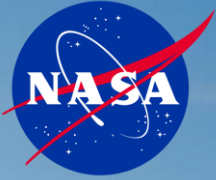


NASA Perspectives on Satellite Passive Remote Sensing

National Aeronautics and
Space Administration



David Franc

ADS support for NASA

September 30, 2026

Objective

To address common areas of misunderstanding related to passive remote sensing.



Earth Exploration-Satellite Service

- A radio service defined in RR No. **1.51**:

Earth exploration-satellite service: A radiocommunication service between *earth stations* and one or more *space stations*, which may include links between *space stations*, in which:

- information relating to the characteristics of the Earth and its natural phenomena, including data relating to the state of the environment, is obtained from *active sensors* or *passive sensors* on *Earth satellites*;
- similar information is collected from airborne or Earth-based platforms;
- such information may be distributed to *earth stations* within the system concerned;
- platform interrogation may be included.

This service may also include *feeder links* necessary for its operation.

- Additionally, RR No. **1.52** states:

meteorological-satellite service: An *earth exploration-satellite service* for meteorological purposes.

Categories of Earth Exploration-Satellite Service

- Data transmission and communications - EESS
 - Transmission of data between EESS spacecraft and Earth stations
 - Links for spacecraft to interrogate ground-based data collection platforms for scientific purposes
- Microwave Passive Remote Sensing - EESS (passive)
 - A spaceborne sensor that measures natural RF emissions from the Earth's surface and atmosphere for scientific purposes.
- Microwave Active Remote Sensing - EESS (active)
 - A spaceborne sensor that conducts measurements of the Earth's surface and atmosphere by transmitting a signal which is returned from the area under measurement and received by the sensor.

Categories of Earth Exploration-Satellite Service

- Data transmission and communications - EESS
 - Transmission of data between EESS spacecraft and Earth stations
 - Links for spacecraft to interrogate ground-based data collection platforms for scientific purposes
- Microwave Passive Remote Sensing - EESS (passive)
 - A spaceborne sensor that measures natural RF emissions from the Earth's surface and atmosphere for scientific purposes.
- Microwave Active Remote Sensing - EESS (active)
 - A spaceborne sensor that conducts measurements of the Earth's surface and atmosphere by transmitting a signal which is returned from the area under measurement and received by the sensor.

EESS in the Table of Allocations (data transmission)

	5.201 5.202
400.15-401	METEOROLOGICAL AIDS METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) 5.208A 5.208B 5.209 SPACE RESEARCH (space-to-Earth) 5.263 Space operation (space-to-Earth) 5.262 5.264
401-402	METEOROLOGICAL AIDS SPACE OPERATION (space-to-Earth) EARTH EXPLORATION-SATELLITE (Earth-to-space) METEOROLOGICAL-SATELLITE (Earth-to-space) Fixed Mobile except aeronautical mobile 5.264A 5.264B
402-403	METEOROLOGICAL AIDS EARTH EXPLORATION-SATELLITE (Earth-to-space) METEOROLOGICAL-SATELLITE (Earth-to-space) Fixed Mobile except aeronautical mobile 5.264A 5.264B

For an EESS allocation used for data transmission and communications, the transmission directionality will be indicated in parentheses.

EESS (passive) and EESS (active) in the Table of Allocations

For an EESS allocation used for passive remote sensing, there is no transmission direction.

“passive” will be indicated in parentheses.

23.15-23.55	FIXED INTER-SATELLITE 5.338A MOBILE
23.55-23.6	FIXED MOBILE
23.6-24	EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) 5.340
24-24.05	AMATEUR AMATEUR-SATELLITE 5.150
24.05-24.25	RADIOLOCATION Amateur

	5.549
35.2-35.5	METEOROLOGICAL AIDS RADIOLOCATION 5.549
35.5-36	METEOROLOGICAL AIDS EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION SPACE RESEARCH (active) 5.549 5.549A
36-37	EARTH EXPLORATION-SATELLITE (passive) FIXED MOBILE SPACE RESEARCH (passive)

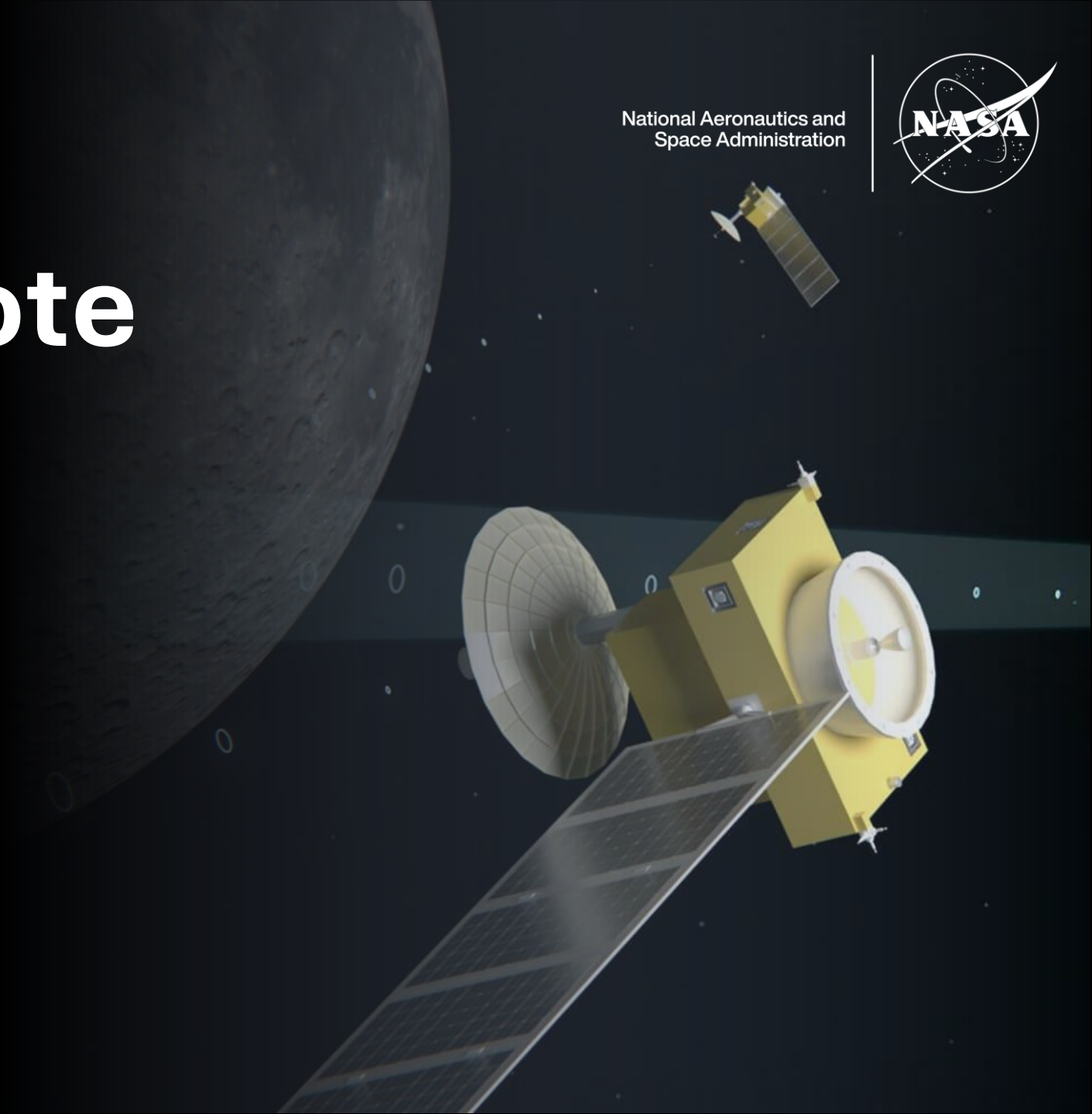
For an EESS allocation used for active remote sensing, there is no transmission direction even though the sensor transmits from space towards Earth.

“active” will be indicated in parentheses.

Microwave Passive Remote Sensing

EESS (passive)

National Aeronautics and
Space Administration

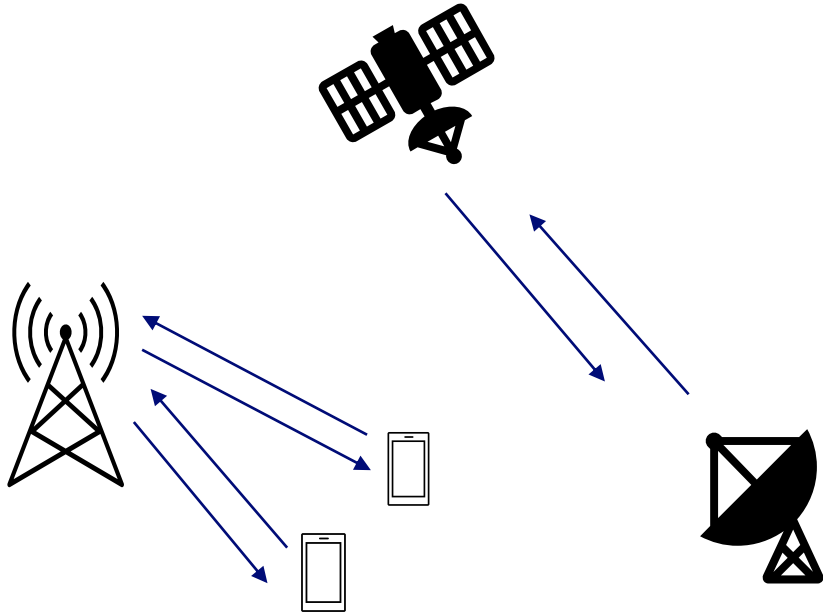


What is Microwave Passive Remote Sensing?

- The Earth and its atmosphere emit low level natural RF radiation.
- The level of these natural RF emissions is affected by temperature, humidity, chemical composition and other atmospheric parameters.
- A passive sensor can be thought of as a highly complex, very sensitive power meter that measures small variations in the levels of these natural emissions at key frequencies.
 - Interference power adds to the desired measured level, thereby biasing the measurement.
 - Interference at high levels can often be identified in post-processing resulting in data being discarded - the measurement bias caused by interference cannot be removed, making the data useless.
 - Worse, interference at low levels may be undetectable, but is significant enough to result in erroneous data being ingested into numerical weather prediction models, causing inaccuracy in the model outputs.

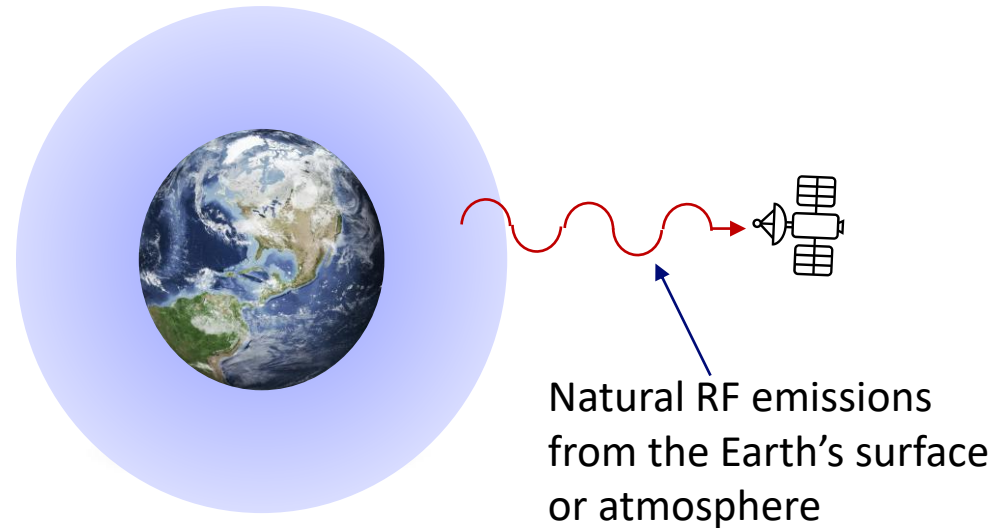
How is passive remote sensing different than radiocommunications?

Radiocommunications



Traditional radiocommunications services involve the intentional transmission of information between two or more stations.

Passive remote sensing



No information is transmitted to the passive sensor – all information is derived from the level of natural emissions radiated from Earth's surface and atmosphere.

Comparison: Traditional Radiocommunications vs. Passive Sensing

Consideration	Radiocommunications	Passive Sensing
Frequency Selection	Flexibility to change frequency within limitations of propagation, design and regulatory requirements.	No flexibility- Frequency is entirely defined by the frequency-dependent physics of the parameter that is being measured.
Transmitter	Designer has flexibility to control the transmit power and antenna gain within practical and regulatory limits.	The Earth's surface and atmosphere is the signal source. There is no mechanism to increase transmitter power or antenna gain.
Receiver	Designed to receive and demodulate transmitted signals.	Designed to detect very small changes in RF levels from low level natural RF emissions.
Interference Effects	Interference consumes link margin up to the point where the margin is gone, then resulting in loss of information.	Sensors directly measure natural RF emission levels, so there is no link margin. Interference adds to the received power and will bias the received power level resulting in an erroneous measurement.

A Common Misconception

A sentiment that has been conveyed at ITU-R meetings and WRCs:

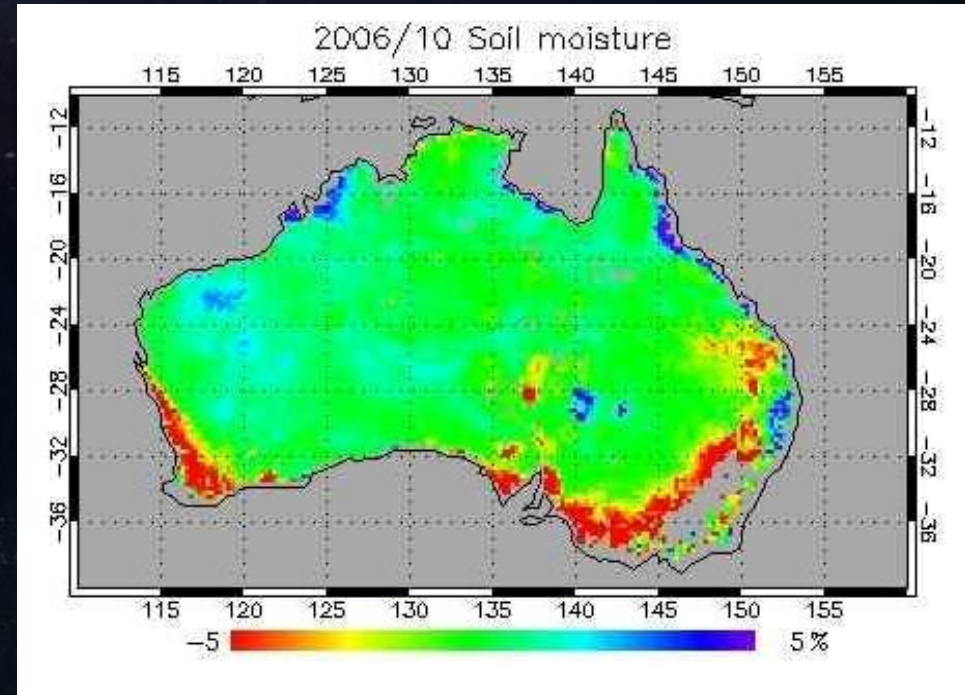
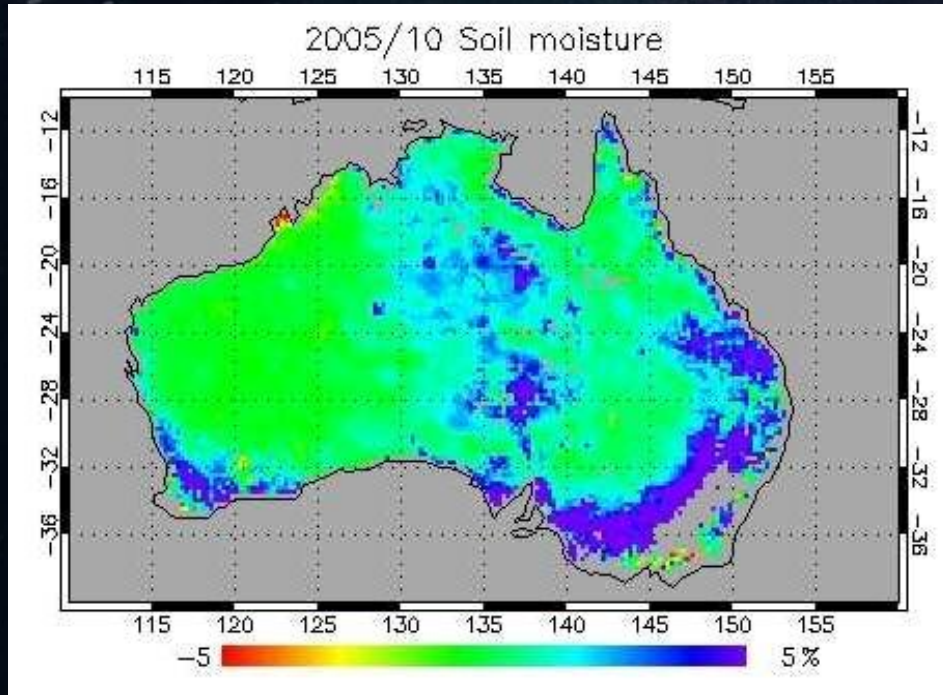
“My administration does not operate passive sensors, therefore protection of them is not an important consideration in establishing our position.”

Why is passive remote sensing important to all administrations?

- Only a limited number of administrations operate satellite passive remote sensing missions.
- From these limited, but important operations, all administrations benefit from the data.
 - The data is used in globally distributed global and regional numerical weather prediction products.
 - Your national meteorological service is using modeling products based on passive remote sensing data.
 - The data is distributed globally for administrations to conduct their own local weather modeling and prediction.
 - Data is also shared globally for applications such as disaster detection/mitigation/response, agriculture, and land use planning.

NASA AMSR-E sensor on AQUA Mission

Soil Moisture Comparison over Australia – October 2005 and October 2006



Red indicates lower soil moisture, while blue indicates higher soil moisture.

Additional Passive Remote Sensing Facts

- The need to detect very low-level natural RF emissions makes passive remote sensing particularly sensitive to unwanted emissions from active services operating in adjacent frequency bands.
- Passive sensors typically operate multiple sensor channels in different frequency bands, each providing a unique measurement, however the data from those multiple channels are used in combination to produce data products.
- Ground-based/lower orbit interference sources can be particularly problematic, however space-to Earth and space-to-space transmissions can also result in interference cases
 - Reflections off the surface of the Earth from space-to-Earth transmissions.
 - Interference into passive sensor cold sky calibration configuration

Cold Sky Calibration

- To meet accuracy/sensitivity requirements, in-orbit passive sensors periodically conduct a routine calibration
 - Measurement of an internal “hot” source at a known temperature
 - Measurement of the deep space cold sky (~ 2.7 kelvin) temperature, with an antenna looking away from Earth
- When the sensor antenna is looking away from Earth, RF emissions from other spacecraft at similar or higher orbits can fall within the antenna main beam or sidelobes.
- Received power greater than from the cold sky will bias the calibration and all measurements using that calibration will be in error.

WRC-27 Passive Remote Sensing Concerns

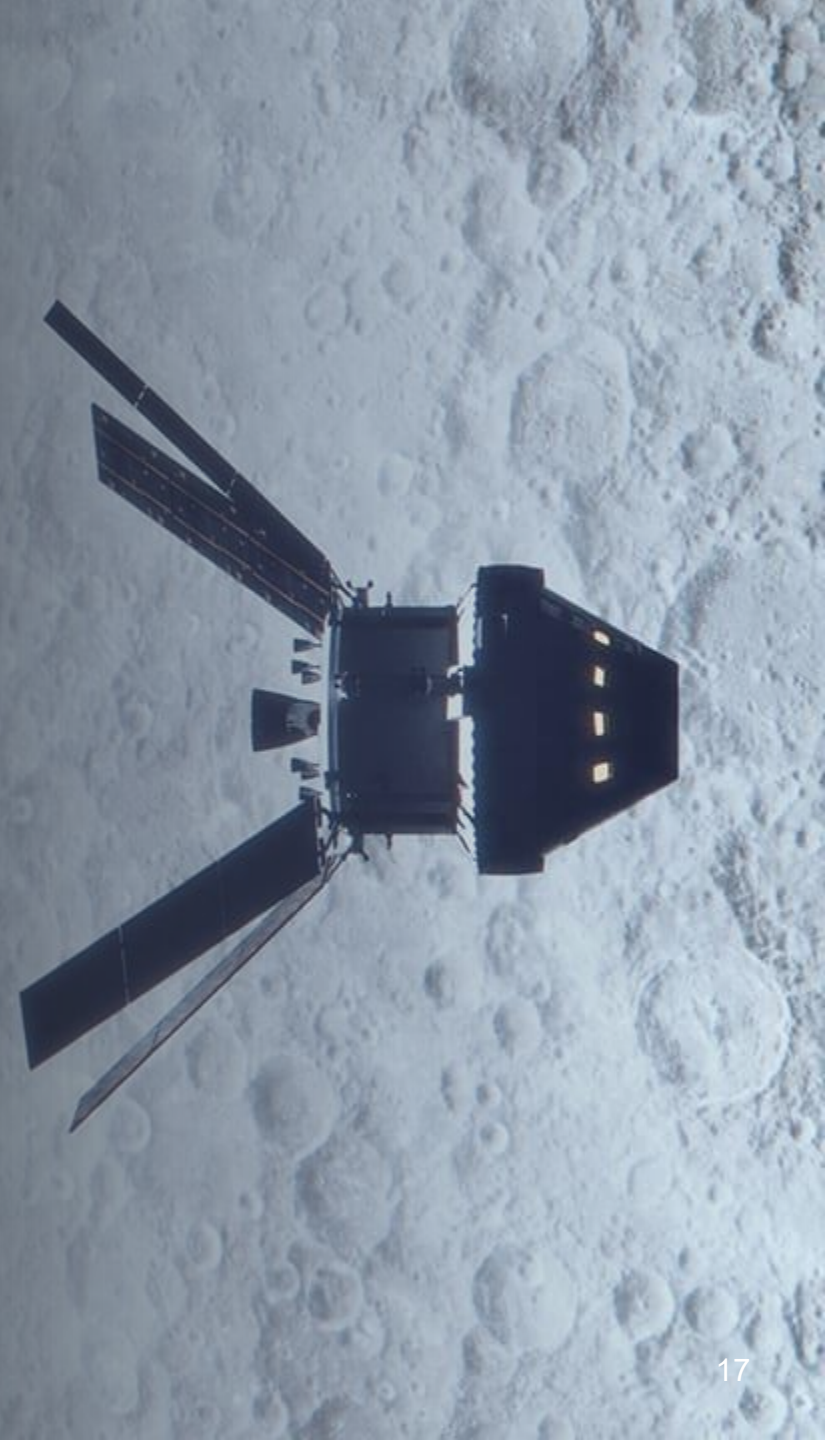
AI 1.1- Ensure protection of EESS (passive) in 50.2-50.4 from non-GSO ESIM deployment in the adjacent bands.

AI 1.3- Ensure protection of EESS (passive) in 52.6-54.25 GHz from unwanted emissions of non-GSO gateways in the 51.4-52.4 GHz.

AI 1.8- Ensure the requirements of EESS (passive) are met when allocating/identifying frequency bands for the radiolocation service

AI 1.18- Establish unwanted emission limits for active radio services operating adjacent to the following frequency bands subject RR No. **5.340**: 86-92 GHz, 114.25-116 GHz, 164-167 GHz and 200-209 GHz.

AI 1.19- New primary allocations to the EESS (passive) in 4200- 4400 MHz and 8400- 8500 MHz.



Future Considerations- EESS (passive)



Passive Remote Sensing Above 275 GHz

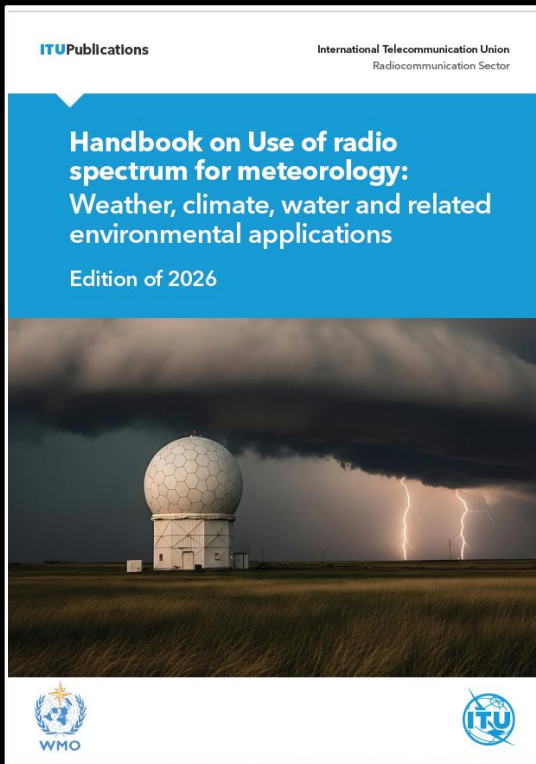
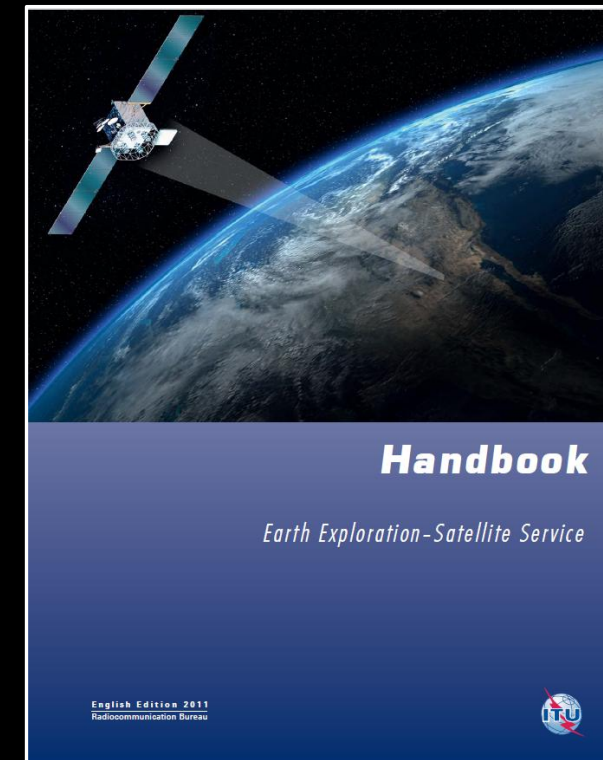
- The Table of Allocations has an upper limit of 275 GHz
- Passive frequency bands above are identified for use under RR No. **5.565**.
- Investment in passive remote sensing operations is occurring above 275 GHz.
- Additional frequency bands identified in RR No. **5.565** being incorporated into sensors under development.
- Passive remote sensing requirements need to be considered when:
 - active services seek new identifications above 275 GHz
 - the upper limit of the Table of Allocations is eventually revised

Summary of Important Points

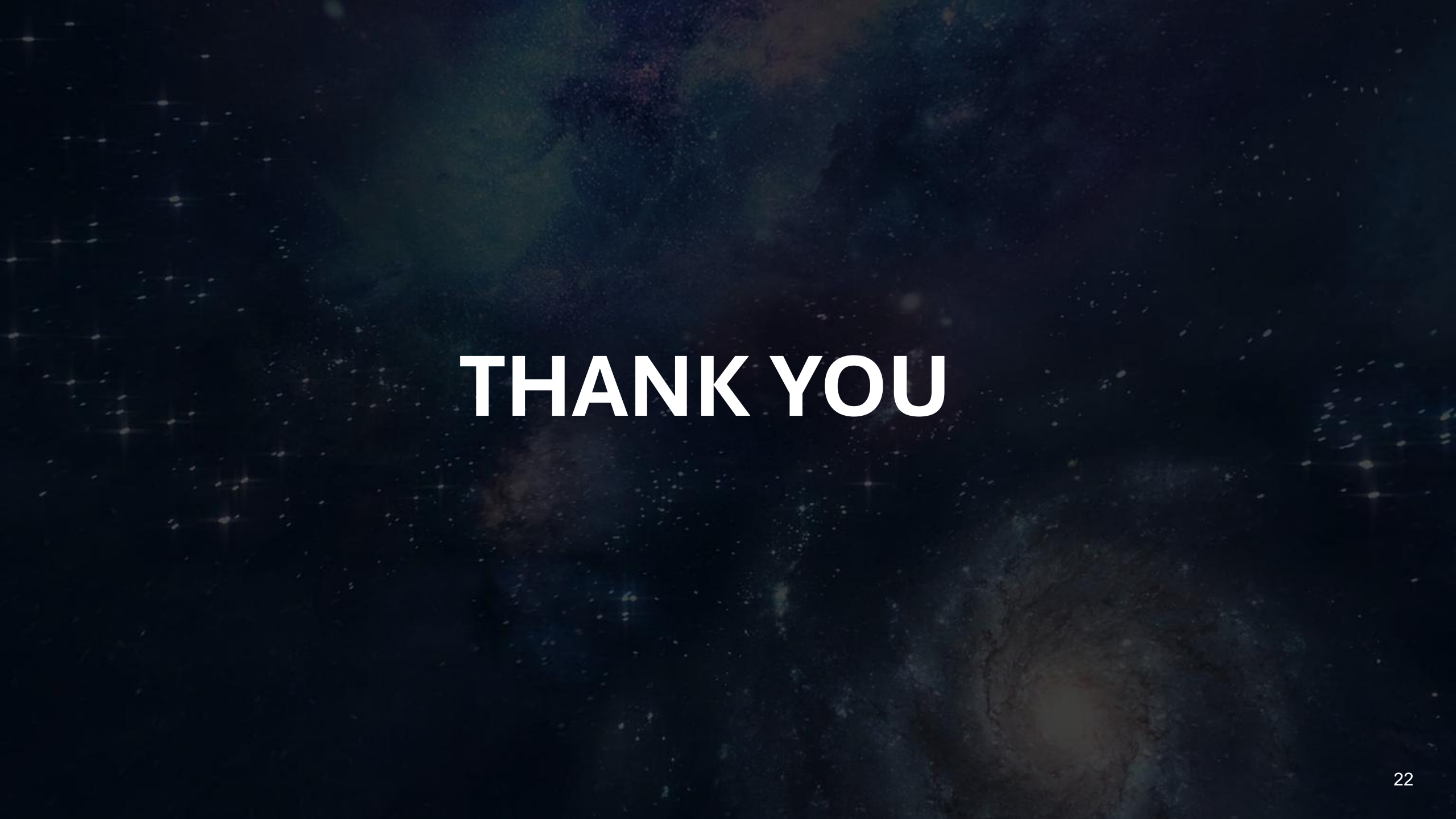
- Passive remote sensing does not have flexibility in selecting frequencies for operation - the measurement frequency is established by physics based on the parameter being measured.
 - The allocations for EESS (passive) cannot be moved to alternative frequency bands.
 - Loss of use of a passive band due to persistent interference leads to loss of capability where there is often no alternative frequency band.
- While passive remote sensing satellites are operated by a limited number of administrations and international organizations, all administrations benefit from the operations.
 - Data is distributed globally for use by administrations.
 - Modeling products based on the measurement data are distributed globally for administrations to use.

Additional Reading

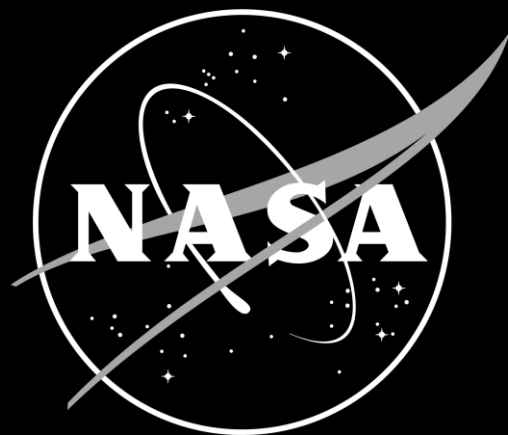
ITU-R Handbook Earth Exploration-Satellite Service



ITU-R Handbook Use of Radio Spectrum for Meteorology: Weather, Climate, Water and Related Environmental Applications

The background of the slide is a deep space image featuring a dark blue and black cosmic scene. It includes several bright, multi-pointed star patterns and faint, wispy structures resembling galaxies or nebulae, creating a sense of vastness and depth.

THANK YOU



SPACE OPERATIONS MISSION DIRECTORATE
SPACE COMMUNICATIONS & NAVIGATION



scan@nasa.gov

nasa.gov/SCaN



