IEEE-GRSS
Frequency Allocations in Remote Sensing (FARS) Technical Committee

Minutes of 2016 Annual Meeting

July 11th, 2016

The meeting is convened at 17:35 in room 306B at the China National Convention Center in Beijing by FARS Technical Committee (FARS-TC) co-chairs Sidharth Misra and Paolo de Matthaeis.

Twelve persons in attendance (not including the committee chairs): Michael Benson, Daniel Czech, Dara Entekhabi, Mike Inggs, Yann Kerr, David Kunkee, David Le Vine, Leland Pierce, Jinzheng Peng, Steve Reising, Thomas von Deak and Marwan Younis.

The meeting starts with Sidharth Misra giving the annual FARS chair report. The activities of FARS since July 2015 were summarized, which included:

1. the new FARS logo was introduced to members. Members were recommended for suggestions on the logo, if any
2. the annual contribution to the Geoscience and Remote Sensing Magazine, written by FARS-TC members Mike Spencer and Fawaz Ulaby on the study "A Strategy for Active Remote Sensing Amid Increased Demand for Radio Spectrum" performed by the US National Academy of Science;
3. sponsoring and getting involved in the organization of a joint workshop on RFI with the Radio Astronomy community, that will take place in Socorro, New Mexico, USA, on October 17-21, 2015 (FARS co-chair Paolo de Matthaeis is also the general technical chair of the workshop for remote sensing and several other FARS-TC members are on the Scientific Organizing Committee);
4. filing a response to a US Federal Communication Commission (FCC) Notice of Proposed Rule Making, focusing on the need for special protection for EESS passive services around 37GHz and revisiting rules prohibiting WiGig instruments on-board aircraft between 57-64GHz, which could impact the performance of instrument such as AMSU, ATMS, GPM and WindSat;
5. attending the SFCG-36 meeting of the Space Frequency Coordination Group in June 2016 and the Spring meeting of the Committee on Radio Frequencies (CORF) in May 2016;
6. further developing the Database of Frequency Allocations for Microwave Remote Sensing and Observed Radio Frequency Interference (RFI).

Co-chair Paolo de Matthaeis gives a brief report on the SFCG-36 meeting.

Leland Pierce presents the improvements on the Frequency Allocations and RFI Observations Database, and Paolo adds a few comments on its new functionalities. The toll is currently password-protected and will soon made available to all FARS-TC members, at which point feedback is encouraged.

Thomas von Deak gives a presentation on the revision of active sensors protection criteria used in ITU-R compatibility studies and on the development of a reporting form for interference affecting passive sensors. He had already presented a summary of the 2015 World Radiocommunications Conference (WRC) results and 2019/2023 WRC agenda items during a 20-minute slot left open by a no-show in the preceding RFI technical session. For more details on all these topics, see also his presentation "ITU-R Sensor Related Matters" included below.

Sid concludes the discussion soliciting the submission of ideas for next year budget, particularly those related to the IEEE-GRSS strategic objectives of crowd-sourcing, education, globalization and interaction with industry and space agencies.

The meeting is adjourned at 18:30.

Action Items:

- give FARS-TC members access to the Database of Frequency Allocations for Microwave Remote Sensing and Observed Radio Frequency Interference (RFI) and collect feedback on it;
- Gather suggestions for new strategic initiatives.

National Aeronautics and Space Administration

SCaN

SPACE COMMUNICATIONS AND NAVIGATION

FARS Report: ITU-R Sensor Related Matters

Tom vonDeak

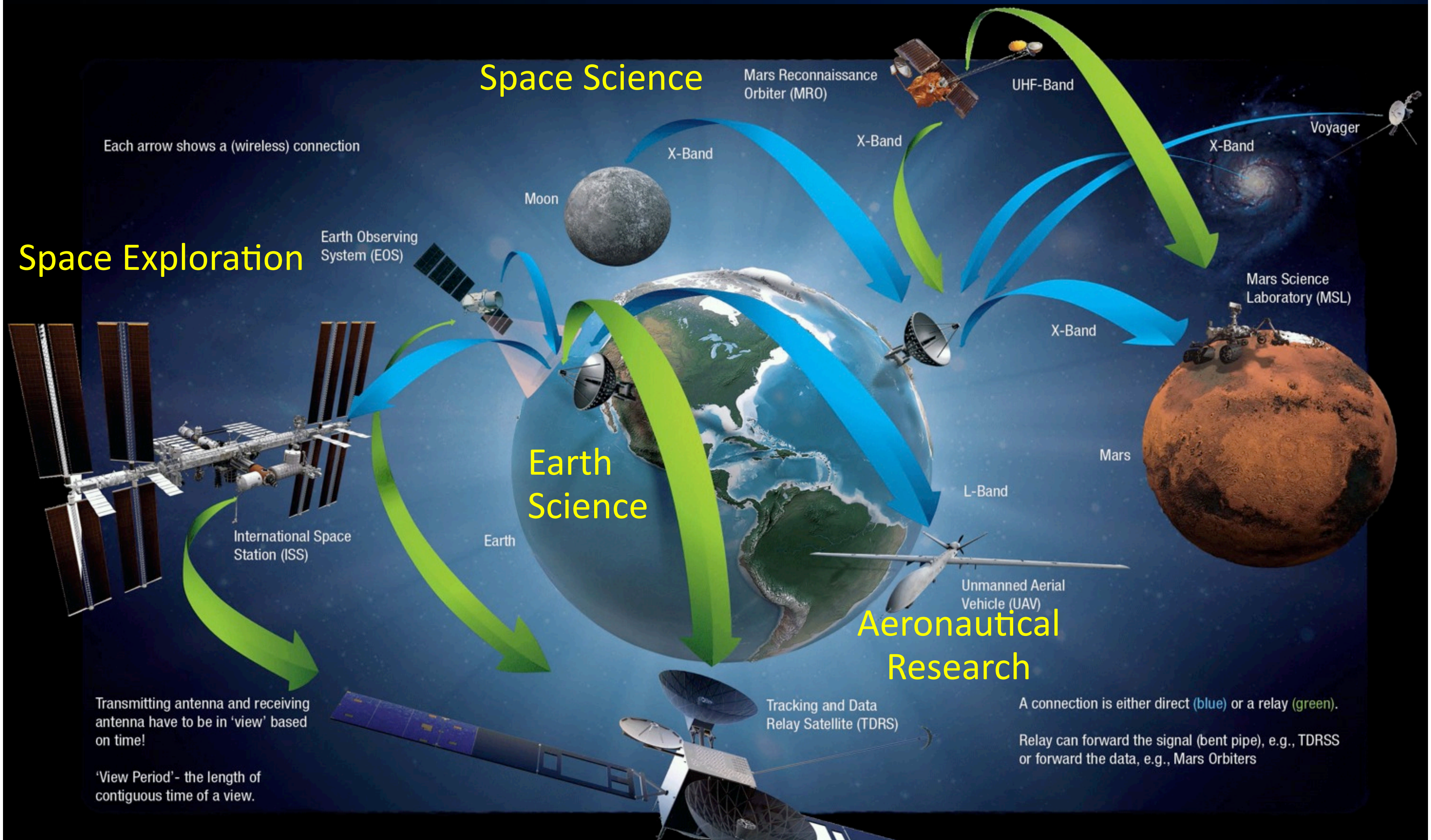
NASA Remote Sensing Spectrum Manager

July 2016

Keeping the universe connected.

www.nasa.gov

NASA Spectrum Overview



Virtually every NASA mission requires radio spectrum

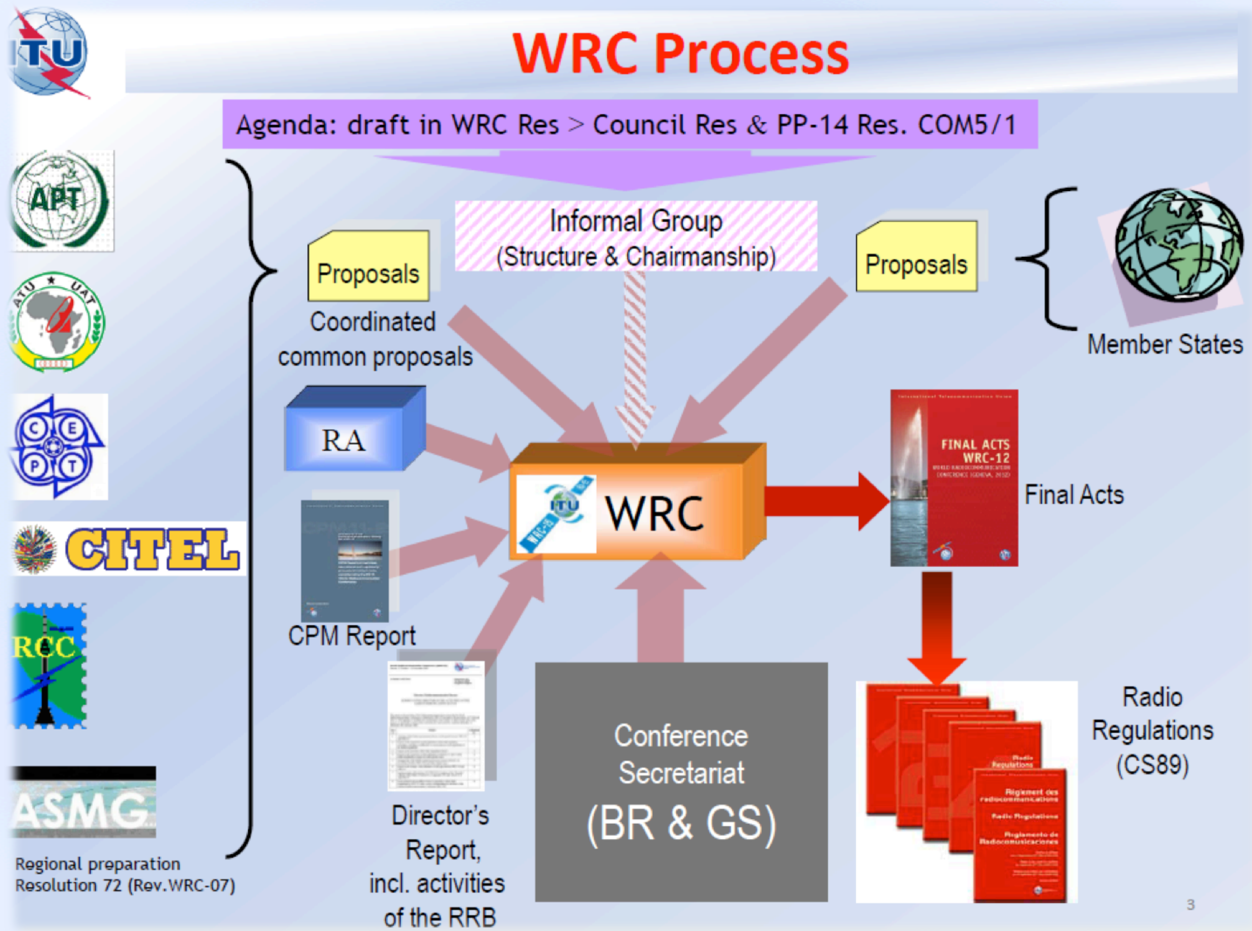
ITU-R Activity Report Topics

- World Radiocommunications Conference (WRC)-2015 results
- WRC-19/23 agenda items
- Active sensor protection criteria revision
- Passive sensor reporting form

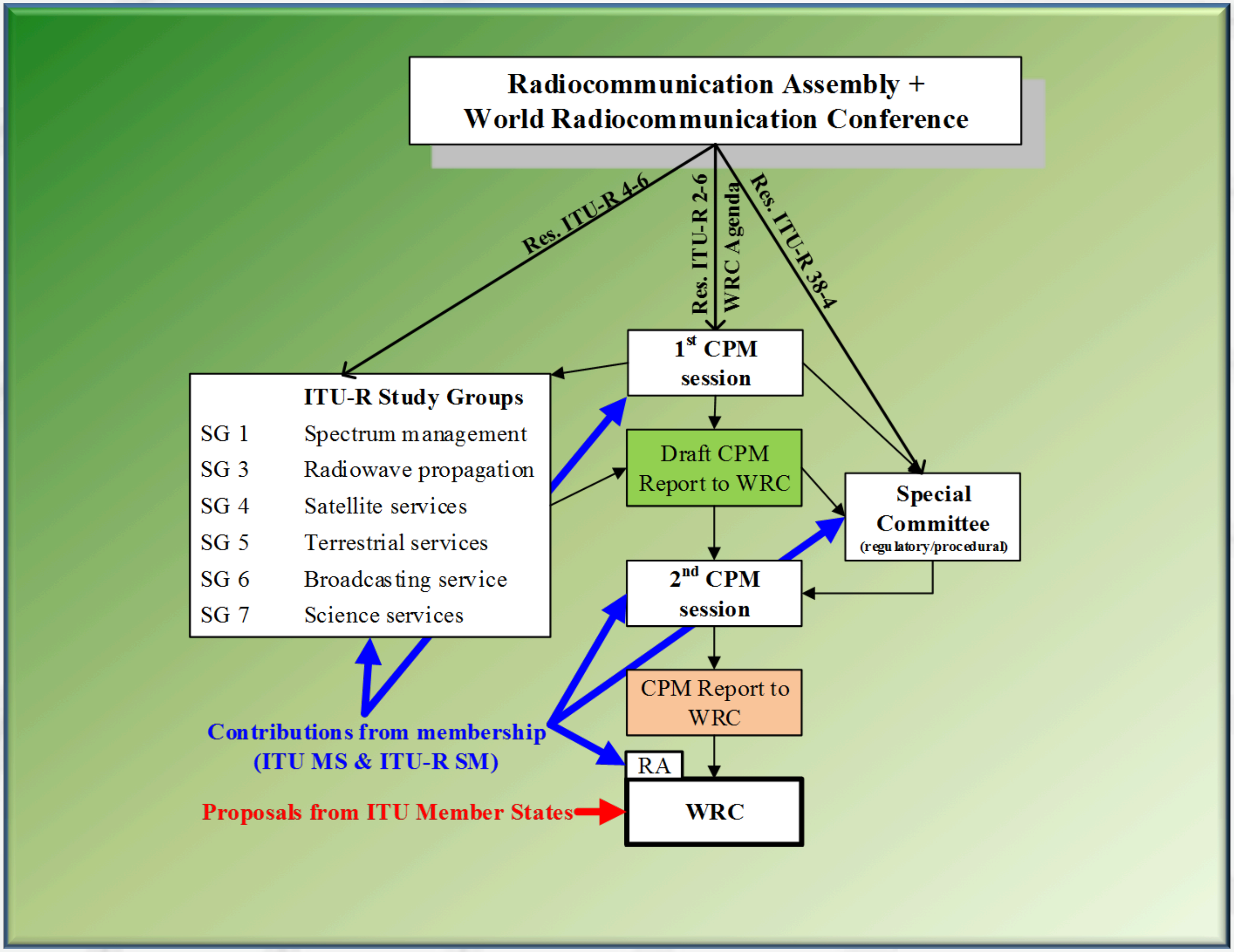
WRC-15 Overview

- 2015 World Radiocommunication Conference (WRC-15) took place in Geneva, SW, 2-27 November 2015
  - Over 160 International Telecommunication Union members participated in treaty-based modifications to the ITU Radio Regulations
- Technical preparatory work done in the ITU Radiocommunication Sector Study Groups
- Conference Preparatory Meeting (CPM) report contained approaches (Methods) for satisfying each agenda item (technical basis upon which Administration proposals are made)
- US Regulators oversee conference preparations by Federal Government (NTIA) and private sector (FCC)
- U.S. Delegation to WRC-15 lead by Ambassador Decker Anstrom (Former Chairman of the Weather Channel companies)

WRC-15 Results: Overview



Organization of the ITU-R conference preparatory work



WRC-15 Agenda Items of Interest to NASA

- **Primary items of NASA advocacy**
  - AI 1.11 – EESS uplink allocation in 7190-7250 MHz range to help alleviate congestion in the 2 GHz bands.
  - AI 1.12 – 600 MHz EESS (active) expansion around 9.5 GHz
  - AI 1.13 – Proposed edits to FN 5.268 to reduce current limits on use of 410-420 MHz for SRS operations near the ISS
  - AI 1.14 - Consideration of the feasibility of achieving a continuous reference time scale
  - AI 5 – Predetermined coordination distance between SRS ground stations and aircraft mobile stations in 2200-2290 MHz
  - AI 9.1.8 - Nanosat/Picosat regulatory issues
  - AI 9.2.2 – Clarification of the use of deep space allocations during near-Earth mission phases

- **Items of U.S. (and NASA) advocacy**
  - AI 1.5 – Use of FSS allocations for beyond line of site UAS command and control

AI 1.12: EESS (active) up to 600 MHz extension within 8 700-9 300 MHz and/or 9 900-10 500 MHz

U.S./NASA Objectives

- To allocate the 9.9-10.5 GHz band to the EESS (active) with regulatory protection for radiolocation, radio astronomy, and the amateur-satellite service.
- To improve the resolution of EESS (active) Earth observation systems operating in the 9.3-9.9 GHz band, while protecting incumbent services.

Rationale

- Larger bandwidth allocation is needed to enable higher resolution data in EESS (active) systems to improve the imaging and geo-information systems used for disaster relief, humanitarian aid, land use study, and surveying.

Results

- Primary EESS (active) allocation in 9200-9300 MHz and 9900-10400 MHz with acceptable provisions to protect existing services.
- Agreement needed to operate over 8 countries

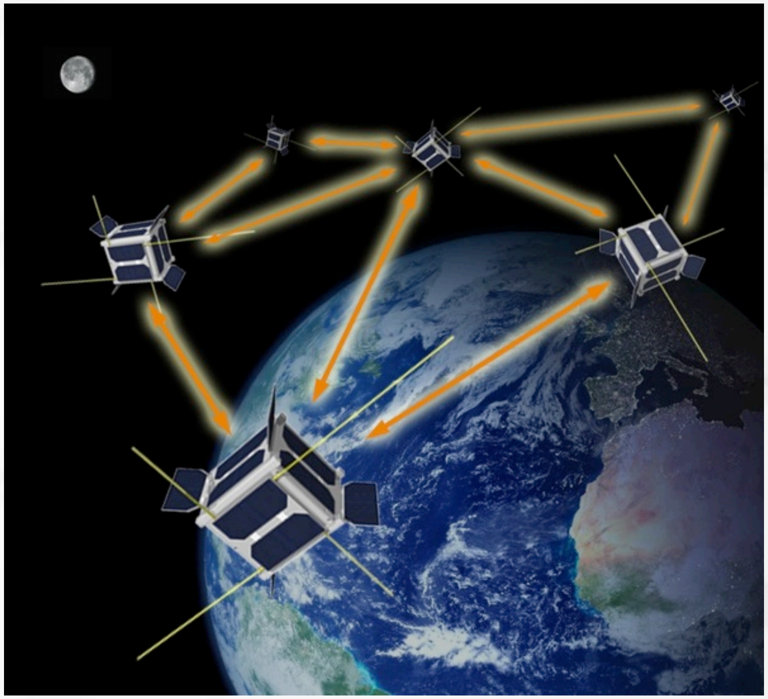
AI 9.1.8: Regulatory Aspects for nano- and picosatellites

U.S./NASA Objectives

- The U.S. supports no change to the RRs for this issue at WRC-15.
- As an item under the Director's Report, there are no Methods associated with this issue.

Rationale

- Issues with nanosatellite and picosatellite filing procedures for registering satellite networks can be addressed under the WRC standing agenda item for issues pertaining to satellite networks pursuant to Resolution 86 (WRC-07).



Results

- No change (NOC) to the Radio Regulations
- Future regulatory issues for nano- and picosatellites can be addressed through standing Agenda item

WRC-15 Agenda Items of Concern to NASA

AI 1.1 – Spectrum allocations for mobile broadband/IMT

- NOC at WRC-15 on 2 GHz bands
- NOC at WRC-15 for 5350-5470 MHz RLANs

AI 1.6.1 – FSS up and down links in Region 1 within 10-17 GHz

- FSS downlink in 13.4-13.65 GHz ensured no FSS uplinks allocation

AI 1.6.2 – FSS uplink spectrum being sought in Regions 2 and 3 within 13-17 GHz

- Limited FSS uplink in 14.5-14.8 GHz; SRS made co-equal with FSS

AI 1.9.2 – MMSS reverse band use in 8025-8400 MHz

- NOC in 8025-8400 MHz protecting EESS downlinks.
- MMSS downlink in 7375-7750 MHz acceptable.

AI 1.18 – New allocation for automotive applications in the 77.5-78 GHz band

- RLS added to the 77.5-78 GHz

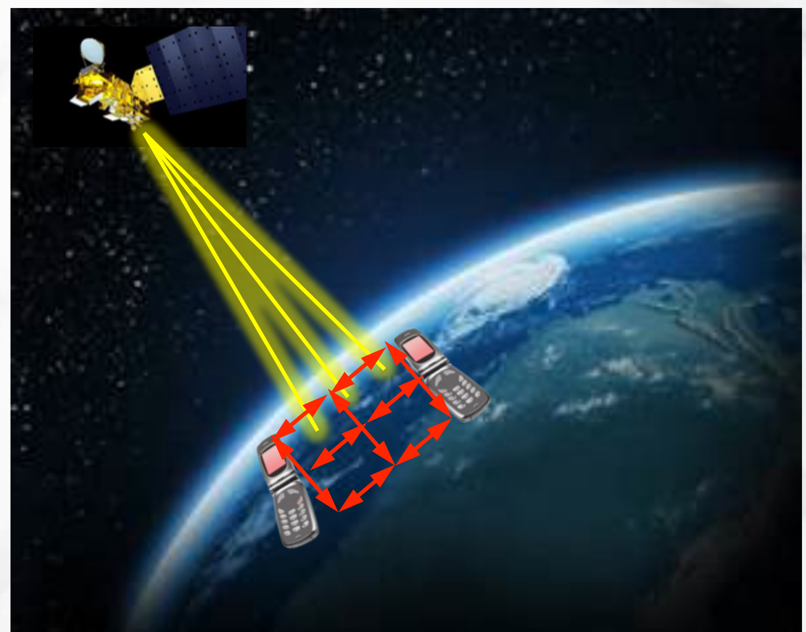
AI 1.1: Spectrum allocations for mobile broadband/IMT – 1427-1525 MHz

U.S./NASA Objectives

- IMT allocation in 1427-1518 MHz while ensuring the protection of critical existing systems
- Require mandatory OOBE limits on IMT to protect EESS (passive) in 1400-1427 MHz. - Res. 750: IMT base stations (-72 dBW/ 27 MHz) and mobile stations (-62 dBW/ 27 MHz).
- The U.S./CITEL IAP called for mandatory limits. NASA was involved in the negotiations within the U.S. and within CITEL to obtain agreement for mandatory limits.

Rationale

- Supporting IMT will expand mobile broadband and economic development throughout the Americas.
- Mandatory OOBE on IMT into 1400-1427 MHz protects spaceborne passive sensors (e.g., NASA's Soil Moisture Active/Passive (SMAP)).



Results

- IMT allocation in 1427-1518 MHz with mandatory OOBE limits on IMT base stations and mobile stations at US/CITEL levels.

AI 1.6.1/1.6.2: New FSS allocations in the 10-17 GHz frequency range

U.S./NASA Objectives

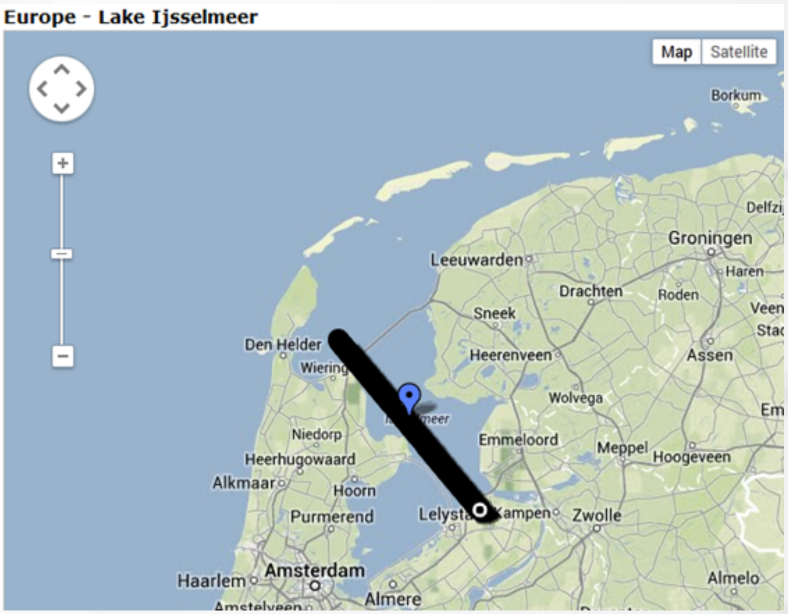
- Prevent an FSS uplink in the 13.25-13.75 GHz frequency region.
- Support an FSS downlink (Region 1) in the 13.4-13.65 GHz frequency band.

Rationale

- FSS uplinks in the 13.25-13.75 GHz band would harm NASA EESS (active) operations; in particular, altimeters such as the one on JASON.

Results

- Analysis of FSS uplink interference to the altimeter “measurement area of interest” proved incompatibility and prevented the allocation of an FSS uplink in the band.
- FSS downlink allocated in the 13.4-13.65 GHz band preventing future FSS uplink allocations. Analysis showed that this downlink allocation may result in very small interference zones at the Nadir points of the FSS GSO satellites operating in the band.



JASON altimeter:
“Measurement Area of Interest” example

Interest to NASA

AI 1.18 – New allocation for automotive applications in the 77.5-78 GHz band

U.S./NASA Objectives

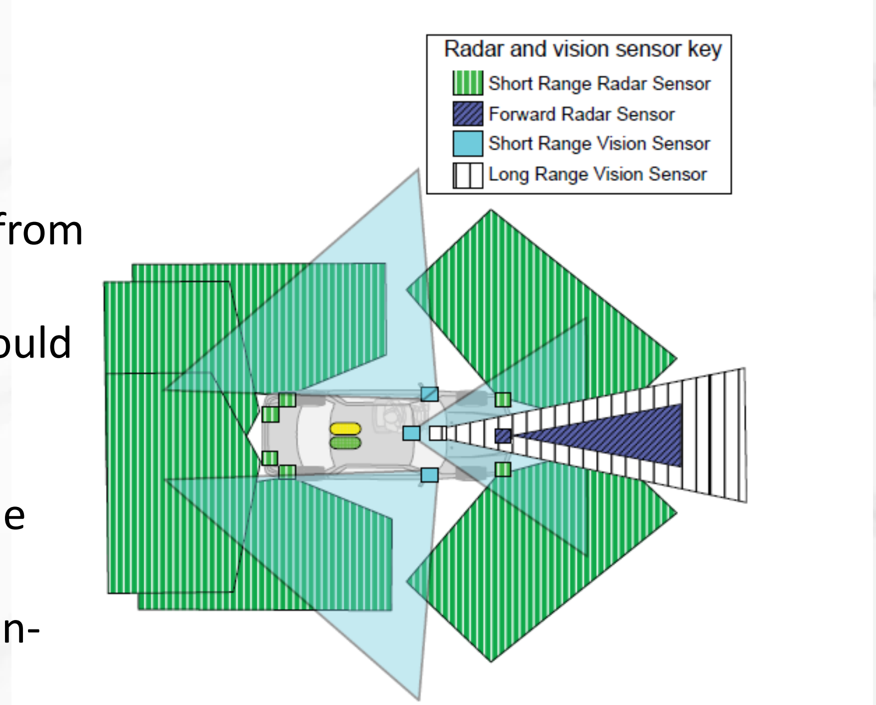
- Supported an RLS allocation in 77.5-78 GHz for automotive applications
- Preferred restricting the use of the potential radiolocation allocation to automotive radars

Rationale

- Would promote removing such applications from the 23.6-24 GHz band.
- Application of these radars on helicopters would potentially affect earth stations of SRS.

Results

- RLS allocation added to 77.5 to 78 GHz for the operation of automotive radar.
- Limited to ground-based applications (i.e. non-airborne).
- New WRC Res 759 for ITU-R studies to assist administrations in ensuring compatibility between the RAS, Amateur and Amateur Satellite services and RLS applications.



Light-vehicle sensor coverage overview (not to scale)

WRC-19 AIs of interest to NASA

WRC-19 Agenda Items of Potential Concern

- AI 1.5 - Earth stations in motion communicating with FSS GSO stations in 17.7-19.7 GHz (s-to-E) and 27.5-29.5 GHz (E-to-s) – WP 4A
- AI 1.6 - NGSO FSS in (s-to-E): 37.5-39.5 GHz/39.5-42.5 GHz and (E-to-s): 47.2-50.2 GHz/50.4-51.4 GHz – WP 4A
- AI 1.13 – Identification of bands for the future development of IMT – WP 5D/TG-5/1
- AI 1.14 – Broadband delivered by high-altitude platform stations – WP 5C
- AI 1.15 – Freq identification for land-mobile and fixed services applications in the range 275-450 GHz – WP 1A
- AI 1.16 - RLANs in bands between 5 150 MHz and 5 925 MHz – WP 5A
- AI 9 Issue 1.4 - Stations on-board suborbital vehicles - WP 5B
- AI 9 Issue 1.9 - Spectrum needs and possible FSS (E-to-s) allocation in 51.4-52.4 GHz band - WP 4A

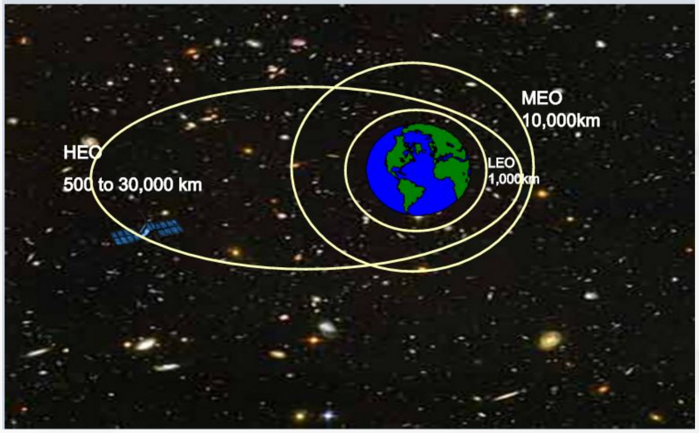
AI 1.6: non-GSO FSS in 37.5-39.5 GHz (s-E), 39.5-42.5 GHz (s-E), 47.2-50.2 GHz (E-s) and 50.4-51.4 GHz (E-s)

- Resolution **238 (WRC-15) identifies the following bands for consideration:**
  - 24.25-27.5 GHz, 37-40.5 GHz, 42.5-43.5 GHz, 45.5-47 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz, which have allocations to the mobile service on a primary basis; and
  - 31.8-33.4 GHz, 40.5-42.5 GHz and 47-47.2 GHz, which may require additional allocations to the mobile service on a primary basis,

NASA Objective

- NASA does not support revisions to the existing regulatory framework for non-GSO FSS systems unless studies conclude the existing protection of space science services, including passive sensing, will be preserved.

NGSO Orbit Types



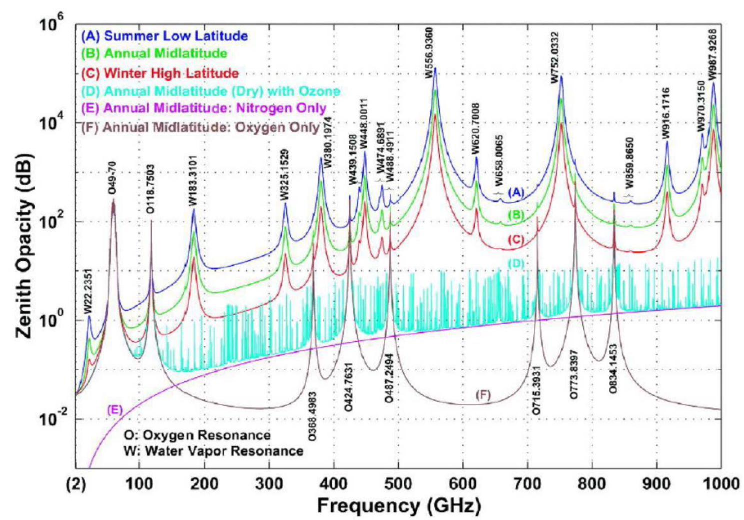
AI 1.15: introduction of land-mobile and fixed services into the frequency range 275-450 GHz

- RR No. **5.565** identifies nine of the bands in this frequency range for use by administrations for EESS (passive) and SRS (passive) applications: 275-286 GHz, 296-306 GHz, 313-356 GHz, 361-365 GHz, 369-392 GHz, 397-399 GHz, 409-411 GHz, 416-434 GHz and 439-467 GHz.

NASA Objective

- NASA supports the identification of frequency bands for use by systems operating in the land-mobile and fixed service by considering technology innovation, as long as these applications do not preclude the passive use of the bands identified in RR No. **5.565**.
- NASA supports the concept that no allocations will be made to any service above 275 GHz at WRC-19

The sensitivity of millimetre and sub-millimetre frequencies to atmospheric temperature and water vapour variations[2]



AI 1.16: WAS/RLAN issues in the frequency range 5 150 to 5 925 MHz

- Part of the work of AI 1.16 is to conduct further sharing studies to identify RLAN mitigation techniques that may facilitate sharing between WAS/RLAN systems and incumbent services in the 5150-5350 MHz, 5350-5470 MHz, 5725-5850 MHz, and 5850-5925 MHz bands.

NASA Objective

- NASA supports:
  - a review of the RLAN spectrum, technical and operational requirements in the 5 GHz range, as requested by Resolution **239 (WRC-15)** as pre-requisite to any further sharing studies in the range.
  - a global revision of the sharing situation in the full 5 GHz range for studying compatibility with RLANs.

SAR2 spot beam with three "groups" of RLAN present

WRC-23 AIs of interest to NASA

Tentative WRC-23 agenda items will be confirmed at WRC-19

- **AI 2.2:** to conduct, and complete in time for WRC-23, studies for a possible new allocation to the Earth exploration-satellite (active) service for **spaceborne radar sounders** within the range of frequencies around **45 MHz**…

  STATUS

  NASA is submitting studies examining the compatibility of the proposed EESS (active) operations with the incumbents. These studies will be used to assess the feasibility of any possibly sharing with the incumbents of the spectrum around 45 MHz and determine if a WRC-23 agenda item is warranted.

- **AI 2.3:** …review the results of studies relating to the technical and operational characteristics, spectrum requirements and appropriate radio service designations for **space weather sensors**…

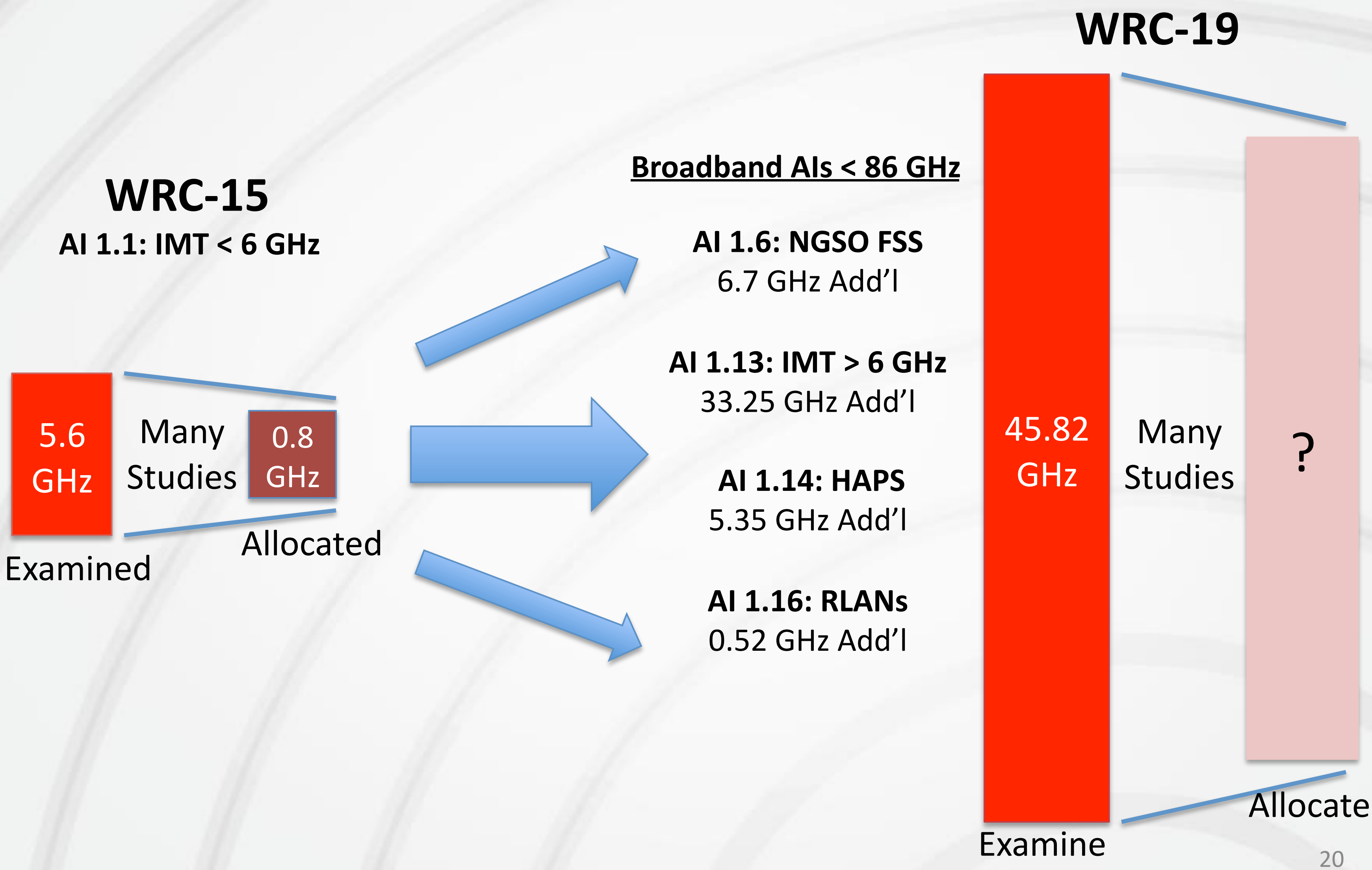
  STATUS

  NASA and NOAA are seeking technical and operational characteristics of space weather sensors for use in determining the scope of the studies needed.

WRC-15/19/23 Conclusions

- WRC-15 results were successful in preserving continued effective active and passive sensing operations.
- WRC-19 imposes challenges to NASA to develop the quantity of studies needed to counter threats to active and passive sensing.
  - NASA has to also preserve spectrum for its telecommunication infrastructure
- WRC-23 – In particular, obtaining space weather sensor technical and operational parameters is a current challenge.

Broadband a Growing Concern



REC. ITU-R RS.1166-4

- **Rec. ITU-R RS.1166-4**
  - Active sensors protection criteria used in ITU-R compatibility studies
  - Last revised in 1998
- **Key Issues**
  - The protection criteria need to be aligned with analysis methods
  - Protection criteria values need to be updated to reflect the state of the art
  - Sensor operational mechanics need to be described

Evaluation Criteria

Recommendation ITU-R RS.1166-4

Performance and interference criteria for active spaceborne sensors

Recommends 2

that the interference and data availability criteria given in Table 2 be applied for instruments used for active sensing of the Earth's land, oceans and atmosphere.

TABLE 2

Sensor type	Interference criteria		Data availability criteria (%)	
	Performance degradation	*I/N* (dB)	Systematic	Random
Synthetic aperture radar	10% degradation of standard deviation of pixel power	–6	99	95
Altimeter	4% degradation in height noise	–3	99	95
Scatterometer	8% degradation in measurement of normalized radar backscatter to deduce wind speeds	–5	99	95
Precipitation radar	7% increase in minimum rainfall rate	–10	N/A	99.8
Cloud profile radar	10% degradation in minimum cloud reflectivity	–10	99	95

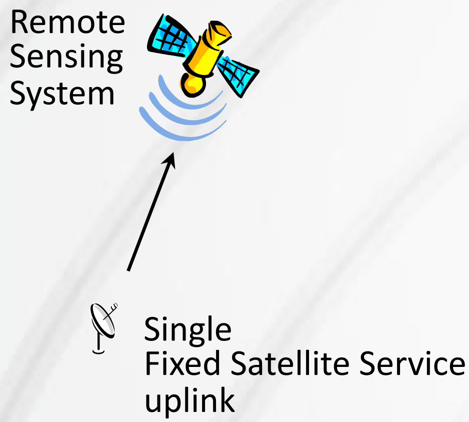
NOTES:.

- Systematic data availability is in regards to the data availability of a particular measurement area of interest.
- Random data availability is in regards to the overall data availability; that is, the availability over the repeat period of the sensor.
- Systematic data availability criteria doesn't apply to precipitation radar.

Compatibility Analysis

Two basic types of analysis

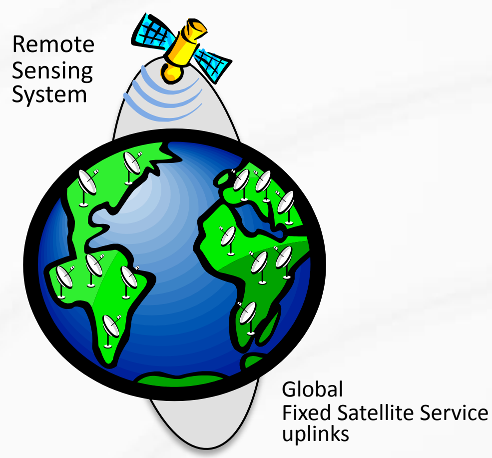
Single entry



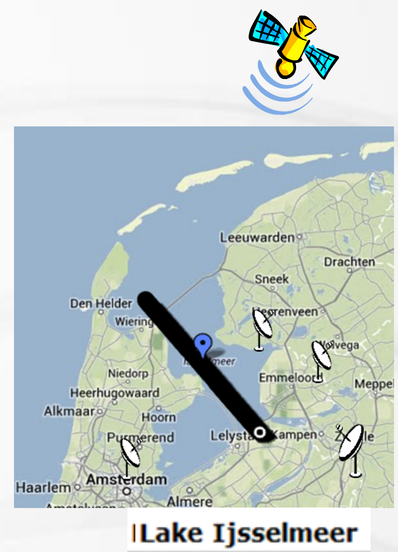
- Worst case characteristics
- Single or multiple scenarios

Dynamic analysis

Random



Systematic



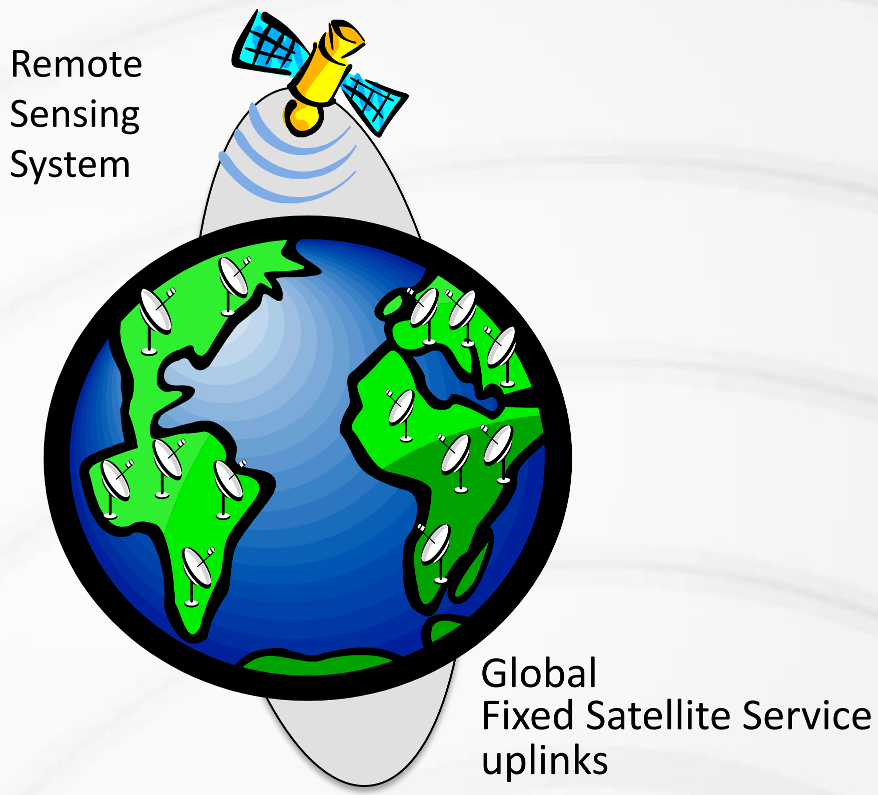
- Entire range of RF interactions are simulated
- Duration of simulation selected to cover the entire range of motion or when results don't vary significantly with additional time

Random Data Availability Criteria

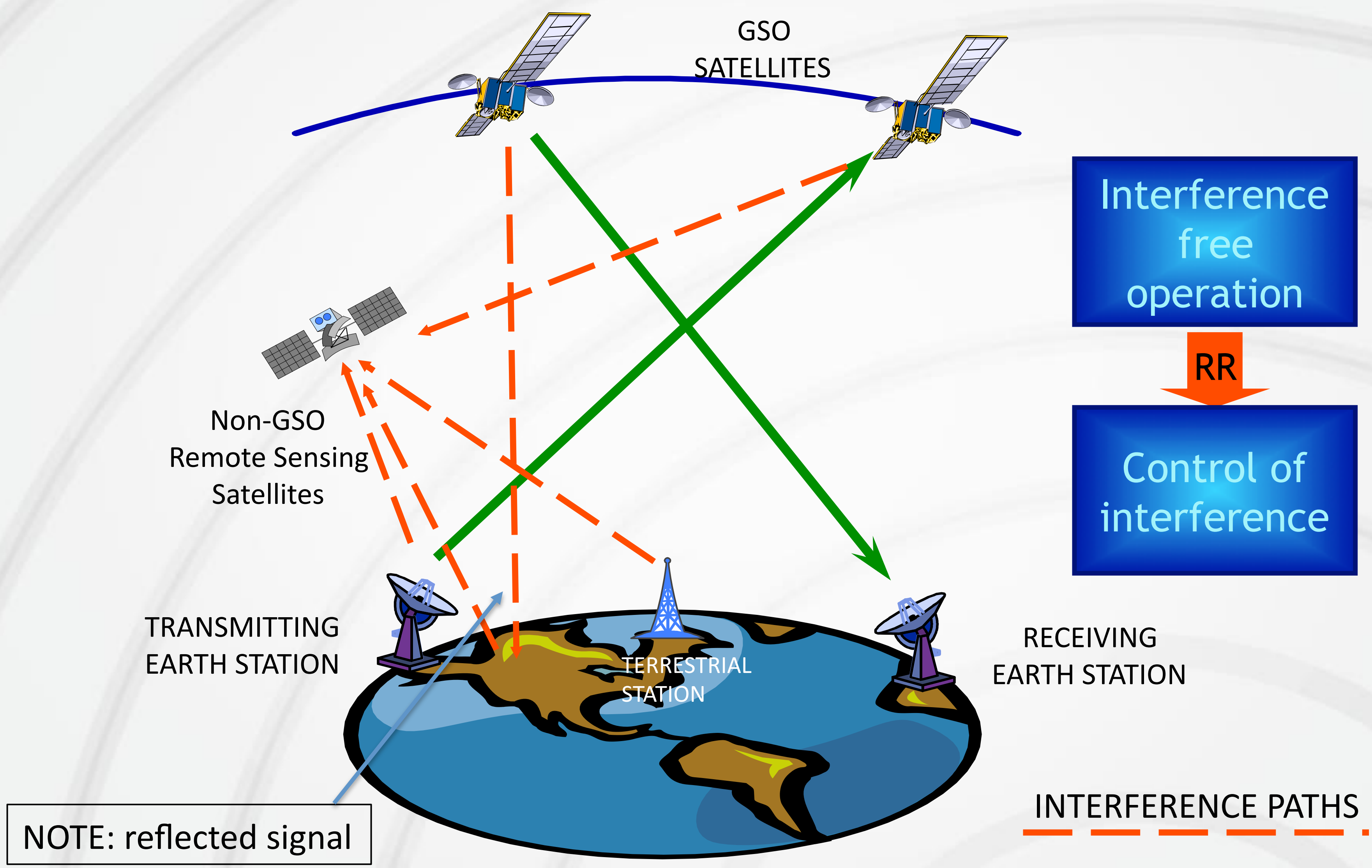
Global analysis simulated over the duration of the spaceborne sensor orbit repeat period.

Analyses are typically performed to determine the percentage of time that the threshold level is exceeded.

A more realistic measure of interference impact may be to determine the percentage of measurement area where the threshold level is exceeded.



Possible Interference paths to remote sensing satellites



Radio Regulations mechanisms for control of interference

Control of Interference

ALLOCATION

Frequency separation of stations of different services

POWER LIMITS

PFD to protect TERR services and EESS/ EIRP to protect SPACE services / EPFD to protect GSO from Non-GSO

REGULATORY PROTECTION

e.g. No. 22.2: Non-GSO to protect GSO (FSS and BSS)

COORDINATION

between Administrations to ensure interference-free operations conditions

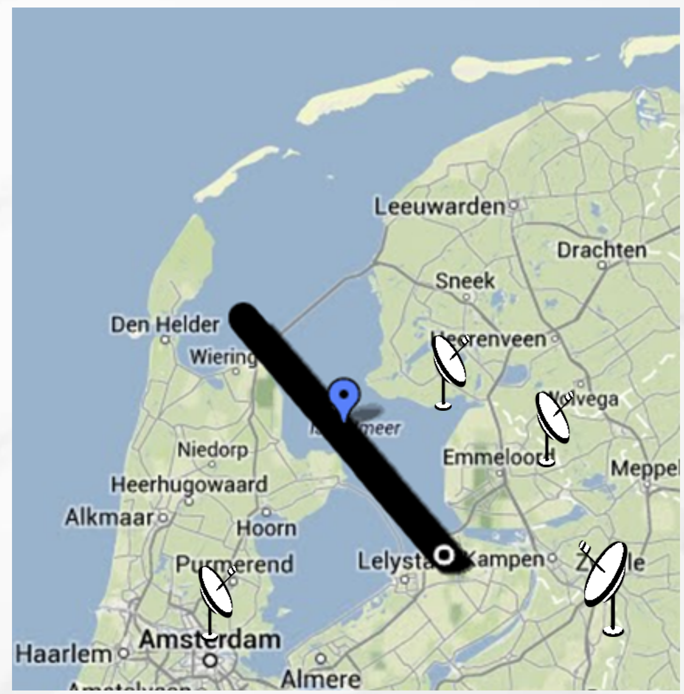
Systematic Data Availability Criteria

Analysis performed to determine interference impact to specific measurement areas.

JASON altimeter
USDA Global Lake and Reservoir Monitoring Program (83 sites)
Swath measured once per orbit repeat period   (10 days)

Average I/N per measurement set was used in determining if the protection threshold was exceeded.

This measurement area is comprised of 178 consecutive footprints. Height measurements can be derived from as few as 10 consecutive footprints.



Lake Ijsselmeer

Sensor Measurement Considerations

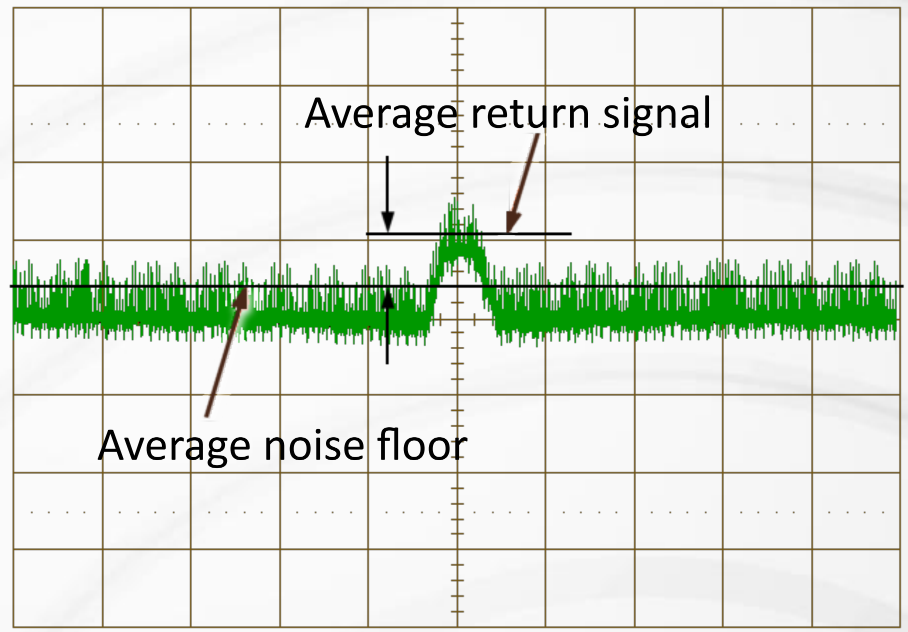
Background noise processing on-board the spacecraft

Active sensors measure the background noise level as well as the return signal.

The mechanism for on-board processing of the return signal and the noise level is not well understood.

What impact, if any, does the use of the background noise level in active sensor measurements have when assessing interference????

Detected radar pulse with background noise



Sensor Measurement Considerations

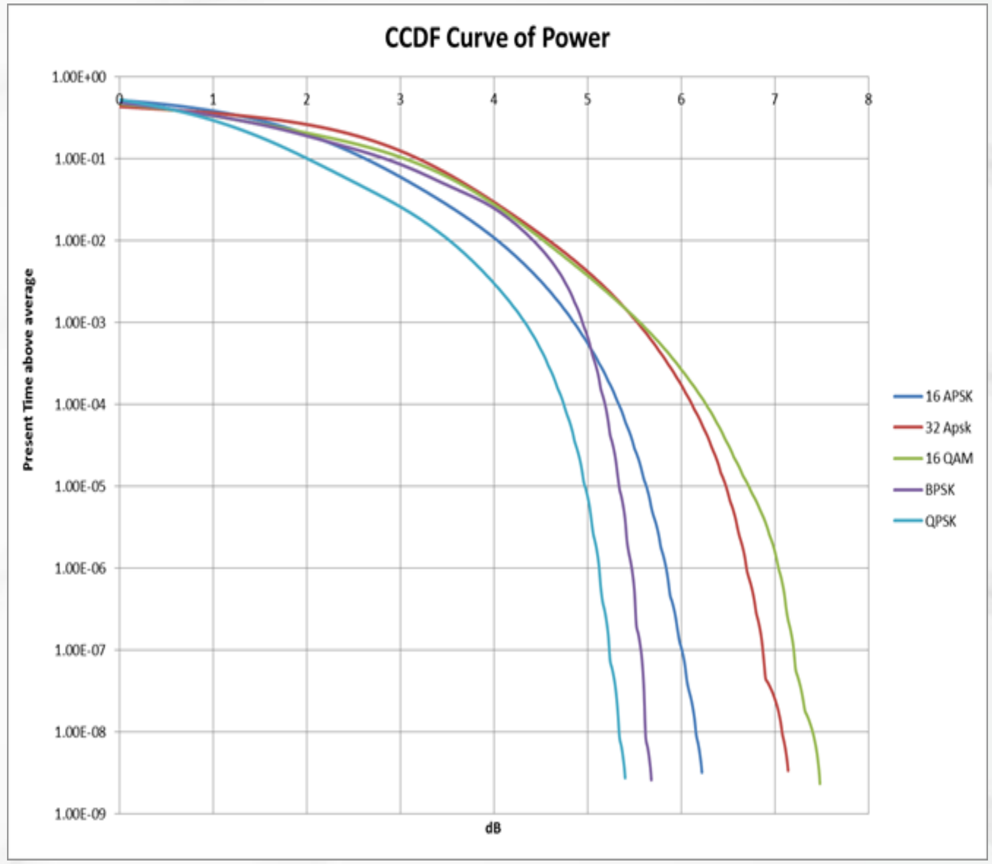
Sensor sensitivity to peak emissions

Altimeters employ peak power detectors and therefore are sensitive to the peak emissions of interference.

Precipitation radar and scatterometers use average power detectors and therefore sensitive only to the average power of the interference source.

These results of measurements show that the peak power exceeds the average power by more than 7 dB.

The application of peak power to impact on measurement degradation is not straightforward.



Statistical distribution of Power for common modulations

Revision of RS. 1166 Summary

- Work has initiated on the revision of Recommendation ITU-R RS.1166-4
- The members of FARS are invited to contribute to this revision process.
- Bearing in mind that participation in the ITU-R meetings may be difficult, FARS members can contribute through:
  - the U.S. WP 7C process
    - Telecons held about every two months
    - Not limited to U.S. nationals
  - Or the SFCG annual meetings

Issue defined at the SFCG-35 meeting in August 2015

"The SFCG recognizes **that almost all passive sensors operating in the Earth explorations-satellite service (passive) experience radio frequency interference (RFI) from various sources** on the Earth that degrade or obstruct the ability to measure target natural emissions."

While instances of harmful interference have already been reported to administrations requesting them to initiate actions to resolve RFI, such **cases were typically not reported to the ITU-R Radiocommunication Bureau (BR)** for the purposes of providing information or requesting assistance. As a result, **the BR is not aware of the magnitude of RFI instances affecting EESS passive sensors and has inaccurately reported that EESS is not as greatly impacted by RFI as other space services**.

Passive Sensor RFI Reporting Form

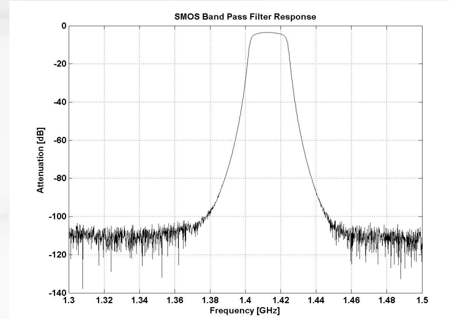
- ESA has been reporting RFI impacting SMOS operations in the 1 400 – 1 427 MHz band
  - RR No. 5.340: “no emissions allowed”
- ESA’s experience with the reporting process has yielded a RFI reporting template that augments the existing Radio Regulation reporting form.
- NASA and ESA have developed a draft ITU-R Recommendation formalizing and defining the use of the form for the reporting of RFI to administrations from where interference is found to occur from.

Initiatives to improve international RFI reporting

SFCG

- Report 32-1R2 “Passive Sensor Filter Characteristics”
  - For express use in analysing the causes of potential interference
- Report A32-1 “Inter-Member cooperation in resolving interference to EESS (active) and EESS (passive) operations”
  - Pledges support amongst members to assist in the resolution of RFI when their administrations are involved.
- Report 34-2R1 “Global RFI Survey …”
  - Global surveys of RFI levels observed by sensors in the EESS (active) band 1215-1300 MHz and the EESS (passive) band 1400-1427 MHz
- Resolution SFCG A36-2 “Reporting of Radio Frequency Interference to Earth Exploration-Satellite Service (Passive) Sensors”
  - Encouraging members to report instances of RFI
  - Adopted in June 2016

https://www.sfcgonline.org



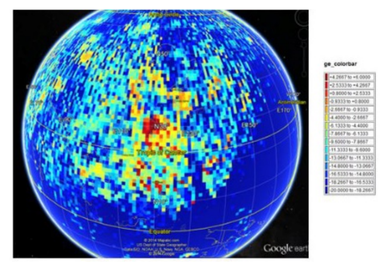
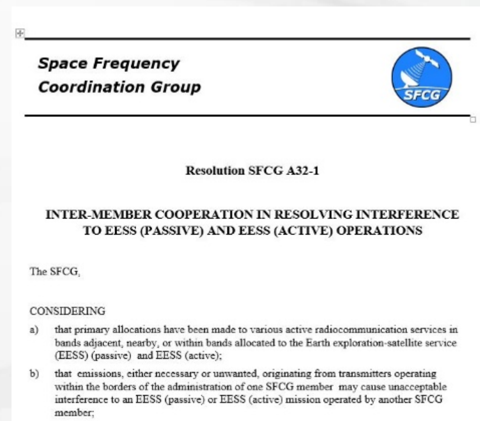


Figure 9 : Map of observed noise power (99.9 %) at Aquarius scatterometer ADC input for Asia (Region 3) (1st Quarter of Year 2014)



Space Frequency Coordination Group

SFCG

Resolution SFCG A32-1

INTER-MEMBER COOPERATION IN RESOLVING INTERFERENCE TO EESS (PASSIVE) AND EESS (ACTIVE) OPERATIONS

The SFCG,

CONSIDERING

a) that primary allocations have been made to various active radiocommunication services in bands adjacent, nearby, or within bands allocated to the Earth exploration-satellite service (EESS) (passive) and EESS (active);

b) that emissions, either necessary or unwanted, originating from transmitters operating within the borders of the administration of one SFCG member may cause unacceptable interference to an EESS (passive) or EESS (active) mission operated by another SFCG member;

Initiatives to improve international RFI reporting

International Space Radio Monitoring Meeting

- Global Radio Regulator Enforcement Agencies
  - Yearly meeting site rotates amongst members
  - 18th ISRRM
    - Seoul, Republic of Korea
    - September 6-8, 2016
- ESA SMOS and NASA attended 17^{th} ISRMM and presented on RFI reporting issues
- NASA cannot attend the 18^{th} ISRMM

Passive Sensor RFI Reporting Summary

- The U.S. has a large number of Earth Observing Missions (~19 currently)
    - Each mission has multiple instruments operating at multiple frequencies
    - NASA is responsible for the majority of the sensor instruments
- According to discussions in the SFCG, RFI has occurred to all the instruments in all the bands
- RFI to EESS (passive) has been underreported to the Administration from where RFI originates and to the ITU-R BR
- The international space science community, through the processes of the ITU-R and SFCG, are undertaking actions to:
    - Improve RFI reporting procedures provided by the RRs for EESS (passive)
    - Increase the frequency and effectiveness of RFI reporting

FINIS

Thank you for your attention

&

Questions?

Thomas vonDeak
NASA Remote Sensing Spectrum Manager
+1 216 433 3233
Thomas.vonDeak@nasa.gov

Acronym List

- AM(R)S – Aeronautical Mobile (Route) Service
- AMSR-E - Advanced Microwave Scanning Radiometer for EOS
- APT – Asia Pacific Telecommunity
- ASMG – Arab Spectrum Management Group
- ATU – African Telecommunications Union
- CEPT - European Conference of Postal and Telecommunications Administrations
- CITEL – Inter-American Telecommunication Commission
- CRS – Cognitive Radio Systems
- EESS – Earth exploration-satellite service
- ENG – Electronic News Gathering
- FS – Fixed service
- HAPS – High Altitude Platform Systems
- IRAC – Interdepartment Radio Advisory Committee
- ISS – International Space Station
- ITU-R - International Telecommunication Union – Radiocommunication Sector
- MSS – Mobile satellite service
- RCC - Regional Commonwealth in the Field of Communications
- RR – Radio Regulations
- SDR – Software Defined Radio
- SFCG – Space Frequency Coordination Group
- SRD – Short Range Device
- SRS – Space research service
- TDRSS – Tracking and Data Relay Satellite System
- UAS – unmanned aircraft systems
- UWB – Ultra-wideband
- WAC – (FCC) WRC-12 Advisory Committee
- WAIC – Wireless avionics intra-communications

NASA Spectrum

SPECTRUM

Virtually every endeavor that NASA undertakes requires communications or data transfer via the electromagnetic spectrum. NASA relies solely on Space Communications and Navigation(SCaN) to provide this vital service to all of its missions. Today and in the coming years, NASA will implement programs encompassing space exploration, scientific research, technology development, and all of these efforts will need access to this limited resource.

GO

NASA's Use Of Spectrum
NASA's requirements for access to the radio frequency spectrum began with the formation of the agency in 1958 and have evolved and grown over the decades to include a wide array of programs and applications. Virtually every endeavor by the agency requires communications or data transfer via the radio spectrum.

Today and in the coming years, NASA will implement programs to achieve missions encompassing space exploration, scientific research, and technology development. These initiatives are taken in response to National Policy directives as well as Congressional legislation.

Earth Science
Earth Science research at NASA has turned space-based observing technology and scientific expertise to the study of our home planet. Planet Earth is an integrated system of land, ocean, atmosphere, ice, and biological processes. From the vantage point of space, we are beginning to understand how these processes work and how they interact.

In order to support the intermediate and long term goals of understanding the Earth, NASA has developed numerous radio sensors designed to fly onboard spacecraft. These sensors may be passive or active in operation. They allow global "pictures" to be taken of the Earth on a daily basis in a wide range of frequencies. Passive sensors emit no energy; instead, they measure the natural emissions of the Earth's various features and its atmosphere at specific frequencies in order to provide a description of the earth's environment. Active sensors are spaceborne radars that provide information on the geological structure of the Earth and the state of and movement of Earth's oceans. The data collected by these sensors is transmitted by radio links to facilities on earth, either directly or through relay satellites.

Space Science
NASA's Space Science missions are intended to examine the mysteries of the universe from origins to destiny, to explore the solar system, to discover planets around other stars, to search for life beyond Earth and to chart the evolution of the universe and understand its galaxies, stars, planets, and life.

Space science missions require highly reliable communications, often over long periods of time and great distances. The large distances involved in deep-space research result in a need for high power transmitters and very sensitive receivers at Earth stations that communicate with the spacecraft, factors which must be taken into account in spectrum planning efforts. Because many deep-space missions continue for periods of several years, and because there are usually several missions in progress at the same time, there is a corresponding need for communication with several spacecraft at any given time. Coverage of simultaneous missions requires nearly continuous usage of radio frequency bands allocated for space research communication.

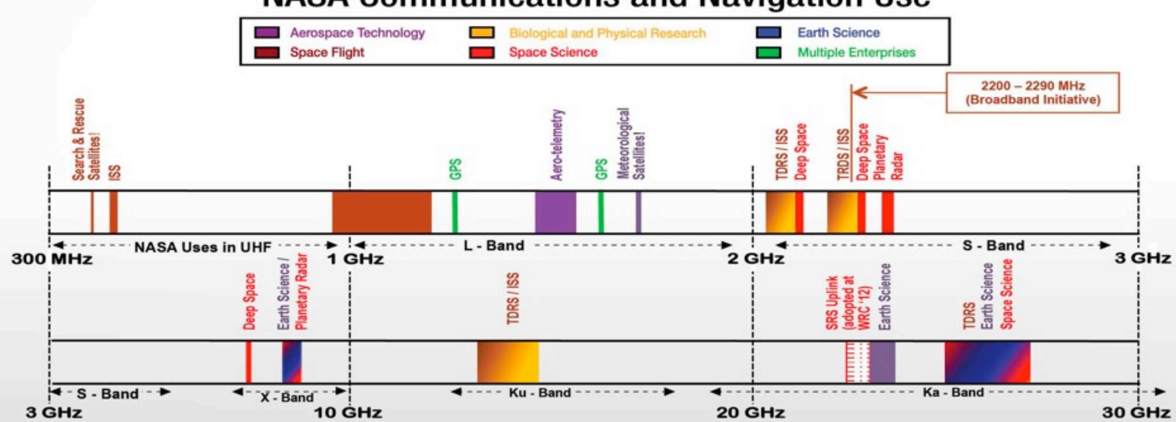
Human Space Exploration
NASA seeks to open the space frontier through exploration with the goal of enabling the development of space and expanding the human experience into the far reaches of the solar system. In exploring space, NASA has brought together a wide range of technologies, machines and people in the development of such programs as the Space Transportation System (STS) commonly known as the Space Shuttle, the International Space Station (ISS) and the various Mars rovers. These programs require extremely complex radio systems, which are critical to their operation and currently include frequencies from about 100 MHz up to more than 30 GHz.

Aeronautics and Space Technology Development
The focus of this program is to pioneer the identification, development, verification, transfer, application, and commercialization of high-payoff aeronautics and space transportation technologies.

NASA requires access to the radio spectrum in order to conduct test and development phases of new technology endeavors in aeronautics and space transportation. In many cases, new technological design test-rigs and/or prototypes undergo their various test and validation phases using conventional spectrum allocations for mobile or point-to-point operations.

For links between in-flight aerospace vehicles and ground systems, NASA requires access to aeronautical telemetry frequency allocations. Currently the radio frequency spectrum is used to provide real time data information from test vehicles to the ground, real time video of cockpit or project information, and real time command and control of the vehicle, including flight termination. Telemetry is used for the real time monitoring of flight research/test parameters that are necessary in order to minimize the risk to the pilot and aircraft during the performance of maneuvers intended to push the flight envelope of flight test vehicles.

NASA Communications and Navigation Use



Representative NASA Spectrum Use (300 MHz – 30 GHz) (NASA spectrum use extends to greater than 300 GHz)

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Acronyms

Acronym	Description	Acronym	Description
AI	Agenda Item	MMSS	Maritime Mobile Satellite Service
BIPM	Bureau International des Poids et Mesures	NGSO	Non-Geostationary Orbit
BLOS	Beyond Line of Sight	OOBE	Out-of-Band Emissions
CITEL	Inter-American Telecommunications Commission	PFD	Power Flux Density
CPM	Conference Preparatory Meeting	RA	Radio Assembly
dBW	Power in Decibels relative to a Watt	RR	Radio Regulations
EESS	Earth Exploration-Satellite Service	S-to-E	Space-to-Earth
E-to-S	Earth-to-Space	SRS	Space Research Service
FSS	Fixed Satellite Service	TT&C	Telemetry, Tracking, and Command
IAP	Inter-American Proposal	WG	Working Group
IMT	International Mobile Telecommunications	WP	Working Party
ITU	International Telecommunication Union	WRC	World Radiocommunicatons Conference