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National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE
CENTER FOR SATELLITE APPLICATIONS AND RESEARCH
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SUBJECT: **Scientific Guidance for the potential study and design of Microwave Sounders (for SounderSat and GEO-XO)**

Background:

This memo is produced in order to support the following efforts:

- October/November 2020 NASA's Instrument Design Lab (IDL) and NASA's Mission Design Lab (MDL) runs. These two design runs will conduct Government studies to propose optimal designs of the next generation microwave sensors and assess the maturity of technology, and provide cost estimates.
- SounderSat and GEO-XO instrument design activities through BAA studies. These studies are undertaken by industry vendors in response to the BAAs.

The efforts above would benefit from guidance on what sensors characteristics are important when exploring the trade space of the sensor design. The Systems performance Assessment Team (SAT) met to discuss these items to set priorities for the factors that have the most impact on performances of microwave sensors. This memo is meant to document the findings of those core-SAT discussions.

Findings and Recommendations:

The list below, while not meant to be comprehensive, shows the major sensors (and constellation) characteristics (or factors) that are expected to have the most impact(s) on the overall performances sought by SounderSat or GEO-XO microwave sensors (or other programs aiming at deploying spaceborne microwave sounders), in decreasing order of priority. The list should be useful as a guidance mechanism to engineers and designers of the satellites hosting microwave sounders. These items represent sensor and/or constellations characteristics that have the most impact on the performances of microwave sounders that measure atmospheric temperature and moisture. The main driver for the prioritization of these characteristics is Global NWP. For each of these characteristics a range of tiers is provided to indicate optimal, nominal, and threshold performances. Note that these tiers are based on a wide range of SMEs opinions, followed by discussions at the SAT general meeting, and then at an internal Government-only core-SAT meeting (which put together this guidance). No thorough studies have been undertaken to assess compatibility between these characteristics and the geophysical performances listed in the BAA or by previous SPRWG publications (listed in terms of temperature and moisture requirements). The list below therefore could be useful in two different ways: (1) ranking of sensors/constellations characteristics by their decreasing impact on the sounding performances for global NWP, and (2) through the comments to guide the engineers in the choices (ranges) to be possible/made for each of the sensor/constellation characteristics.

Notes:

- The tiers presented below were developed based on multiple factors: (1) knowledge of current and upcoming (smallsats) sounders and their associated capabilities, (2) potential risks such as RFI due to 5G-based telecommunication systems, with the associated potential impact on some of the low frequencies, (3) knowledge of SounderSat objectives which include developing and infusing new technology that is cost effective.
- Specific for SounderSat: It is important to remind leads that these tiers below are meant for the SounderSat program which is planned to be run in parallel to the JPSS program (with CrIS and ATMS sounder sensors). So the early SounderSat flights should be viewed as a complement to the JPSS program, at least for the next decade or two. This is important when considering the best choices to be made within the Tiers ranges.
- Note1: most parameters (i.e., each row) should be viewed independently from the other parameters, except when noted, for matters related to Tiers tradeoffs. For example, we might select Tier 1 for parameter X and then Tier 3 for parameter Y. In other words, tradeoff within the 3 Tiers, is envisioned to be done on a parameter-by-parameter basis.
- Note 2: also that some of the guidance here in this memo is relatively vague by design, to avoid constraint too drastically what potential studies that aim at assessing tradeoffs of performance versus cost, risk and technology maturity.
- Note 3: The LO design should have central frequencies (mentioned below) that must be stable, in order to allow accurate simulation and calibration of the data.

Factors Impacting Performances				
Priority#	Factor impacting performances	**Tier 1:** Ideal capability if we can afford it and if technology allows.	**Tier 2:** Status Quo capability (consistent with current capability)	**Tier 3: Walkaway** Acceptable capability (potentially degraded capability but still useful)
1	Channels for direct Temperature Sounding	*20 Channels or more around 50-60 GHz (ATMS spectral locations) band and 118GHz line	*13 Channels or more around 50-60 GHz band	*12 Channels or more around 118 GHz O_2 line (TROPICS-type)
2	Channels for direct Moisture sounding	*10 Channels or more around 183 GHz	*5 Channels or more around 183 GHz	*TEMPEST-type Channels around 183 GHz (or mm/sub-mm freqs like 325 GHz)

3	Channels for cloud, precip, ice detection for direct all-sky assimilation and NWP QC	At least 4 channels at low freqs such as 22-23 (priority#1) , 31-37 (priority#2) and 89 GHz (priority#3) and 18 GHz (priority#4) if possible, channels for TPW integration,cloud/precip detection and surface signal distinction	At least 2 channels at 22-23, 31-37, 89 or around 18-19 GHz channels	Use channels in the 200-300 GHz band for cloud, rain, and ice detection.
4	Spatial coverage (daily global coverage)	Global	Global	Global
5	Swath width and impact on orbital gap* (scan angle)	No orbital gap at equatorial crossing (TBD: consistency across columns)	JPSS-type gap (or better) at equatorial crossing	NOAA AMSU Type of orbital gap
6	Satellite Altitude	Not directly relevant for performances. Listed here because it is usually a driving factor for the swath width and it is a question that gets asked by sensor/satellite design engineers.	Not directly relevant for performances. Listed here because it is usually a driving factor for the swath width and it is a question that gets asked by sensor/satellite design engineers.	Not directly relevant for performances. Listed here because it is usually a driving factor for the swath width and it is a question that gets asked by sensor/satellite design engineers.
7	Noise Level (NEDT) for Temperature sounding channels (real values,not requirements)^	ATMS-type NEDT levels (ATMS_NEDT) or better	ATMS_NEDT x 1.5	ATMS_NEDT x 2
8	Noise level (NEDT) for moisture sounding channels (real values,not requirements)^	ATMS-type NEDT levels (ATMS_NEDT) or better	ATMS_NEDT x 1.5	ATMS_NEDT x 2
9	Spatial horizontal resolution	ATMS-type or better spatial horizontal resolution or better: About 15 kms at nadir at moisture channels (could be changing with angle and channel)	About 25 kms or better at nadir (changing with angle and channel)	About 50kms at nadir or better (changing with angle and channel)
10	Viewing geometry	Cross track or conical	Cross track or conical	Cross track or conical
11	Continuity with ATMS channels	Yes for similar channels	Yes for ATMS T(p) channels	Not necessarily
12	Polarization	Yes if low frequencies are used *(18,22,37 GHz or equivalent)*	Single linear polarization (similar to ATMS), mixed as a function of scan angle	Single linear polarization mixed as a function of scan angle

13	Spatial sampling	Oversampling *(Spatial Nyquist sampling at a minimum)* to allow higher spatial resolution	Contiguous footprints (or better)	Non-contiguous footprints
14	Calibration accuracy	0.75 K-1 K depending on channels (0.4K max non-linearity)	1 K-1.5 K depending on channels (1 K max non-linearity)	1 K-2 K depending on channels (1.5 K max non-linearity)
15	Temporal refresh	every 2 hours	every 3 hours	Every 6 hours
16	Instrument lifetime	7 years	5 years	3 years

- *These should be chosen to maximize information content: with appropriate bandwidths to cover the range of vertical temperature sounding and to maximize the vertical resolution.
- Stability of the measurements: ability to meet spec requirements over the lifetime of the sensor.
- Bandwidths of temperature and moisture channels should be similar to those of ATMS for similar channels. Additional channels should aim at increasing vertical resolution (spaced out weighting functions).
- ^The NEDT guidance here refers to the overall noise level of the channels. Particular attention should also be paid to the striping effect, which should be minimized as much as possible (or eliminated) when designing the sensor.

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