

National Aeronautics and Space Administration



Soil Moisture
Active Passive
Mission

SMAP

Cal/Val Workshop #6

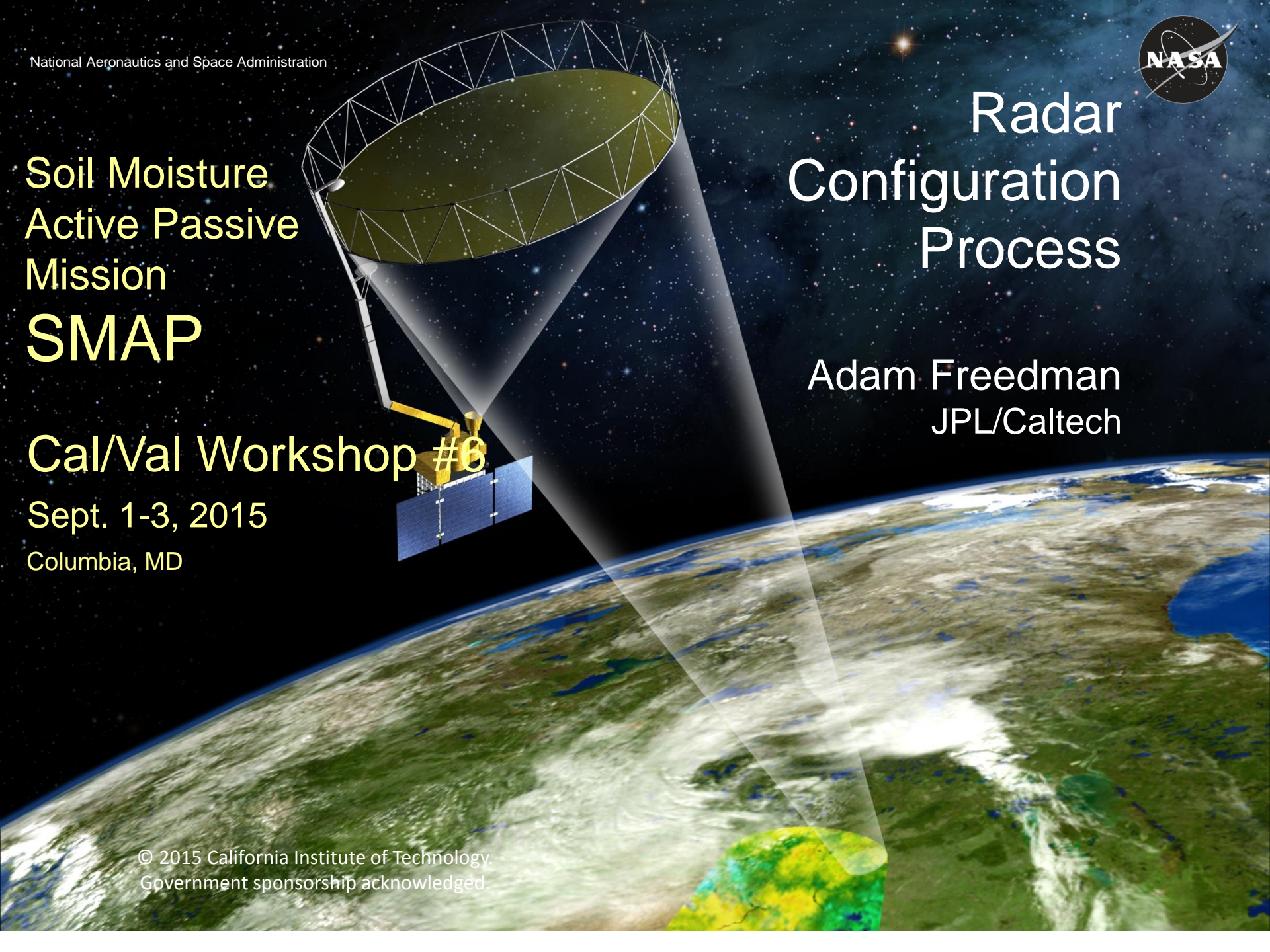
Sept. 1-3, 2015

Columbia, MD

Radar Configuration Process

Adam Freedman
JPL/Caltech

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Government sponsorship acknowledged.





Objective



- We have an **extremely well pointed, stable platform** for soil moisture and other science observations
 - We had a **full and very successful Commissioning period** to get SMAP to this point.
 - **All objectives of Commissioning were met.**
 - I summarize here the instrument calibration events during Commissioning, and significant events following Commissioning
 - These were required to configure the instrument for nominal science operations and to ensure subsequent “calibratability” of the instrument
 - There has sometimes been a need to go back to look at early, calibration data in researching issues about current science data
 - Included are dates, half-orbit numbers, and a brief description of the activity and configuration
 - Events from Observatory Checkout (3/31/15) through the present are captured in Master IOT Events List spreadsheet
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Instrument Commissioning Overview

Mission Phase

Launch

Comm. Subphase

Day 1 - Acquire SN, acquire NEN, watch S/C

Day 2-7 - GNC Checkout

Commissioning Maneuvers

Orbit: Science Orbit
Injection Orbit

GNC: RCS Control
RWA Control

Other Subsystem Checkout

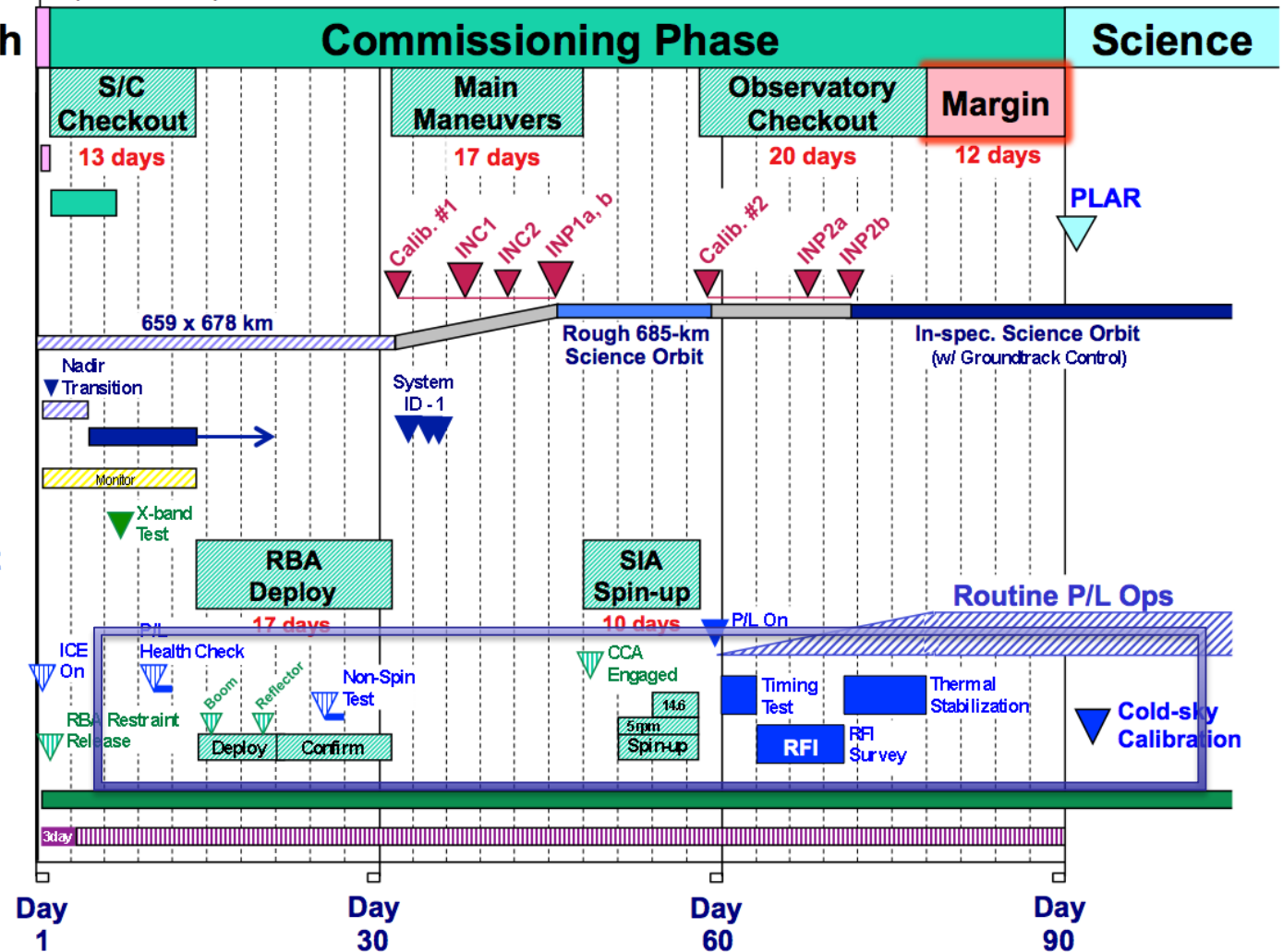
Payload Deployment and Testing

NEN Support

SN Support (TDRS)

Liftoff

(06:20:42 PST)





Instrument Health Check Test



- Test Objectives
 - Instrument health checkout: Do SAR and RAD power on in a healthy, expected state?
 - SAR cannot yet transmit due to bakeout restrictions
 - Collect radiometer view of cold sky prior to reflector deploy for aid in future calibration
 - Assess radome emissivity using its large temperature swings over an orbit against a stable background without reflector
- Test Results
 - Instrument healthy
 - Some Science data gaps due to X-band downlink issues
 - Radome emissivity ambiguous
- Begin test
 - 2/12/15 16:45 Begin power-on sequence
 - DOY 043
 - Orbit 0176_D
- End Test
 - 2/13/15 22:15 End power-off sequence
 - DOY 044
 - Orbit 0195_A
- Radiometer
 - High rate data
 - Mostly RAD LUT 744; LUT 6,7,8,38 cal
- Radar
 - Receive only
 - 25% high-res every scan
 - PRI mostly 354.4 μ sec
- Other
 - Not yet spinning
 - Antenna not deployed



Instrument Non-Spin Test



- Test Objectives

- Verify Instrument health and function after reflector/boom deployments
- Verify health of radar transmit chain
- Confirm echo power and radar timing
- Evaluate performance of deployed reflector prior to spin-up.
- Collect early data to validate timing/pointing algorithms and RFI survey tool

- Test Results

- Instrument healthy following deployment
- Radar transmit power stable
 - No sign of anomalous RF behavior
- REV commanding for PRI vs latitude
- Echo power levels close to expected values and pointing errors are small
- Successful deployment!
 - 0.2° pointing bias, 2 dB echo bias, echo shape and RAD TB match predictions, all within expected uncertainty

- Begin test

- 2/25/15 23:09 Power-on radar in receive-only mode
- DOY 056, Orbit 0372_A
- 2/27/15 17:54 Enable SAR transmit, preceded by radiometer power on
- DOY 058, Orbit 0397_D

- End Test

- 2/28/15 19:24 Disable SAR Transmit
- DOY 059, Orbit 0413_A
- 3/1/15 00:16 End power-off sequence
- DOY 060, Last data Orbit 0415_A

- Radiometer

- Manual REV LUT control to match radar; high-rate data; LUT 6,7,8,38 cal

- Radar

- Manual REV control for PRI vs lat; alternating hi/low res collection around orbit

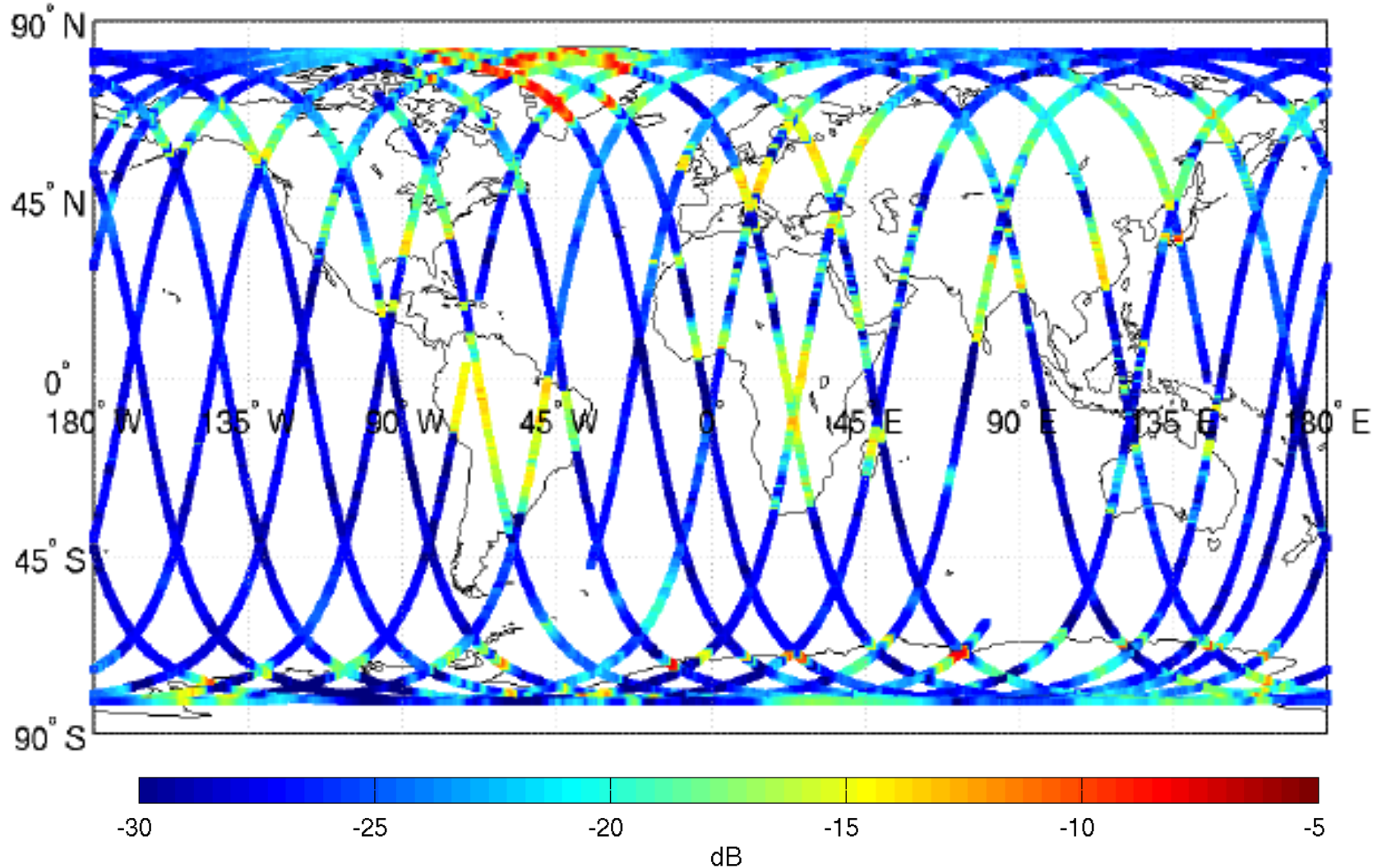
- Other

- Antenna deployed, but not yet spinning
- First-light maps of “string-bean” swaths



“First Light” Radar Image

One-day normalized radar cross-section (σ_0 HH) from Non-Spin Test (low-res radar L1B data)





Observatory Checkout: Timing Test



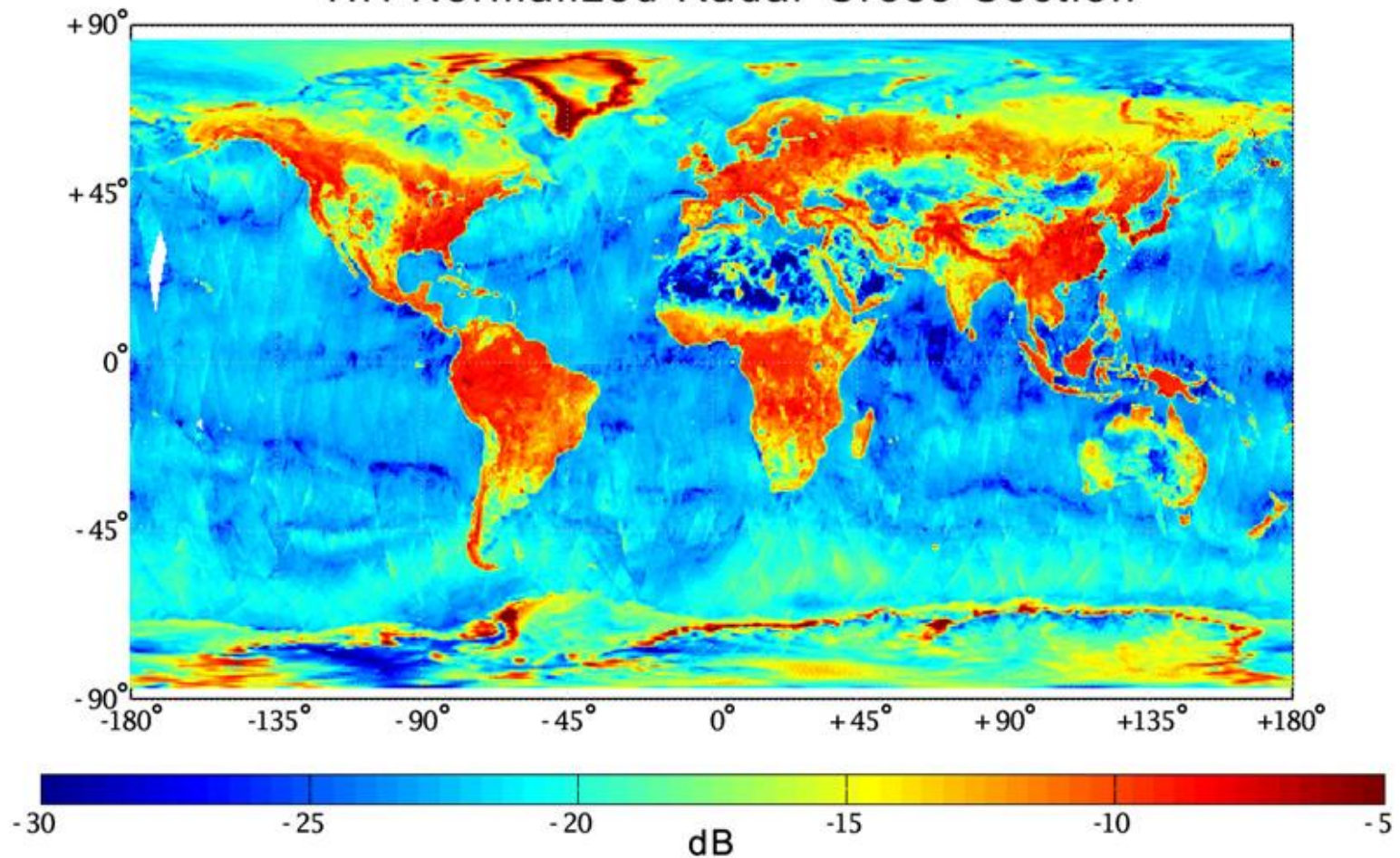
- Test Objectives
 - Assess health of SAR and radiometer following CCA pyro firing and release, and spin-up
 - Estimate nadir pointing offset of spacecraft
 - Estimate look angle offset of reflector
- Test Results
 - Instrument operating nominally following CCA release and spin up
 - Corrections estimated for attitude adjustment
 - 0.07° Rx roll, 0.02° Ry pitch
 - Confirmed after attitude adjustment
 - Estimated look angle offset
 - 0.3° outward (angle wrt nadir of 35.8°)
 - First global maps: “second-look” full swath maps
- Begin test
 - 3/31/15 16:25 Begin instrument power-on sequence
 - DOY 090, Orbit 0866_A
- End Test
 - 4/3/15 16:30 Disable SAR transmit
 - DOY 093, Orbit 0908_A
 - 4/3/15 16:38-19:59 RAD LUT 38 collection
- Radiometer
 - Continuous high-rate data collection for 3 days
 - 3 orbits of LUT 38 for rad calibration
- Radar
 - Timing Test LUT: Alternates hi-res and low-res data collection over every orbit
- Other
 - Antenna spinning
 - Not yet fully nadir pointed



“Second Light” Global Radar Image

March 31 - April 3, 2015

HH Normalized Radar Cross-Section

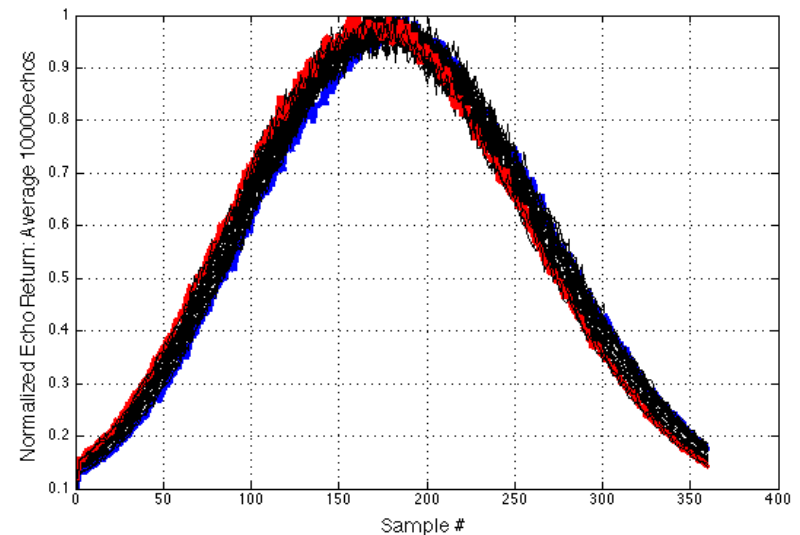
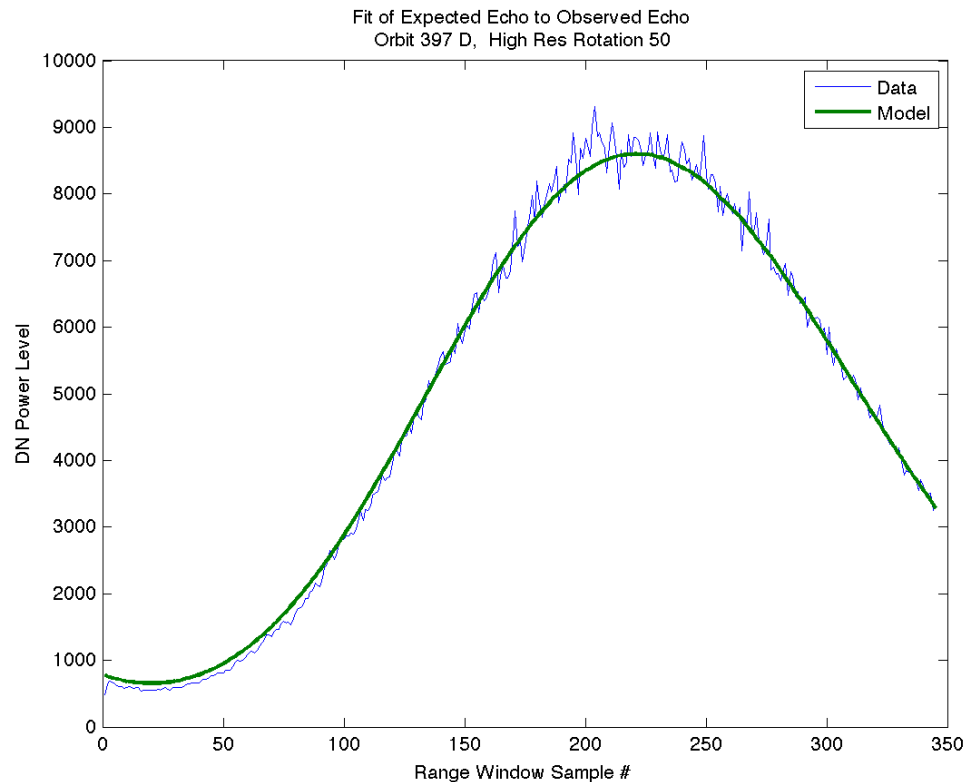


Sigma-0 HH from low-res radar L1B; 3-day collection from timing test



Sample of Commissioning Test Results

- Fit of model echo for fully-deployed reflector to measured echo after reflector deployment
- Variation in echo after spin-up due to small error in nadir pointing
- Echo “vibrates” back and forth as we spin





Observatory Checkout: RFI Survey

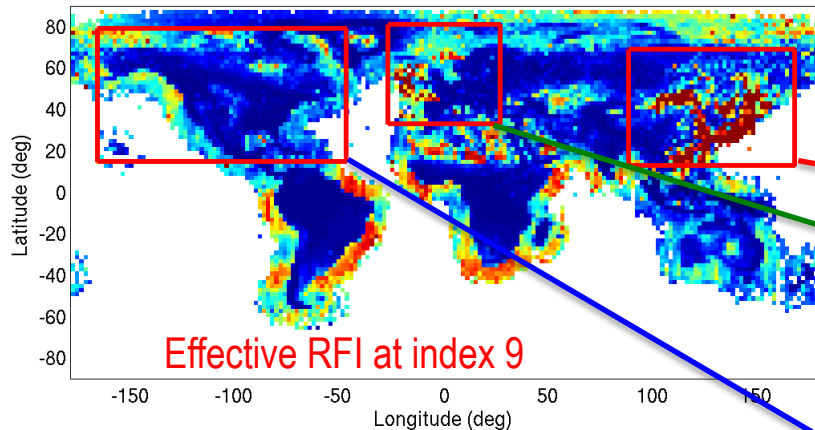


- Test Objectives
 - Assess RFI density across the SAR frequency spectrum both regionally and globally
 - Identify the least RFI-cluttered frequency or frequencies for long term SAR operation
 - Radiometer Bake-out
- Test Results
 - RFI density assessed globally
 - All frequencies were sampled, but 5 focus frequencies chosen
 - Frequency index 5 is preferred
 - Center 1225 MHz, V-pol 1223.5, H-pol 1226.5
 - One of cleanest RFI regions
 - Avoids GPS at 1227.6 MHz
 - Predicted echo error due to RFI
 - ~0.01 dB co-pol, vs 0.4 dB requirement
 - ~0.08 dB cross-pol, vs 0.8 dB requirement
 - 2-4 times better than worst frequencies
- Begin test
 - 4/3/15 21:40 Start of RFI Survey 12-frequency sequence
 - DOY 093, Orbit 0912_A
 - 4/6/15 16:51 RFEA Bakeout begins
 - 4/7/15 18:17 Switch to 48-freq sequence
 - 4/10/15 16:58 RFEA Bakeout ends
 - 4/10/15 18:30 Switch to 5-freq sequence
- End Test
 - 4/13/15 17:10 SAR Transmit enabled
 - DOY 103, Orbit 1055_D
- Radiometer
 - Nominal LUT-controlled data collection
 - 3-day bakeout at 28 C, then return to 20 C
- Radar
 - Radar in receive-only mode, special RFI Survey collections, LUT hi-res control
- Other
 - First nadir pointing bias adjustment

RFI Regional Statistics— Globally and Regionally Benign at Index 5

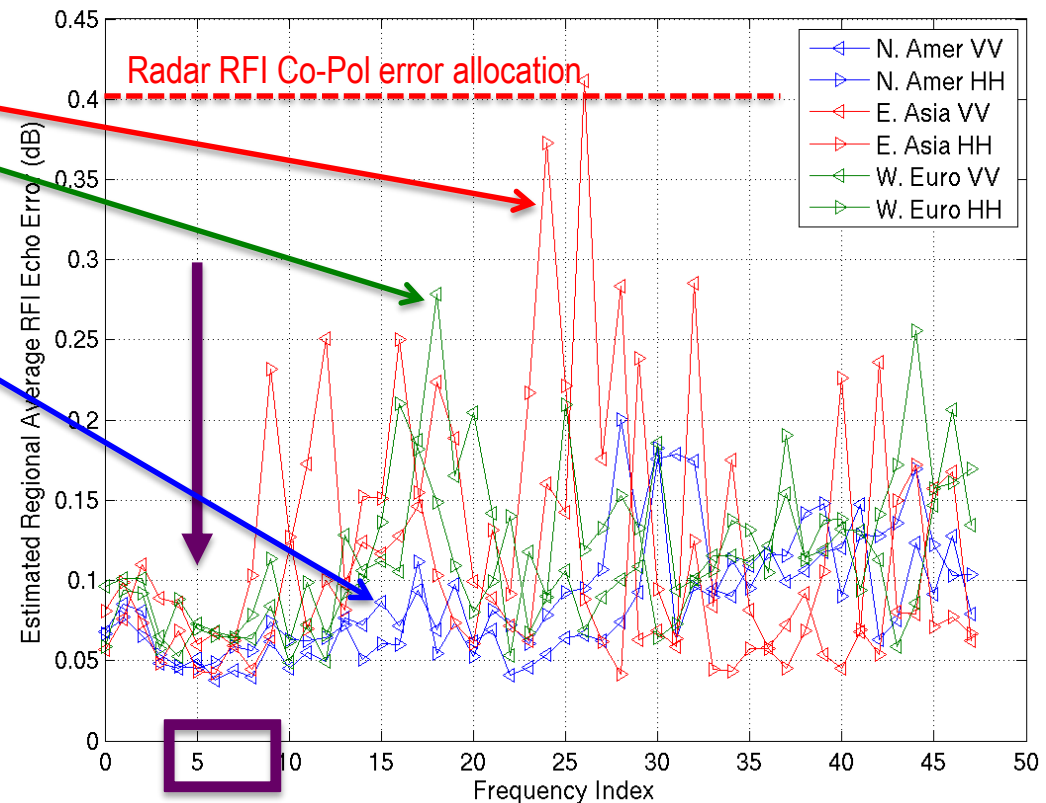


HH RFI Echo Error, Data Thru 01055A (f09; Meas XPol SNR; 6,15 dB Thresh) [0-0.4 dB color lim]



- Plot shows RFI error averaged over regions shown on map
- RFI error depends on SNR, so plot is not direct measure of raw RFI
- One frequency will be used globally

RFI Echo Error, Meas XPol SNR, Data Thru 01055A (6,15 dB Thresh)



f05-f07 looks best everywhere

RFI environment is manageable with one transmit frequency globally

Observatory Checkout: Final Stabilization



- Test Objectives

- Final configuration for science data collection
- Nadir pointing correction
- Science LUT
- Thermal stabilization
- Initial Cold-Sky Calibration (CSC)

- Test Results

- Needed second Timing Test to confirm pointing correction
- Pointing correction was wrong sign; needed second nadir pointing correction and third Timing Test to confirm
- First CSC-110 successful; 110 degree pitch aft to view deep space for rad cold calibration
- LUT evolution to an “all-land” (excluding Antarctica) high-res SAR data collection strategy using frequency index 5

- Begin phase

- 4/13/15 17:10 SAR Transmit enabled
- DOY 103, Orbit 1055_D

- End Phase

- Near end of Commissioning
- 5/4/15 21:04 Activated All-Land LUT
- DOY 124, Orbit 1365_A

- Radiometer

- Under LUT control for PRI and hi/low data rate collection

- Radar

- Under LUT control, transmit enabled, HV high-res cross-polarization, initially freq index 9, changing to index 5

- Other

- RFEA front end ATC control tightened from 1 C to 0.1 C on 4/14/15 16:48



Nominal Science Phase Events



- Eclipse Season
 - Begins 5/6/16
 - Maximum eclipse 6/22/15
 - Ends 8/4/15
 - Large scale spacecraft cooling during eclipse period
 - Outside of eclipse, temps governed by solar beta angle
- CSC
 - Monthly CSC with 110 deg turn aft
 - One CSC with 180 deg turn over ocean-Amazon transition on 6/22/15
- Power cycle events
 - Spacecraft safing event due to SRU lockup; instruments powered down
 - 5/12/15 – 5/14/15
 - Flight Software (FSW) update 4.3
 - Instruments powered down
 - 6/15/15 – 6/17/15
 - Allows bad-block table updates; two have been performed plus earlier BB table updates during power cycling events
- HPA Anomaly
 - SAR Transmit ceases
 - 7/7/15 21:16
 - DOY 188, Orbit 2301_A
 - Recovery and diagnosis activities
 - 7/9/15 Reset and power cycle HPA
 - Radiometer put into diagnostic mode (no science data) during subsequent HPA testing
 - 7/13/15 Power cycle radar
 - 7/14/15 Power cycling HPA to ascertain switch health and current draw
 - 7/16/15 HPA Under-voltage protection test
 - 7/23/15 HPA 100-power-cycle test for current draw statistics
 - 7/28/15 HPA 6-hour test for thermal dissipation/power
 - 8/24/15 HPA 6-hour test repeat
- Post-Anomaly
 - RAD placed in continuous high-rate mode
 - LUT frequency change to index 6 for bistatic GPS studies, PRI fixed for RAD calibration



Current Operations Status (as of 9/1/15)



- Spacecraft mode is SYS_SCIENCE
 - S/C maintained by reduced Flight Ops Team with significant automation
 - Instrument in “new” nominal science mode
 - Radiometer collecting hi-rate data continuously at fixed PRI
 - Radar in receive-only mode with inoperable HPA, LUT-controlled hi-res data collected for all land areas and Atlantic Hurricane Alley, frequency index 6 for bistatic GPS
 - Monthly cold-sky calibration (CSC) maneuvers where S/C pitches aft by 110 degrees to observe the galaxy with reduced side-lobes directed to nadir.
 - Orbit trim maneuvers (OTMs)
 - Expected roughly every 3 months to maintain science reference trajectory
 - Update and activate new LUT when requested
 - Planning automatic bad-block repair
 - Current average daily data volume (radar + radiometer) slightly exceeds allocated data volume, but do not expect any problems
-

Master IOT Events (1/2): End of Commissioning



| Date | Time Start | Time End | DOY | Orbit# | Description | Instrument Power | SAR TX | LUT | Attitude | Calibration | Data Quality |
|---------|------------|----------|-----|--------|---|------------------|--------|-----|----------|-------------|--------------|
| 3/31/15 | 16:25 | 18:14 | 090 | 866.0 | Instrument powered on, TX Enabled, Timing Test LUT, radiometer high-rate data collection for 3 days | X | X | X | | | |
| 4/3/15 | 16:30 | approx | 093 | 908.0 | SAR transmit disabled, LUT 38 RAD test, begin RFI survey, RFI-survey Science LUT | | X | X | | | X |
| 4/6/15 | | | 096 | | Radiometer bake out for 3 days (DOYs 96-100) | X | | | | | X |
| 4/10/15 | 20:16 | | 100 | 1013.5 | Nadir bias adjustment | | | | X | | |
| 4/13/15 | 17:10 | | 103 | 1055.5 | SAR transmit enabled after RFI survey | | X | | | | X |
| 4/13/15 | 18:39 | | 103 | 1056.0 | ALT1 Science LUT activated, Index 9 | | | X | | | |
| 4/14/15 | 16:48 | | 104 | 1069.5 | ATC set point reduced from 1.0 to 0.1 degree | | | | | X | |
| 4/16/15 | 17:10 | 17:35 | 106 | 1099.0 | Orbit trim maneuver (OTM) #1 (17:20:00) | | | | X | | |
| 4/16/15 | 20:39 | | 106 | 1101.5 | Timing Test LUT | | | X | | | |
| 4/17/15 | 20:28 | | 107 | 1116.0 | Re-activated ALT1 Science LUT | | | X | | | |
| 4/17/15 | 20:29 | | 107 | 1116.0 | Radiometer begins 3 days of continuous high-rate data collection | | | X | | X | |
| 4/20/15 | | 20:38 | 110 | 1159.5 | Radiometer high-rate collection ends | | | X | | X | |
| 4/22/15 | 22:25 | | 112 | 1190.0 | Activated Timing Test LUT | | | X | | | |
| 4/23/15 | 16:58 | | 113 | 1201.5 | Cold Sky Calibration, 110 degrees | | | | X | X | |
| 4/23/15 | 19:12 | | 113 | 1203.0 | Nadir bias adjustment | | | | X | X | |
| 4/24/15 | 16:26 | | 114 | 1215.5 | Activated ALT1 Science LUT with freq Index 5 | | | X | | | |
| 4/29/15 | 17:05 | 17:13 | 119 | 1289.5 | Activated N&S_AMERICA LUT | | | X | | | |
| 5/4/15 | 20:56 | 21:04 | 124 | 1365.0 | Activated ALL_LAND LUT | | | X | | | |

- Updating LUTs to increase radar high-res data coverage
- Adjust, then correct nadir bias of spacecraft
- Initial Cold-Sky Calibration slew
- 3-day continuous radiometer data collections for ocean calibration
- First Orbit Trim Maneuver (OTM)

Master IOT Events (2/2): Nominal Science Ops



| Date | TimeStart | TimeEnd | DOY | Orbit# | Description | Instrument Power | SAR TX | LUT | Attitude | Calibration | Data Quality |
|---------|-----------|----------|---------|---------------|--|------------------|--------|-----|----------|-------------|--------------|
| 5/6/15 | | | 126 | | EclipseSeasonBegins | | | | | X | |
| 5/12/15 | 9:58 | | 132 | 1475.0 | SMAPentersSafeMode(InstrumentsOff) | X | | | | | |
| 5/14/15 | 16:25 | 18:13 | 134 | 1509.5 | InstrumentsTurnedBackOn | X | X | | | | X |
| 5/27/15 | 15:01 | 15:29 | 147 | 1697.5 | ColdSkyCalibration,110Degrees(15:10-15:16) | | | | X | X | |
| 6/1/15 | 21:12:24 | | 152 | 1774.5 | SmallLUT-syncOffsetof63seconds | | | X | | | |
| 6/15/15 | 18:13:30 | 18:15:38 | 166 | 1977.5 | SARtransmitdisabled,SARRF/HPApoweredDownforFSW upgrade | X | X | | | X | X |
| 6/16/15 | 13:46 | | 167 | 1989.0 | RadiometerpoweredDown;RadarDig/synthpoweredOff | X | | | | | |
| 6/17/15 | 20:17 | | 168 | 2008.0 | RadiometerpoweredOn | X | | | | | |
| 6/17/15 | 21:51:30 | | 168 | 2009.0 | SARtransmitEnabled | X | X | | | | X |
| 6/22/15 | 09:23 | 10:04 | 173 | 2074.5 | ColdSkyCalibration,180Degrees(09:38-09:48) | | | | X | X | |
| 6/22/15 | | | 173 | | MaximumEclipse | | | | | X | |
| 6/30/15 | 14:36 | 15:04 | 181 | 2194.5 | ColdSkyCalibration,110Degrees(14:45-14:51) | | | | X | X | |
| 7/7/15 | 16:52 | 17:00 | 188 | 2298.5 | ActivateAtlanticHurricaneLUTwithRev_endand hstart/hstopcorrections | | | X | | | |
| 7/7/15 | 21:16:12 | | 188 | 2301.0 | HPApower-offanomaly;SARTXleaves | X | X | | | X | X |
| 7/9/15 | 19:48 | 19:55 | 190 | 2329.5 | AnomalyTesting(precededbyplacingSARinSafeState) | X | | X | | | |
| 7/13/15 | 15:44 | 17:25 | 194 | 2385.5-2386.5 | PowercycleRadar,RadiometerinDiagnosticmode | X | | | | | X |
| 7/13/15 | 19:48 | | 194 | 2388.0 | RadiometerResettoScienceMode | X | | | | | X |
| 7/14/15 | 16:21 | 19:36 | 195 | 2400.5-2402.5 | AnomalyTesting,RADinDiagnosticmodeforthisperiod | X | | | | | X |
| 7/16/15 | 17:26 | 17:29 | 197 | 2430.0 | AnomalyTesting,RADinDiagnosticmodeforthisperiod | X | | | | | X |
| 7/23/15 | 21:01 | 22:45 | 204 | 2535.0-2536.0 | AnomalyTesting,RADinDiagnosticmodeforthisperiod | X | | | | | X |
| 7/28/15 | 16:35 | 00:04 | 209-210 | 2605.0-2609.5 | AnomalyTesting,RADinDiagnosticmodeforthisperiod | X | | | | | X |
| 7/29/15 | 19:01:13 | | 210 | 2621.5 | RadarReceive-modeoperationEnabled | | | X | | | X |
| 7/30/15 | 16:58 | 17:24 | 211 | 2635.0 | OrbitTrimManeuver(OTM)#2(17:07:57) | | | | X | | |
| 8/4/15 | 14:49 | 15:16 | 216 | 2706.5 | ColdSkyCalibration,110Degrees(14:58-15:04) | | | | X | X | |
| 8/4/15 | | | 216 | | EclipseSeasonEnds | | | | | X | |
| 8/6/15 | 17:25 | | 218 | 2737.5 | BadBlockTableUpdated | | | | | | X |
| 8/11/15 | 21:14 | | 223 | 2813.0 | Radiometerbeginscontinuoushi-rateDataCollection | | | X | | X | |
| 8/19/15 | 23:40 | | 231 | 2931.5 | BadBlockTableUpdated(2SAR,1RAD,BBs) | | | | | | X |
| 8/20/15 | 17:41 | 17:49 | 232 | 2942.0-2942.5 | NewLUTwithFreqIndex6andConstantPRIActivated (LOAD_LUT_AH2NPR_G150810210248_ALTFR6.bin) | | | X | | X | |
| 8/20/15 | 17:50 | | 232 | 2942.5 | SARhi-rescross-polSettoVH | | | | | X | |
| 8/24/15 | 17:01 | 23:11 | 236 | 3000.5-3004.0 | ~6hourThermalTestofpoweredHPA,RADinDiagnostic | X | | | | | X |
| 8/24/15 | 23:15 | | 236 | 3004.0 | RadReset,BVDTEnabled,continuoushi-rateDataCollection | | | | | | X |

- Safe Mode and FSW-update power cycling
- Regular CSC-110 slews, one CSC-180 slew
- Eclipse season
- SAR HPA failure; subsequent trouble shooting
- Orbit trim maneuver (OTM)
- Bad block table updates
- RAD put into continuous high-rate mode
- Radar coverage, frequency, PRI modified



Master IOT Events: Explanation of Terms



- Bad block table update
 - Non-volatile flash memory (NVP) has blocks that degrade over time. When one occurs, science data are corrupted. Updating the table tells FSW to not write to these bad blocks
- Cold Sky Calibration (CSC)
 - Turn spacecraft to point to sky for radiometer calibration. Most are 110 deg turns to the aft, but one was a 180 deg zenith turn for backlobe calibration
- LUT update/activation
 - The LUT controls the radar high-res data collection and operating frequency. We gradually increased radar mapping as we verified the data volume downlink process
- LUT-sync offset
 - Aligned the LUT control more accurately with spacecraft location
- Nadir bias adjustment
 - Small reorientation of the spacecraft to better align the spin axis with nadir
- Orbit Trim Maneuver
 - Spacecraft orbit correction to maintain true orbit close to reference trajectory
- Radiometer: diagnostic mode and science reset
 - For HPA trouble shooting, we put the RAD into diagnostic mode (no science data collected), then reset to science mode afterwards
- Radiometer: high-rate data collection
 - Allows the radiometer to collect high-rate, sub-band data continuously
- Safe Mode
 - Spacecraft safing turns off power to both Radiometer and Radar, requiring a restart and thermal stabilization period