IVS NEWSLETTER

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Unicycle Vigilante

With Benedikt Soja the IVS has a new Analysis Coordinator who will bring his unicycle skills to the analysis front—as another form of machine learning. Explore what he has to say about AI, Genesis, and other matters relevant to the future of VLBI analysis. Beyond this, also learn about the newest in VLBI technology and the importance of spectrum management.

Inside this issue

Board Meets at Haystack

Masafumi Ishigaki
Geospatial Information Authority of Japan

The 51st IVS Directing Board Meeting was held at MIT Haystack Observatory, in conjunction with the 9th International VLBI Technology Workshop. It was a great season to enjoy the autumn leaves in Westford turning beautiful red and yellow colors, and the weather was very pleasant over the whole period. During coffee breaks, I walked around the forest along an old railway for mobile VLBI antennas near the venue. A lot of squirrels were running and gathering nuts to prepare for the approaching winter. It was a relaxing and enjoyable time.

In the meeting, several important topics were discussed. A guideline for new VGOS antennas was shared by Alexander Neidhardt (Network Coordinator). Since new antennas can face mechanical or operational problems, it was decided that feedback from correlators should be given to stations during test sessions before starting regular operations.

Directing Board members visiting the Westford site.

The information about the ongoing election for the next IVS Directing Board was also addressed. The terms of five current members—Pablo de Vicente (Network Representative), Oleg Titov (Analysis and Data Centers Representative), Hayo Hase,

(continued on p. 11)

New IVS Analysis Coordinator Benedikt Soja

At the end of the General Meeting week in Tsukuba, Japan, in March 2024, the IVS Directing Board elected Benedikt Soja to be the next IVS Analysis Coordinator ("ACo"), succeeding John Gipson in this position. So, in a way, we are in the pontificate of Benedikt I. Our new ACo has been a professor for space geodesy at ETH Zurich (Switzerland) since the spring of 2020, and he is the lead of their local analysis center. Newsletter editor Hayo Hase caught up with Benedikt via email. The following exchange was slightly edited for clarity.

Benedikt, how did you get involved in geodetic VLBI?

I was first introduced to VLBI during my studies in "Geodesy and Geoinformation" at TU Wien, Austria. The study program is quite broad, from surveying to cartography, providing diverse opportunities for specialization. Since I was also interested in physics and astronomy, the lectures about space-geodetic techniques, and especially VLBI, fascinated me the most. Something really clicked for me as I ended up doing both my Bachelor's and Master's theses on VLBI—it was an obvious choice for me.

After graduating from TU Wien, what were the next steps in your career and how did they relate to VLBI?

Although my career has brought me to many different places, VLBI has been the common thread throughout. During my PhD at GFZ Potsdam, I focused on improving VLBI analysis through Kalman filtering. At NASA JPL, I worked on developing terrestrial and celestial reference frames using VLBI. Now, at ETH Zurich, we have established an IVS Associate Analysis Center and contribute to the joint IVS Operation Center "DACH."

You currently hold a professorship at ETH Zurich. What areas of teaching and research do you cover?

My professorship is the only one in Zurich dedicated to space geodesy, which requires a broader thematic focus. As a result, our research extends beyond VLBI to include GNSS and gravimetry. With the significant growth of my group in recent years, I am no longer able to do hands-on research myself. Instead, I focus on providing the best possible supervision for my team members and writing grant proposals. Our teaching covers a wide range of topics related to the various space-geodetic techniques, reference systems, physical geodesy, navigation, and parameter estimation.

VLBI analysis was developed in the 1980s during the early days of geodetic VLBI. After the founding of the IVS in 1999, the position of IVS Analysis Coordinator was created. The position was held by Axel Nothnagel, John Gipson, and now by yourself. What do you consider to be the main tasks of this position?

Benedikt Soja at the Westford Radio Telescope

Benedikt at Ishioka during GM2024.

First, it is a great honor to follow in the footsteps of such highly influential figures in the VLBI community.

As IVS Analysis Coordinator, my primary goal is to ensure the delivery of high-quality VLBI products, including Earth orientation parameters and station positions. This encompasses both operational products—where dUT1, provided exclusively by VLBI, is of highest importance and must be determined reliably and in a timely fashion—and reprocessing efforts—particularly for terrestrial reference frames which must consistently follow state-of-the-art methods.

Benedikt competing in a unicycle event.

My role also involves encouraging comparisons, both among different VLBI solutions and against those from other space-geodetic techniques, as well as developments of new models and methods to enhance IVS products. Additionally, I am responsible for coordinating IVS analysis activities with external organizations such as the IERS, GGOS, and IAU.

Finally, I will organize IVS Analysis Workshops, coordinate the IVS contribution to IAG Unified Analysis Workshops, and help promote VLBI products to the broader research community.

What are the major challenges of VLBI analysis and how do you intend to address them?

One of the main challenges—and opportunities—toward better VLBI products is the ongoing transition to VGOS. While promising results have been achieved, many operational issues remain to be addressed. Modeling improvements, such as for source structure, and refined analysis strategies, for example for exploiting the high cadence of observations in terms of the troposphere, will also be beneficial. Regarding terrestrial reference frames, understanding the anomalous behavior of the network scale is a current research focus, with a new working group established by Karine Le Bail to investigate this issue. For celestial reference frames, integrating solutions from different frequencies will become increasingly important. A combined celestial frame based on solutions from multiple Analysis Centers should be the goal, as it is the standard for the TRF and EOP.

A long-standing challenge is the lack of consistency between TRF, CRF, and EOP as well as systematic errors between different space-geodetic techniques. While there are positive developments, such as software supporting combination at the observation level, they are still in the early stages. The upcoming Genesis mission could drive significant progress in this area. I encourage the IVS analysis centers to support this mission—VLBI is a unique aspect of this mission, and its success would reinforce VLBI's role in the geodetic community.

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Currently it is fashionable to incorporate methods of artificial intelligence in all kinds of decision-making processes. Where do you see possibilities to introduce AI methods in geodetic VLBI?

I see promising potential for AI across the entire VLBI processing chain. For instance, in simulations AI's generative capabilities could create more realistic synthetic observations. In scheduling, at ETH we are already using AI-based methods for more efficient parameter optimization. In terms of analysis, AI could lead to automation of certain tasks such as anomaly detection (e.g., clock breaks). AI also has potential for radio source imaging, where astronomers have made significant advances, yet to be adopted by the IVS community. Beneficial to VLBI is also that AI has shown great promise in improving tropospheric modeling (considering that the best weather prediction models today are based on AI) and helping to overcome the latency in VLBI products by providing better EOP predictions.

What limitations of AI do you anticipate for geodetic VLBI analysis or in the provision of geodetic VLBI products?

A certain limitation of AI is often its acceptance within the community. A common concern is that AI models due to their complexity act as "black boxes," making it difficult to understand and trust their results. For this reason, it is important to make AI methods explainable and trustworthy as far as possible, for example, by conducting feature sensitivity analysis and providing uncertainty quantification.

For AI methods, especially deep learning, to perform well, large amounts of data are required. Therefore, it would be highly beneficial if various types of logs, metadata, results, and other relevant information were readily available and stored in a machine-readable format. There are ongoing efforts in this direction, such as an Open Research Data project led by Matthias Schartner at ETH, which aims to collect and store such data in a database (*https://glovdh.ethz.ch/*).

A pair of local breweries dedicated a bockbier to the Unicycle Vigilante. This hero is supposed to personify Gemütlichkeit and good cheer. Our man Benedikt can claim mission accomplished.

You mentioned the Genesis mission earlier. Which impact do you expect such space-geodetic missions—where a VLBI transmitter is flown on a satellite—to have on geodetic VLBI analysis? Are the correlation and analysis software packages prepared for this?

The topic of observing satellites with VLBI has been investigated for about a decade, leading to a lot of interesting research. However, until now, we have lacked a high-quality mission to apply these scientific developments, and there has not been a strong need for analysis centers to expand in this direction. With the Genesis mission (and other promising initiatives such as GRITSS), this is about to change, and I expect satellite observations to become an important part of VLBI analysis. Right now, as a community, we are not well prepared, as most software packages currently do not support such observations. In the next 2–3 years, we must make significant progress in this area.

What is on your agenda as IVS Analysis Coordinator over the next few years?

In the short term, I aim to continue meeting with key individuals involved in VLBI analysis and those relying on IVS products, both within and outside the IVS, to better understand their ideas and expectations. I also plan to complete setting up a new website related to IVS analysis activities. Minghui Xu, Sabine Bachmann, and I have recently taken over the organization of IVS Analysis Center and Combination Center meetings, as well as the management of the community on the BSCW server, and we will continue this work. Additionally, one of my most important tasks is to organize my first IVS Analysis Workshop in conjunction with the EVGA meeting in Matera. Beyond that, my focus will be on addressing the various challenges I mentioned earlier.

With all your duties keeping you busy, what is your favorite activity when you have some time on your hands?

By far, my favorite hobby is unicycling, especially in the mountains. It's a great way to clear my mind from work, as it requires constant focus to stay balanced. In the summer, I ride my unicycle in the Swiss Alps and attend unicycling events and competitions. This year was quite successful, as I defended my world champion title in Unicycle Cross Country and became the first Swiss champion in Unicycle Downhill. In the winter, I've recently started doing ski tours and riding indoors on virtual platforms like Zwift (on two wheels, at least until someone creates a unicycle version). I'm also excited about my new digital piano. I used to play as a child but stopped when I moved abroad. Now, my goal is to relearn all the beautiful pieces I have great memories of.

Unicycling in the Swiss Alps.

Highlights from the 9th International VLBI Technology Workshop

José A. ("Pepe") López-Pérez, VTC Chair

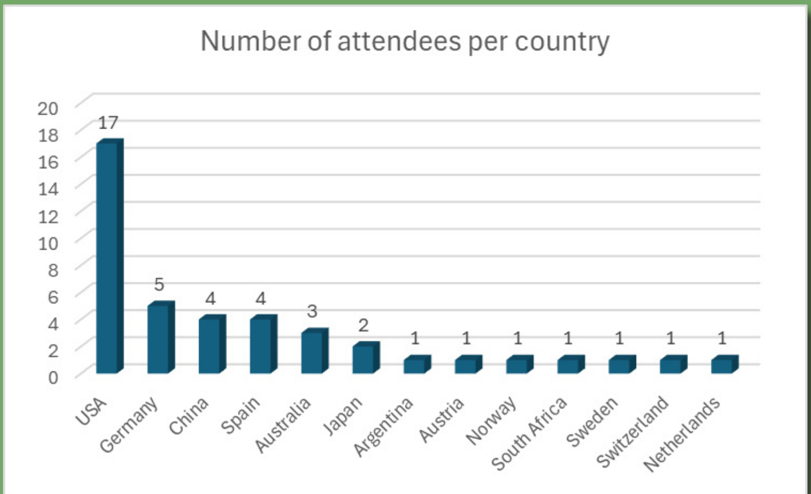
The 9th International VLBI Technology Workshop (IVTW) took place at MIT Haystack Observatory from 21 to 23 October 2024, bringing together technology experts in the fields of geodetic and radio astronomy VLBI. The workshop was followed by a meeting of the IVS Directing Board on 24 October. We would like to thank the local organizing committee, led by Chet Ruszczyk, for this well-organized workshop.

Group photo of IVTW attendees at MIT Haystack Observatory.

The last event in this series was held five years ago. The 8th IVTW took place in Sydney, Australia, from 18 to 20 November 2019 and was organized by CSIRO. The main reason for the large time gap between workshops was the global pandemic caused by the SARS-CoV-2 virus.

The 2024 event was attended by 42 participants from 13 different countries. A total of 34 talks were delivered, and one poster was presented. The presentations showcased recent advances in VLBI technology and underlined the important role of technological developments in improving the quality of VLBI observations, which are crucial for a better understanding of the Earth and the Universe. There were presentations on new digital architectures, developments, and advancements in VLBI—like the ones described for the VLBA, Effelsberg Direct Digitization, MeerKat, ALMA, and ESCAPE.

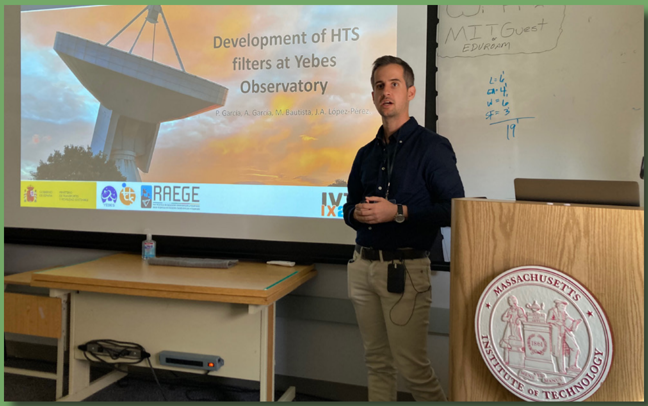
Status updates and progresses in VLBI projects and observatories worldwide were also shared, such as those from LBA, GVA, the Chinese 40-m dish, RAEGE Gran Canaria, AuScope, Haystack, Onsala, ATCA, and CART. Particularly noteworthy were the presentations on combining GNSS and VLBI techniques through NASA's GRITSS and ESA's GENESIS missions, aiming to establish space-based local ties. New tools and methods for source structure correction, cross-polarization gain calibration, and mitigation of atmospheric spatial-structure errors were also presented.



Another notable topic was radio frequency interference and its impact on VLBI observations.

Presentations covered measurement methods, real observations of RFI from mega-constellations, mitigation techniques using high-temperature superconducting (HTS) filters, and spectrum management. Notably, there was a dedicated discussion panel on this subject.

The coffee breaks, as well as the lunch and dinner hours, during the conference provided opportunities for attendees to exchange ideas and experiences in a friendly and relaxed atmosphere. All presentations are available on the conference website at *https://www.haystack.mit.edu/ivtw2024*. Onsala Space Observatory, near Gothenburg in Sweden, volunteered to host the next edition of the IVTW. Aiming to restore the regular schedule of this workshop, this edition will be in 2025.



Pablo García (IGN Yebes) presenting his developments on HTS filters.

Armstrong Moves On

Dirk Behrend, NVI, Inc./NASA GSFC

Deputy General Editor Kyla Armstrong has moved on. As of the end of November 2024, having worked on 34 newsletter issues over 11 years (Issues 36–69, August 2013 through August 2024), she decided to take one giant leap to a different location. The eagle has landed—on another moon.

During her tenure as editor, about 5 years in, we moved from having a printed version of the Newsletter mailed out to the Associate Members to only publishing online. Until then, Kyla made sure that the paper version got out on time and reached its intended destination. She prepared the address labels, worked through the red tape at NASA for shipping overseas, and interacted with the Mailroom to initiate the mass mailing. I am sure she was "particularly fond" of getting approval for mailing to designated countries—this was always an adventure.

Many of you have worked with Kyla on a number of IVS publications, from the Biennial Report to the General Meeting Proceedings to the IVS Newsletter. In addition, she has helped with managing the IVS mailing lists as well as other IVS clerical tasks. Please join me in wishing Kyla all the best for the new chapter in her life.

Outgoing editor Kyla Armstrong.

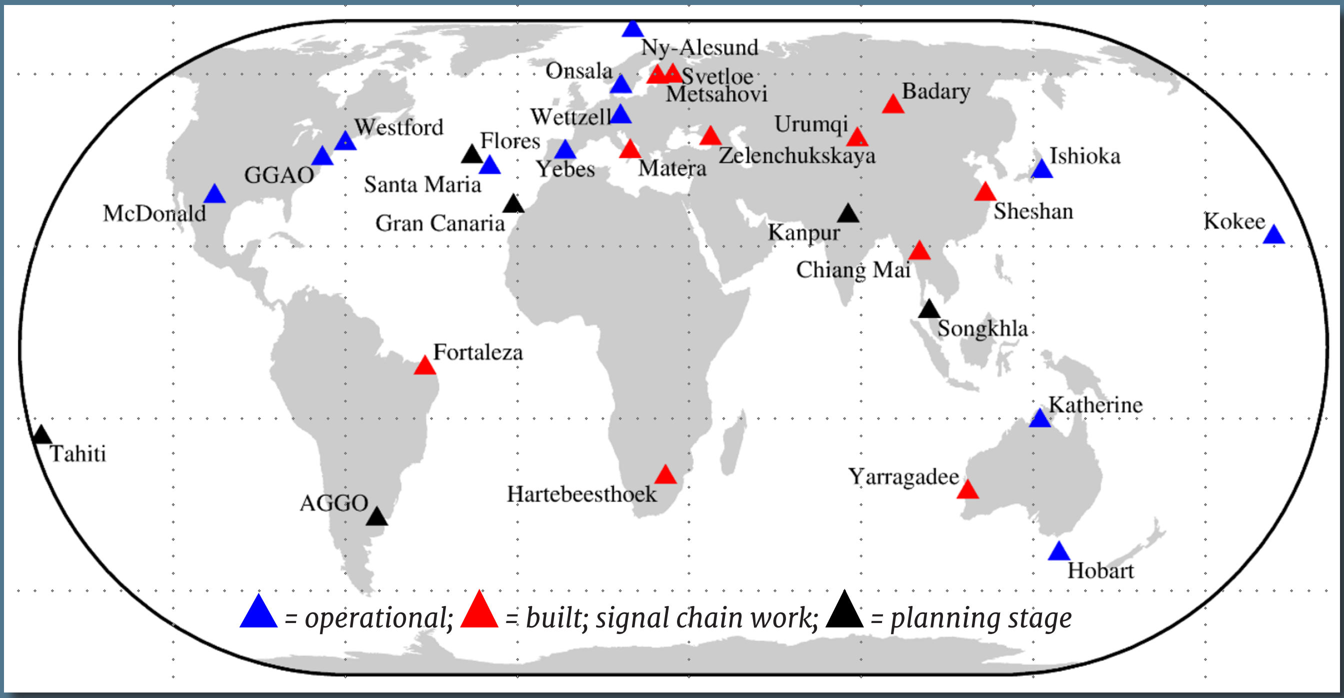
Geodetic VLBI and Spectrum Management

Hayo Hase, BKG

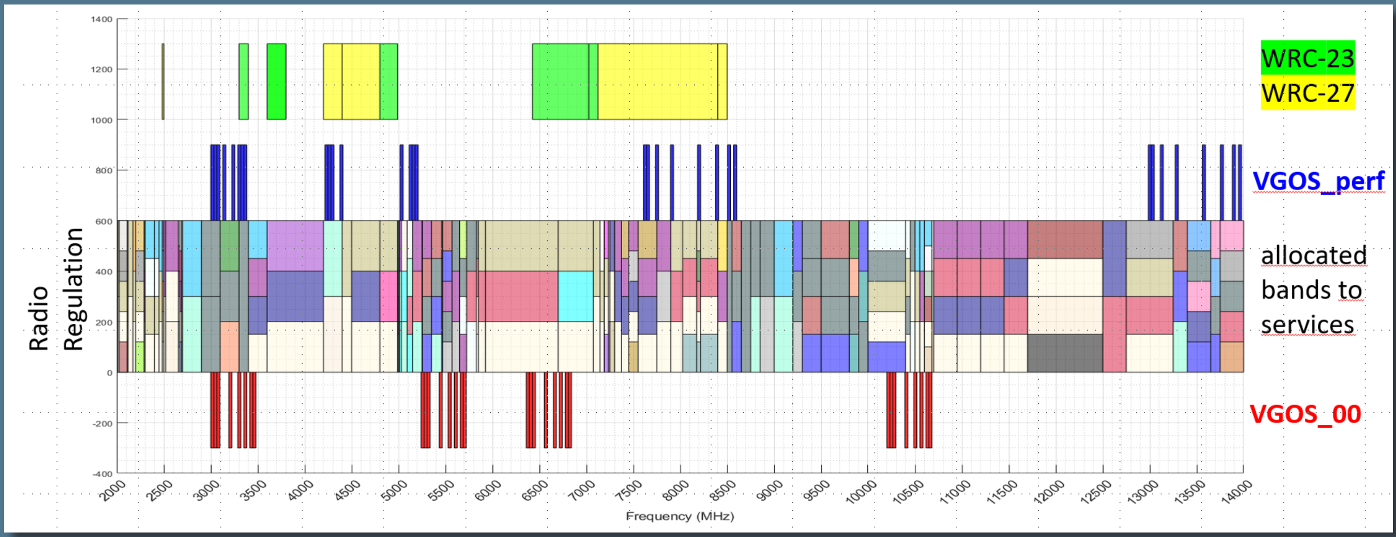
For decades, geodetic VLBI was observed in S-band (2.2–2.35 GHz) and X-band (8.1–8.9 GHz). These spectral ranges are allocated to space communications. When there were only a few space agencies operating a small number of satellites, there was rarely a problem between active up/downlinks and passive observations of cosmic radio sources with VLBI.

In the current decade, the commercial use of space has led to a boom in privately funded satellite projects. By 2030, some 100,000 transmitting satellites will fill up almost every square degree of sky with transmitting antennas. At the same time, we are also observing the expansion of mobile telecommunication networks, with each generation (3G, 4G, 5G, 6G) requesting its share of the electromagnetic spectrum. National policy goals are to provide mobile communication infrastructure for the complete national territory. These developments are not conducive to conducting geodetic VLBI, because any manmade electromagnetic signal is magnitudes stronger than the natural cosmic radiation from quasars at the edge of the universe.

The faint quasar radiation can be detected only by top-notch receivers, which operate amplifiers in conditions similar to empty space in a few-Kelvin, cryogenic environment. The reflector of a radio telescope collects the low radiation energy, and its directivity enables to link the moving and turning Earth to (quasi-)fixed quasar reference points in the universe. Therefore, geodetic VLBI is essential for any kind of reference frames in global geodesy and fundamental for any kind of positioning on land, sea, air, and space.



VGOS world map showing the global infrastructure of geodetic VLBI for reference frames. It underlines the need for many countries to become engaged in spectrum management for the protection of geodetic VLBI against unwanted electro-magnetic emissions.



Color-coded allocations to different services according to the Radio Regulations. The top line marks allocation requests by International Mobile Telecommunication (IMT) to be decided at WRC23 (green) and WRC27 (yellow). The benchmark "VGOS_00" setup is shown with red channels, while a suggested performance setup "VGOS_perf" is depicted with blue channels. With radio-quiet areas for geodetic VLBI being hard to find, protection zones for observatories are becoming more and more important.

The increasing concentration of transmitters near geodetic VLBI stations, or near the signal path from the quasars, lead to unwanted electromagnetic radiation overlaying the cosmic radiation. Possible degrading consequences for geodetic VLBI include:

- If the environmental noise level increases by 50%, the signal-to-noise ratio drops by 18% and increases the uncertainty of the delay by 18%. The target accuracy of geodetic VLBI cannot be reached.
- If one or more observation channels (with 32 MHz bandwidth each for VGOS) are superimposed by a carrier frequency at one station, they may not correlate and will be lost. A loss of channels decreases the accuracy of the interferometer and, hence, of the geodetic product.
- Strong signals may saturate the first amplifier stage. This would affect all 32 channels and the observations on baselines to the affected station will be lost entirely.
- The worst case would be a very strong signal destroying the sensitive first low-noise amplifier. The typical damage level is only 15 mW (12 dBm). Such destruction has already occurred: by ship radars, but also by Synthetic Aperture Radar satellites. The associated loss can easily amount to several US$10,000 due to the needed replacement parts, repair work, and downtime of the radio telescope.

The VGOS specifications aim to provide a millimeter measuring system at a global scale. Although the VGOS observations have proven their potential, it is unclear whether this high level can be guaranteed in the future.

What geodetic VLBI stations need is preferably a radio-quiet zone, in which national regulations apply to ground-based transmitters, so that undisturbed observations can be taken. A less restricted zone is a coordination zone, which applies to many populated areas near observatories (e.g., in Europe). In either case, the national spectrum authority would have to implement regulations if not already done.

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National spectrum authorities very often follow the ITU Radio Regulations (RR), which is the reference book for frequency allocations to therein defined services. To keep the VLBI observation channels free of unwanted electromagnetic noise, the geodetic VLBI community has to strive for its own frequency allocations just as the industry does. According to the terms of the RR, the reception of cosmic radiation falls into the category Radio Astronomy Service (RAS). From the beginning of radio astronomy, some natural spectral lines have been allocated to RAS. However, the allocated bandwidth to RAS within the VGOS frequency range of 2–14 GHz is insufficient, which is why the geodetic VLBI community has to ask for more spectrum allocation for RAS.

So far, geodetic VLBI has been performed using an opportunistic approach. When the VLBI community noticed that S-band became more and more occupied by Wi-Fi, WLAN, mobile phone, and the like, the idea was born of the VGOS broadband system that would enable observations in a flexible manner using channels not contaminated by broadcast signals. Today, some 20 years later, all spectrum has been allocated to three or more broadcasting services, making it almost impossible to find undisturbed common channels for the global VLBI network.

So, how do we manage to get the observing channels of geodetic VLBI into the RR? This is where spectrum management comes in. Geodetic VLBI is a global task; and while national rules may protect a local geodetic site, a global VLBI network needs global regulations. Most nations use the RR for the implementation in national laws following this set of internationally agreed upon rules. (That is why mobile phones work well across borders as well as search-and-rescue operations.)

The World Radio Conference (WRC) is a forum of ITU member states and the place where new regulations are established. In our case, the WRC2031 should have an agenda point on "geodetic VLBI." The agenda of WRC2031 will be decided based on a preliminary agenda at the previous WRC in 2027. That is, the WRC agenda is always fixed four years in advance. This four-year period (here 2027–2031) is required for studies on the impact of the possible changes in the regulation due to "geodetic VLBI." The onus of the studies will be on the VLBI community. Consequently, in 2025 and 2026 the IVS will have to advertise and convince many national spectrum authorities to put "geodetic VLBI" onto the preliminary agenda for WRC2031 before 2027.

The IVS together with the European Committee on Radio Astronomy Frequencies (*CRAF*) will need the interaction between the owners of the IVS network stations and the national spectrum authorities to set up a joint proposal by several spectrum authorities requesting our agenda item. A first coordinated action will be the compilation of a list of contacts for the IVS network stations together with the "scientific services" (ITU term) person at the corresponding national spectrum authorities. Once we know who to communicate with at the station and at the authority, we can interact with both and try to form the joint group of national spectrum administrations in favor of geodetic VLBI.

Spectrum management for geodetic VLBI is both a national and a global challenge, and the IVS has never taken such an initiative before. Given the adverse situation for VLBI observations, the IVS Directing Board endorsed this activity. It is planned that the stations will be contacted soon by the IVS Network Coordinator Alexander Neidhardt.

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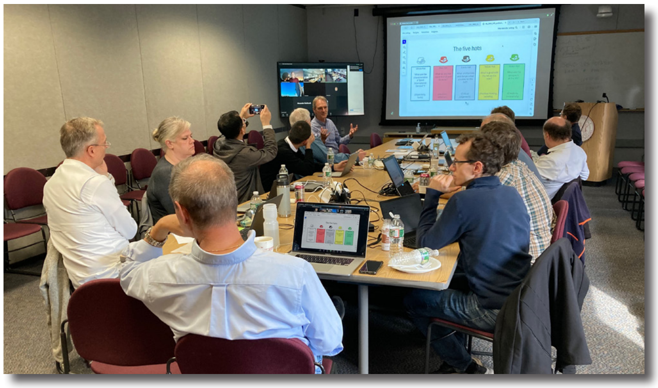
Fengchun Shu, and Masafumi Ishigaki (At-large Members)—will end in February 2025. The positions for the Network Representative and Analysis Representative are elected by the IVS Associate Members, which will be decided by the end of November 2024. After that, the At-large election will be conducted by the Board.

Participants also took part in a brainstorming session on "How to make the IVS more professional?" We were divided into small groups and discussed the current situation and future possibilities for IVS using "five hats." We switched our perspectives in turn by changing our "hats": white (objectivity), red (intuition), black (critical judgement), yellow (positive thinking), and green (creativity).



The Board forming groups for the "five hats" discussion.

Chet Ruszczyk at the Westford air lock vent.

As part of the lunch break, we had a tour of the Westford antenna which is used for VGOS observations. The antenna is covered by a radome supported by air pressure, protecting the antenna from snow and storms. We felt the difference in air pressures between the inside and outside of the radome when we went in.

This meeting was the last one for the current Board members. The newly elected members will join the next IVS Directing Board Meeting in Matera in April 2025. I'm looking forward to seeing them and experiencing the beautiful landscape of southern Italy!

2024 Meetings

9–13 December	AGU Fall Meeting, Washington, DC, USA

2025 Meetings

6–11 April	27th EVGA Working Meeting, Matera, Italy
27 April–2 May	EGU General Assembly 2025, Vienna, Austria
4–8 May	Thirteenth IVS Technical Operations Workshop, Haystack Observatory, Westford, MA, USA

The IVS Newsletter is published three times annually, in April, August, and December. Contributed articles, pictures, cartoons, and feedback are welcome at any time.

Please send contributions to the General Editors; the deadline is one month before the publication date. The editors reserve the right to edit contributions.

General Editor	Dirk Behrend (*dirk.behrend@nasa.gov*),
Feature Editor	Hayo Hase (*hayo.hase@bkg.bund.de*)
Layout Editor	Nancy Kotary (*nwk@mit.edu*)

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IVS Coordinating Center NASA GSFC, Code 61A.1 Greenbelt, MD 20771
https://ivscc.gsfc.nasa.gov | *ivscc@lists.nasa.gov* | phone: 301-614-5939