **drought warnings**
 - Improved **flood and landslide predictions**
 - Improved **agricultural production predictions**
 - Better understanding of the **global carbon cycle**
- Near-polar, sun-synchronous orbit of **680 km**
- Launched on **January 31st, 2015** from **Vandenberg AFB**



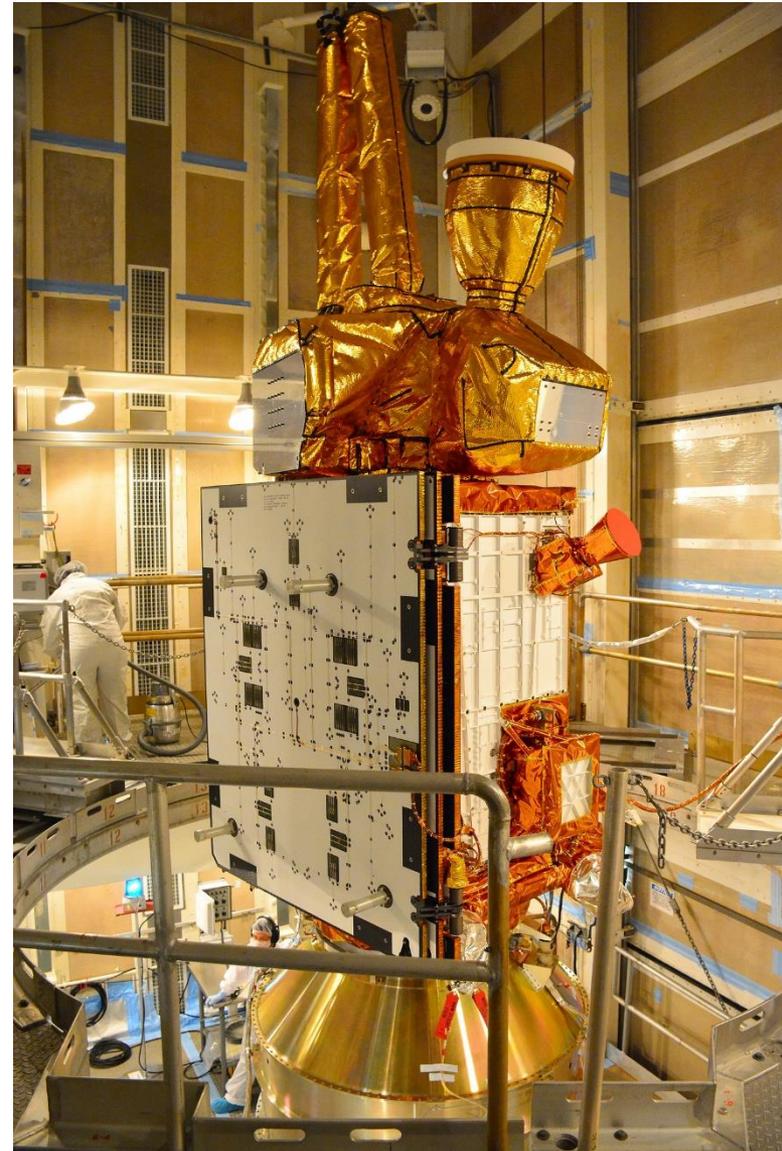


Instrument Overview

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

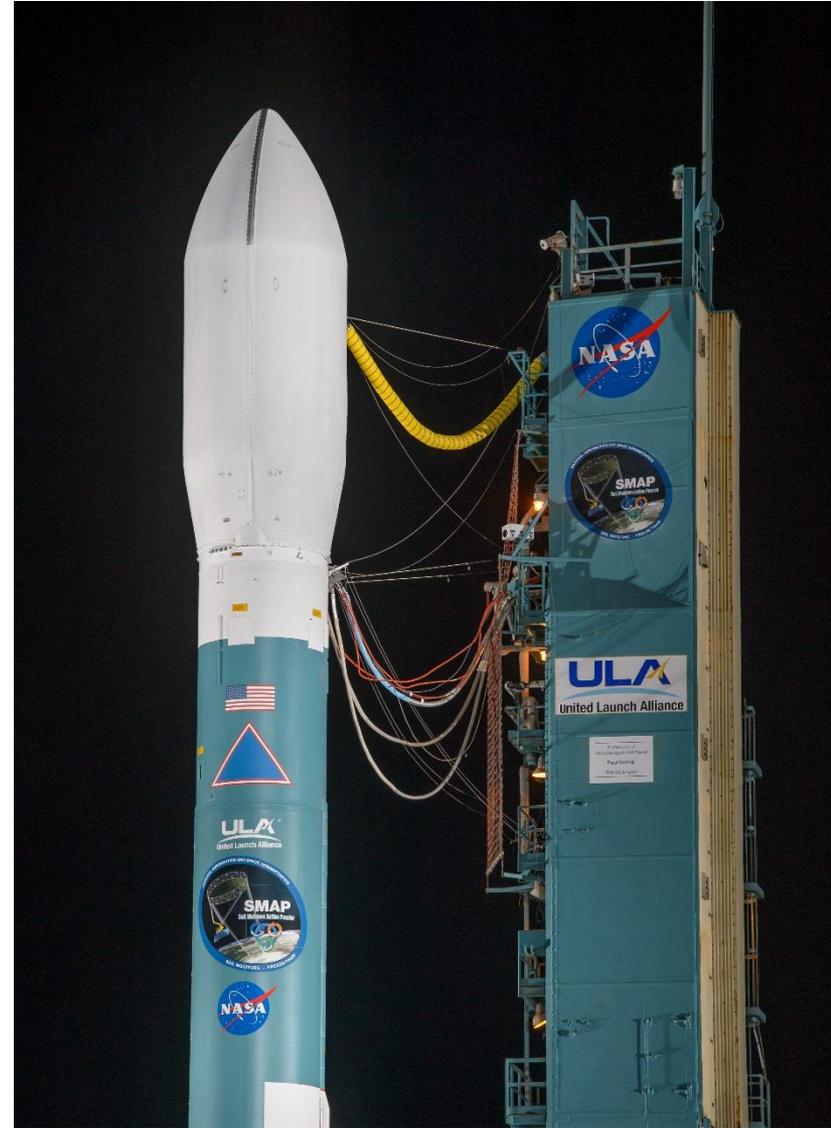


Delivery to Vandenberg AFB and Integration





Delta II Launch Vehicle





Ignition and Lift off

January 31st, 2015 @ 6:23AM PST







Mission Timeline

- Launched in January 2015
- Successfully began active mission in May 2015
- In July 2015 the radar ceased its operations due to a sudden failure of the low voltage power supply
- Radiometer is still operational and so far has provided over 1 year worth of calibrated soil moisture data on a global scale

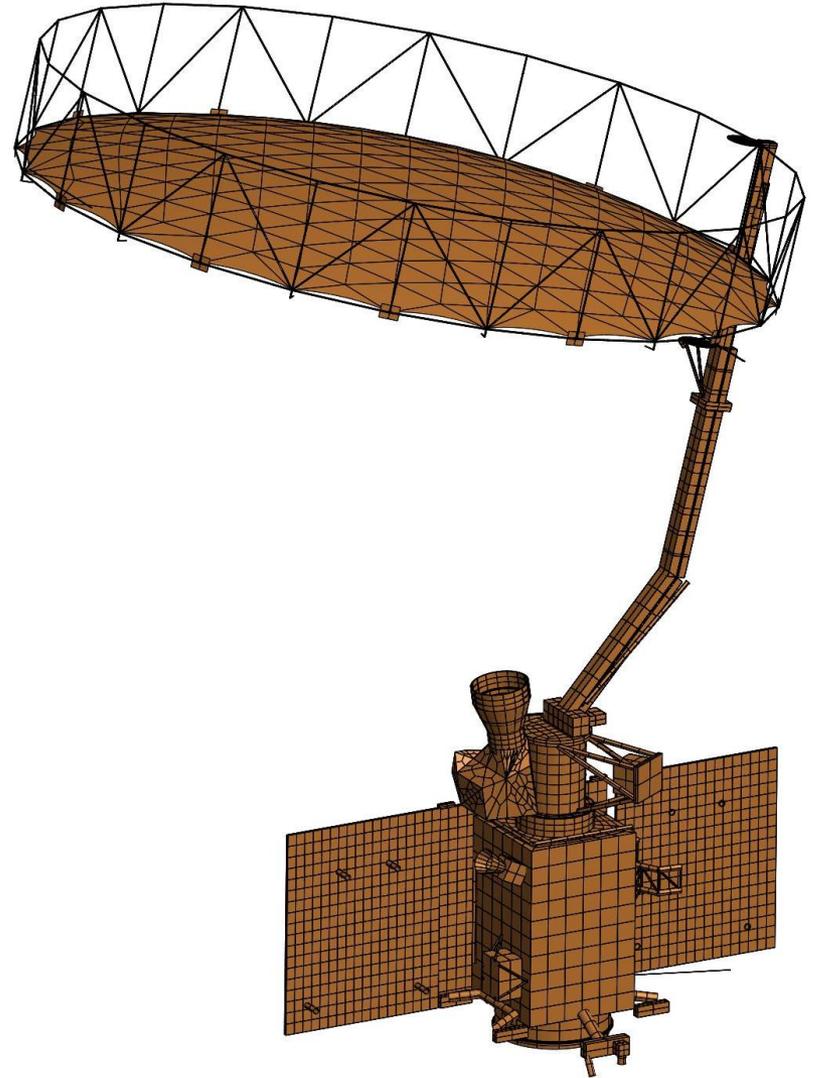
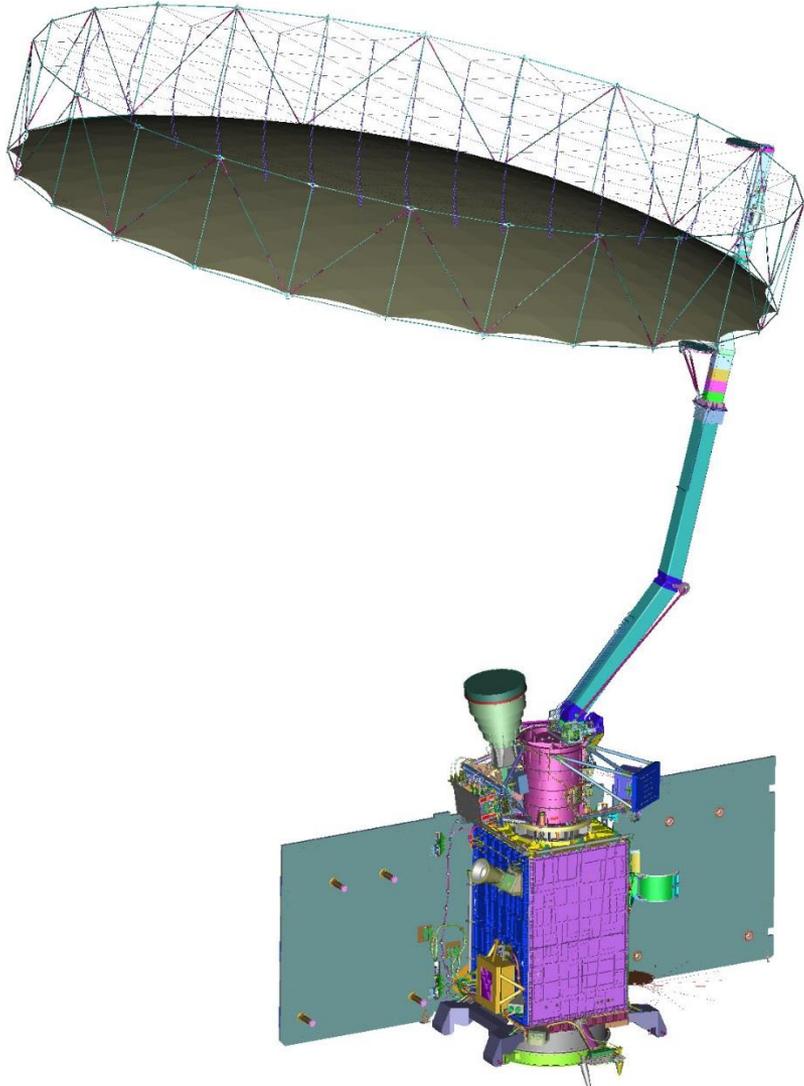




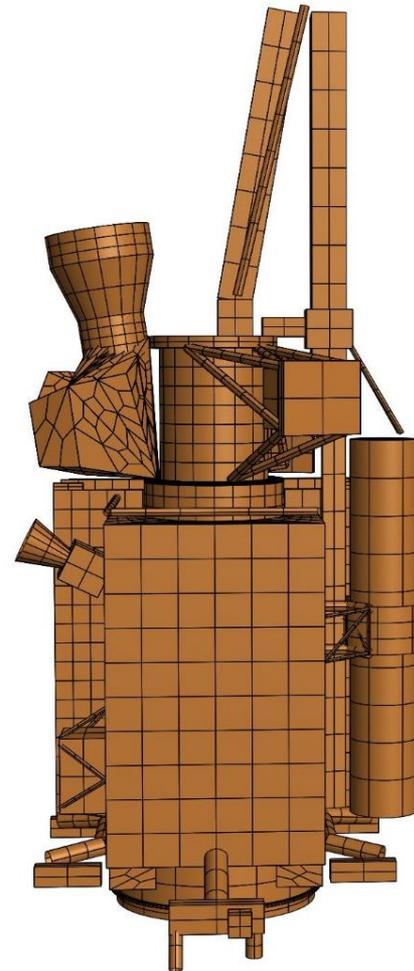
Instrument Implementation Strategy

- The 6-m offset **Reflector is an AstroMesh™ antenna** from Northrop Grumman, Astro Aerospace
- The **Feed Assembly is a JPL in-house design**
- An **Accurate antenna pattern knowledge was required** for the RAD performance calibration
- The **reflector antenna radiation pattern was not measured** before launch
- Extensive and **very accurate modeling** was done with several software packages to predict RF performance of the complete instrument antenna
- A **1/10th scale model** of the antenna and spacecraft was also built to verify the RF performance
- The **requirements verification** was done with a combination of
 - Flight Feed Assembly measurements
 - Scale Model predictions and measurements
 - Flight Model predictions

SMAP CAD & RF Models

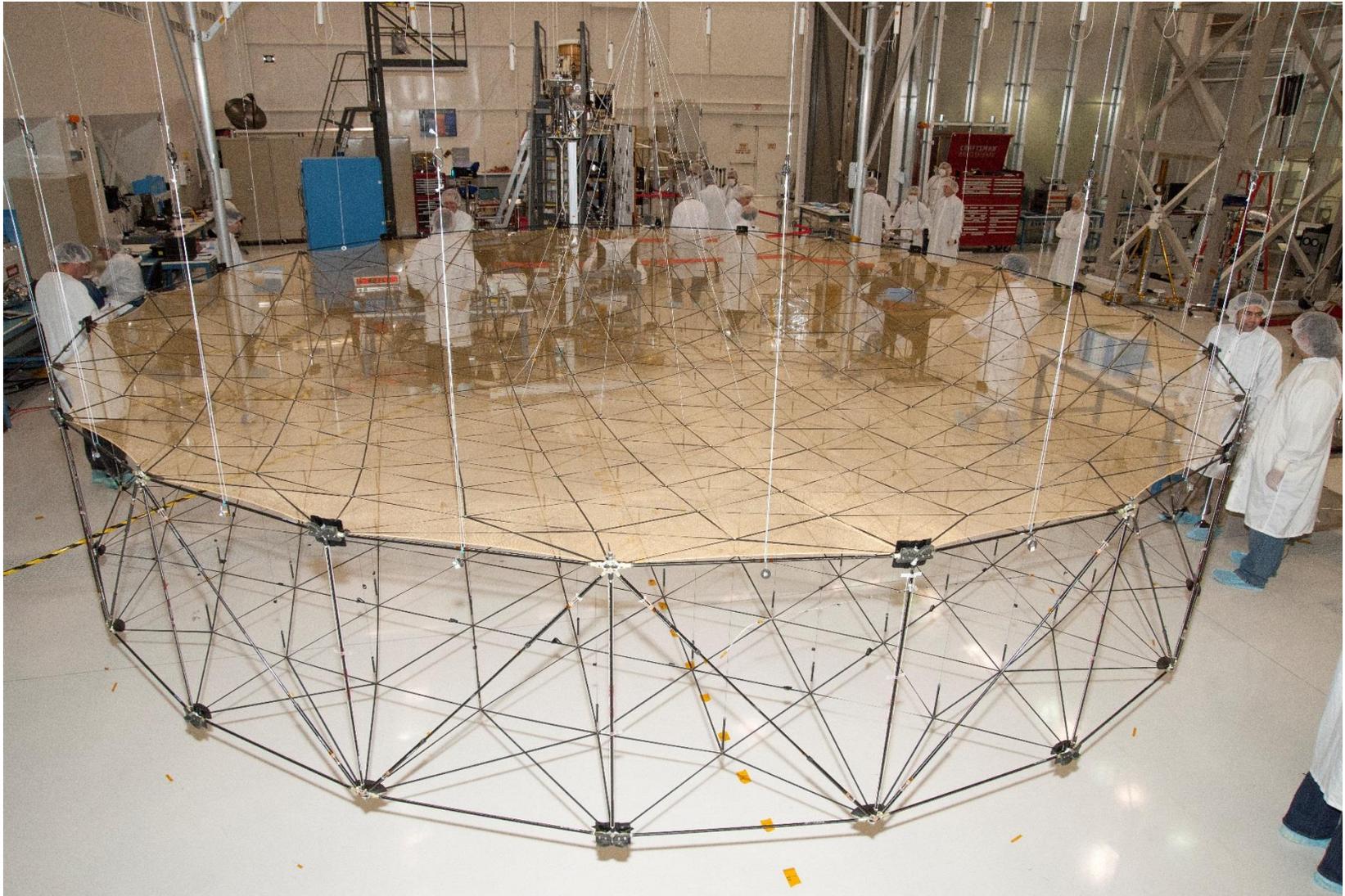


Fully Assembled S/C with Stowed AstroMesh™ Reflector





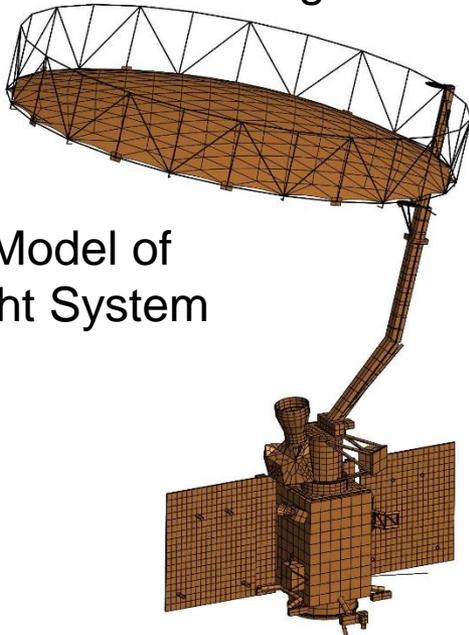
Fully Deployed AstroMesh™ Reflector



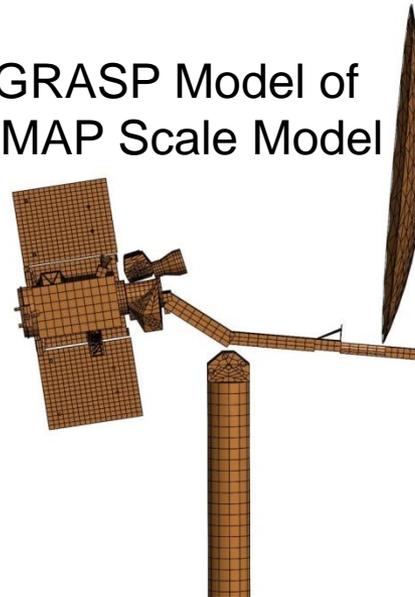
SMAP RF Modeling

- SMAP modeling was mostly performed using the **GRASP PO/MoM** modeling approach (PO+PTD for the reflector, MoM for everything else)
- A **GRASP model** of the **as-built scale model** was also made for comparison with scale model radiation pattern measurements
- A **HFSS model** was also done as an additional method of validating the GRASP model (FEM for the Feed Assembly, IE for everything else)
- The **Feed Assembly radiation pattern** was provided either in the form of an HFSS model calculation or Flight Feed Assembly measurements when eventually available

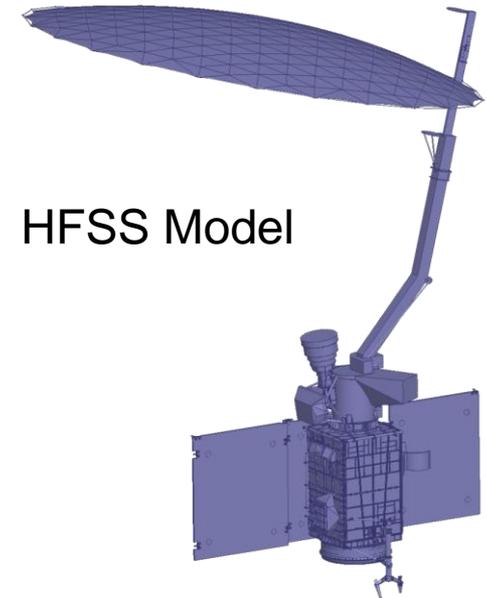
GRASP Model of
SMAP Flight System



GRASP Model of
SMAP Scale Model

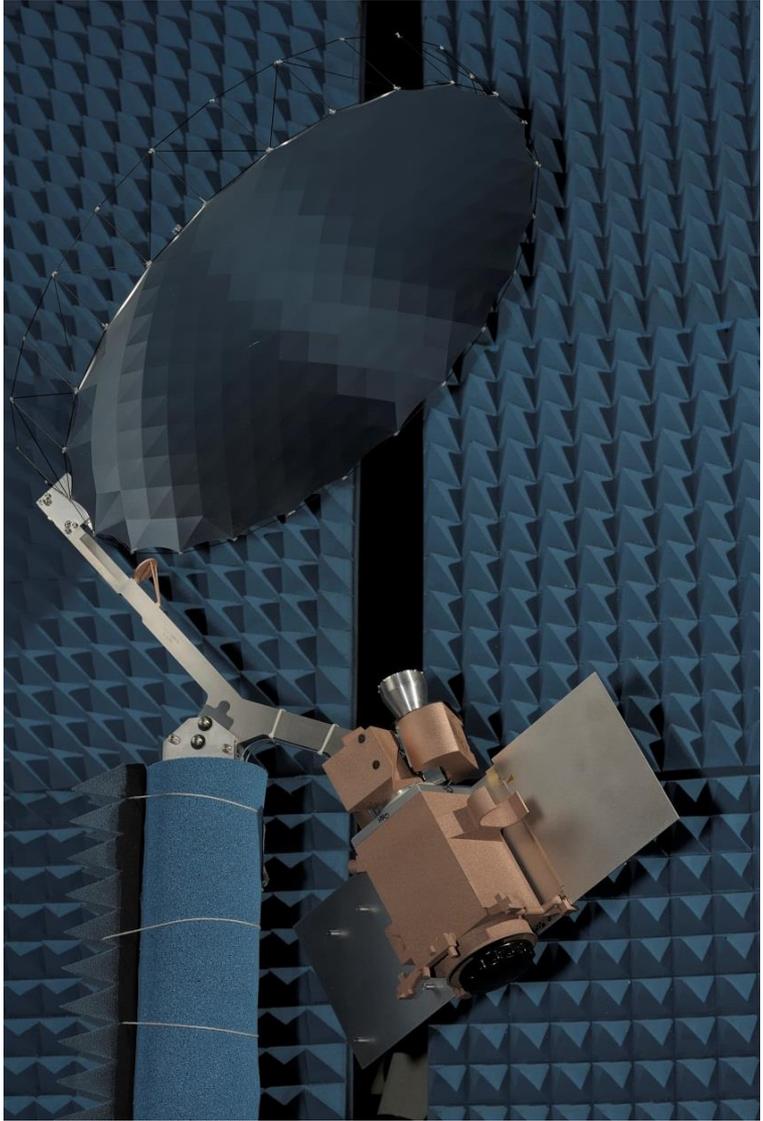
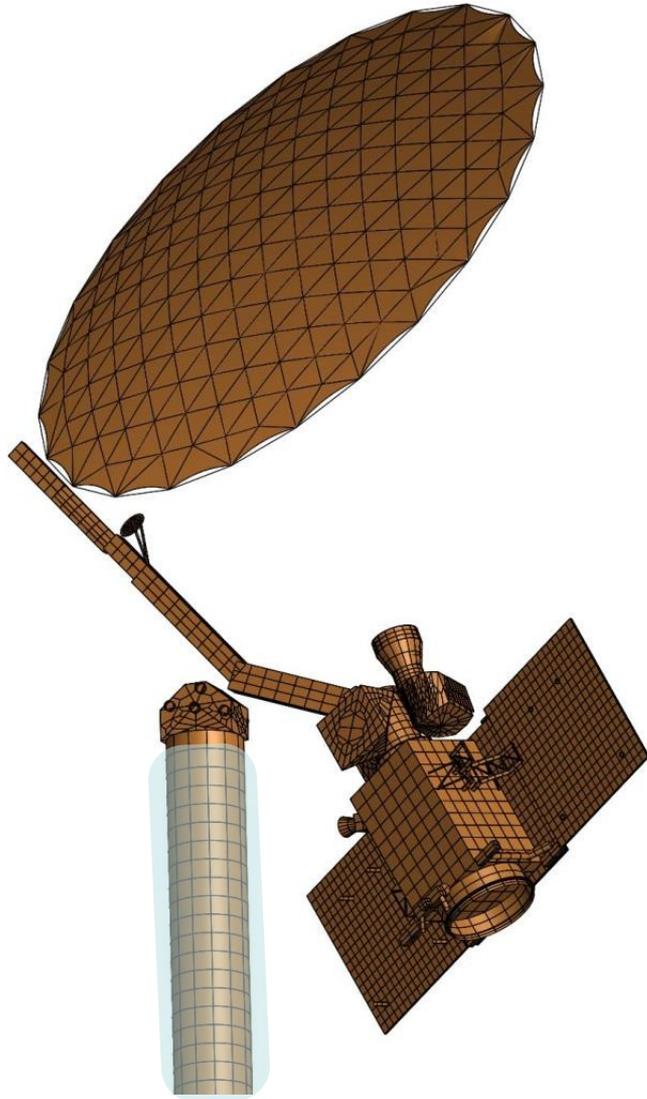


HFSS Model



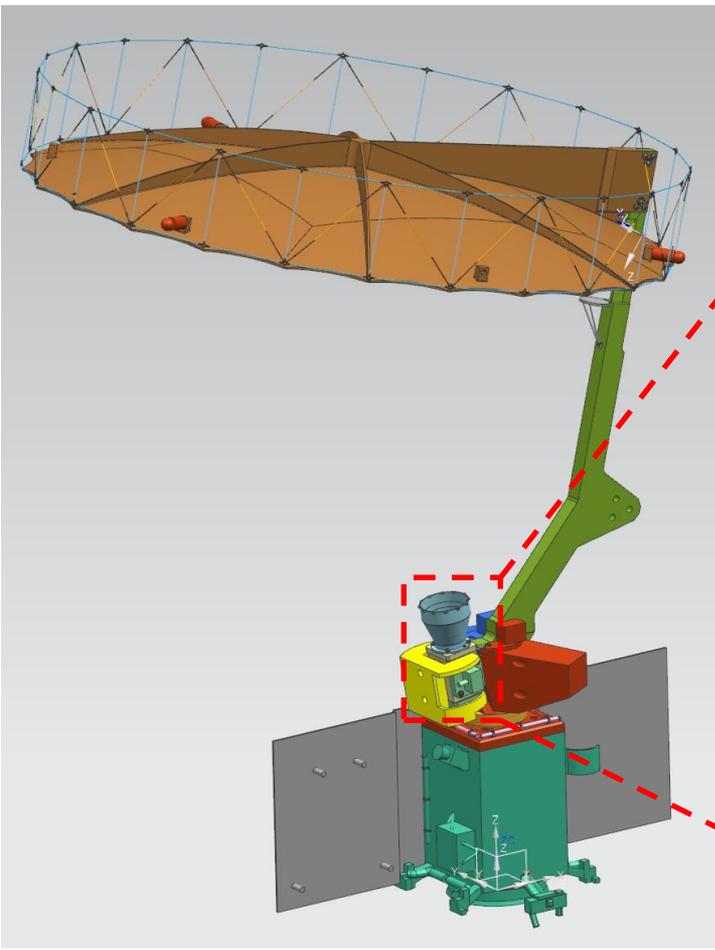


SMAP 1/10th Scale Model



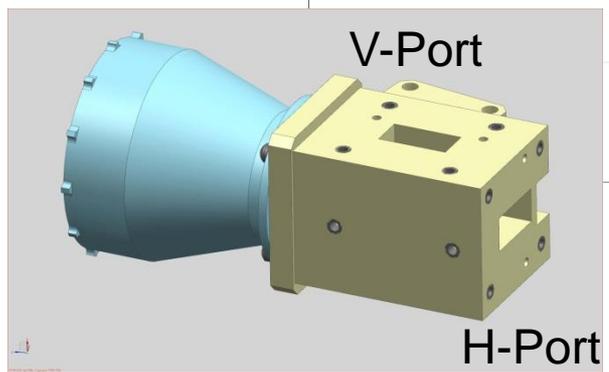
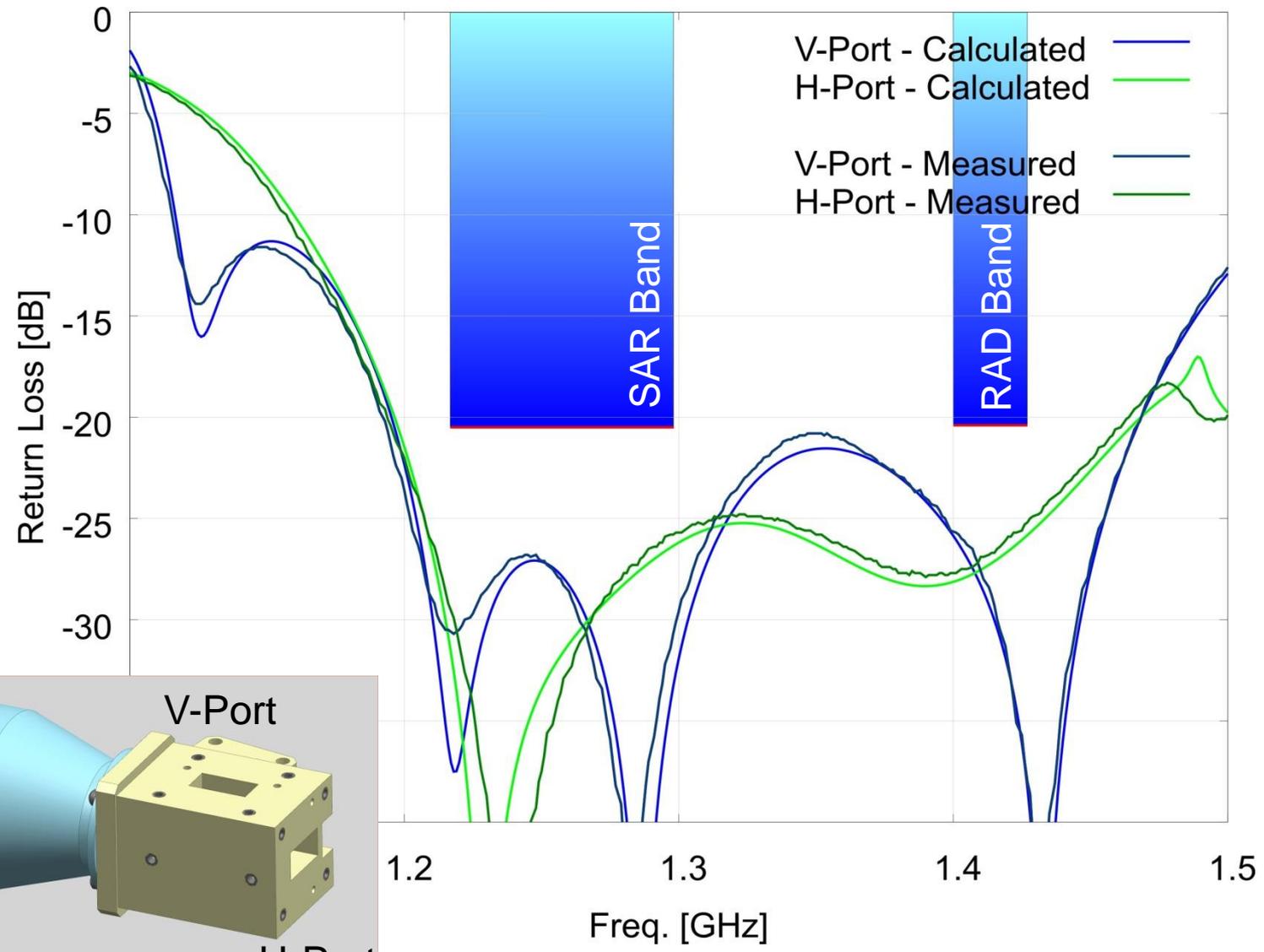


SMAP Scale Model





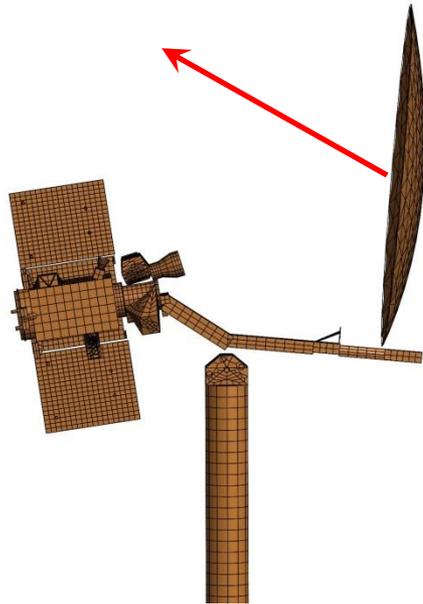
Feed Horn RL into SM OMT



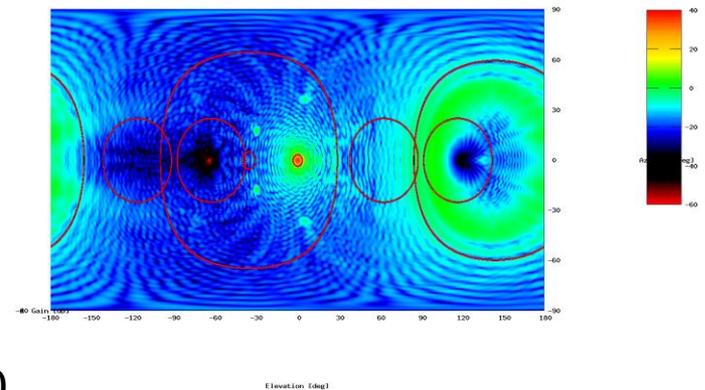
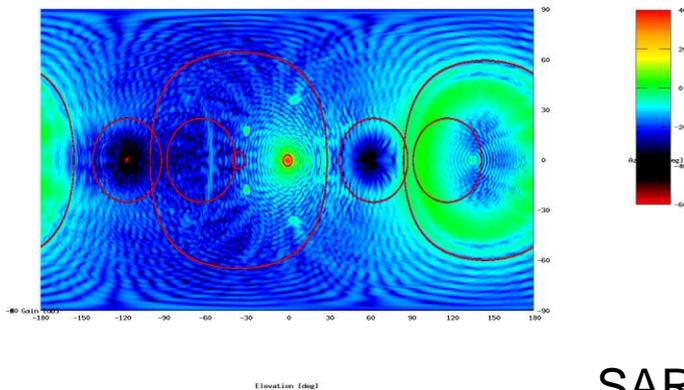
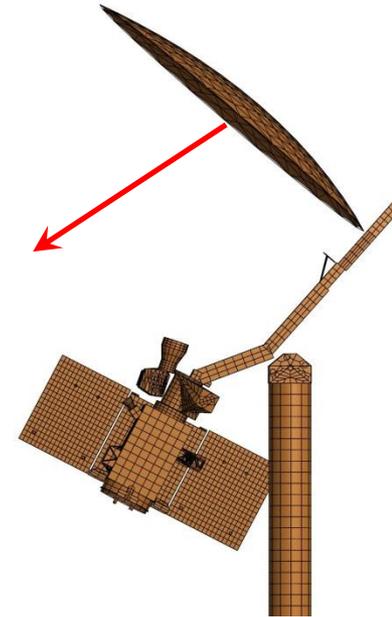
Examples of Scale Model Measured Patterns



+27° Position



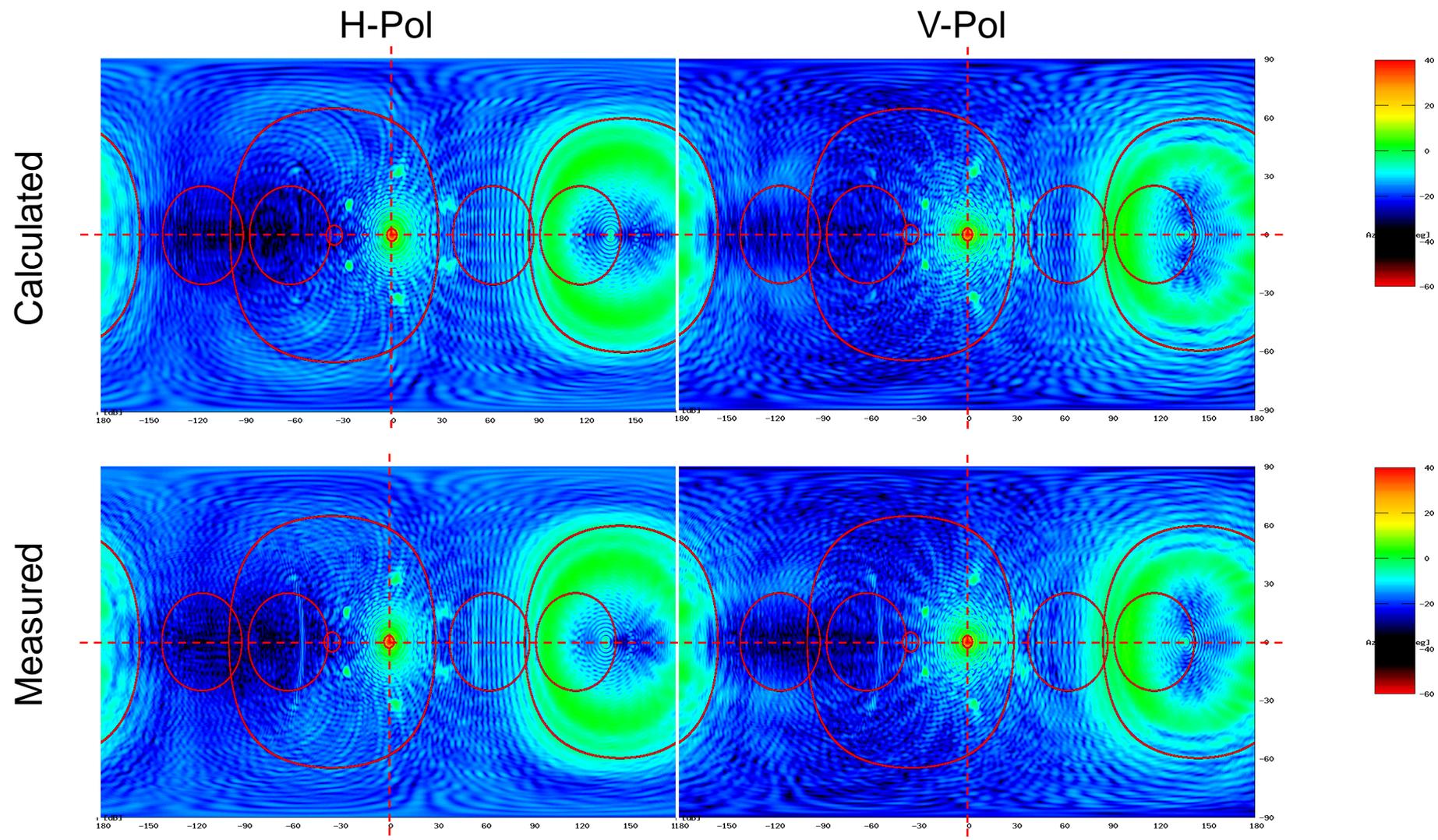
-27° Position



SAR V-Pol, 090

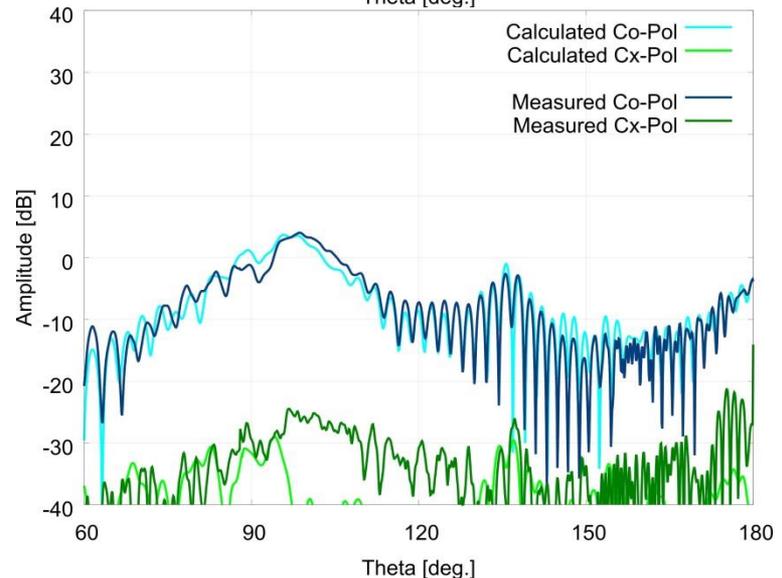
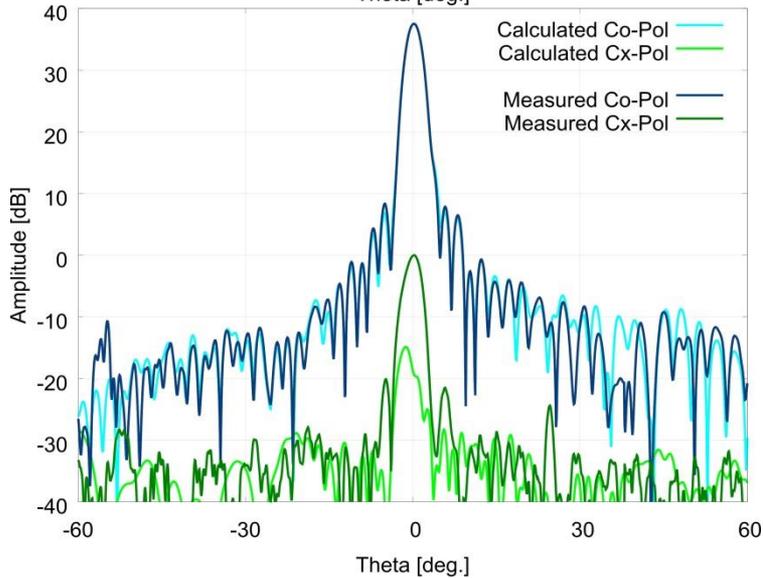
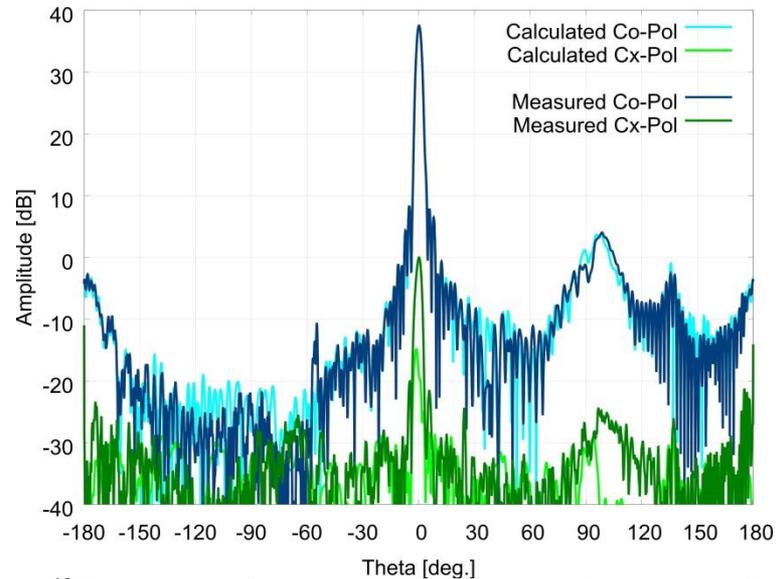
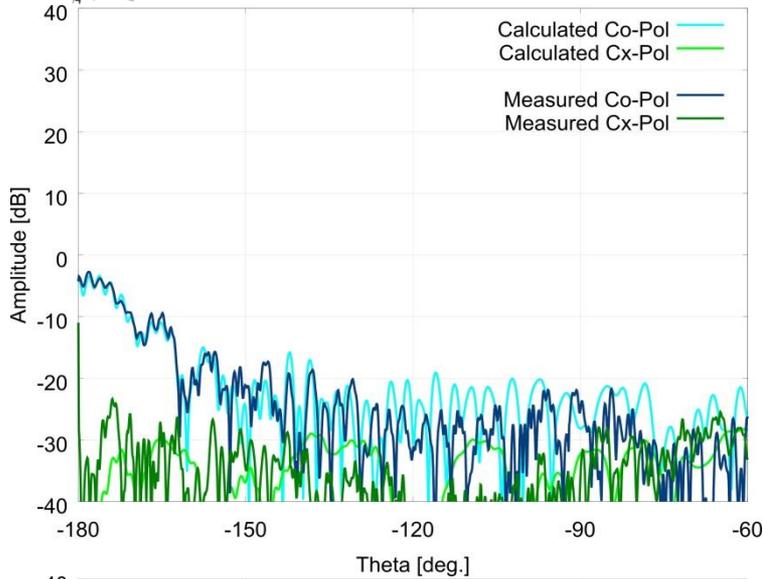


Radiation Pattern Comparison: RAD, 000



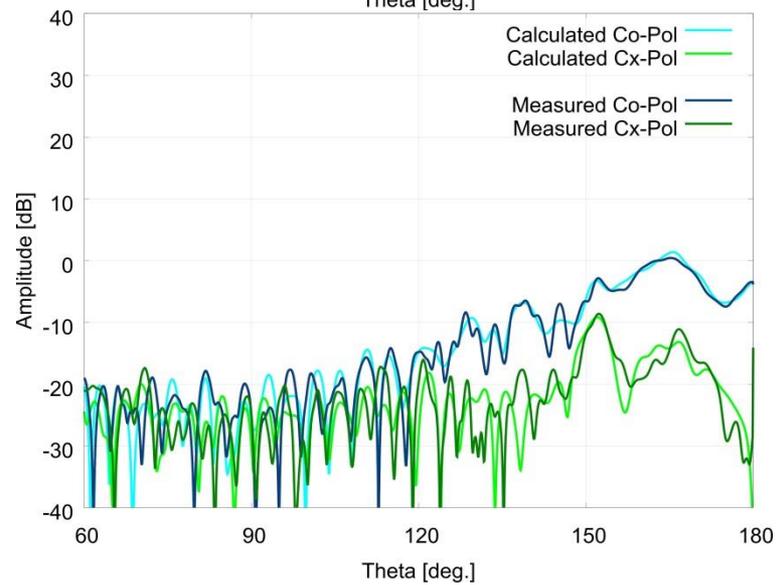
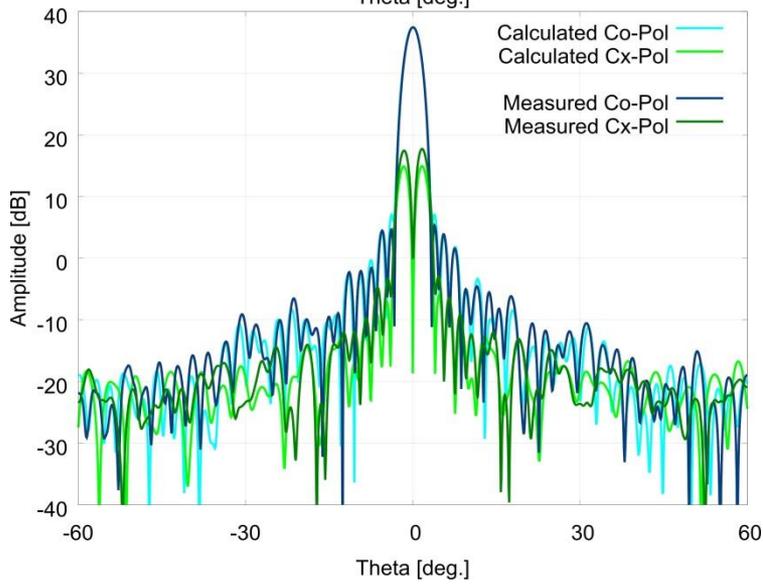
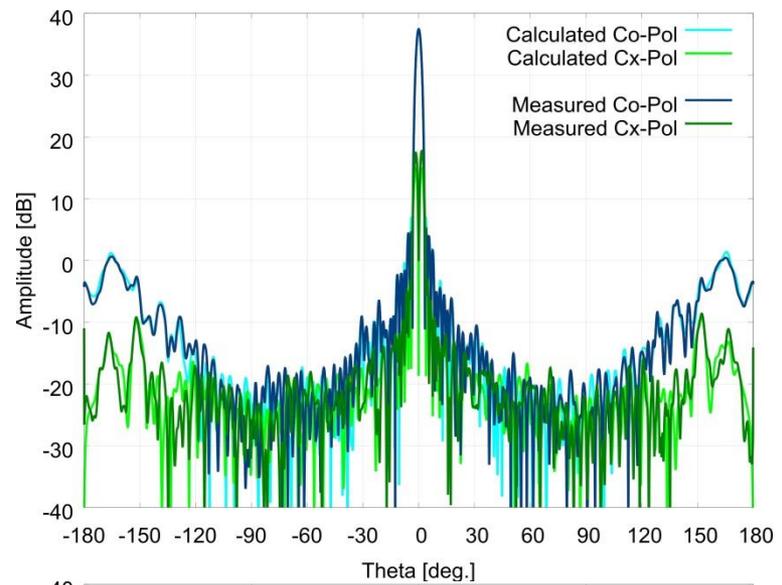
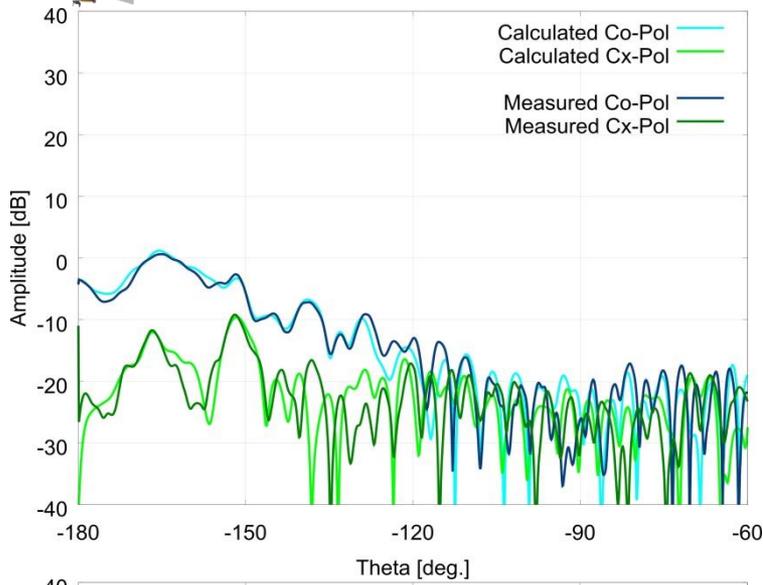


RAD V-Pol, Elevation Cut, 000





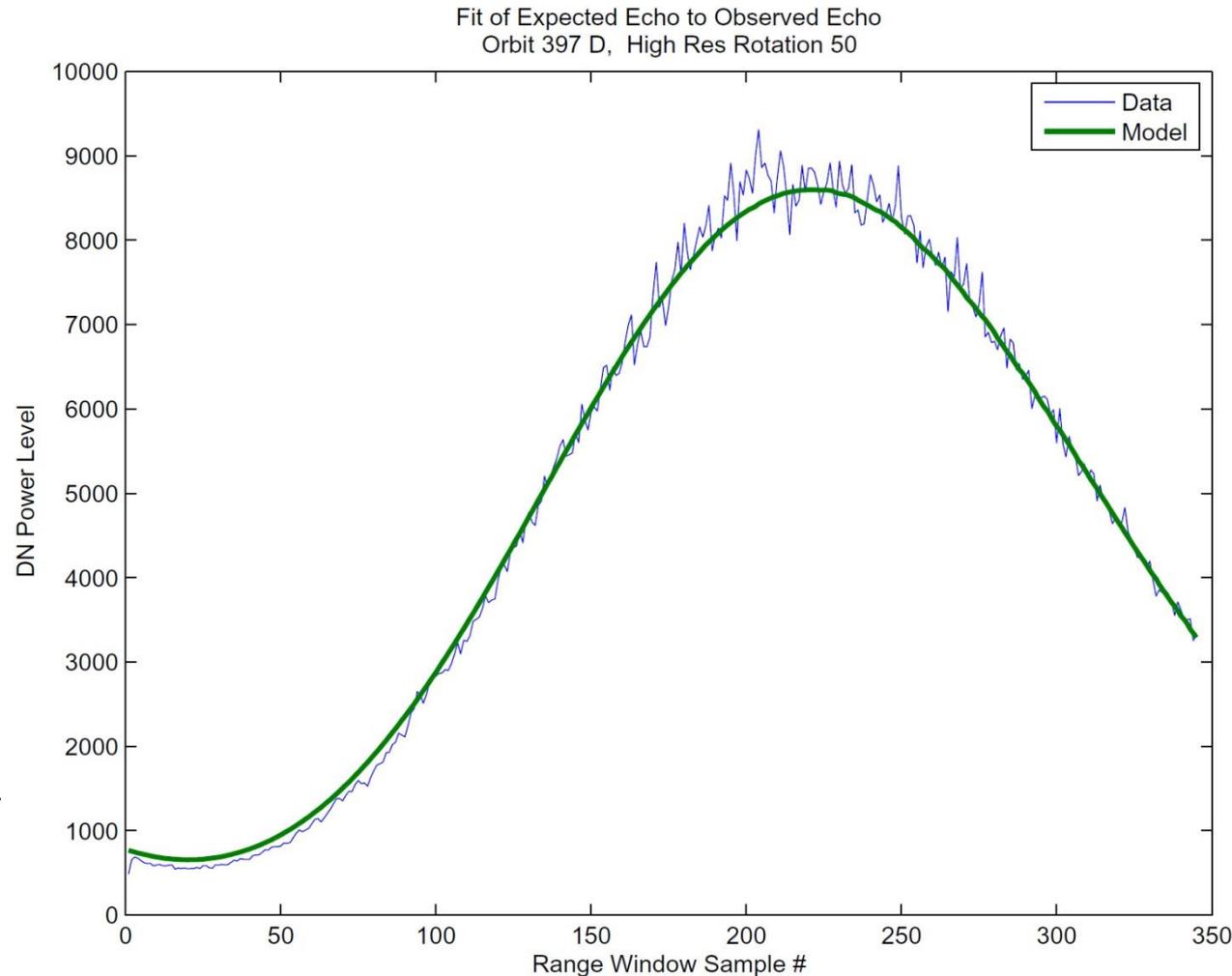
RAD V-Pol, Azimuth Cut, 000



Measurement of Radar Echo from Space

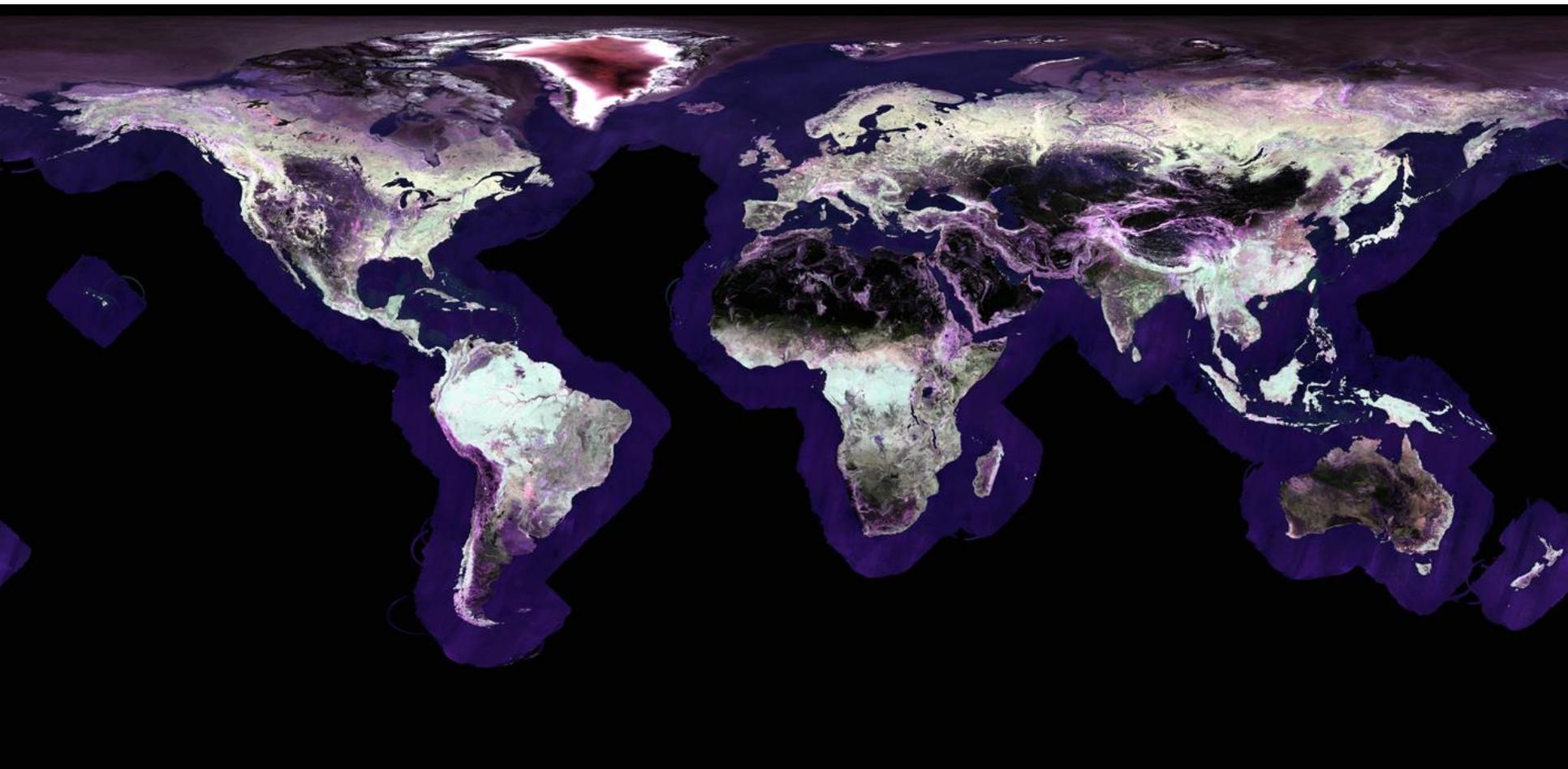


- Calculated radiation pattern was able to predict on-orbit performance extremely well
- SAR Pointing was predicted to be 0.270° from nominal according to the RF Model
- With the help of corner reflectors on the ground, it was measured to be 0.291° , only 0.021° off from our calculations





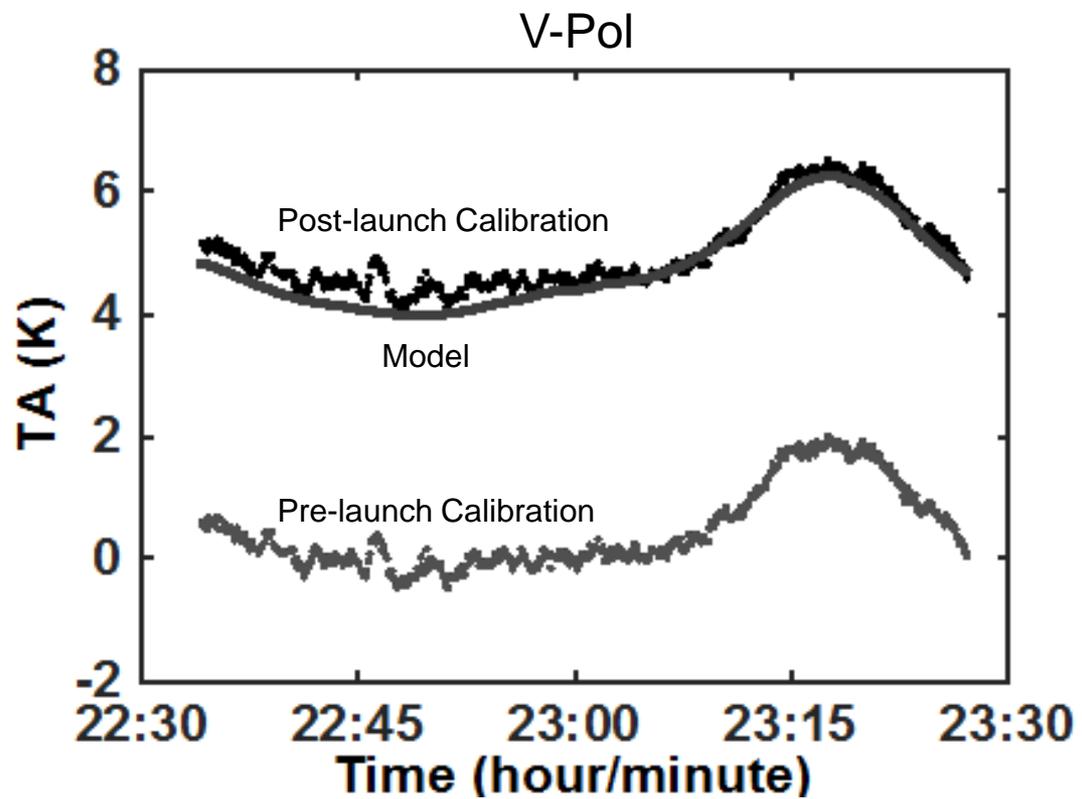
Radar Backscatter Cross Section from SAR Data



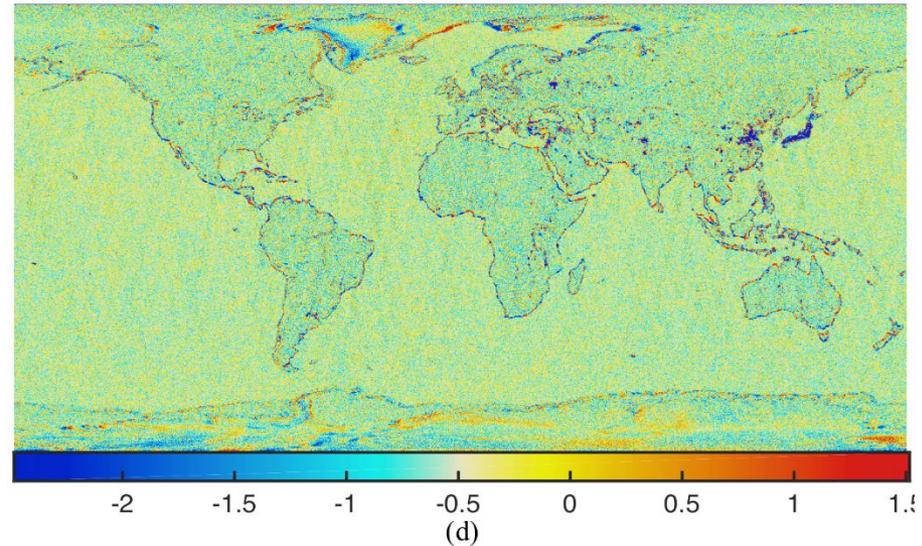
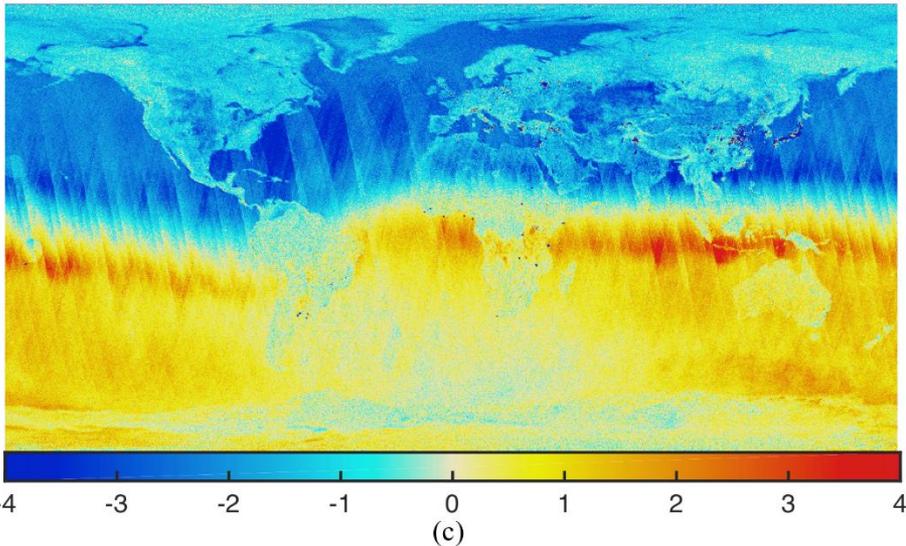
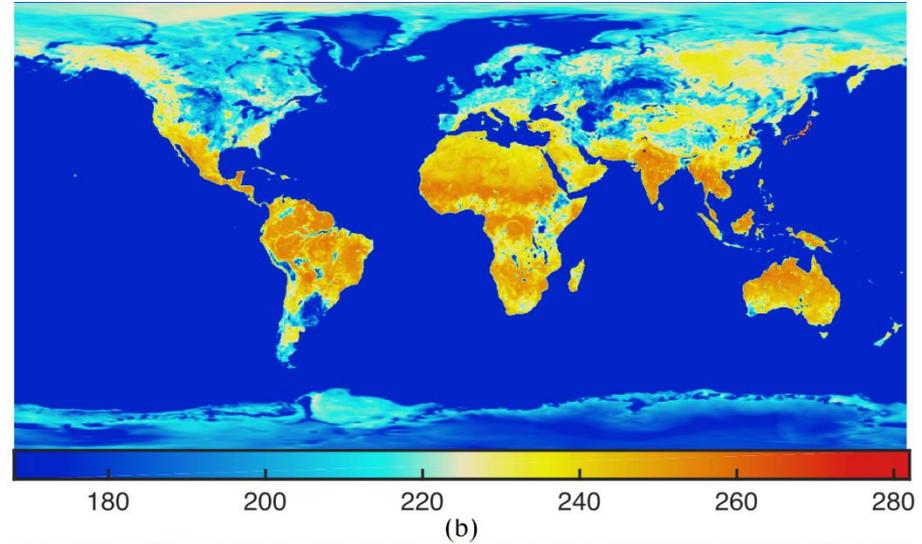
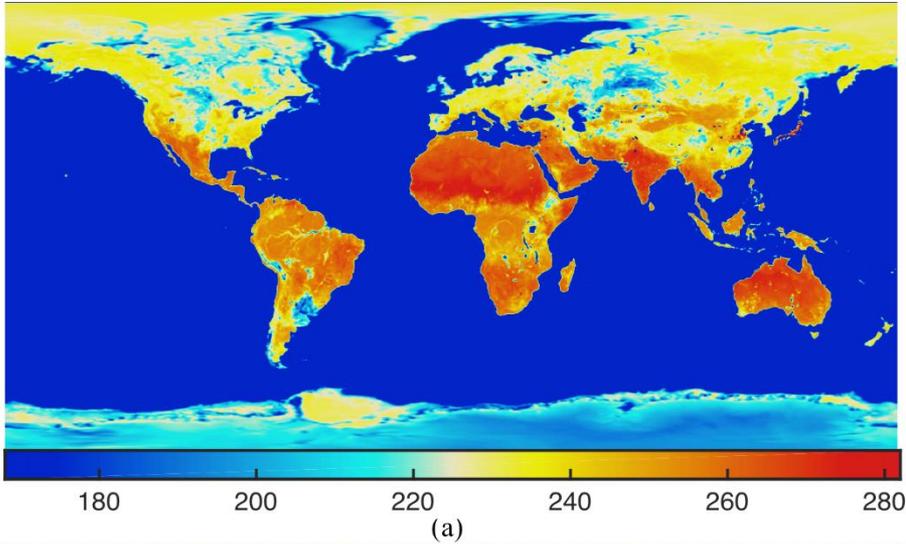


Radiometer Calibration

- First Radiometer Calibration was performed before reflector deployment with the Feed-horn pointed at cold sky
- Initial result for V-Pol has a 5°K bias, consistent with pre-launch calibration uncertainty
- H-Pol showed a smaller 1°K bias
- After reflector deployment the antenna pattern correction error was calculated to be of the order of 0.1%, about 10 times smaller than what was calculated for AQUARIUS

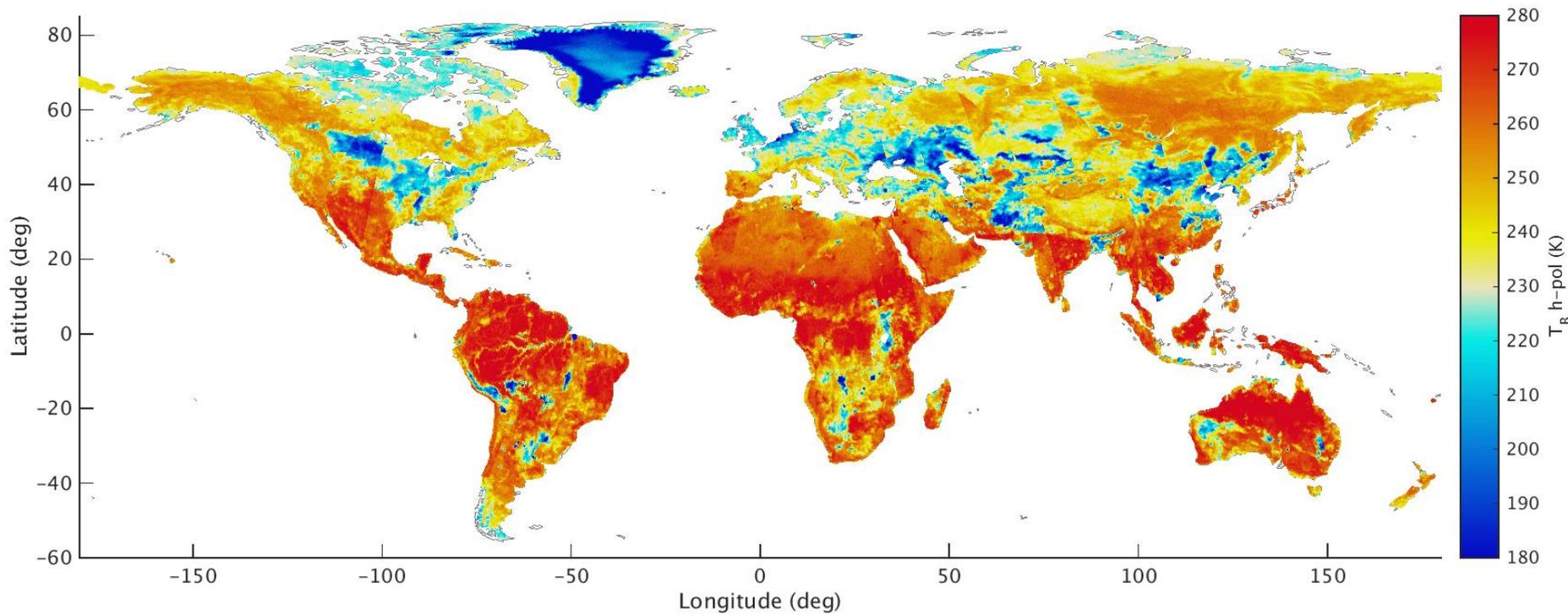


Radiometer Stokes Antenna Temperatures



(a) Vertically polarized, (b) Horizontally polarized, (c) Third and (d) Fourth Stokes parameters, respectively

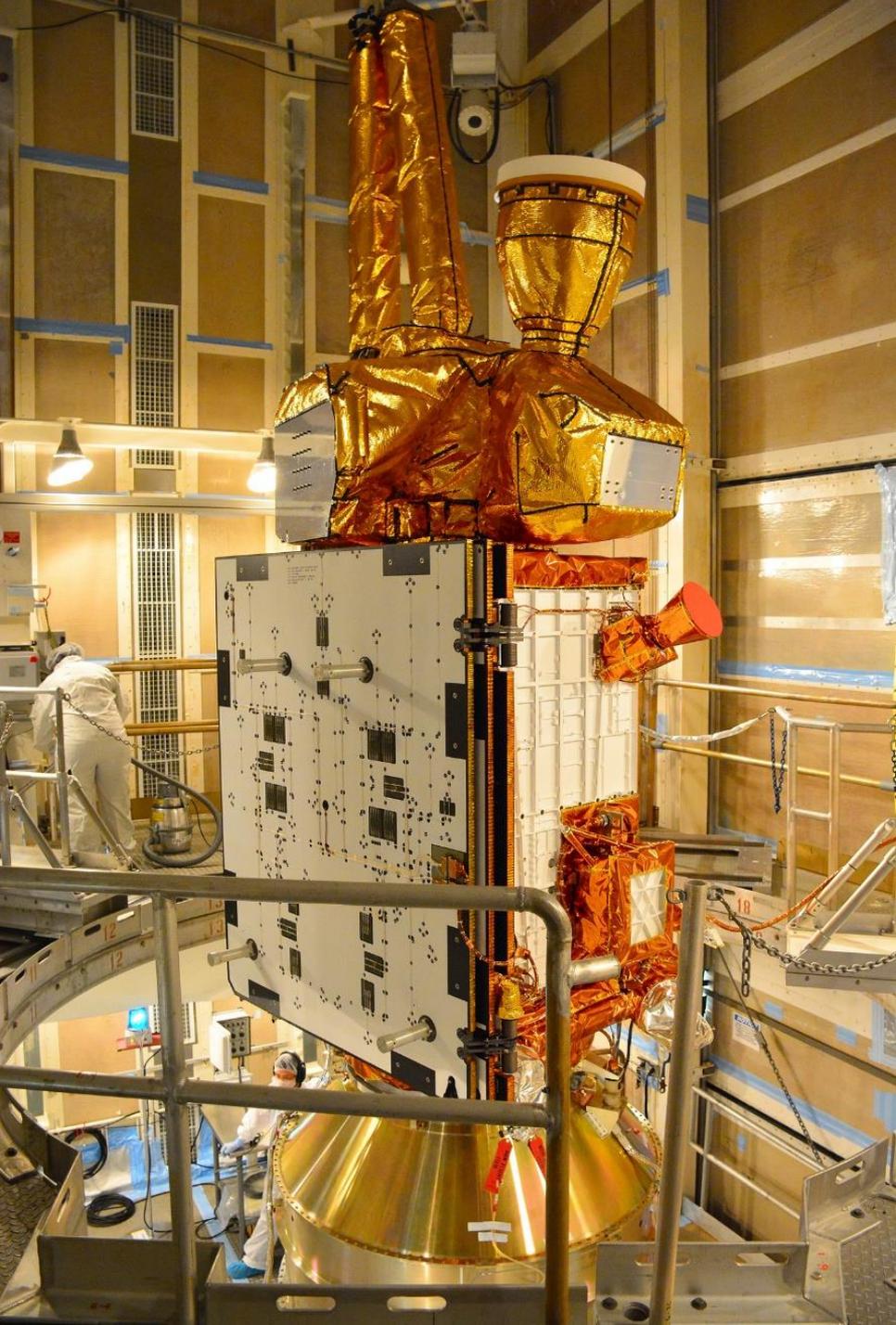
RAD Brightness Temperature (H-Pol) for First 4 Days





Conclusions

- High fidelity RF Models allowed us to predict the performance of the SMAP Instruments with extreme accuracy as demonstrated by
 - Scale Model measurements
 - Flight System Data from space
- Radiation patterns were predicted with unprecedented accuracy resulting in a residual antenna pattern correction error of just 0.1%
- Validation & Verification plans can now be based on model predictions rather than flight hardware measurements when necessary and/or cost effective
- Other missions (COWVR, SWOT, NISAR...) are already following the same strategy



Thank you!

<http://smap.jpl.nasa.gov>



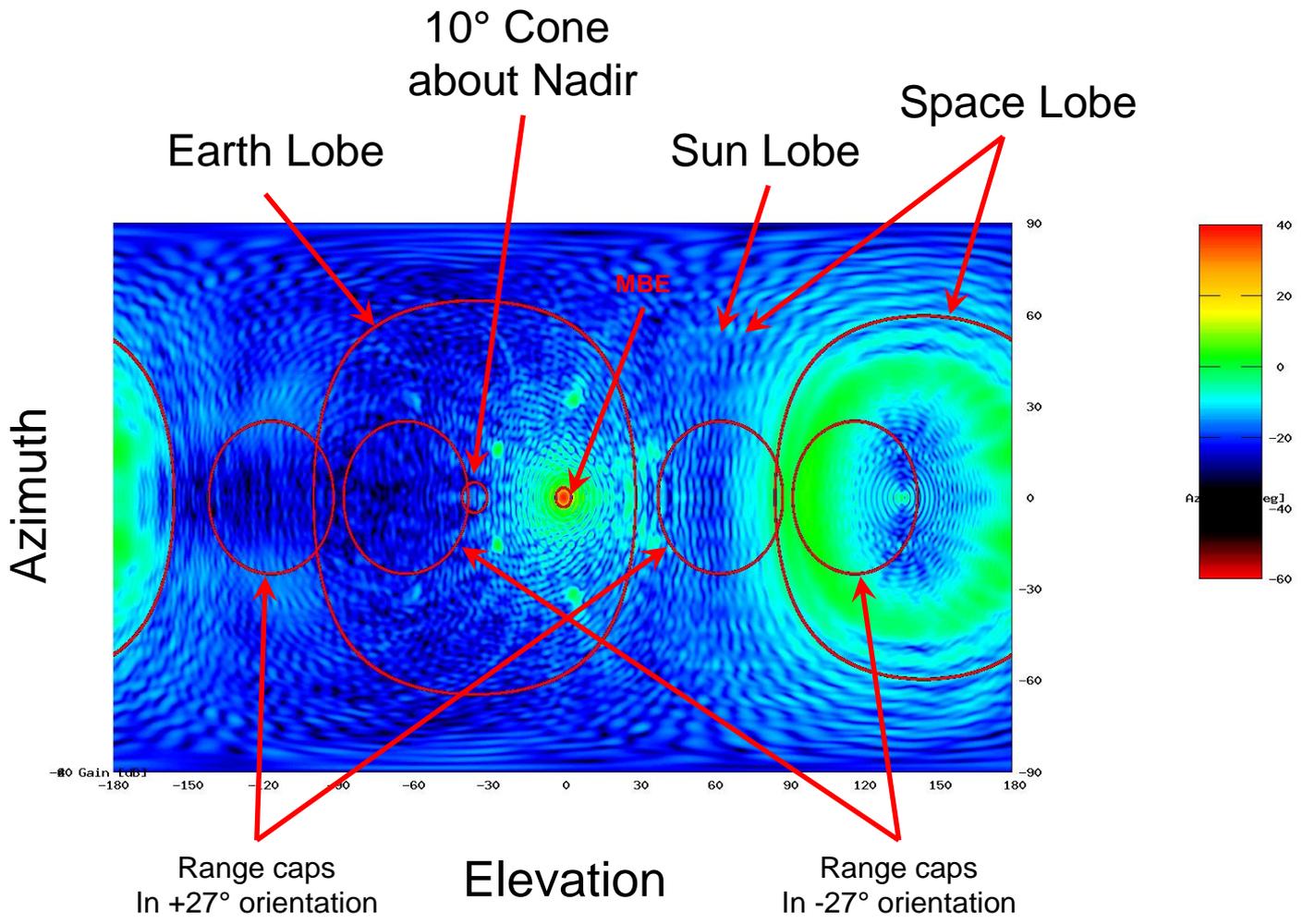
Soil Moisture Active Passive Mission

SMAP

Back-up



Pattern Legend

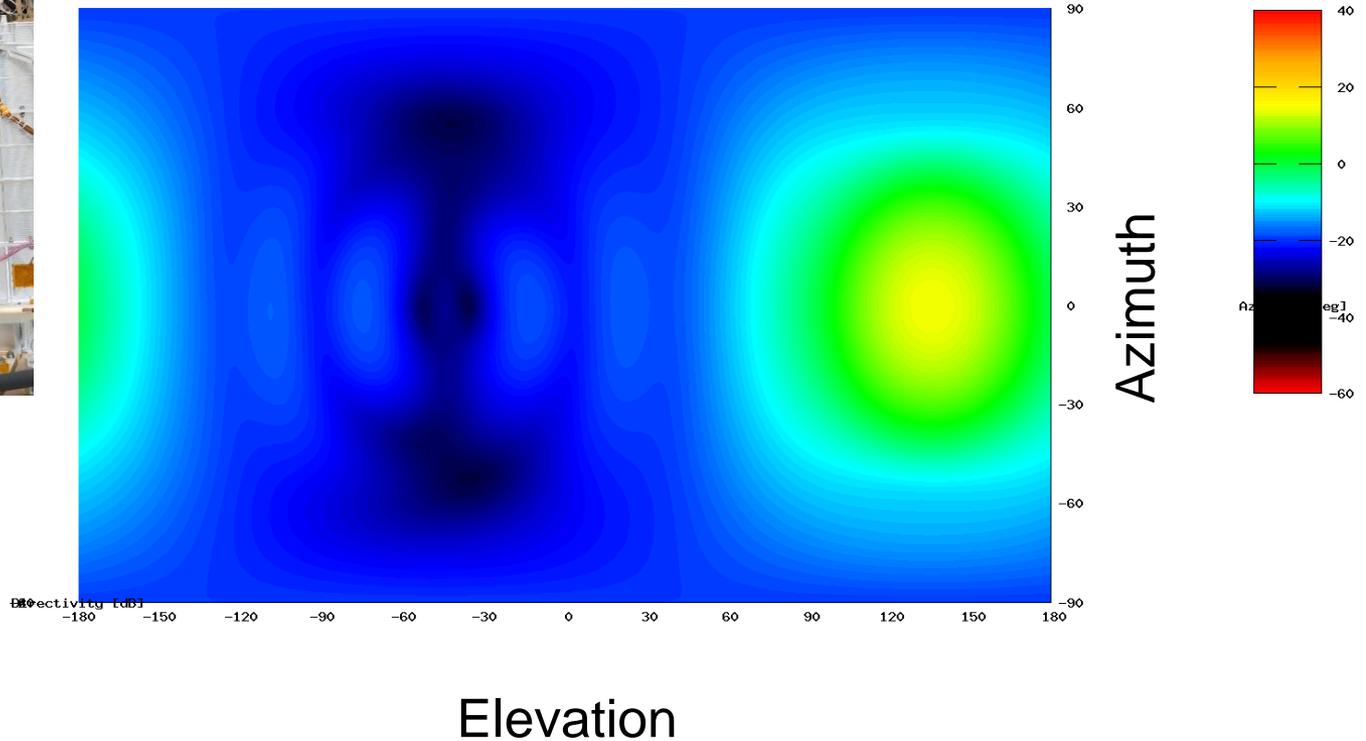


Radiation Pattern Components



Measured Feedhorn Pattern

SAR V-Pol

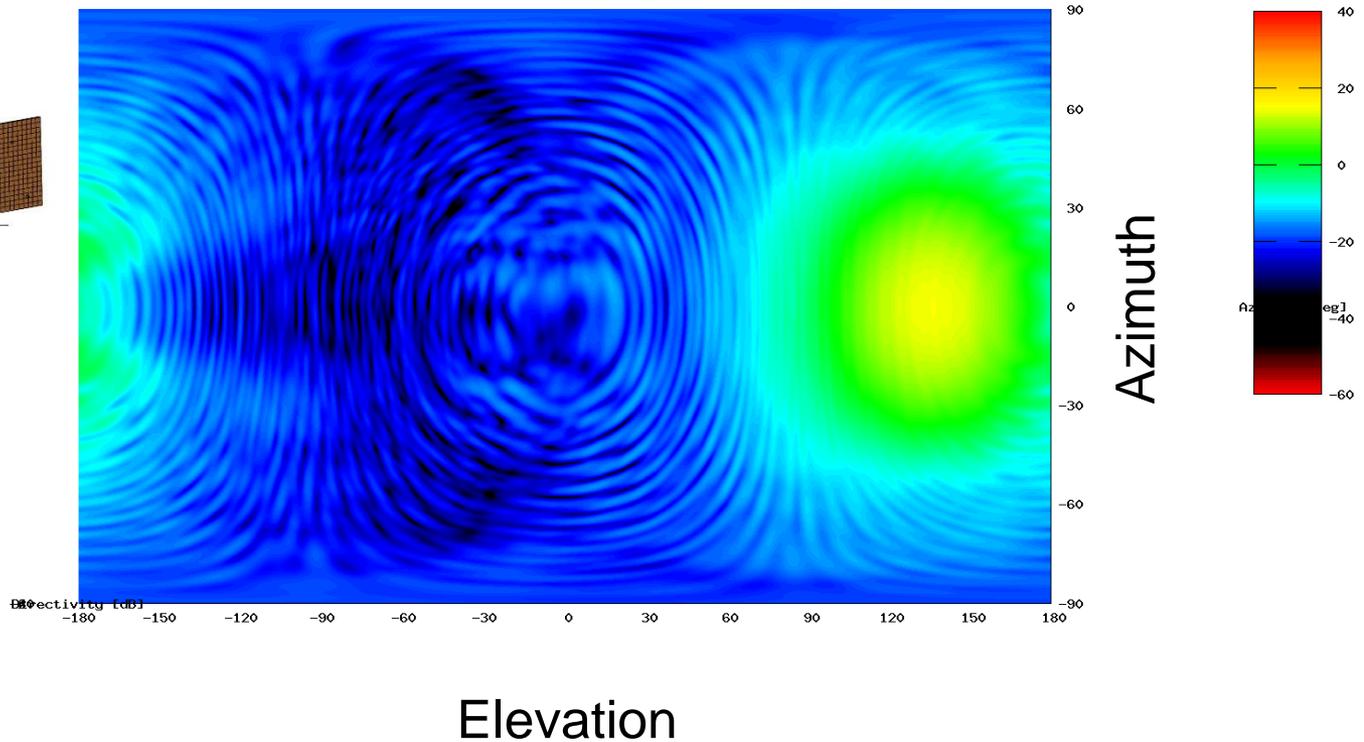
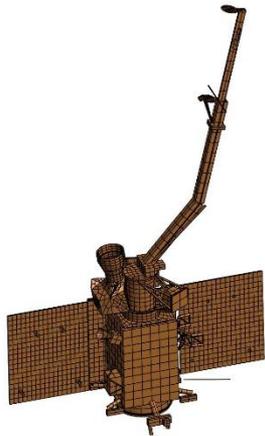


Radiation Pattern Components

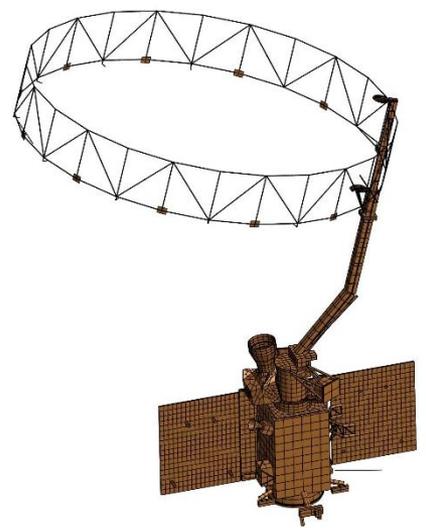


SAR V-Pol

Measured Feedhorn Pattern +
Scattering from S/C & Boom

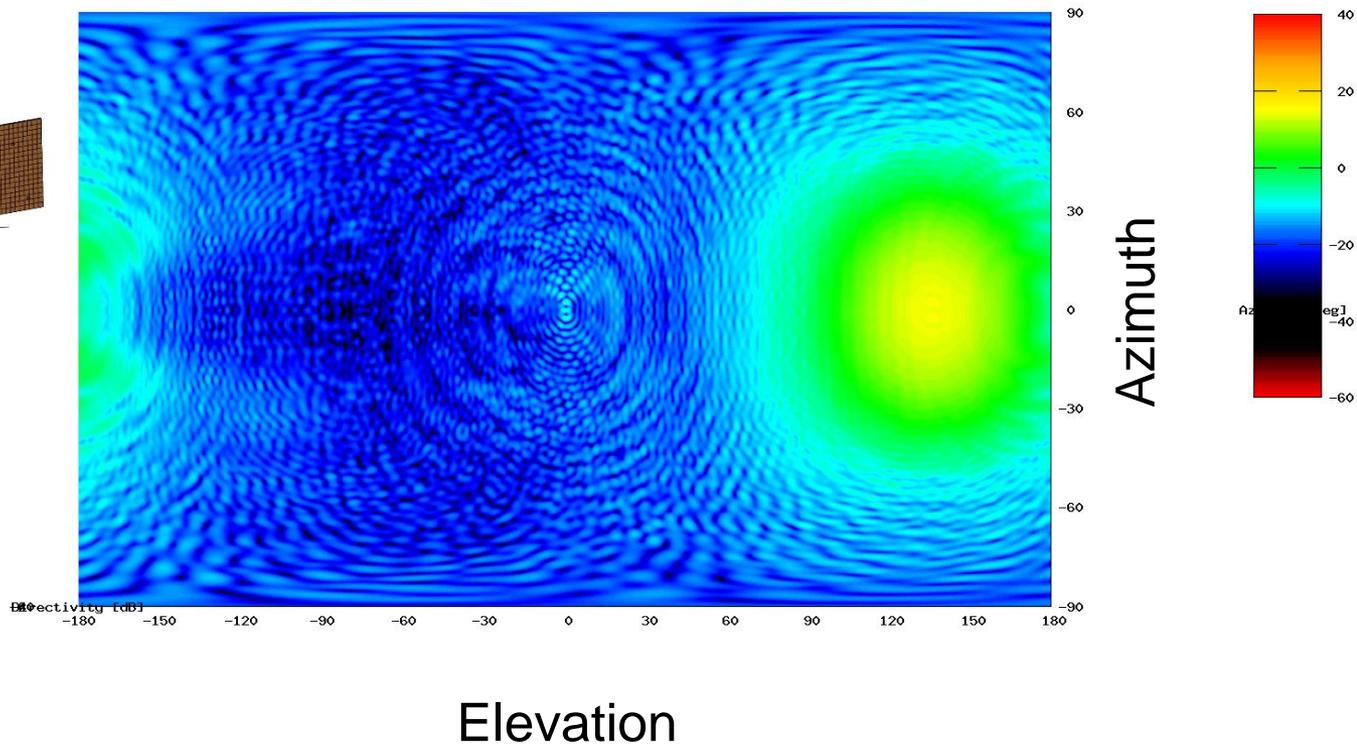


Radiation Pattern Components

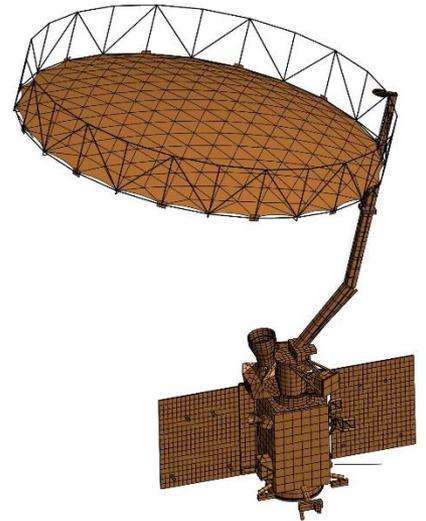


Measured Feedhorn Pattern +
Scattering from S/C, Boom & Truss

SAR V-Pol

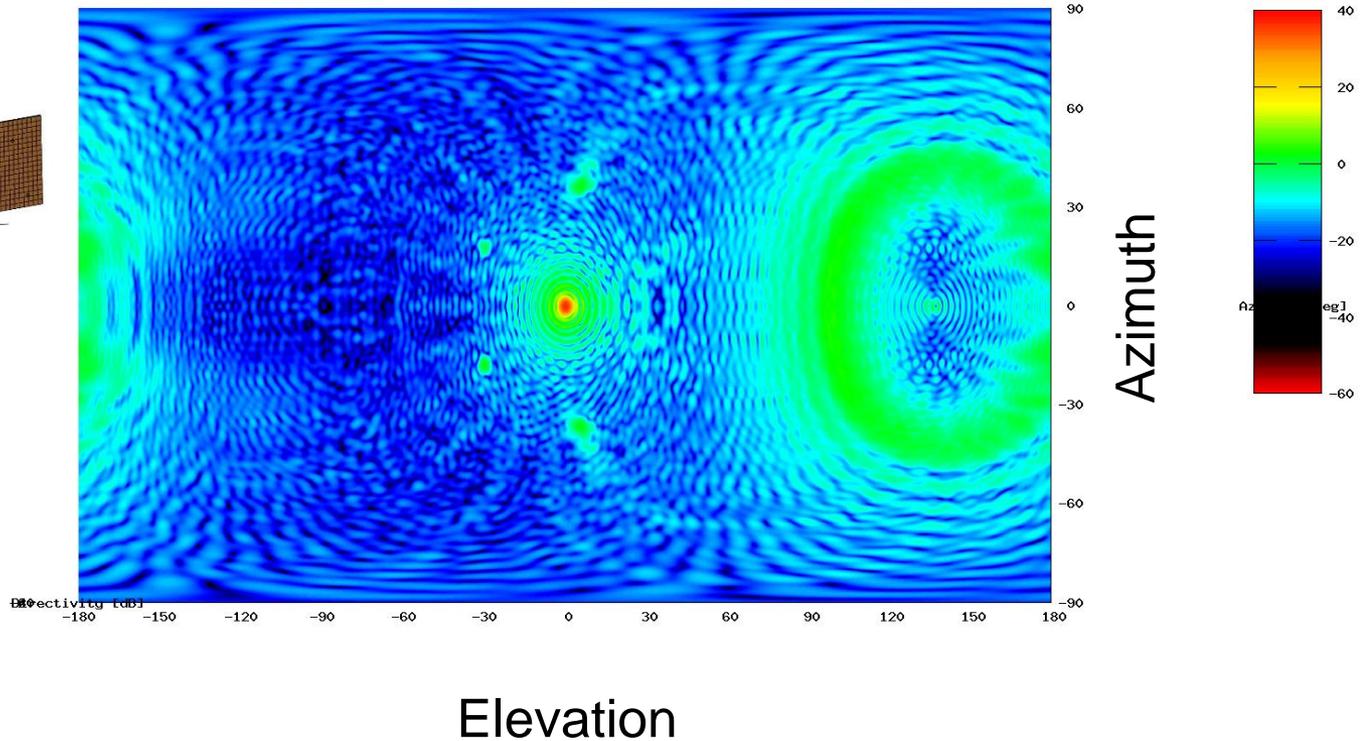


Radiation Pattern Components

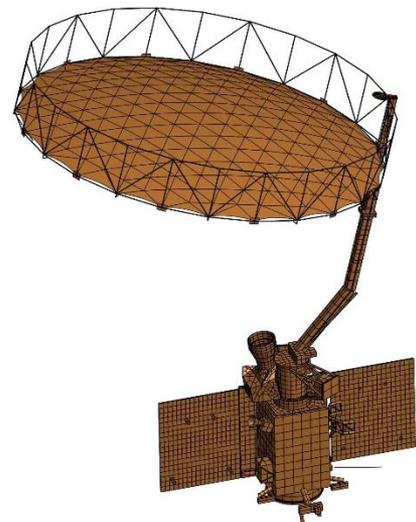


Measured Feedhorn Pattern +
Scattering from S/C, Boom & Truss +
Reflector

SAR V-Pol

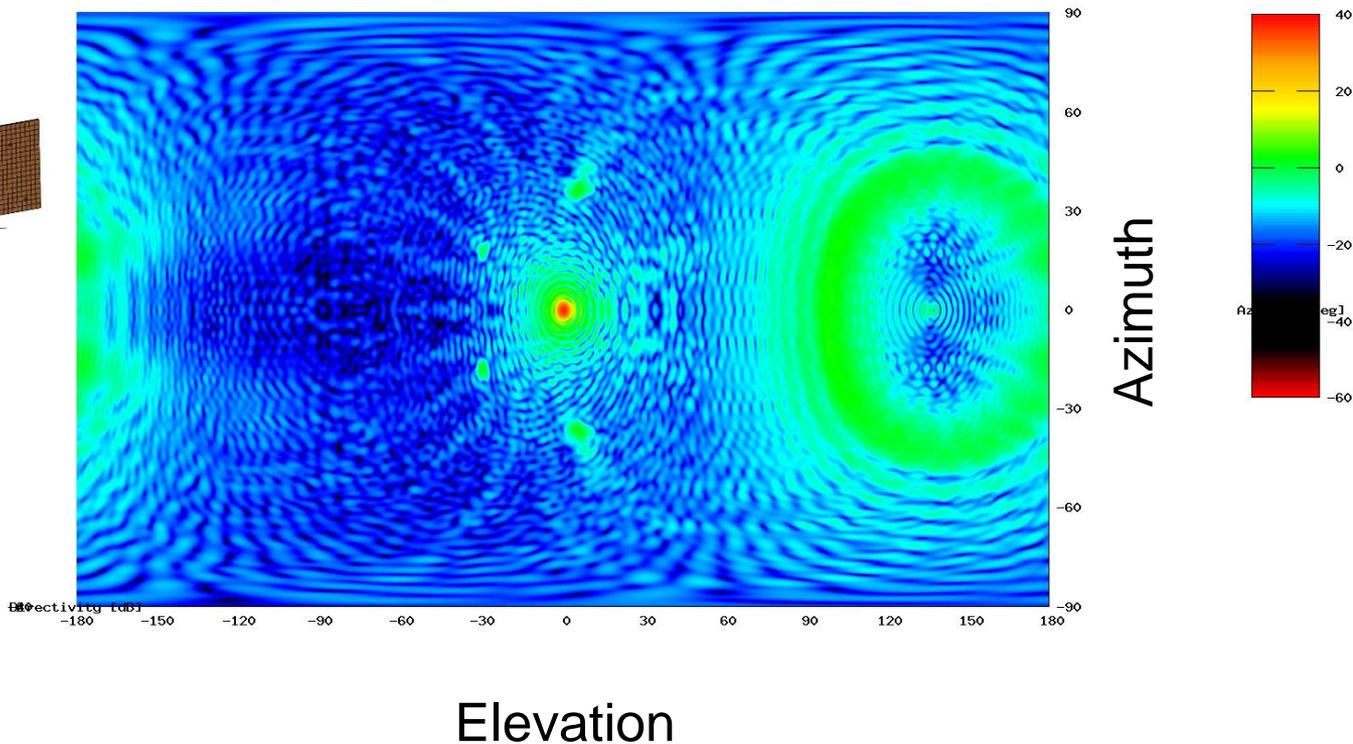


Radiation Pattern Components



Measured Feedhorn Pattern +
Scattering from S/C, Boom & Truss +
Reflector + 2nd Order Scattering

SAR V-Pol





Effect of the Spinning Reflector

SAR V-Pol

