Statement of

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Before the

Committee on Science, Space, and Technology

U.S. House of Representatives

"Spectrum Needs for Observations in Earth and Space Science"

Chairwoman Johnson, Ranking Member Lucas, Members of the Committee for this hearing, thank you for the opportunity to contribute today. It is an honor to be asked to testify on an issue that brings together two areas that have been central to my technical work over the last 35 years: the scientific use of passive sensed data from space for environmental applications, and the spectrum management aspects of space systems.

I work for The Aerospace Corporation on spectrum management as it relates to meteorological satellites and space systems. For those who may be unfamiliar with Aerospace, we are a non-profit that was established by the US Congress in 1960 to provide independent and objective technical advice to military, intelligence, and civil space programs. We have a national security STEM workforce of about 3,000 space experts – over three quarters of our organization – who work quietly behind the scenes to support essentially every US agency that is engaged in space. As a federally chartered non-profit, our only motivation is to help the US achieve success in its space missions.

My 35 years of spectrum experience includes two major environmental satellite programs for NOAA, one of which is the Joint Polar Satellite System or JPSS. JPSS has a sounder instrument, specifically a microwave radiometer, which performs passive measurements worldwide in 22 passive frequency bands, including the 23.8 Gigahertz spectrum. This sensor is essential to the timeliness and accuracy of weather predictions around the world.

Because making passive measurements of subtle atmospheric conditions from space requires listening very carefully for natural phenomena against a background of human-created electromagnetic energy from our billions of radios, I have become very familiar with the International Telecommunications Union (ITU) study process and closely monitored the study reports and discussions through the ITU that resulted in the 24 Gigahertz spectrum emission limits in 2019.

Today, I want to make three main technical points to the Committee. First, that the same regulatory protection limits cannot be applied to a space-based passive sensor and a smartphone or other communications receiver. Their operation and sensitivities are vastly different, because passive weather sensors are measuring the very subtle noise floor. Most communications engineers consider the noise floor unusable and would not be concerned with emissions at or below that level. Second, that moderate levels of contamination caused by radio frequency interference created by neighboring services are harder to identify and hence more damaging than very high or very low levels. And third, that there is no mitigation for such contamination of weather sensors – the best one can do is identify that contamination and avoid propagating that data into supercomputers and the weather models.

I also want to make the overarching point that scientific input into the spectrum regulatory process is essential for successful and informed outcomes.

<u>Differences Between Communications Receivers and Space-Based Passive Sensors</u>

Communications receivers, such as those in our smartphones or in ground stations, rely on an active transmitted signal originating from an antenna to carry our voice or videos. But space-based passive sensors are very different technologies that do not have the same functionality or protection requirements. Unlike communications receivers, these satellite microwave radiometers are extremely sensitive power measurement devices for detecting energy emissions. One analogy about the sensitivity of space-based passive measurements: it is like trying to hear a whisper in San Francisco while standing 500 miles away in San Diego.

Passive measurement instruments seek to measure the minute natural variations in the noise floor. What is the noise floor? While this is a complex technical subject, the term noise refers to unwanted electrical signals that are always present in electrical systems. The primary natural source of noise in radio systems - that cannot be eliminated - is caused by the thermal motion of electrons. A representation of the noise floor is shown in Figure 1.

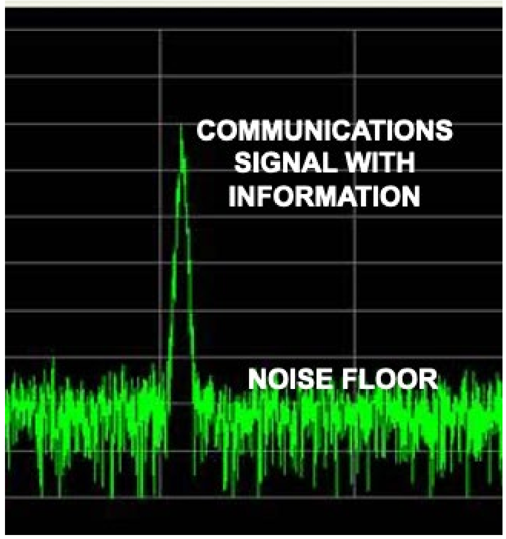

Figure 1. The noise floor.

A traditional communications device is designed to detect and maximize the signal content while discarding the noise, but a radiometer is designed to detect the small changes in that noise level caused by properties in the atmosphere. This critical difference between radiometers and traditional communications devices may not be understood by communications engineers who have not worked with these sensitive instruments. And it may also not be understood that these space-based radiometer measurements are crucial to weather forecasting.

Weather Forecasting and Contaminated Signals

Space-based radiometers use the radio spectrum noise floor to measure the weak emissions of the atmosphere. From these data, temperature, water vapor and other values may be determined.

Contamination of these frequencies by terrestrial manmade sources is therefore a concern to accurate weather forecasting. Contamination can be grouped into three categories: obvious contamination, which is easily detected and can be worked around; undetectable contamination, which is too small to have any effect on weather measurements; and insidious contamination, which is too small to be obvious, but big enough to have an adverse effect on measurements. Insidious levels of contamination are the greatest concern for weather forecast accuracy. (Figure 2)

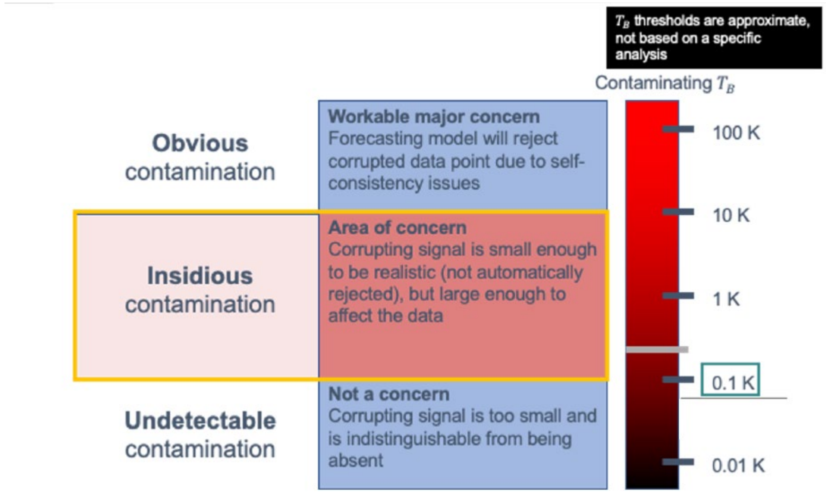

Figure 2. Types of spectrum contamination.

While terrestrial communications radio equipment may not direct their signals upward intentionally, that operation may still result in contaminated measurements. Some technologies are more likely than others to have their energy bounce upward off the ground, nearby buildings, or the terrain in a way that can be observed by passive sensing satellites.

Microwave-based passive measurements make a significant contribution to weather forecast accuracy: scientific experts that assimilate data into supercomputer models report that data sensed from multiple passive frequency ranges are used together for inputs that account for 30 to 40% of the overall improvement of short-range weather forecasting skill[1]. The practical effect of this is that without the microwave data from satellites as model inputs, there could be a 3-to-6-hour reduction in warning issuance for a 3-day weather forecast.

On Detecting Contaminated Signals

The best way to detect the presence of contaminated passive measurements is to use a space-based enhanced capability on board the same satellite that is collecting the operational weather data. Such a device for JPSS has been preliminary designed, but it currently lacks the funding needed to be developed and deployed on upcoming JPSS satellites scheduled for launch in the next few years.

An additional method, also lacking funding, would detect the presence of unwanted energy in the passive bands and perform measurements of 5G emissions using a separate small satellite or airborne-based instrument that surveys the radio frequency environment.

[1] Radio-Frequency Interference (RFI) Workshop, European Centre for Medium-range Weather Forecasting (ECMWF), Reading UK, September 2018 found at https://events.ecmwf.int/event/96/attachments/958/1675/Workshop_report.pdf

It is important to highlight that if contaminated measurements are identified, those data will be omitted from model input, meaning there is less information to inform weather forecasts. There is no method to recover passive measurements once they are contaminated – since as I described above there are no techniques to mitigate interference given the nature of passive measurements. When passive measurements are identified as contaminated, the data being sought is simply unavailable for that specific area and time.

The Need for Scientific Input

In closing, I would like to highlight that scientific input into the spectrum regulatory process is essential. For example, in the future, the FCC may consider service rules for terrestrial services adjacent to passive bands, such as the 50 Gigahertz passive bands used to determine atmospheric temperatures. The passive measurements in that band are critical contributors to weather models. I am heartened that this hearing is being held to examine these issues, and I would like to thank the committee for this opportunity to testify. I look forward to answering your questions.

Publications and References relevant to this hearing topic:

ECMWF (European Centre for Medium-range Weather Forecasting)**, 2018, Radio Frequency Interference (RFI) Workshop Final Report**, (held 13 – 14 September 2018 at, Reading UK.) https://events.ecmwf.int/event/96/attachments/958/1675/Workshop_report.pdf

GAO, "Spectrum Management: Agencies Should Strengthen Collaborative Mechanisms and Processes to Address Potential Interference", GAO-21-474, released July 19, 2021

Institute of Electrical and Electronic Engineers (IEEE) Geoscience and Remote Sensing Society (GRSS), Comments in Federal Communications Commission Engineering and Technology (ET) Docket 21 – 186, posted June 29, 2021.
https://ecfsapi.fcc.gov/file/1062804433840/GRSS_FARS_FCC_24GHZ_comments_final.pdf

Liu, Quanhua (Mark), Cao, Changyong, Grassotti, Christopher, and Lee, Yong-Keun, "How Can Microwave Observations at 23.8 GHz Help in Acquiring Water Vapor in the Atmosphere over Land?" Remote Sensing, 2021, 13, 489. https://doi.org/10.3390/rs13030489

Lubar, D.G., Kunkee, D.B., Avery, S., Cashin, L. M., "Developing a Sustainable Spectrum Approach for 5G Services & Critical Weather Forecasts," January 13, 2020, Aerospace Center for Space Policy. https://aerospace.org/paper/developing-sustainable-spectrum-approach-5g-services-critical-weather-forecasts

National Telecommunications and Information Administration, Comments in Federal Communications Commission Engineering and Technology (ET) Docket 21 -186, dated June 28, 2021
https://ecfsapi.fcc.gov/file/106280511404913/NTIA%20Comments%20re%2024%20GHz%20Emission%20Limits%20(ET%20Dkt.%20No.%2021-186%2C%20GN%20Dkt.%20No.%2014-177).pdf

Official Journal of the European Union, L 127/13, "**Commission Implementing Decision (EU) 2019/784 of 14 May 2019 on harmonization of the 24.25 – 27.5 GHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services in the Union**" consolidated with Official Journal of the European Union, L 138/29, "**Commission Implementing Decision (EU) 2020.590 of 24 April 2020 amending Decision (EU) 2019/784 as regards an update of relevant technical conditions applicable to the 24.25-27.5 GHz frequency band**," https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02019D0784-20200430&from=EN