NOAA-20/JPSS1 ATMS performance and RFI plans for future NOAA sounders

Edward Kim

NASA GSFC, JPSS

GSICS MWSG workshop

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JPSS-1/NOAA-20 ATMS Performance Data Resources

- **ATMS Cal Data Book**
- available at https://www.star.nesdis.noaa.gov/jpss/documents/ATMS_SRF/CM-RELEASE-COPY-RE-20319_RevD_CalibrationDataBook-X.pdf
- or just search for ‘noaa star atms’

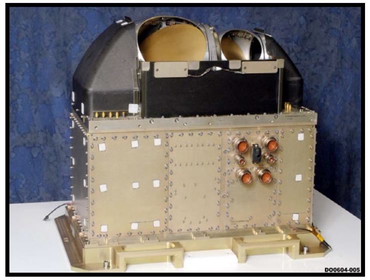
- **MicroRad 2018 presentation**
- **Title:** Pre- and Post-Launch Performance of the Advanced Technology Microwave Sounder (ATMS) on the Joint Polar Satellite System-1 Satellite (JPSS-1)

- **IEEE TGRS paper**: just accepted; available in TGRS early access
- **Title:** "An evaluation of NOAA-20 ATMS instrument pre-launch and on-orbit performance characterization"
- **DOI:** 10.1109/TGRS.2022.3148663

Pre- and Post-Launch Measurements

Pre-launch (TVAC)

- Sensitivity (NEDT)
- Accuracy, nonlinearity
- Noise power spectrum, striping, inter-channel correlation
- Antenna pattern/sidelobe characterization
- Dynamic range
- Pointing
- Spectral response functions



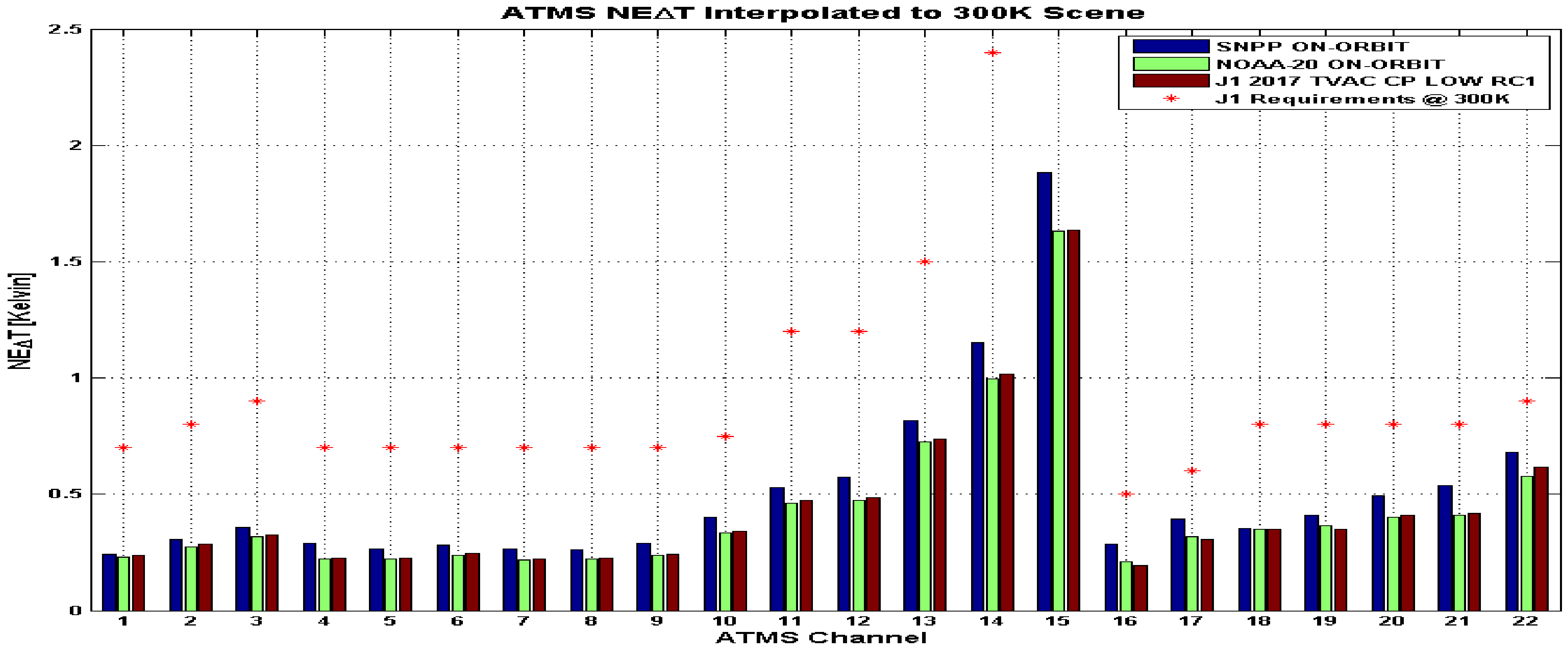
Northrop Grumman

Post-launch first 90 days

- Sensitivity (NEDT)
- Noise power spectrum, striping, inter-channel correlation
- Antenna pattern/sidelobe characterization
- Scan angle bias (flat field) determination
- Reflector emissivity determination
- Ka-band RFI check
- Cold cal position selection
- Lunar intrusion mitigation
- Dynamic range
- Pointing/geolocation

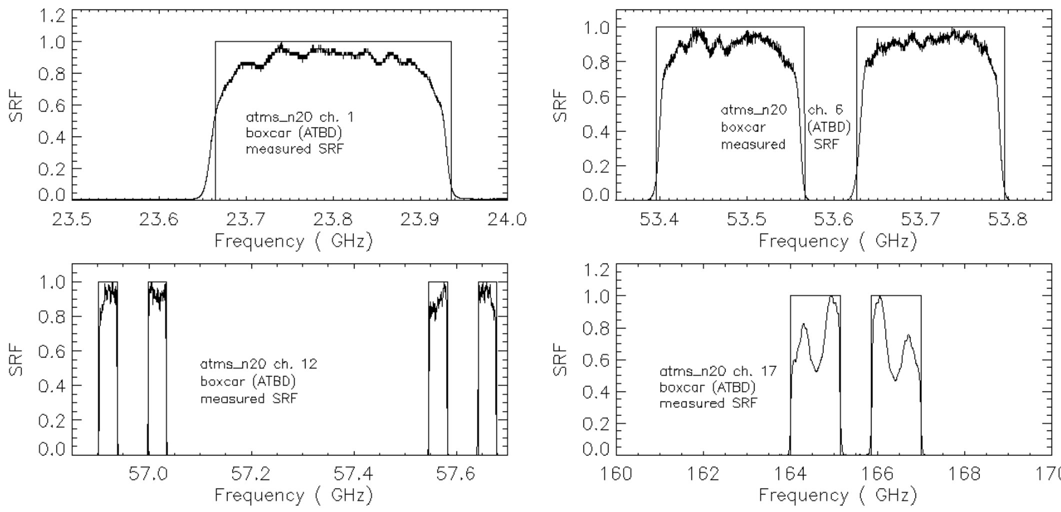
NEDT

Comparison of SNPP on-orbit, J1 Pre-Launch, NOAA-20 on-orbit



N-20 NEDT on-orbit ~ same as pre-launch and better than S-NPP

SRFs and Pointing

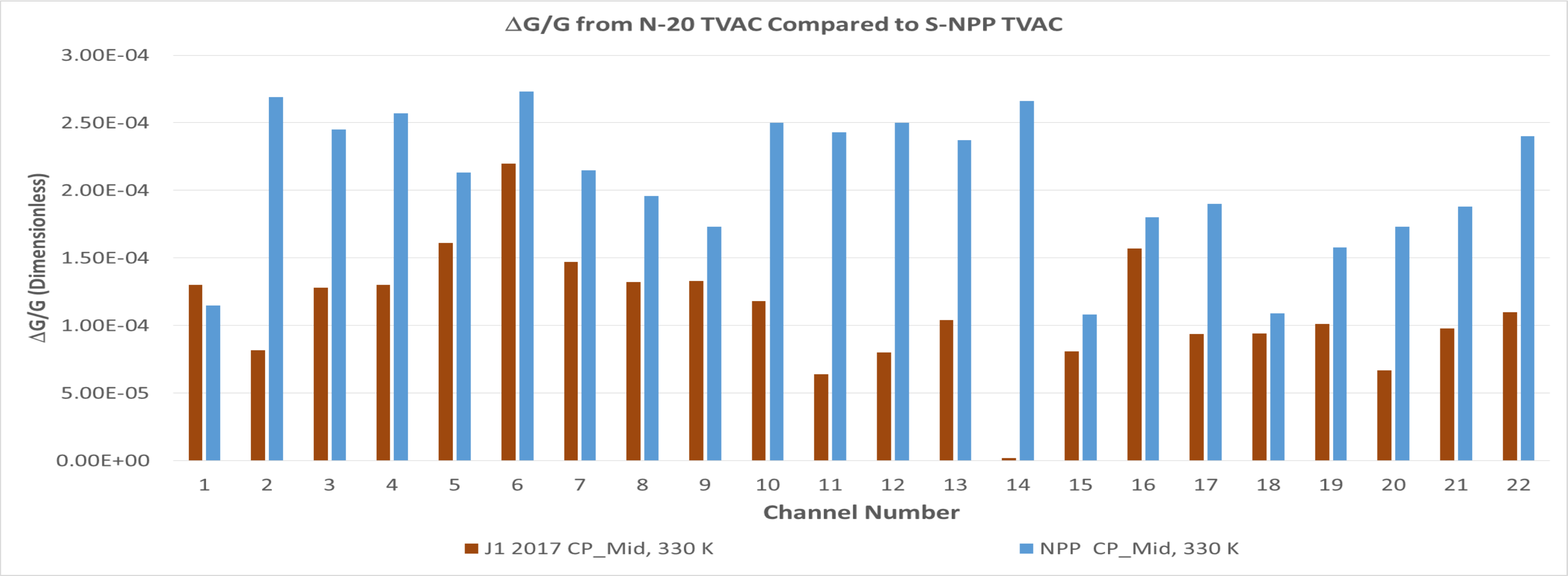


Spectral Response Functions (SRFs) for all channels are on the same webpage as the Cal Data Book

TABLE V
POINTING ACCURACY PERFORMANCE (ARCSEC)

	CH	Antenna Pattern Boresight Error Measured	Scan Control Error Max	Static Knowledge Error Max	Dynamic Knowledge Error Max	Total [RSS]
Roll Error Allocation	1,2	-295	-126	185	40	373
	3-15	-310	-126	185	40	384
	16-22	-576	-126	185	40	619
Pitch Error Allocation	1,2	-382	0	185	40	426
	3-15	-306	0	185	40	360
	16-22	-432	0	185	40	472
Yaw Error Allocation	1,2	-189	0	185	40	268
	3-15	-152	0	185	40	243
	16-22	-214	0	185	40	286

S-NPP vs N-20 ΔG/G



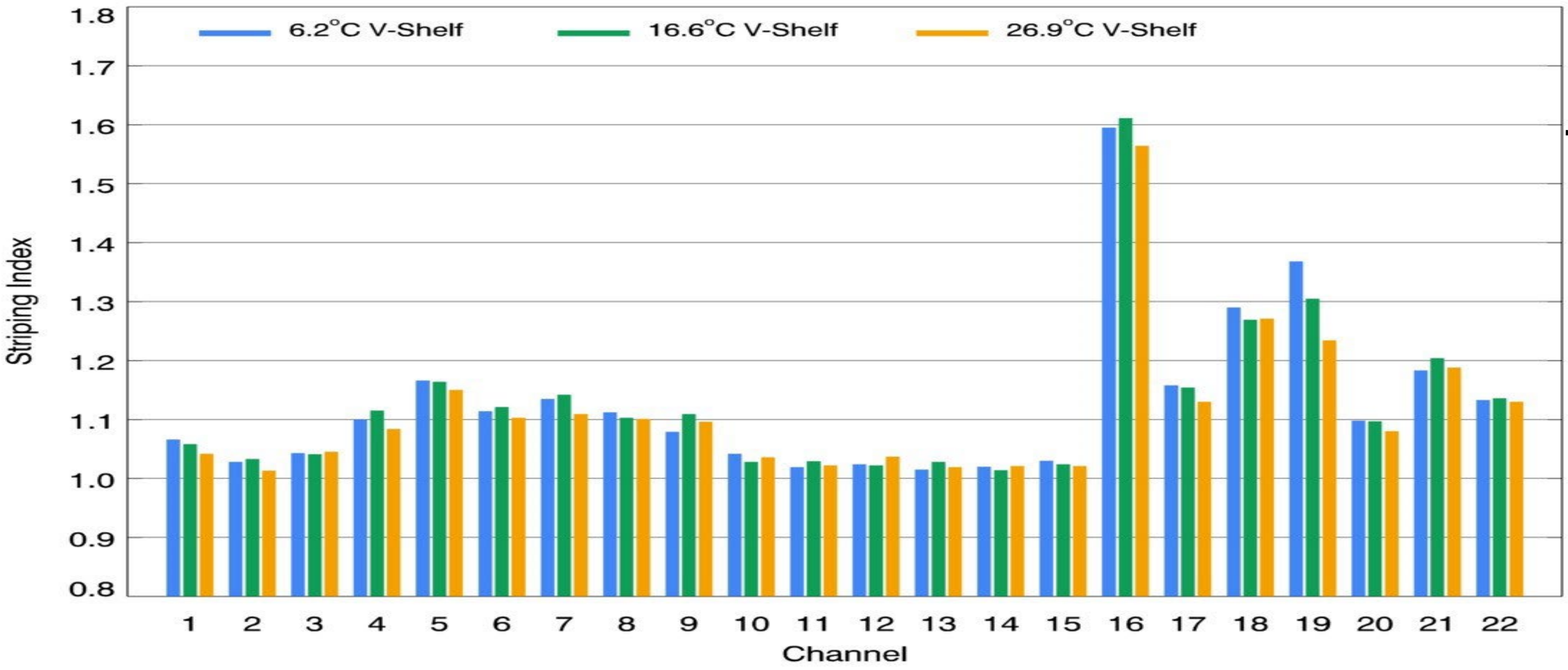
$$\frac{\Delta G}{G} = \frac{T_{pink}}{T_{sys}}$$

J.Lyu/C.Smith/ NASA GSFC

TVAC CP_Mid from both N-20 and SNPP

N-20 ΔG/G significantly smaller than S-NPP for 19 channels ➔ significantly reduced striping

Striping Index

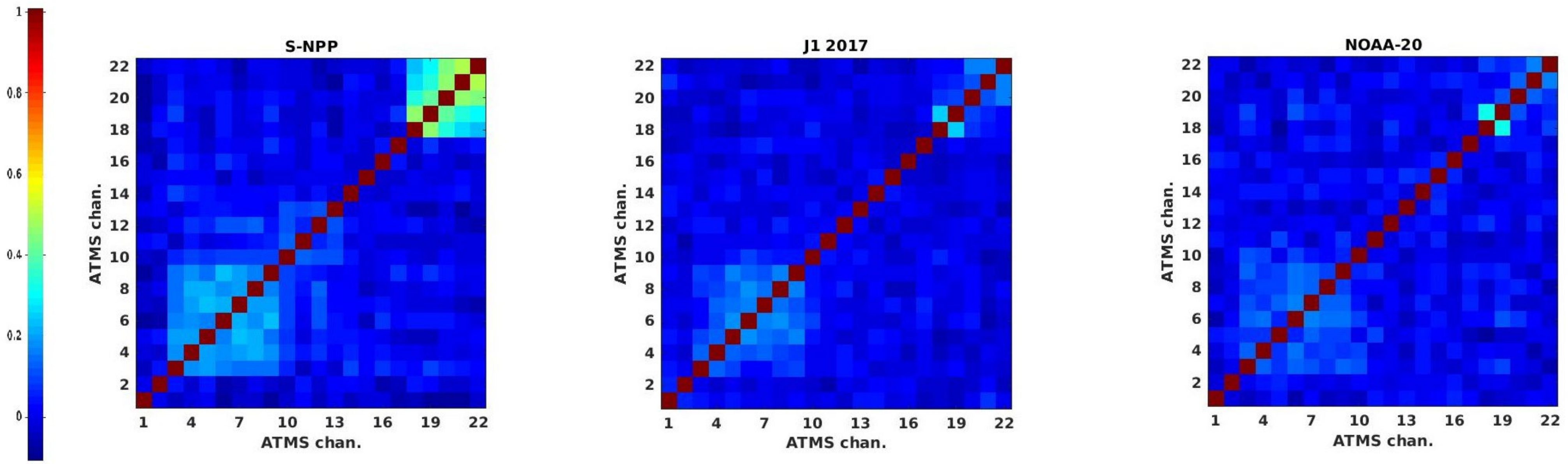


$$\text{Striping index} = \frac{\text{along track TB variance}}{\text{cross track TB variance}}$$

Striping Index for N-20 ATMS using pre-launch TVAC calibration data at three different instrument temperatures. The V-shelves contain the receiver front end and intermediate frequency components of the V-band channels (Chan. 3--15).

Inter-Channel Noise Correlation

Comparison of SNPP on-orbit (left), JPSS-1 Pre-Launch (center), NOAA-20 on-orbit (right)



N-20 Noise Correlation is Much Better than S-NPP for all Channels

Summary of J1 ATMS performance

- NOAA-20 ATMS is working well after 4 years on-orbit
- NOAA-20 ATMS compares well vs. S-NPP ATMS
  - NEΔTs slightly better than S-NPP
  - Inter-channel noise correlation much lower than S-NPP
  - Striping better than S-NPP
- No S–NPP type scan drive issues

Now a few slides from

SECOND GENERATION RFI DETECTION OPTIONS FOR IMT SIGNALS AND NWP APPLICATIONS

Edward Kim, NASA Goddard Space Flight Center

NOAA/NASA Joint Polar Satellite System

February 16, 2022

RFI 2022

Introduction

- Focus: RFI detection options for future satellite MW sounders for NWP
- Motivations:
  - MW sounders provide highest-impact obs to NWP forecasts → essential backbone
  - Expanding deployment of IMT (5G) RFI sources over next decade
  - Existing satellite MW sounders have no RFI capabilities, but many are beyond end-of-design-life
  - Replacement sounders are being launched; ATMS on JPSS-2/3/4 to last until 2040
  - But due to long development times, those (e.g., ATMS) don't include RFI capabilities
  - NOAA's post-JPSS "LEO" architecture is being designed right now, for operational use starting around 2040, to last until maybe 2060
  - Identifying RFI options for this future LEO system needs to happen now, before the system design becomes fixed

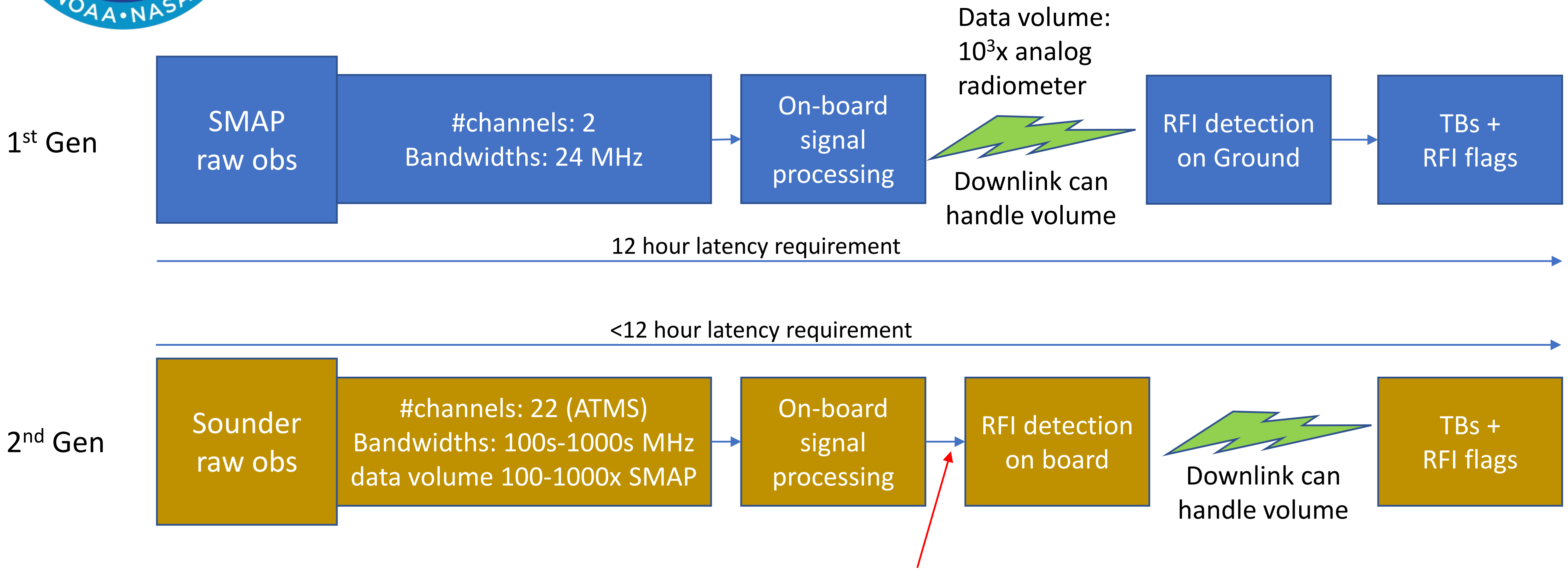
"1st Generation" RFI detection

- Best (only) example = SMAP
- 1.4 GHz passive, 24 MHz used
- 6m real-aperture rotating imager
- First dedicated RFI subsystem in space
- Digital back end, 16 x 1.5 MHz subbands
- Time & freq domain 'spike' detection; cross-frequency detection
- 3rd & 4th Stokes detection, kurtosis detection
- Designed to handle narrowband RFI
- Relatively forgiving application: soil moisture 3K/percent; 4% requirement

Digital back end technology:

- 96 Msps ADC x 2 IF signals
- Space-qualified FPGA could handle
- on-board time & frequency slicing, 4-Stokes, 1st-4th moments, kurtosis
- 1000x traditional data volume downlinked
- L1 data latency requirement: 12 hrs
- Thresholding performed on ground
- Detection, excision, and replacement of contaminated data

Data Volume and Latency Drivers on System Design



Data volume at this point: 10^5-10^6x analog radiometer
→ too large to downlink →must do RFI detection on-board
→ impacts detection algorithms/strategy, conops

“2nd Generation” RFI detection

Key differences 2nd Gen vs. 1st Gen from previous slide

- Must digitize 10-100x wider signals in a channel; 10+ Gsps ADCs exist today
- Must perform all processing through RFI detection on-board
  - Including any FFT type operations
  - Fast FPGAs or ASICs exist today; some space-qualified or soon will be
- RFI detection algorithms choices likely more limited
- Downlink bandwidth limitations won’t allow downlinking full intermediate variables, only final counts or TBs, RFI flags, and simple data
- NWP latency requirements are tighter → less time to generate results
- NWP worries about errors of ~0.1K vs. SMAP ~few kelvins

RFI detection expectations for future NWP satellites

This decade:

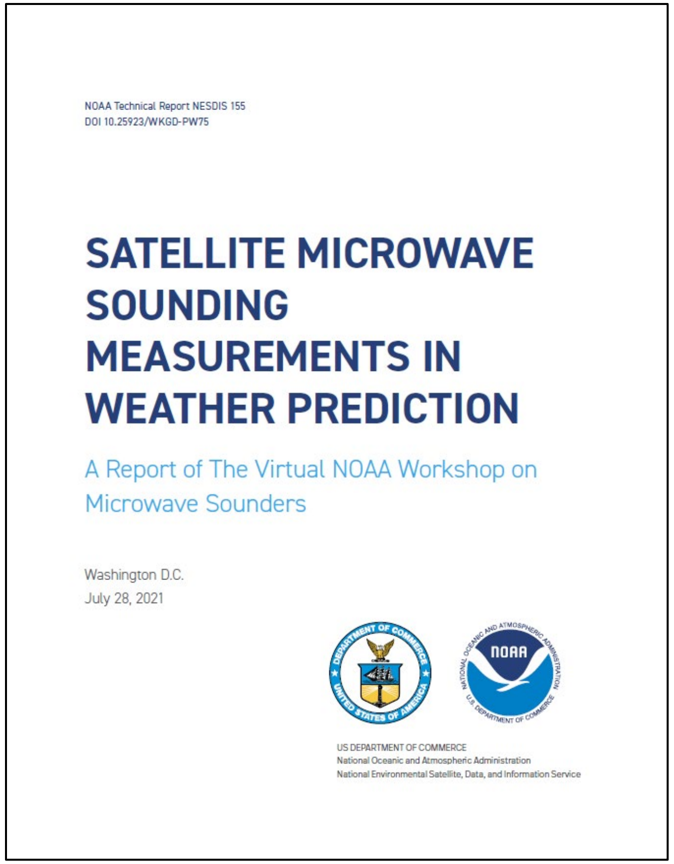
- NOAA plans to launch QuickSounder ~2025 to explore smallsat capability; currently no RFI detection capability planned
- Multiple cubesat sounders from academia/industry; expect some to include RFI detection capability
- Earliest chance for on-orbit RFI capability currently limited by programmatic constraints; hopefully this decade, but that will be well into deployment of 5G systems

- Latency requirements for future mw sounder obs may shrink to 3hrs or less. This can be met with multiple cubesats. Resulting high coverage duty cycles would reduce spectrum sharing availability.

Future NWP MW Sounder Fleet Configuration?

A just-released report from a NOAA workshop that asked major NWP organizations what they need from future MW sounders. https://doi.org/10.25923/wkgd-pw75

- Backbone sounders w/ATMS-like channels (23-183 GHz); qty 3-6 depending on int'l partners & exact architecture details
- Augmentation by cubesat/smallsat sounders (50-183 or 118-183 GHz due to size limits); qty 2-dozens
- Interest in MW hyperspectral sounders (10s to 100s of channels)
- Recognition of RFI threat (see next slide)


NOAA Technical Report NESDIS 155
DOI 10.25923/WKGD-PW75

SATELLITE MICROWAVE SOUNDING MEASUREMENTS IN WEATHER PREDICTION

A Report of The Virtual NOAA Workshop on Microwave Sounders

Washington D.C.
July 28, 2021

US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Future NWP MW Sounder Fleet Configuration?

Executive Summary includes 2 items of interest with respect to future MW sounder observing architecture

11. Expanding commercial demand for Radio Frequency (RF) spectrum can degrade the ability to maintain and to improve NWP forecast capability. Both future backbone and supplemental MW sounder missions should incorporate technology to address radio frequency interference (RFI). Periodic real-world RFI surveys would provide highly valuable guidance.

12. A constellation architecture that combines diverse backbone and supplemental missions with differing launch dates and mission lifetimes needs a robust calibration strategy that recognizes inter-calibration, absolute calibration, and traceable calibration as intertwined. This will also help achieve NWP advances from future coupled models.

Summary for RFI topic

- Noise-like nature of IMT signals + wide bandwidth sounder channels require "2nd Gen" approach to RFI detection for satellite MW sounders
- Adjacent-channel detection scenario may present best chance of RFI detection → requires signal reception outside nominal sounding channel edges
- Future mw sounder fleet architecture under development now: ATMS-like backbone augmented by cubesats
- RFI threat is real and recognized; programmatic factors currently limiting earliest chance of on-orbit RFI capability in JPSS sounders
- Future satellite sounder designs (post-JPSS for backbone sounders, today for cubesats) will incorporate digital back ends (DBEs)
  - DBEs are well-suited for implementing RFI detection
  - More robust calibration: important for short-lived radiometers like cubesats
  - Flexibility: some designs would allow reprogramming after launch
  - "post-ATMS" could begin late-2030s to 2040; earlier opportunities for infusion of 2nd Gen desirable
  - Space-qualified capabilities already exist (GHz bandwidths) and keep improving rapidly
- 2nd Gen RFI designs also generate challenges
  - Larger data volume & rates → system design & algorithm choices
  - Some DBE designs require significant power & thermal accommodation (extra 10s to 100s of watts of power and waste heat)
  - Can scale back to fit available power, etc. but performance must also scale back (# channels, bandwidths, NEDT, etc)

A note on Spectrum Sharing

From NASA's Spectrum Office:

NASA is always open to discuss and consider technical solutions that enable equitable spectrum access and recognizes that novel techniques may be needed to facilitate NRDZs. NASA is investigating the use of NRDZs as a potential solution to sharing on a case-by-case basis. NASA Spectrum does not currently support or oppose spectrum sharing in passive bands. There are issues related to the practicality of implementing, monitoring, and enforcing the complex regulations that would need to be addressed prior to adopting such an approach.

My own thoughts:

Spectrum sharing sounds nice on paper, and the technology exists to an extent (although it might require connectivity that isn't available everywhere/all the time). But I believe there are major practical and regulatory challenges, and it sets a scary 'slippery slope' paradigm for the future.