Sounder for Microwave-Based Applications (SMBA): the Next-Gen Backbone Microwave Sounder for the Near Earth Orbit Network (NEON)

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Outline

- Backdrop: JPSS, NEON, microwave sounders
- Basic capabilities
- New features
- Trades, trades, trades
- Summary

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Backdrop for Operational MW Sounders

- MW sounders provide the highest-impact observations for NWP
- Continuous coverage by microwave sounders since 1980s
- Current gen = ATMS on JPSS (designed in 1990s)
- JPSS is operational through ~2040
- NEON timeframe: 2030-2050
- MW sounder for NEON = Sounder for Microwave-Based Applications (SMBA)
- SMBA = successor to ATMS

- 9 flight units →backbone segment of NEON architecture
- Potential "augmentation" segment not discussed here; smaller/cheaper sats, more limited sensors
- Draft requirements, desires, etc. from:
  - Systems performance Assessment Team (SAT), Scientific Guidance for potential study and design of Microwave Sounder (for SounderSat and GEO-XO).
  - NOAA workshop on MW sounders: https://doi.org/10.25923/wkgd-pw75
  - 2019 NOAA SounderSat studies

Familiar Basic Capabilities

- Priorities:
  1. Temperature sounding
  2. Humidity sounding
  3. Other applications
- MW sounding users require[1]
  - Bands
    - Existing ATMS bands 23-183 GHz
    - Plus 118 GHz
    - 183 GHz + window channel(s)
    - 118 GHz cannot replace 50 GHz
  - Channels → vertical profile
    - performance no worse than today
    - Baseline design: similar # channels as ATMS

- Performance
  - NEDT, etc. no worse than today
  - Baseline similar to actual values rather than today's specs
  - 5-year lifetime (Class C)
- Coverage
  - 2 backbone orbits
  - Polar sun-synch
  - Daily global coverage

[1] NOAA workshop on MW sounders: https://doi.org/10.25923/wkgd-pw75

New Features

- SMBA has 3 significant new features (requirements)
  1. Hyperspectral MW sounding
  2. RFI detection
  3. Inter-calibration
- Plus other new requirements on
  - Striping
  - Noise power spectrum
  - Interchannel noise correlation

- Design tradespace as wide as possible for now; multiple inter-related trades (not a full list)
  - Example: Conical or cross-track scan
  - NEDT, nonlinearity, accuracy
  - Channel bandwidths vs. noise vs. vertical resolution
  - Footprint size, spatial sampling
  - Heterodyne vs. direct detect
  - Polarizations
  - Calibration method (black body, noise diode, etc)
  - Striping (1/f noise)
  - Hyperspectral channelization
  - RFI detection algorithms
  - Inter-calibration approach

4 SMBA SCIENCE REQUIREMENTS

To provide guidance on microwave sounder instrument performance capabilities, Table 4.0-1 details the relative prioritization of the various performance factors associated with the next generation microwave instrument.

From Phase A PSD:
Draft baseline & aspirational performance targets, prioritized

Table 4.0-1. Microwave Instrument Performance Capabilities Prioritization[1]

Factor Order	Performance Factor	Baseline Target	Aspirational Target
1	Channels for direct Temperature Sounding	13 Channels around 50-60 GHz and 7 channels around 118 GHz line	> 20 channels around 50-60 GHz and > 10 channels around 118 GHz line
2	Channels for direct Moisture sounding	5 Channels or more around 183 GHz	10 Channels or more around 183 GHz
3	Window channels; channels for cloud, precipitation, ice detection for direct all-sky assimilation and NWP QC	Channels at 23.8, 31.4, 88.2. One channel at 165.5 (TBR) and/or 229 (TBR) GHz channels	Baseline Targets and: a) At least 4 channels at low frequencies (priority order) (i.e. 22-23 GHz(a), 31-37 GHz(b), 89 GHz(c) and 18 GHz (d)) b) 200-325 GHz channels for cloud/precipitation detection and surface signal distinction
4	Spatial coverage (daily)	95% Global Coverage	100% Global Coverage
5	Noise Level (NEDT) for Temperature sounding channels	See Table 4.1-1	See Table 4.1-1
6	Noise level (NEDT) for Moisture sounding channels	See Table 4.1-1	See Table 4.1-1
7	Spatial horizontal resolution (nadir)	32 km (T) 16 km (q)	8 km (T) 5 km (q)
8	Spatial sampling	Contiguous footprints (or better)	Oversampling *(Spatial Nyquist sampling at a minimum)* to enable higher spatial resolution
9	Scan geometry	Cross track or conical	
10	Polarization	Single linear polarization	Baseline and: Dual polarization (vertical/horizontal) for window channels below 50 GHz
11	ATMS Channels Continuity	Yes, for similar channels	
12	Calibration accuracy	See Table 4.1-1	Less than values in Table 4.1-1

[1] Systems performance Assessment Team (SAT), Boukabara, S.(chair), Gallagher, F.(co-chair). [Scientific Guidance for potential study and design of Microwave Sounder (for SounderSat and GEO-XO)]. Retrieved from NOAA/NESDIS Center for Satellite Applications and Research.
September 17, 2020.

This table taken from PSD document at
https://sam.gov/opp/2c6dad01ed0c4d67844272689 4a6f800/view

Hyperspectral MW Sounding

- Theoretical studies have shown benefits to NWP, PBL & other applications
- Limited real-world demos to date
- 3 NOAA Joint Venture (JV) projects are in-progress to perform real-world demos to help inform SMBA
  - Airborne
  - Balloon
  - Cubesat

Trade topics for JVs and SMBA Phase A:

- Digital backend technology is available to do the signal processing
- But which bands, how many channels, how wide, etc?
- FPGAs require significant power and generate significant heat, re-programmable on orbit
- ASICS use less power/less heat, but are not re-programmable
- Intermediate data volume is large

RFI Detection

- The RFI threat is real, passive MW sensors need to have the means to address it
  - Contaminated data can impact products
  - Detection (flagging) required
  - SMAP-like excision (removal) not required, but open to hear ideas
  - RFI threat to sounders primarily from IMT (5G) signals → SMAP-type algorithms not expected to work so well
  - algorithm development/testing needed
- Digital backend technology offers possible new options for RFI detection
- But, data volumes likely to require some on-board processing
- Exact balance of on-orbit vs. ground processing is a TBD trade
- RFI will evolve in space & over time → dynamic capability may be nice

- Constellation RFI simulation tool under development
- Little/no real-world RFI data available for testing
- Airborne RFI surveys are needed; opportunity may come during hyperspectral JV activities
- On-orbit RFI surveys require careful interpretation; nothing seen doesn't necessarily mean 'no threat'

Inter-Calibration

- NIST definition of inter-calibration, so beyond GPM-style inter-comparison
- Long precedent in VIS/IR/thermal IR communities
  - Methodology is known
  - MW-specific technology needs work
- Holy grail: inter-calibration across *all* MW radiometers
  - From all countries
  - Sounders and imagers
- Opportunity to finally make SI-traceable *microwave* obs
- Spinoff: GRSS activity on standards for RFI measurements

- Current variational bias 'correction' schemes still require sensor absolute cal to be 'close', and take ~2 years per sensor
- New NWP model developments may require new calibration approaches
  - Next big leap in NWP (coupled models) involves addn'l constraints
- Some NOAA retrievals still depend on absolute TB accuracy
- NWP benefits from improvements in both GNSS-RO and MW sounder accuracy; these are complementary

SMBA Notional Timeline

- Phase A study Request for Proposals (RFP) released Feb 23, 2023
  - https://sam.gov/opp/2c6dad01ed0c4d678442726894a6f800/view
  - 4 vendors began work October 2023
  - Study duration 1 year
  - Currently halfway through Phase A
- Phase B-D (building SMBA): a separate procurement
- First SMBA notional launch: early 2030s
- Notional operational period (assuming 9 flight units): approximately 2030-2050

- Note: *before* SMBA, refurbished ATMS EDU will be launched into the 1730 orbit on QuickSounder in 2026

QuickSounder

- Pathfinder for NEON
- Risk reduction for smaller bus, downlink, backhaul, ingest, etc
- Sensor performance is not a mission driver→ Fly a well-understood sensor on a free flyer smallsat bus
- Still planning full pre-launch sensor characterization

- Refurbished ATMS EDU was first unit built in early 2000s
- Refurbished to be flightworthy, but as-is performance, no upgrades
- Will “succeed/join” AMSU-A on METOP-C in 1730 orbit
- 2026 launch

Summary

- Sounder for Microwave-Based Applications (SMBA) is the next-gen US operational MW sounder
- Initial sensor for NEON program (successor to JPSS)
- Draft threshold and aspirational specs released in PSD
- 3 new capabilities: hyperspectral, RFI detection, inter-calibration
- Significant trade studies in work

- 9 flight units, disaggregated NEON architecture → free-flyers
- Phase A (trade studies) began Oct. 2023, 12-months, 4 vendors
- SMBA is a Backbone sensor, along with European MWS, will populate same 3 sun-sync orbits as today
- Earliest SMBA launches in early 2030s
- Overlap with JPSS-3/4 (launches in 2027, 2032)
- QuickSounder (pathfinder for NEON) to launch in 2026

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