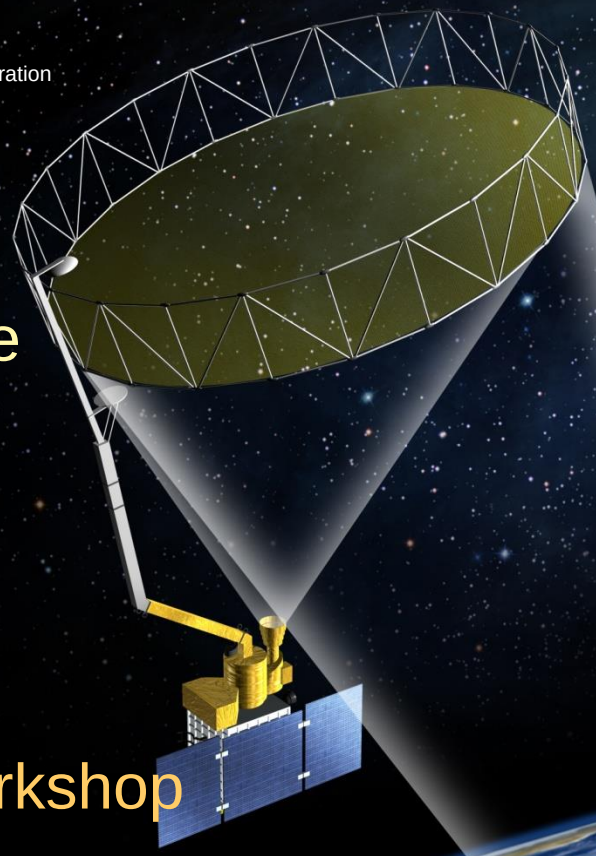
National Aeronautics and Space Administration



Soil Moisture Active Passive Mission SMAP

L1 Radiometer T_B

Ed Kim, L1TB Cal/Val Lead
J. Piepmeier, P. Mohammed,
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D. Hudson, D. Dawson

4th Cal/Val Workshop

Pasadena, CA

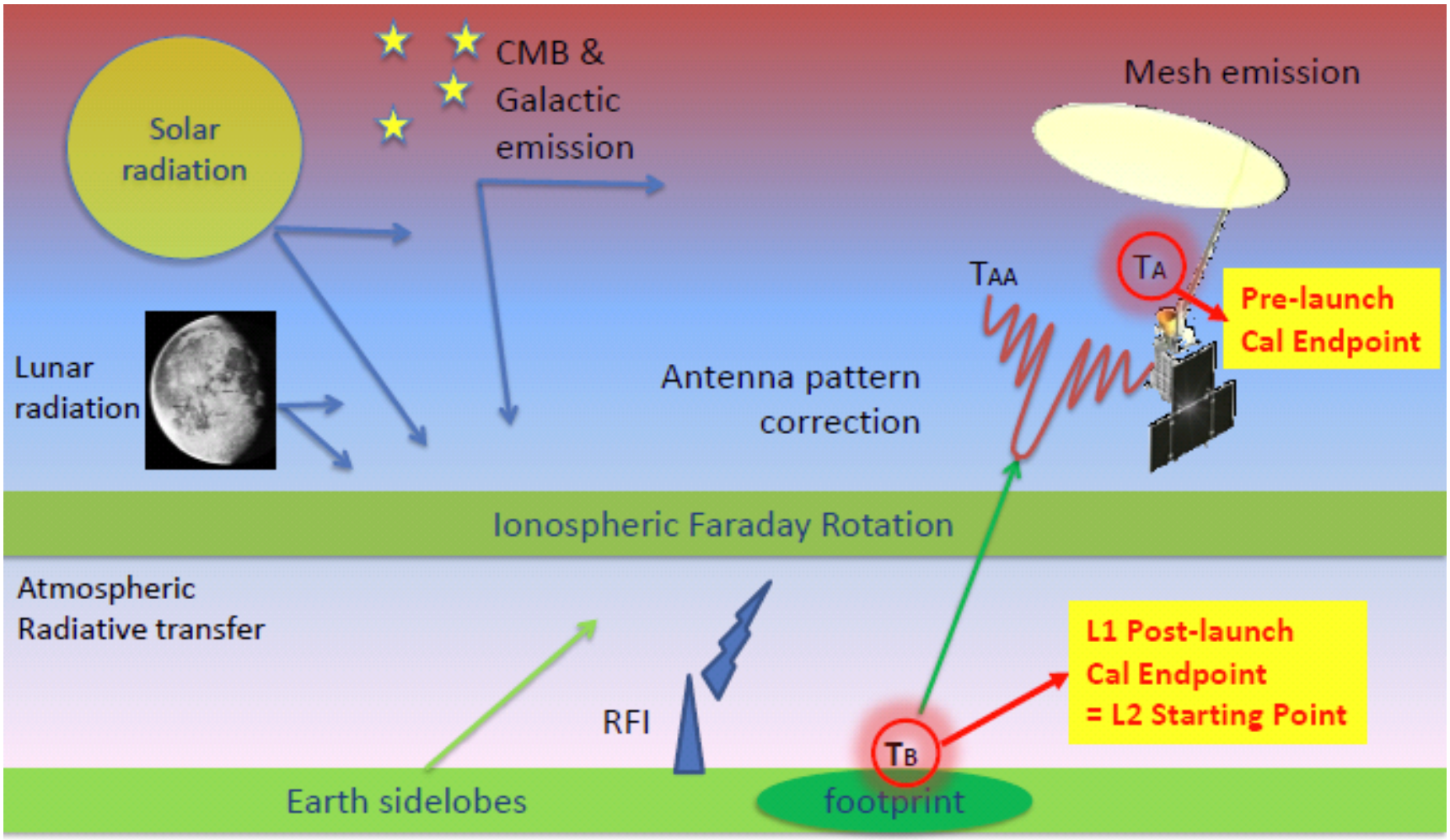
November 5-7, 2013

L1B_TB product Cal/Val

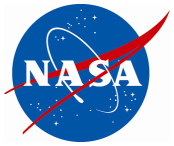
- L1 Cal/Val Plan Document
  - Identifies set of tools, data sources, and cal/val activities for the L1 cal/val period post launch
  - IOC checkout, L1 Radiometer, and L1 Radar

- L1 Radiometer Cal/Val Activities
  - Internal Calibration Validation
  - External Calibration (Terrestrial Targets and Cold Space)
  - Geolocation Validation
  - RFI Removal Validation
  - Antenna Emissivity Calibration and Validation
  - Antenna Pattern Correction Validation
  - Faraday Rotation Correction Validation
  - Atmospheric Correction Validation
  - Long-Term Drift Detection and Correction
  - Inter-Comparison with other L-band Radiometers

L1_TB Required Corrections



Radiometer L1B Cal/Val at-a-glance



L1B algorithm ancillary data

L1B algorithm processor

L1B cal/val

Cal/val ancillary data

Spacecraft Telemetry from SMAP GDS in SPICE Kernel Format

*Noise diode and front-end losses

*Linearization coefficients

*RFI detection threshold masks

Dynamic Ancillary Data Sets land surface temperature map and solar flux value

Static Ancillary Data Sets galactic background map, surface elevation map, permanent water map

*Antenna pattern correction coefficients

Radiometer L1A Product

Geolocation

Compute calibration coefficients

RFI detection and removal from calibration data

Radiometric (T_A) Calibration

RFI detection and flagging

RFI removal and footprint averaging

Antenna Pattern Correction

Faraday Rotation Correction

Atmospheric Correction

Radiometer L1B_TB

RFI and External Cal Analysis Product

Users

Validate & tune geoloc

Validate & tune internal cal

Validate & tune Antenna emissivity

Validate & tune RFI thresholds

Validate & tune APC

Validate & tune Faraday

Validate & tune atmos

External Cal & tune + inter-comparison

Cal/Val Static Ancillary Data galactic background, TEC, B-field

Cal/Val Dynamic Ancillary Data land surface temperature, soil parameters, NDVI, soil moisture, SST, SSS, ocean winds, antarctic physical temp

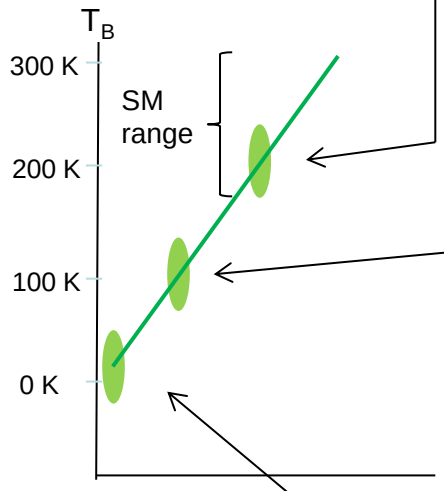
Other Radiometer Tb's

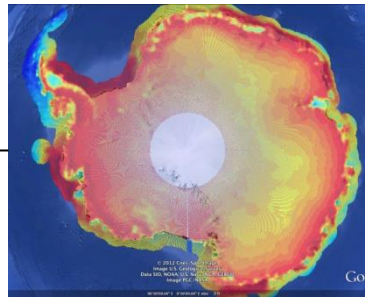
Ancillary Data For Cal/Val

Category/Usage	Ancillary Data Set	Data Source	Frequency of Delivery
Ocean Surface External T_B Calibration	Sea Surface Temperature	NCEP	Daily for Cal/Val, weekly thereafter
	Sea Surface Salinity	WOD09 (HYCOM)	Daily for Cal/Val, weekly thereafter
	Ocean Surface Winds	NCEP	Daily for Cal/Val, weekly thereafter
Antarctica External T_B Calibration	Antarctic Ice Temperature	NCEP	Daily for Cal/Val, weekly thereafter
Cold Space External T_B Calibration	Galactic Maps of L-band T_B	Le Vine & Abraham (Aquarius)	Static
Third Stokes T_B Calibration Faraday Rotation Validation	Earth Magnetic Field	IGRF	Delivered once very five years
	Ionosphere Total Electron Content	IGS	Daily
Land Surface Brightness Temperature Validation	Land Surface Temperature	GEOS 5.7.2	Daily for Cal/Val, weekly thereafter
	Normalized Difference Vegetation Index	MODIS NDVI	Daily for Cal/Val, weekly thereafter
	Soil Moisture (5 cm)	GEOS 5.7.2	Daily for Cal/Val, weekly thereafter
	Sand and Clay Fraction	HWSD	Static
	Open Water Fraction	MODIS MOD44W	Static
	h Roughness Parameter	GSFC	Static
	Land Cover Classification	MODIS IGBP	Possible update, but apply to all mission data

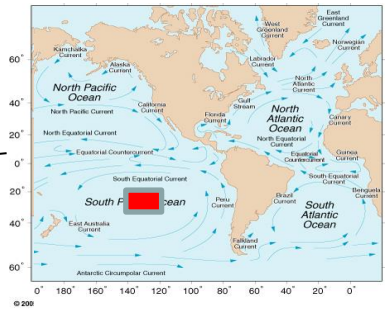
External Calibration

- **Purpose**
  - Enables end-to-end cal since an on-board beamfilling target is not feasible
- **Target Criteria**
  - beamfilling, homogeneous, stable, and have known T_B
  - Use views of external targets w/different T_B's to characterize gain, offset, NL, drift
- **Candidate targets**
  - ***East Antarctica*** *(~200K)*
    - SMOS work shows promise
    - Near pole→Visible 6 times/day
    - No maneuver or special mode required
    - RFI very small, highly localized
  - ***Ocean*** *(~100K)*
    - leverage Aquarius work on same
    - No maneuver or special mode required
    - Absolute T_B cal depends on ocean model accuracy
    - RFI still possible, but likely very small
  - ***Cold Space*** *(~10K)*
    - Requires s/c maneuver; limits how often (monthly)
    - Avoid looking toward celestial source regions
    - RFI unlikely

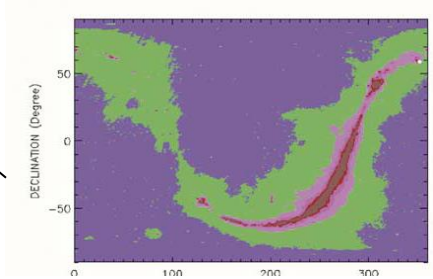




Antarctica



Ocean



Cold Space

TB Inter-Comparison with other L-band Obs

Satellite L-band TB

- SMAP will leverage TB's from other missions—e.g., SMOS, Aquarius to inter-compare TB's
- Simultaneous overpasses
- Views of same external targets

- There are active funded projects now working on L-band inter-comparison: SMOS & Aquarius
- There is a long history of *inter-calibration* for microwave sounders (data since 1970s; >10 satellites; Climate Data Records, papers in Science, etc.)

Airborne L-band TB

- TB's from airborne campaigns may be another source of inter-comparison data.
- SMAP can leverage non-SMAP airborne campaigns.
- Not required, but may be useful
- Scaling must be well-characterized

Ground-based L-band TB

Inter-comparison vs. ground TB observations useful only if the point-to-pixel scaling is well characterized

RFI Cal/Val activities from plan

- SMAP is flying the 1st ever dedicated RFI processor
- We expect RFI detection & mitigation to be needed to meet mission data loss requirements
- The RFI algorithm employs 4 types of detection methods
- a priori, we do not know the optimum thresholds
- The detection thresholds can be separately set for 1-degree geographic cells & will need tuning on orbit, plus continual checking vs. a dynamic RFI environment (e.g., SMOS)
- To assist with the threshold optimization, a special product will be generated with super-detailed RFI and other cal/val information
- The special product is not intended to be for everyone, but if you really want it…..you better have a huge disk drive and an army of analyzers
- One additional use of this detailed info is spectrum regulation enforcement
- Cal/Val tools are needed to map RFI, map & generate statistics—including data loss--as a function of threshold settings, azimuth angle, asc/des direction, and other parameters

Cal/Val Tools for L1B TB

Tool Description	Test Data for Rehearsal 2	Responsible Person
Internal Cal tool	sim'd half orbits of L1A; TVAC data; hardware parameters	Derek H.; Priscilla M.
External Cal tools: •Target TB estimators •Cold space orbit selector •Target data extractors •Backlobe calculator	sim'd half orbits of L1A; antenna pattern; target maps; L-band sky map; land/water mask; AQ global ocean mask; ice temp; SSS,SST, ocean surface state	Ed K., (Potential ST involvement: Le Vine, Misra, Jackson)
Long term drift tool	sim'd half orbit L1A & L1B of whole earth	Ed K., Priscilla M.
Geolocation Val tool: •Coastline crossing check •fore/aft differences •Pitch/roll bias calculators	half orbits of L1B TB with sim'd biases, sim'd SPICE; orbit map; land/water map; antenna pattern; ocean forward TB model	Giovanni D.

Cal/Val Tools for L1B TB

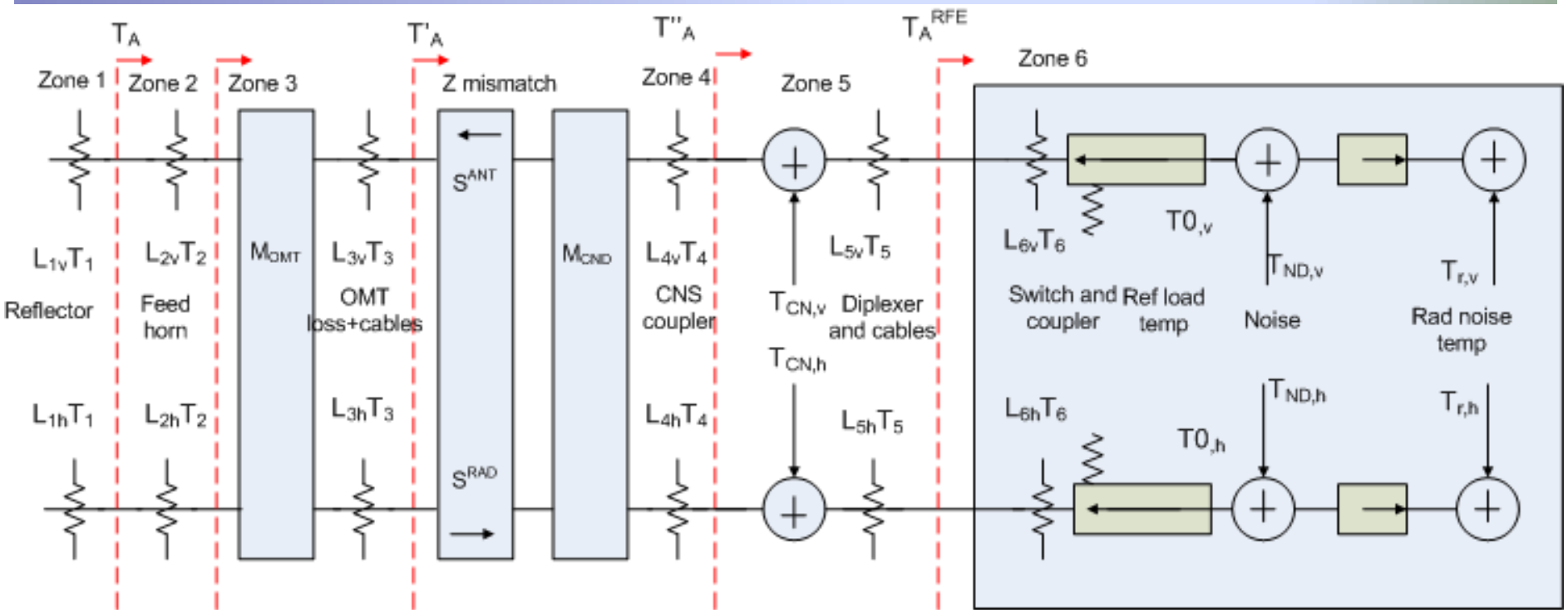
Tool Description	Test Data for Rehearsal 2	Responsible Person
RFI cal/val tools: •Data loss calculator •Threshold optimizer •RFI map generator	sim'd half orbits of L1B TB, w/TVAC RFI	Priscilla M. (potential ST involvement: Johnson, Misra)
Antenna Emissivity validation tools: •eclipse event tool •emissivity adjustment tool	sim'd half-orbit L1A and L1B; eclipse info, ant pattern, thermal model; ocean TB model	Giovanni D., Jinzheng P
Antenna Pattern Correction validation tools: •Sidelobe checker •Unwanted source checker	sim'd half-orbit L1B; SPICE info	Jinzheng P., Ed K., Giovanni D. (potential ST involvement: Le Vine)
Faraday rotation correction validation tools: •Viewer/comparison tool •Alt algorithm calculator	sim'd half-orbit L1B; IGS TEC; B-field	Giovanni D., Jinzheng P (potential ST involvement: Le Vine)

Cal/Val Tools for L1B TB

Tool Description	Test Data for Rehearsal 2	Responsible Person
Atmospheric correction validation tools: •Map viewer •Higher-fidelity Atmos model	sim'd half-orbit L1B; Q,T,P, elevation; GMAO anc data	Jinzheng P.
Cross-comparison tools: •Matchup calculator •Data extractors	sim'd half-orbit L1B; orbit, antenna pattern, & instrument info for SMOS, AQ;	Ed K. (Potential ST involvement: Le Vine, Misra, Jackson)
L1B internal Cal QA tool •Gain/offset, TA, flag checker •Noise spectrum checker	sim'd half orbits of L1A; TVAC data; internal cal info	Priscilla M.

BACKUP

Internal (T_A) Calibration

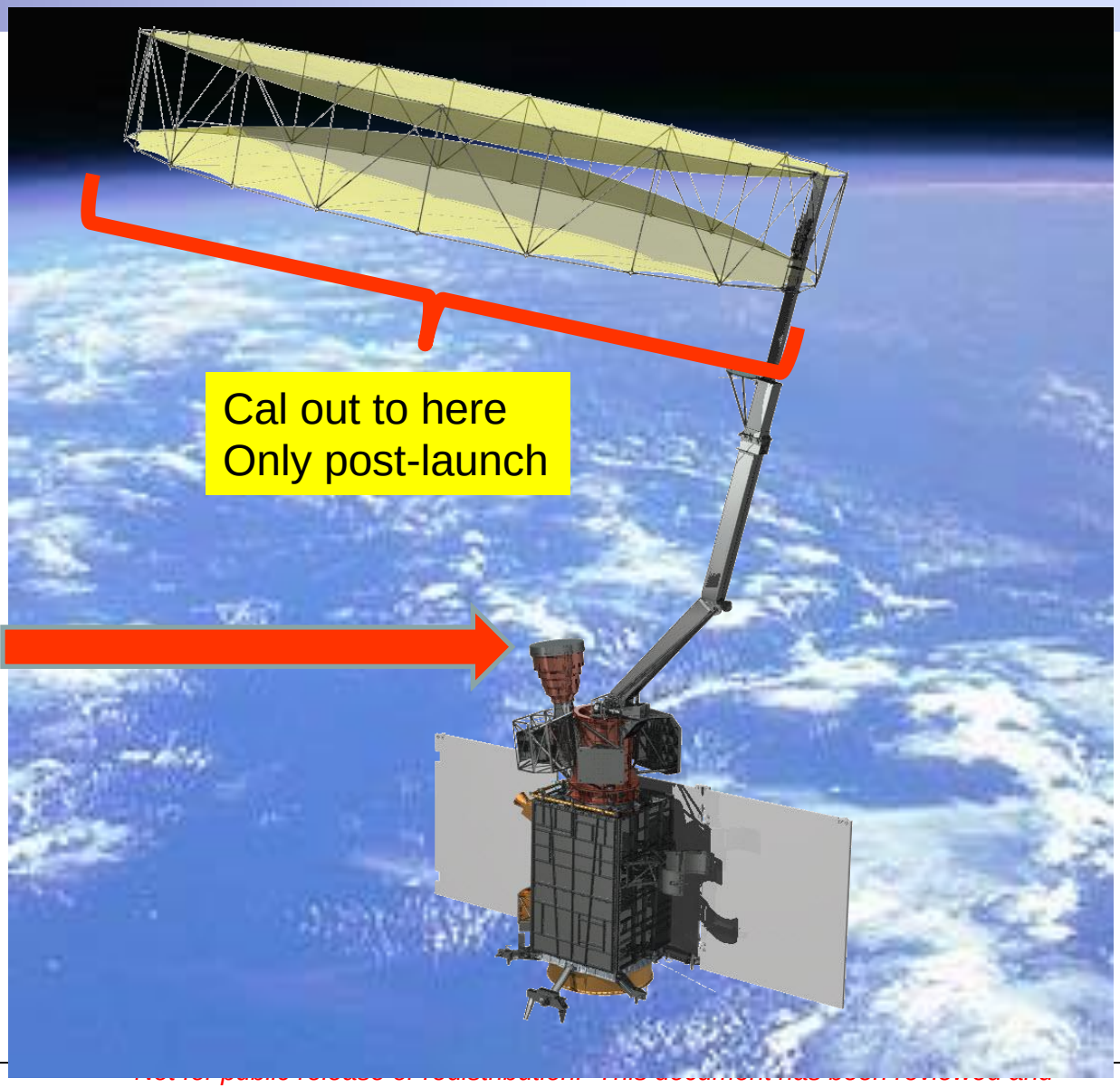


Model accounts for losses, temps, mismatches

- $L_{\#,v,h}$ losses for zone # and polarization v or h
- $T_{\#}$ Physical temperature for zone #
- T_X Radiometric antenna temp Stokes vector
- M Mueller matrix
- S Two port S-Parameter matrix

- Only a few of the parameters are key, but all are included for completeness
- All parameters characterized pre-launch
- Most parameters won't differ much from pre-launch values
- Post-launch adjustments will be few & small

Calibrating the SMAP Radiometer



Radiometer L1_TB Error Budget/Margins

L2-SR-45 : The L1B_TB brightness temperatures shall have mean uncertainty from all sources (excluding rain) of 1.3 K or less (1-sigma)

Driven by instrument design or pre-launch calibration

Driven by post-launch calibration

- **L3-Instr-TBD** Atmospheric Correction : 0.1 K
- **L3-Instr-232** Antenna Pattern Correction : 0.6 K
- **L3-Instr-169** NEΔT 0.65 K
- **L3-Instr-599** Long Term Drift 0.4 K
- **L3-Instr-507** RFI 0.3 K
- **L3-Instr-685** Antenna Temperature Calibration 0.5 K

- "Non-calibration" error terms:
  - NEΔT is random term essentially unaffected by calibration.
- Calibration error terms:
  - Antenna temperature (T_A) calibration
  - Antenna pattern correction. Includes effects of side-lobes and mesh emissivity.
  - Atmospheric correction
  - Long-term drift
- RFI term is due to residual error after removal of RFI contamination. Not strictly "calibration" but mitigation algorithm parameters will be tuned in SDS.

Error Term	Allocation	PDR CBE	CDR CBE
Antenna Pattern Correction	**0.60 K**	0.35 K	0.40 K
NEΔT	**0.65 K**	0.51 K	0.54 K
Antenna Temperature Calibration	**0.50 K**	0.4 K	0.44K
RFI	**0.30 K**	0.17 K	0.19 K
Long Term Drift	**0.40 K**	0.4 K	0.20 K
Atmospheric Correction	**0.10 K**	0.1 K	0.04 K
RSS Total		0.86 K	0.85 K
Requirement	**1.3 K**	**1.3 K**	**1.3 K**
"Linear" Margin		0.9 K	0.44 K
"RSS" Margin		0.44 K	0.92 K