



Federal Agency for
Cartography and Geodesy



Frequency Protection for geodetic VLBI - Support for an Agenda Item at WRC-31

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UN-GA Resolution 69/266:

A global geodetic reference frame for sustainable development

United Nations

A/RES/69/266



General Assembly

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11 March 2015

Sixty-ninth session
Agenda item 9

Resolution adopted by the General Assembly on 26 February 2015

[without reference to a Main Committee (A/69/L.53 and Add.1)]

69/266. A global geodetic reference frame for sustainable development

The General Assembly,

Reaffirming the purposes and principles of the Charter of the United Nations,

Reaffirming also its resolution 54/68 of 6 December 1999, in which it endorsed the resolution entitled “The Space Millennium: Vienna Declaration on Space and Human Development”,¹ which included, inter alia, key actions to improve the efficiency and security of transport, search and rescue, geodesy and other activities by promoting the enhancement of, universal access to and compatibility of space-based navigation and positioning systems, including Global Navigation Satellite systems,

Reaffirming further its resolution 57/253 of 20 December 2002, in which it endorsed the Plan of Implementation of the World Summit on Sustainable Development (Johannesburg Plan of Implementation),² and means of ...

...

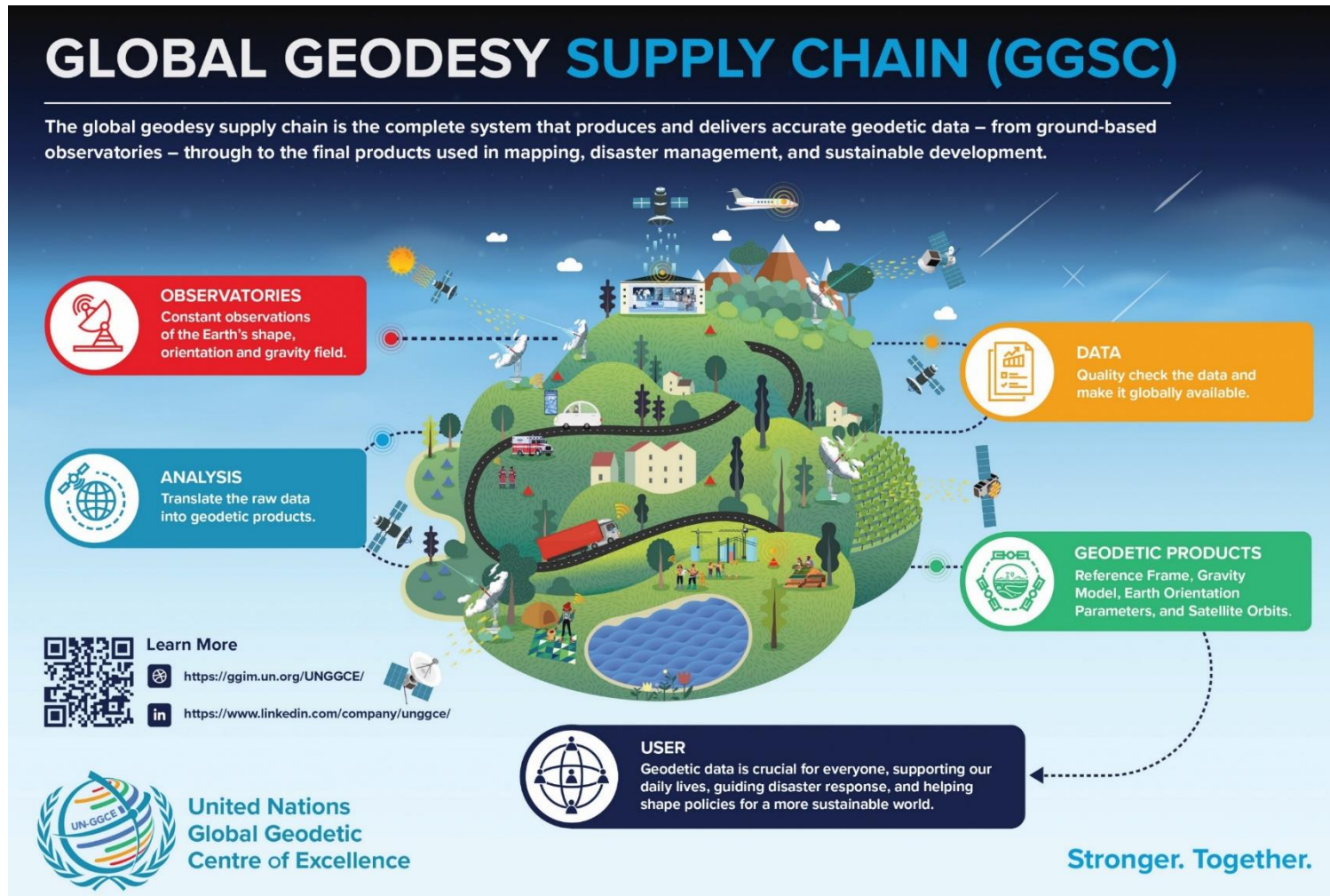
3. **Urges Member States** to implement open sharing of geodetic data, standards and conventions, on a voluntary basis, **to contribute to the global reference frame** and regional densifications **through relevant national mechanisms and intergovernmental cooperation**, and in coordination with the International Association of Geodesy;

...

<https://docs.un.org/en/A/RES/69/266>



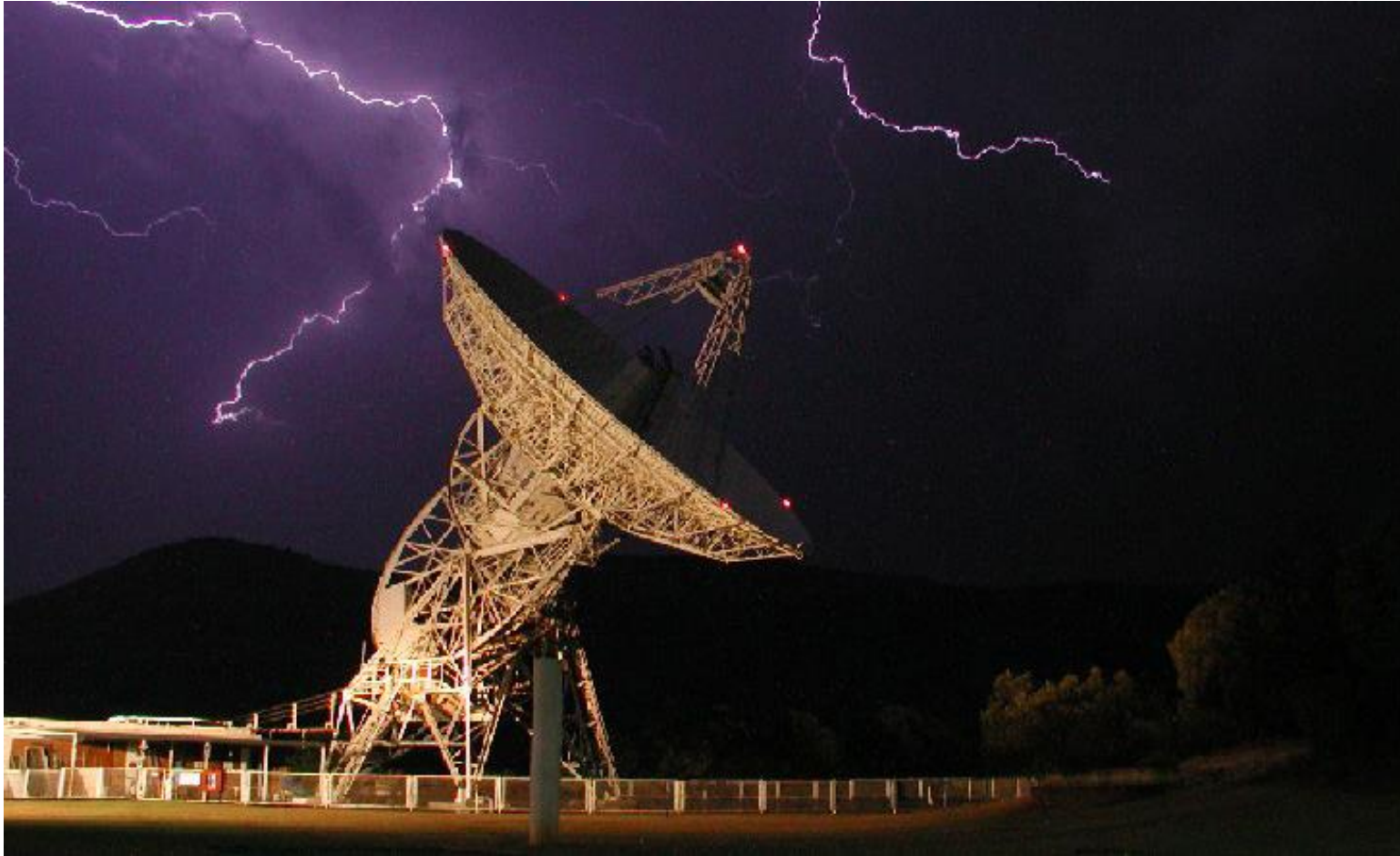
The global geodesy supply chain



Geodesists answer users' everyday questions:

- **Where?** Establishing spatial references, georeferencing
- **Where to? When?** Positioning, navigation, timing (PNT)
- **What?** Geoinformation, cartography
- **Why? How much?** Science: climate change, sea level, geodynamics, space weather

Where does the global geodesy supply chain start?



- Land boundaries require a coordinate system that never shifts.
- Because stars within our own galaxy move constantly, geodesists use **quasars** via the International Celestial Reference Frame (ICRF) to establish a frame of **truly static "zero points" in space**.
- Quasars are observed with Very Long Baseline Interferometry (VLBI).

Patrick Moore

https://assa.saao.ac.za/sections/history/telescopes/harte_radio/

How do quasar signals look like?



- Quasars are quasi-stellar objects known as active galactic nuclei (AGN).
- A rotating black hole in its center consumes matter and emits energy at radio wavelengths.
- The quasar's signal is **red noise**.
- Signal power at quasar: $\sim 10^{40}$ Watts ($\sim 25 \times 10^{12}$ suns)
- Distance quasar – Earth: $\sim 2.6 - 12 \times 10^9$ years of light
- Signal power density at Earth: $\sim 10^{-14} - 10^{-16} \text{ W/m}^2$
- Quasar radiation can only be detected by radio telescopes with reflectors and cryogenic cooled receivers.



Cellphone:
 $1-10 \text{ W/m}^2$

Credit:ESA/Hubble, L. Calçada (ESO), <https://esahubble.org/images/heic1511a/>

VLBI Global Observing System (VGOS) is a global sensor



- VGOS network stations are coordinated by the **International VLBI Service for Geodesy and Astrometry (IVS)**.
- National infrastructure is committed to the IVS.
- IVS is a non-profit organisation.
- VGOS network is growing, global coverage is important.
- VGOS observations require the **same frequency setup globally** (for all 3 ITU-regions).
- **Protection** is needed **in spectrum** and **for observatory sites**.

Frequency Allocation - All Regions

Service

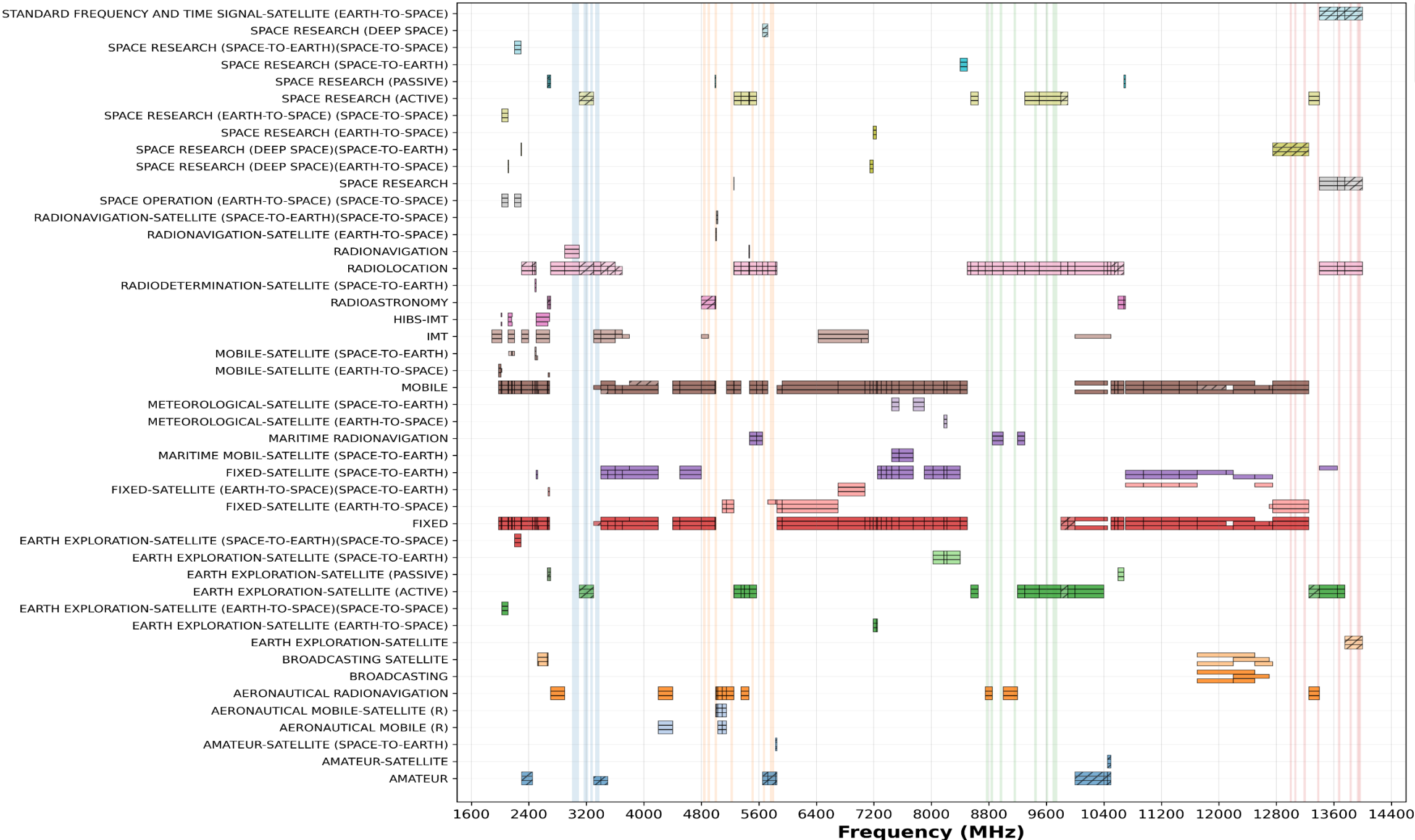
Frequency Bands

A-band

B-band

C-band

D-band



Why satellite constellations are problematic for geodetic VLBI?

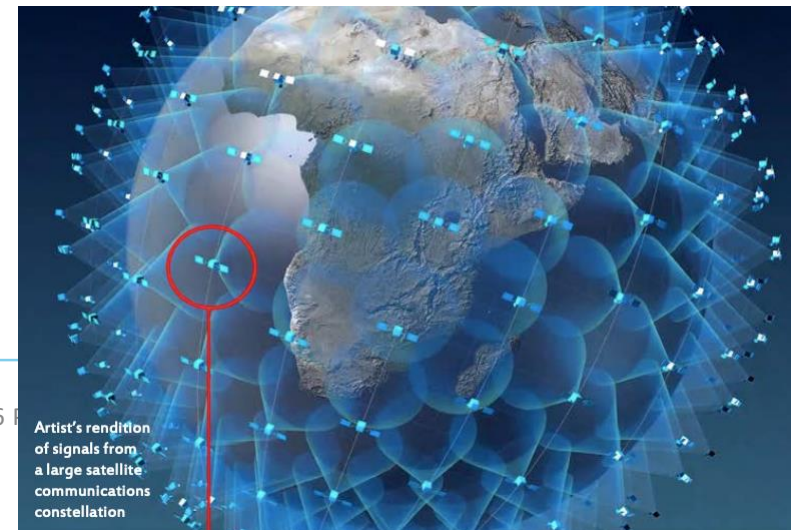


Starlink satellite
Photocreo Bednarek/Stock.adobe.com

Each satellite adds electro-magnetic emission and radiation to the sky.

- **Intended emission** within the satellite's licensed allocation
- **Unwanted emission** which are out-of-band emissions (RR 1.144), modulation sidebands and spectral regrowth immediately outside the necessary bandwidth; and spurious emissions (RR 1.145), comprising harmonic emissions, intermodulation products and frequency conversion products.
- **Unintended electromagnetic radiation** (UEMR), a broadband noise from electronics and power converters

NASIC image



What can we do? – Satellite Radio Astronomy!

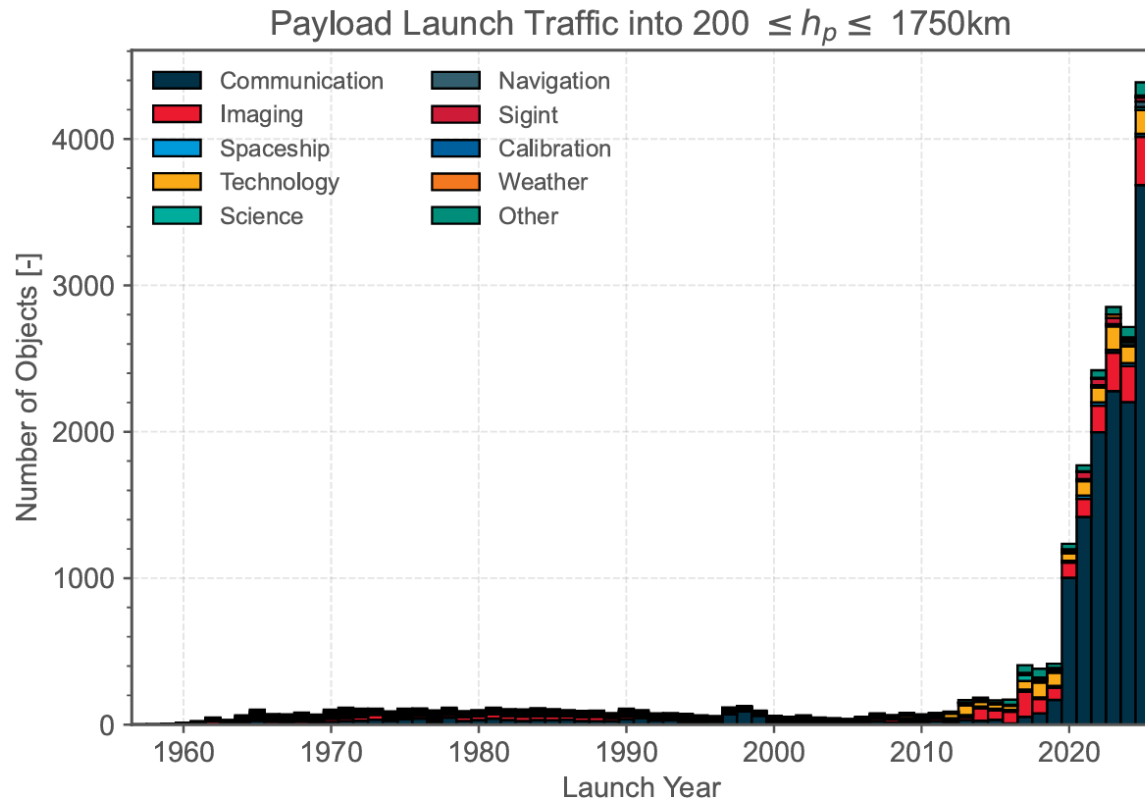


AI created image: radio telescope observing a satellite

Indermuehle, Lourenco: SNIFFLES-I, <https://doi.org/10.1093/mnras/stag1133>

- Observed 4629+ satellites and detected 2345 instances of emissions/radiations at more than 300 unique frequencies.
- Detections were made on: original Starlink, Starlink V2-mini, Huianwang-Digui satellites.
- Several detections fall in primary RAS allocations!
- **Intended emission:** Direct-To-Cell signals (DTC) with MJy with risk of saturating receiver
- **Unwanted emission** (out-of-band, harmonics): up to **4th harmonic of Starlink DTC transmission**
- **Unintended radiation:** from satellite platform electronics and subsystems

Problem: More and more active users share the finite spectrum



Differentiated payload launch traffic 1960-2026 into 200-1750 km altitude

Source: ESA'S ANNUAL SPACE ENVIRONMENT REPORT 2026

- In **2026** we count **14.200 active satellites** in orbit of **~19.000** in total
- Estimations foresee **30 – 60.000 active satellites** in **2030**
- ITU-R has in the filings constellations with an aggregated number of **>1 million satellites**.
- When thousands of these satellites blanket the sky, their overlapping emissions **elevate** the **global radio noise floor**.
- This effectively **blinds** supersensitive **radio telescopes** looking for faint, ancient cosmic signals.

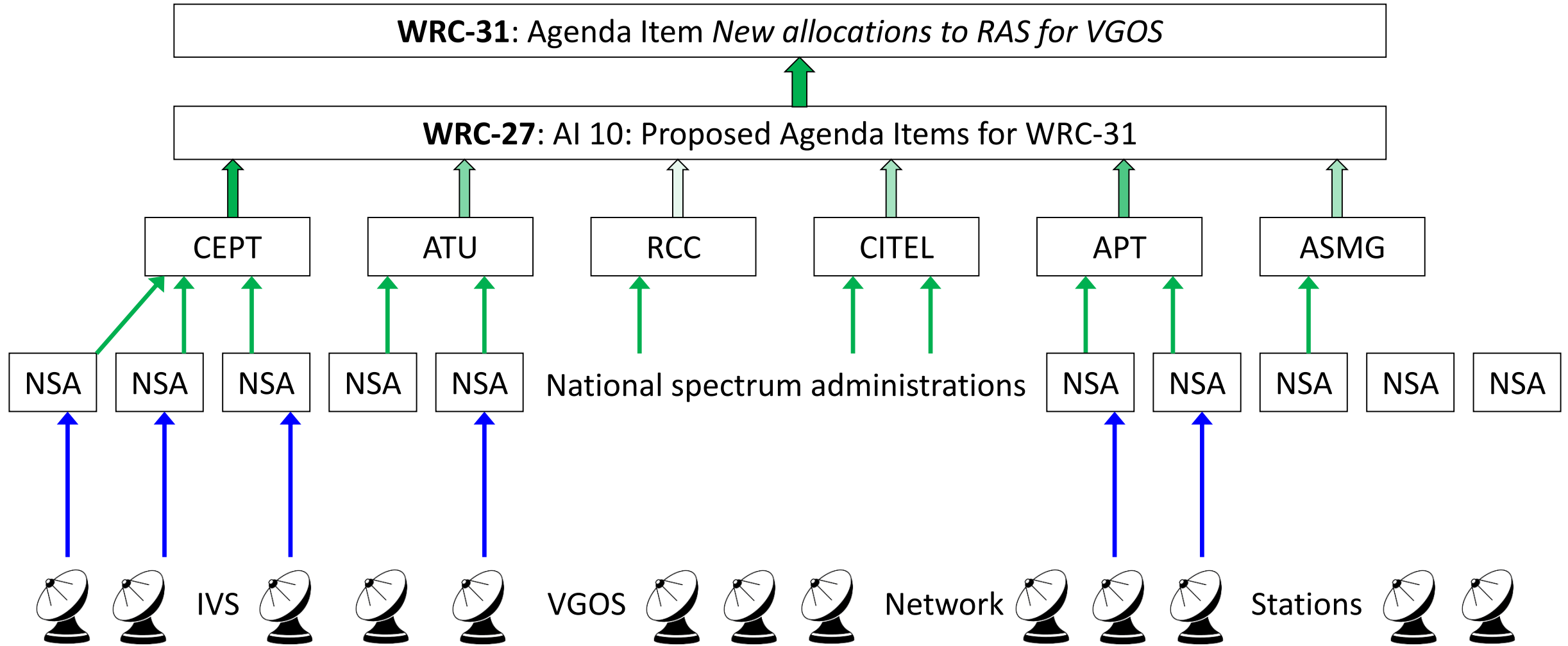
The path to protection by the Radio Regulations of ITU-R

- 2021: **Question 258/7 to ITU-R SG** *“What are the technical and operational characteristics of geodetic VLBI?”*
- 2022: **ITU-R Report RA.2507** *“Technical and operational characteristics of the existing and planned Geodetic Very Long Baseline Interferometry”* https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-RA.2507-2022-PDF-E.pdf
- 2026: **ITU-R Recommendation RA.2178-0** *“Global geodetic very long baseline interferometry networks”* <https://www.itu.int/rec/R-REC-RA.2178/en>

Supported by:

- 2021: **IAU General Assembly Resolution B1**: *“In support of the protection of geodetic radio astronomy against radio frequency interference”*
- 2023: **IUGG General Assembly Resolution 1**: *“Improving Protection of Geodetic Observatories from Active Radio Services”*
- 2025: **UN-GGCE Policy Brief No. 3**: *“Safeguarding VLBI Radio-Frequencies”* https://www.researchgate.net/publication/391667349_Safeguarding_VLBI_Radio-Frequencies

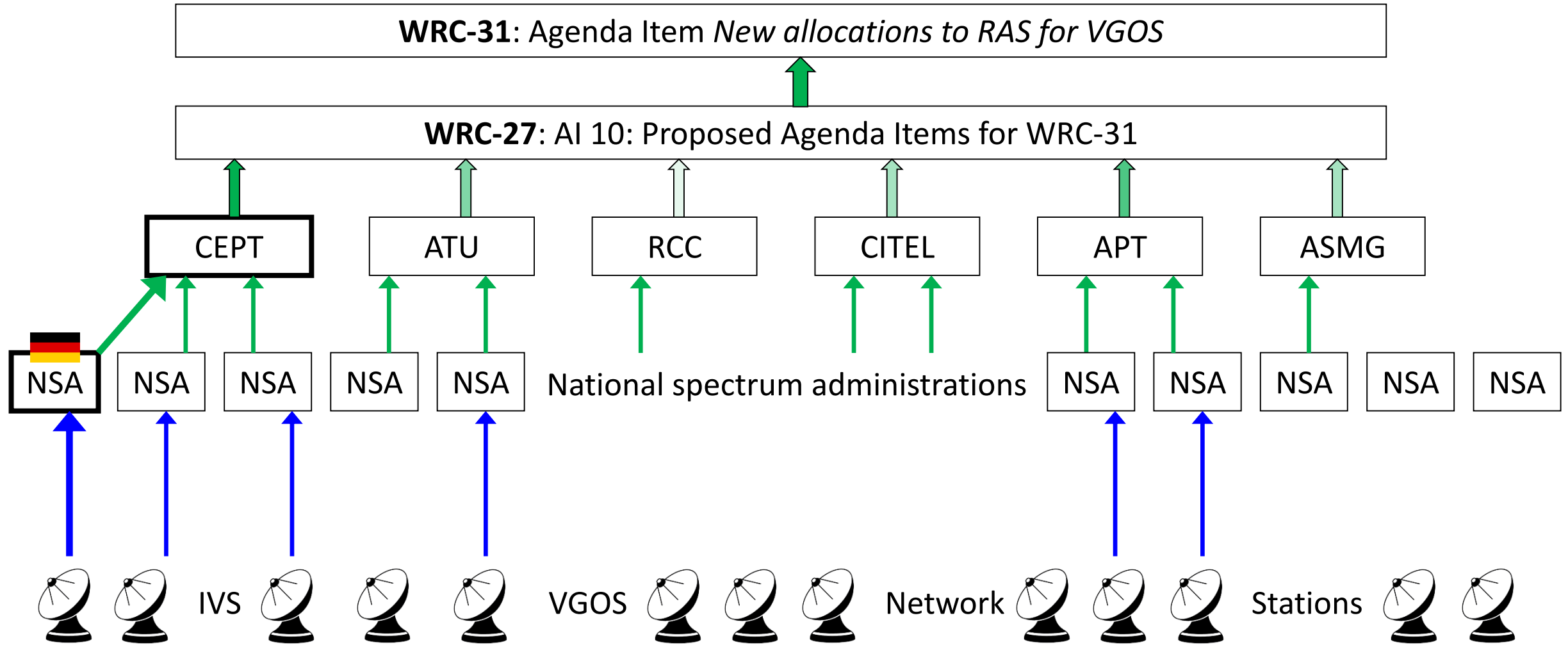
The path to an Agenda Item at WRC-31 requires actions



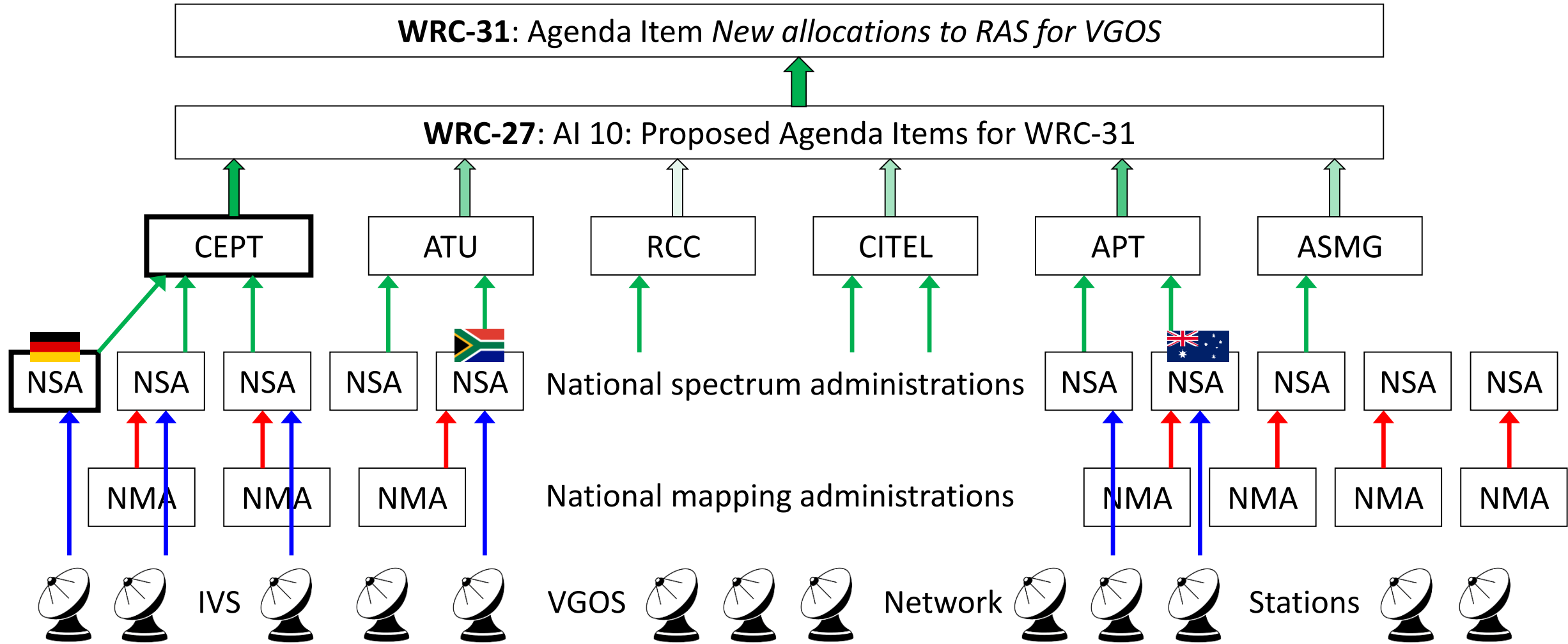
Spectrum management for VGOS is a global affair with a few VGOS stakeholders

- CEPT (46 countries): Norway, Sweden, Finland, Germany, France, Portugal, Spain, Italy
- ATU (52 countries): South-Africa, (Nigeria?)
- RCC (9 countries): Russia
- CITELE (35 countries): USA, Brazil, Argentina
- APT (38 countries): Japan, China, Australia, New Zealand, South-Korea, (Thailand?), (Indonesia?), (India?)
- ASMG (22 countries): (Saudi-Arabia?)

The path to an Agenda Item at WRC-31 requires actions



The path to an Agenda Item at WRC-31 requires actions



Conclusions

1. The [Global Geodesy Supply Chain](#) begins with access to the quasars that define the quasi-inertial celestial reference frame—and that access is [at risk](#).
2. The ITU-R Radio Regulations do not provide for frequency allocations for geodetic VLBI.
3. Without regulatory protection, the observational conditions for geodetic VLBI will change dramatically due to the predicted increase in electromagnetic interference from mega-satellite constellations.
4. Protecting geodetic VLBI requires amendments to the Radio Regulations as part of an Agenda Item at WRC-31, which is to be decided upon at WRC-27 under Agenda Item 10.
5. UN member states are called upon to support “A Global Geodetic Reference System for Sustainable Development,” which means: “[Support an Agenda Item recognizing geodetic VLBI at WRC-31.](#)”
6. [Contact your spectrum management authority.](#) Make your voice heard at the WRC preparatory meetings at the national and regional levels!!!

Further Reading

- ITU-R Blog series on Spectrum Management for Radio Astronomy
<https://www.itu.int/hub/2026/09/radio-astronomy-at-the-regulatory-crossroads-wrc-27-and-beyond/>
- UN-GGCE Policy Brief No. 3
https://www.researchgate.net/publication/391667349_Safeguarding_VLBI_Radio-Frequencies

Some spare slides

D2D – alias 6G replaces terrestrial base stations by satellites

DIRECT-TO-DEVICE SATELLITE CONNECTIVITY

Seamless connectivity. Anywhere on Earth.

- NO SPECIAL HARDWARE**
Works with standard smartphones.
- NO EXTRA SIM**
Uses your existing mobile plan and number.
- NO SATELLITE PHONE**
No bulky devices. Just your phone.
- STAY CONNECTED**
Messaging and data today. Voice and SMS coming soon.

LIVE. GROWING. GLOBAL.
The UK is now the 3rd largest D2D market in the world.

BUILT FOR THE MOMENTS THAT MATTER MOST

- REMOTE AREAS
- COASTAL REGIONS
- NATURAL DISASTERS
- OFF-GRID COMMUNITIES

HOW IT WORKS

1. Your phone connects to a low Earth orbit (LEO) satellite.
2. The satellite acts as a base station in space.
3. The signal is routed through a ground gateway.
4. You're connected to the wider mobile network.

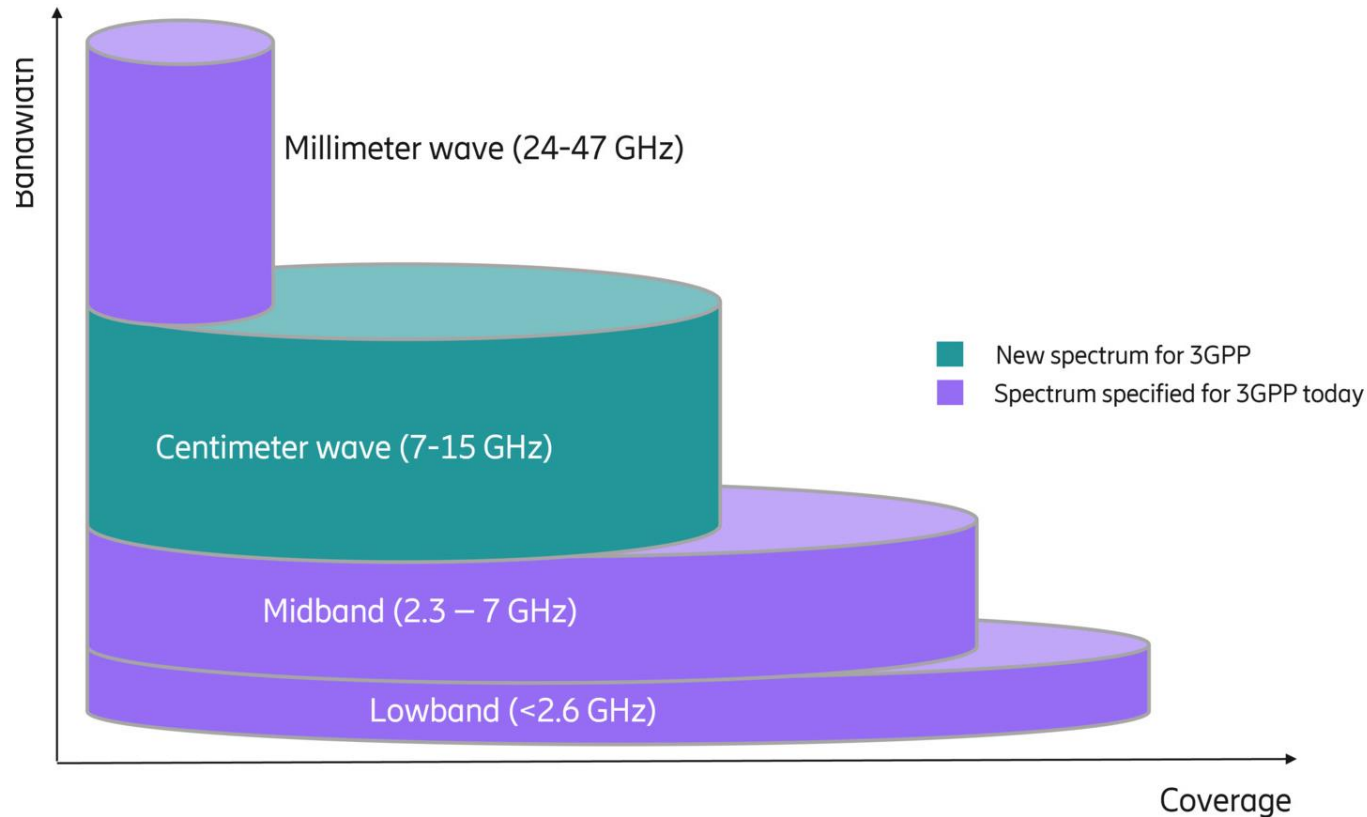
NOT A REPLACEMENT, A POWERFUL BACKUP

- ✓ Lower speeds and higher latency than 4G/5G
- ✓ Requires a clear view of the sky
- ✓ Complements, not replaces, terrestrial networks

6G – Roadmap

- **2024-early 2027:** Research, requirements, spectrum allocation
- **March 2027-March 2029:** Normative standardization
- **2028-2029:** Pre-commercial trials, carrier field testing
- **Late 2029-2030:** Initial commercial launch (South-Korea, Japan, UAE)
- **2031-2034+:** Global expansion, maturity, large-scale global infrastructure buildouts

Direct-to-device / 6G mobile telecommunication

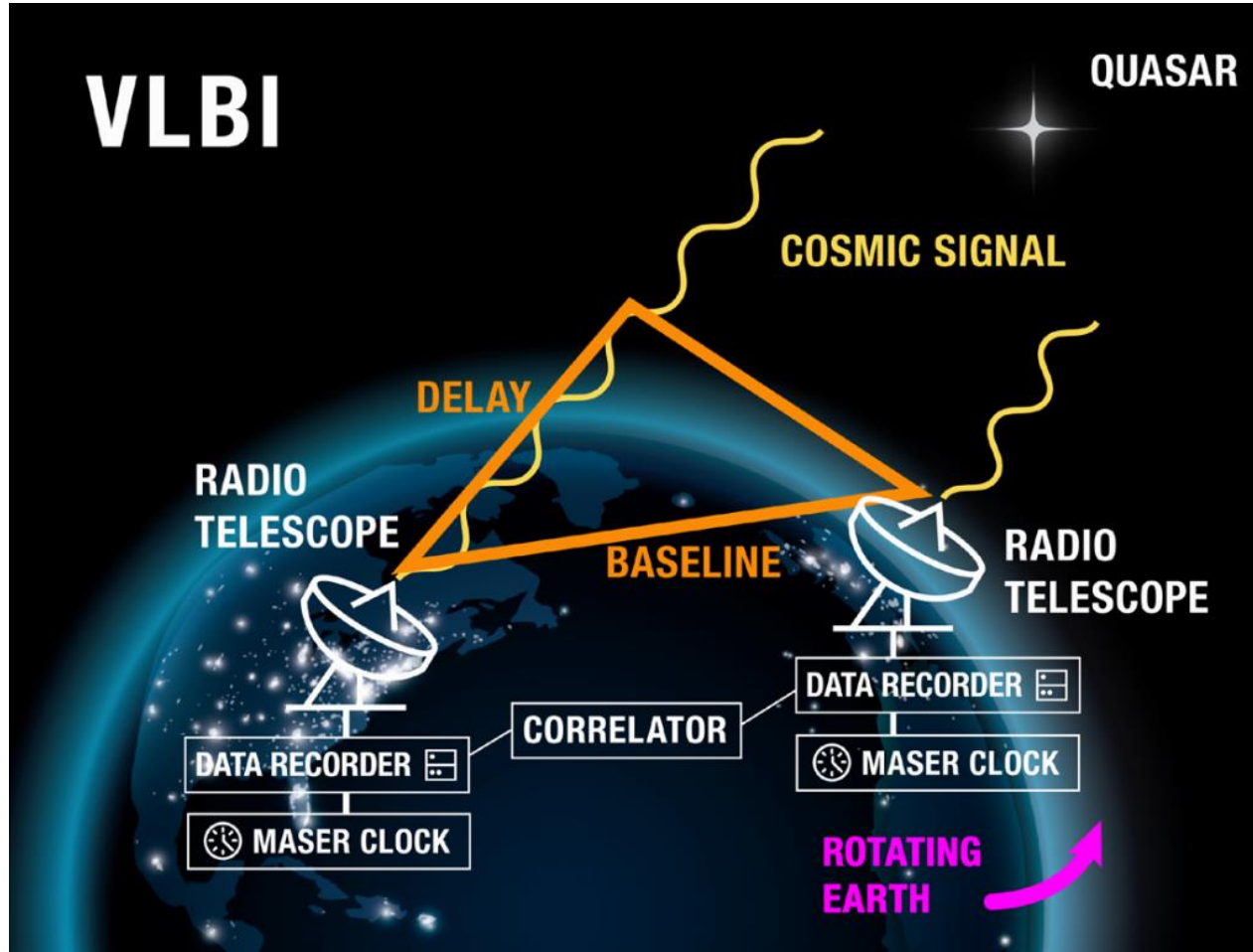


How mobile communication company Ericsson is planning to fill up the microwave spectrum for their purposes.

The missing piece 7-15 GHz coincides with the two upper VGOS bands C and D.

<https://www.ericsson.com/en/blog/2026/4/5g-6g-spectrum-sharing-mrss>

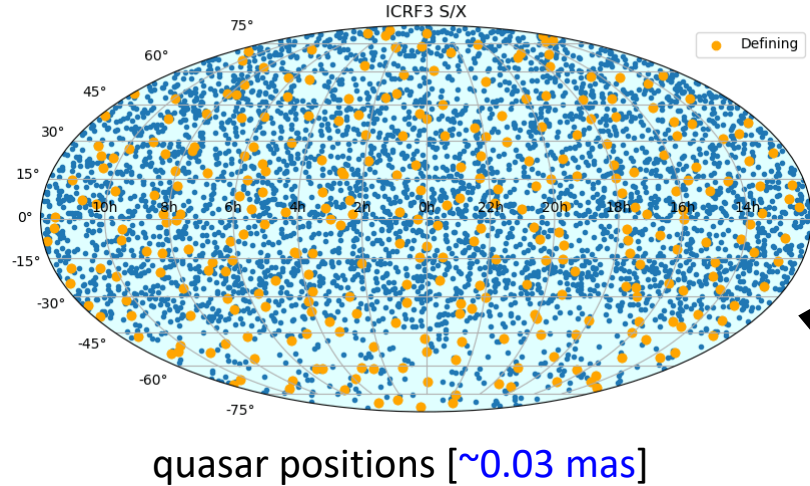
What is Very Long Baseline Interferometry (VLBI)?



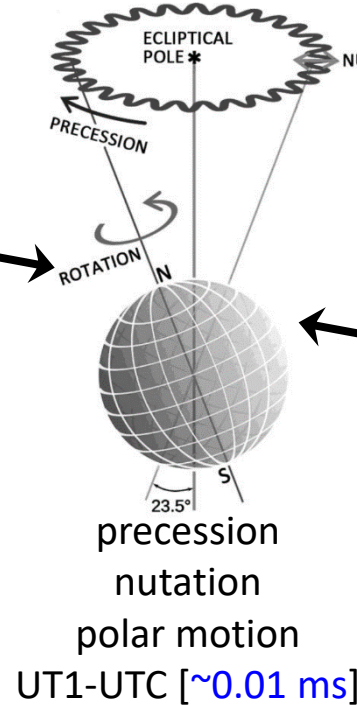
- Radio telescopes on different continents observe **simultaneously** the same cosmic radio source (quasar) in the distance of 10 billion light-years.
- A plane wavefront of cosmic radiation arrives at telescopes at different times causing **delays**.
- While observing the Earth rotates, causing **delay rates**.
- The network of radio telescopes is **one global sensor** for Earth rotation (length of day, rotational axis).

Why is geodetic VLBI unique for reference frames and time reference?

International Celestial Reference Frame **ICRF**

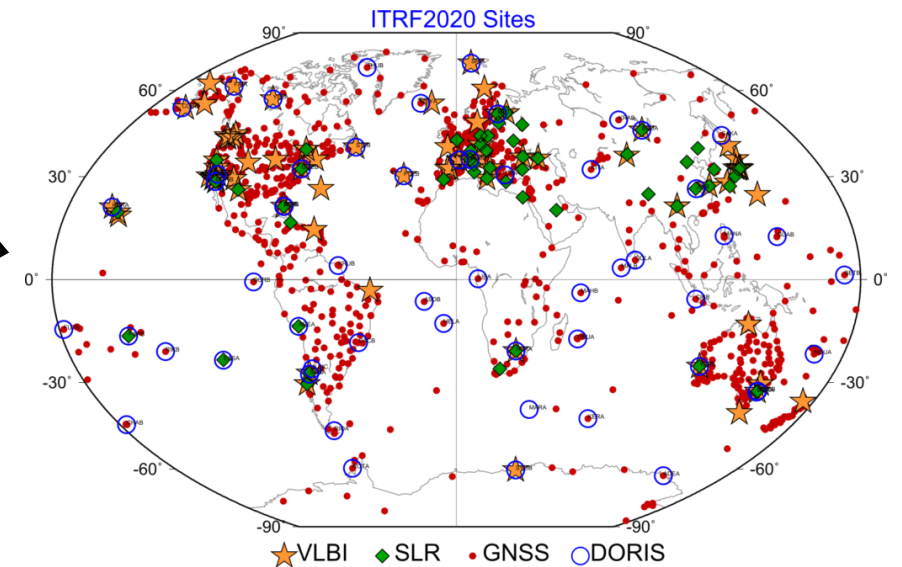


Earth Orientation Parameters **EOP**



Geodetic VLBI is **essential** for any kind of space activities.

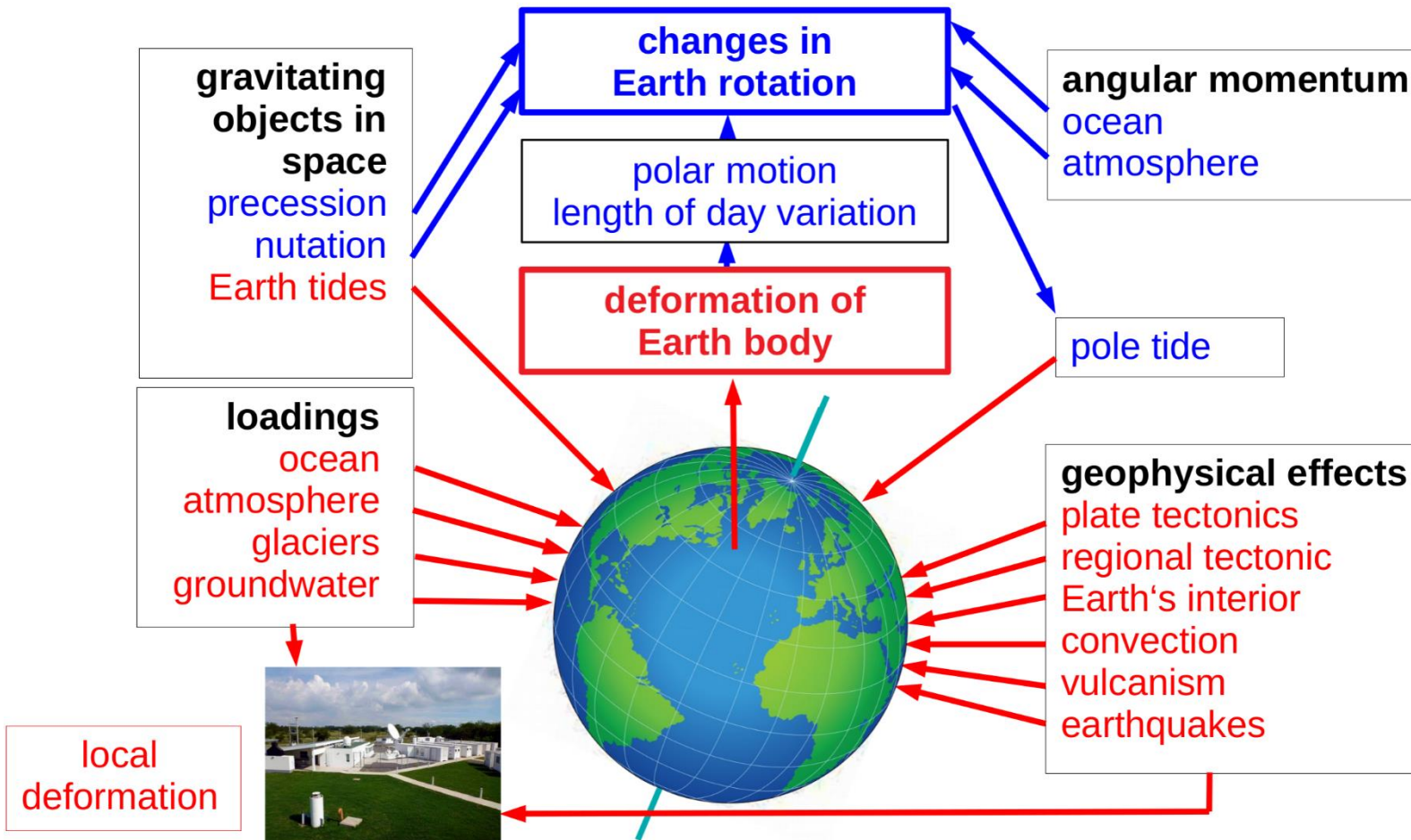
International Terrestrial Reference Frame **ITRF**



VLBI is the **only method** providing data to both reference systems and for the determination of all Earth rotation parameters.

positions and velocities of reference points [~ 1 mm, 0.1 mm/y]
time series
baselines

Which geophysical effects are present in VLBI measurements?



Changes in the geometry of global geodetic VLBI networks are related to geophysical phenomena.

Earth surface suffers continuous deformations, which varies the Earth rotation.

Geodetic VLBI observations sense these changes. Complementary measuring devices at VLBI sites allow improved modelling.

A geodetic VLBI network is a sensor for global changes.

What is the difference between legacy S/X VLBI and VGOS?

	Legacy S/X VLBI	VGOS	VGOS benefit
Antenna size	5 – 100m dish	12 – 13m	Reduced cost, homogeneous network
Antenna kinematics	0.3 – 3 deg/s	> 6 deg/s	More observations for better troposphere sampling
Sensitivity (SEFD)	200 – 20000 Jy	< 2500 Jy	More homogeneous network
Frequency coverage	Dualband receiver 2.2-2.35 GHz 8.1-8.9 GHz	Broadband receiver 2.0-14.0 GHz	Precise ionosphere delay , even with high solar activity
Signal processing	Analog/digital	digital	Stable instrumentation
Data rate	128, 256, 512 Mbps	8, 16, 32 Gbps	Increased sensitivity , shorter scans
Data transfer	Ship discs, e-transfer	E-transfer	Automatization , distributed correlation
Observation scans	~ 30/h, ~ 720/24h	120/h, 2880/24h	Better troposphere sampling

[VGOS was designed to provide globally 3D positions with precision of 1 mm and its rate with 0.1 mm/year.](#)

How do VGOS radio telescopes look like?



What are the objectives of the VLBI Global Observing System (VGOS)?

- Provision a **stable global geodetic reference frame** (GGRF) with position accuracy of 1mm and a position velocity of 0.1mm/year.
 - => *demand for sea level rise monitoring*
- **24/7 monitoring of Earth rotation**
 - => *demand from science and GNSS operation*
- About **40 globally distributed stations** (~25 are reality)
 - => *improved understanding of system Earth by a more homogeneous distribution of stations*

VGOS characteristics to address these objectives:

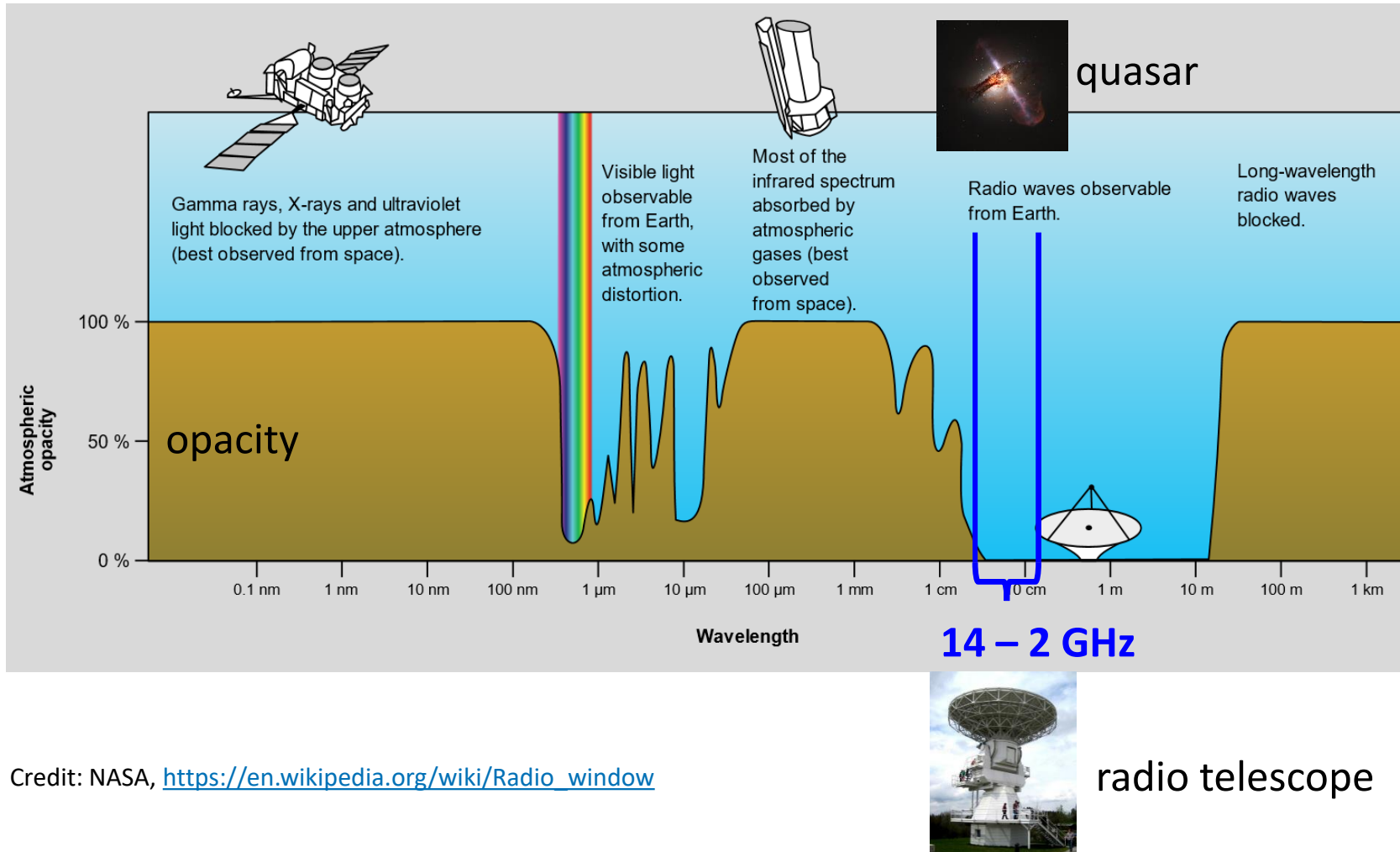
- *Broadband observations* for **better time resolution** and hence smaller uncertainties in coordinates
- *Cryogenically cooled feeds* for **more sensitivity**
- *High-sample rates + short observation times + fast slewing radio telescopes* for **better atmospheric sampling** improving the modelling and hence the coordinates



Why is geodetic VLBI important?

- VLBI is
 1. the **unique** technique to determine **Earth rotation parameters** in a quasi-inertial reference frame by quasars
 2. the most precise technique to establish the **celestial reference frame** for geodesy, astronomy and deep space missions
 3. one of the few measuring techniques to determine **baselines** between continents for a global **terrestrial reference frame**
- VLBI is a fundamental tool
 - for any kind of **in-space operation** that requires updating Kepler elements (dUT1)
 - for **atomic clocks synchronization** that are far apart
 - in geodesy to provide infrastructural products for applications in **positioning, navigation, timing** (PNT) and geoinformation.
 - in **science**.

Why is geodetic VLBI operated in 2-14 GHz?



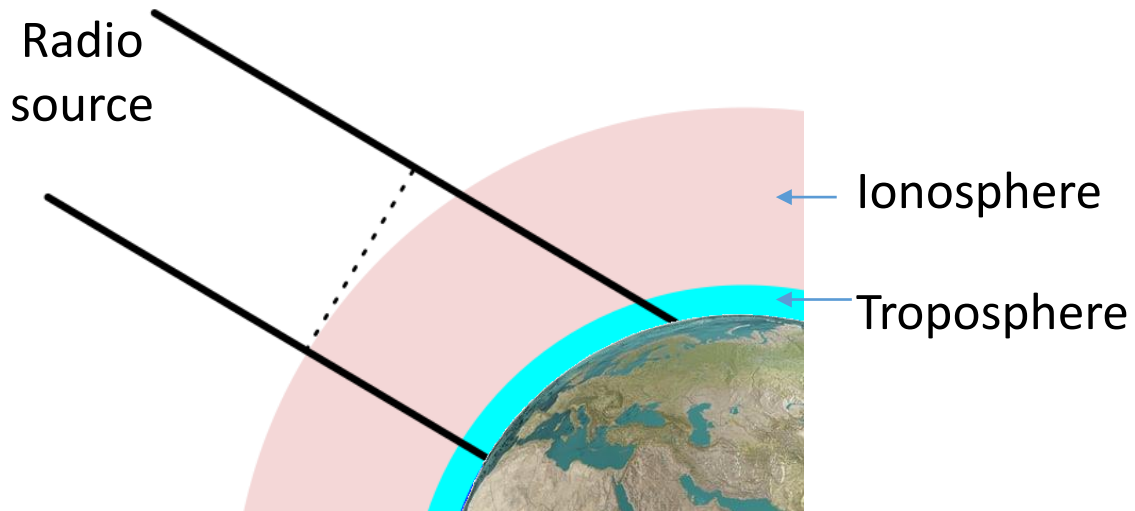
Credit: NASA, https://en.wikipedia.org/wiki/Radio_window

- The **transparency** of the atmosphere for microwaves (radio window) is exploited for the detection of the faint cosmic signals.
- The **shorter wavelengths** / higher frequencies provide a **higher accuracy** in the geometry of the interferometer.
- The spectrum of **2-14 GHz** is **optimal** for geodetic VLBI.

Why is VGOS observing 4 sub-bands with 8 observations channels (bw=32 MHz) each?

Delay τ is observable in the correlation

$$\tau = \tau_{geo} + \tau_{ion} + \tau_{trop} + \dots$$

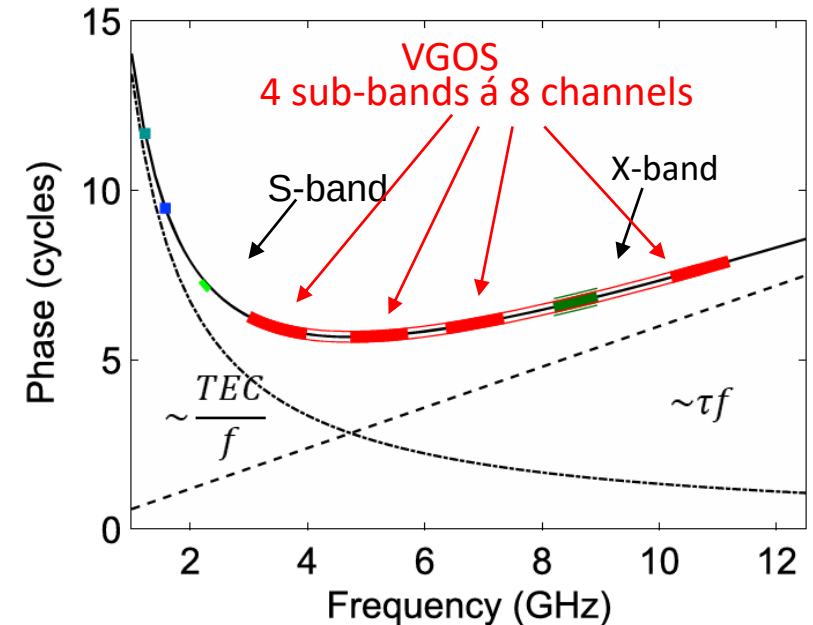


Troposphere, typical zenith-delay = 2 ... 3 m:

- Delay depends on air pressure, humidity and elevation angle
- Frequency-independent

Ionosphere, typical TEC-delay = cm ... m:

- Delay depends on “Total Electron Content”
- Lower frequencies dispersive, higher frequencies non-dispersive



VGOS improves geodetic VLBI by better modelling of the troposphere and a better determination of the TEC.

Why is VGOS with 4 sub-bands better than S/X legacy VLBI?

Characteristics	Legacy S/X	VGOS	1 TEC unit (TECU)
Observation channels	6x 8MHz, 2.1-2.3 GHz 8x 8MHz, 8.1-8.9 GHz	8x 32MHz, 3.0-3.4 GHz 8x 32MHz, 4.82-5.82 GHz 8x 32MHz, 8.76-9.76 GHz 8x 32MHz, 12.98-13.98 GHz	3.2 GHz: $\tau \approx 39$ mm 5.3 GHz: $\tau \approx 14$ mm 9.3 GHz: $\tau \approx 5$ mm 13.5 GHz: $\tau \approx 2$ mm
TEC treatment	Post-deletion of the delay through differentiation	Direct physical estimation des dTEC in fringe-fitting process of correlation	
Precision	Higher noise levels due to large frequency gaps	Extremely low noise (< 0.07 TECU precision)	
Robustness	Prone to systematic errors during periods of high solar activity	High stability and accuracy even during active space weather conditions	

Typical TECU
2-5 night
5-15 day
30-50 equator
>200 extreme

VGOS outperforms legacy S/X VLBI observation.

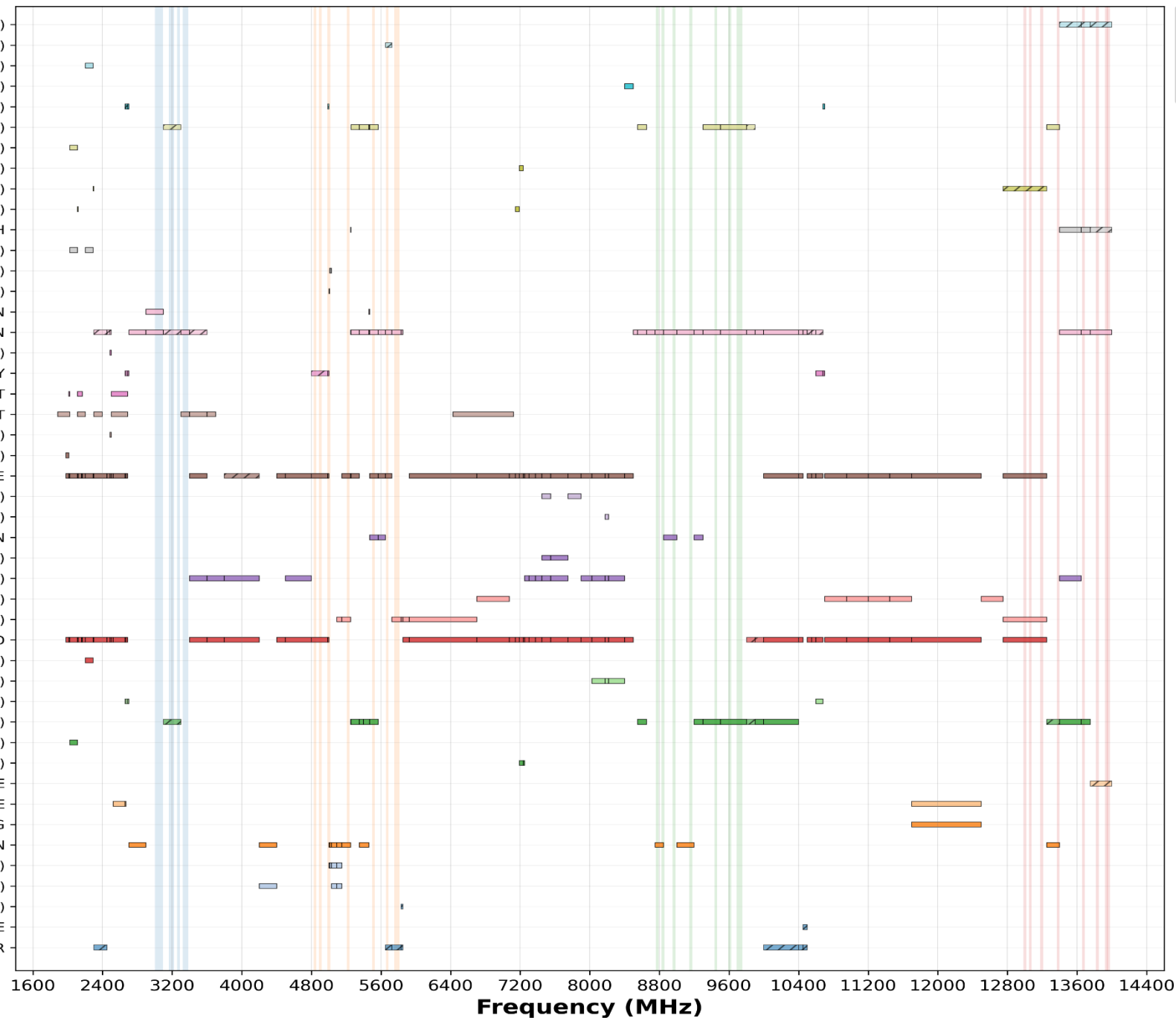
VGOS meets the requirements of the Global Geodetic Observing System (GGOS); 3D ≈ 1 mm.

Frequency Allocation - Region I

Service

STANDARD FREQUENCY AND TIME SIGNAL-SATELLITE (EARTH-TO-SPACE)
SPACE RESEARCH (DEEP SPACE)
SPACE RESEARCH (SPACE-TO-EARTH)(SPACE-TO-SPACE)
SPACE RESEARCH (SPACE-TO-EARTH)
SPACE RESEARCH (PASSIVE)
SPACE RESEARCH (ACTIVE)
SPACE RESEARCH (EARTH-TO-SPACE) (SPACE-TO-SPACE)
SPACE RESEARCH (EARTH-TO-SPACE)
SPACE RESEARCH (DEEP SPACE)(SPACE-TO-EARTH)
SPACE RESEARCH (DEEP SPACE)(EARTH-TO-SPACE)
SPACE RESEARCH
SPACE OPERATION (EARTH-TO-SPACE) (SPACE-TO-SPACE)
RADIONAVIGATION-SATELLITE (SPACE-TO-EARTH)(SPACE-TO-SPACE)
RADIONAVIGATION-SATELLITE (EARTH-TO-SPACE)
RADIONAVIGATION
RADIOLOCATION
RADIODETERMINATION-SATELLITE (SPACE-TO-EARTH)
RADIOASTRONOMY
HIBS-IMT
IMT
MOBILE-SATELLITE (SPACE-TO-EARTH)
MOBILE-SATELLITE (EARTH-TO-SPACE)
MOBILE
METEOROLOGICAL-SATELLITE (SPACE-TO-EARTH)
METEOROLOGICAL-SATELLITE (EARTH-TO-SPACE)
MARITIME RADIONAVIGATION
MARITIME MOBIL-SATELLITE (SPACE-TO-EARTH)
FIXED-SATELLITE (SPACE-TO-EARTH)
FIXED-SATELLITE (EARTH-TO-SPACE)(SPACE-TO-EARTH)
FIXED-SATELLITE (EARTH-TO-SPACE)
FIXED
EARTH EXPLORATION-SATELLITE (SPACE-TO-EARTH)(SPACE-TO-SPACE)
EARTH EXPLORATION-SATELLITE (SPACE-TO-EARTH)
EARTH EXPLORATION-SATELLITE (PASSIVE)
EARTH EXPLORATION-SATELLITE (ACTIVE)
EARTH EXPLORATION-SATELLITE (EARTH-TO-SPACE)(SPACE-TO-SPACE)
EARTH EXPLORATION-SATELLITE (EARTH-TO-SPACE)
EARTH EXPLORATION-SATELLITE
BROADCASTING SATELLITE
BROADCASTING
AERONAUTICAL RADIONAVIGATION
AERONAUTICAL MOBILE-SATELLITE (R)
AERONAUTICAL MOBILE (R)
AMATEUR-SATELLITE (SPACE-TO-EARTH)
AMATEUR-SATELLITE
AMATEUR

Frequency Bands
A-band
B-band
C-band
D-band





Federal Agency for
Cartography and Geodesy



Thank you for your kind attention!

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