IVS NEWSLETTER

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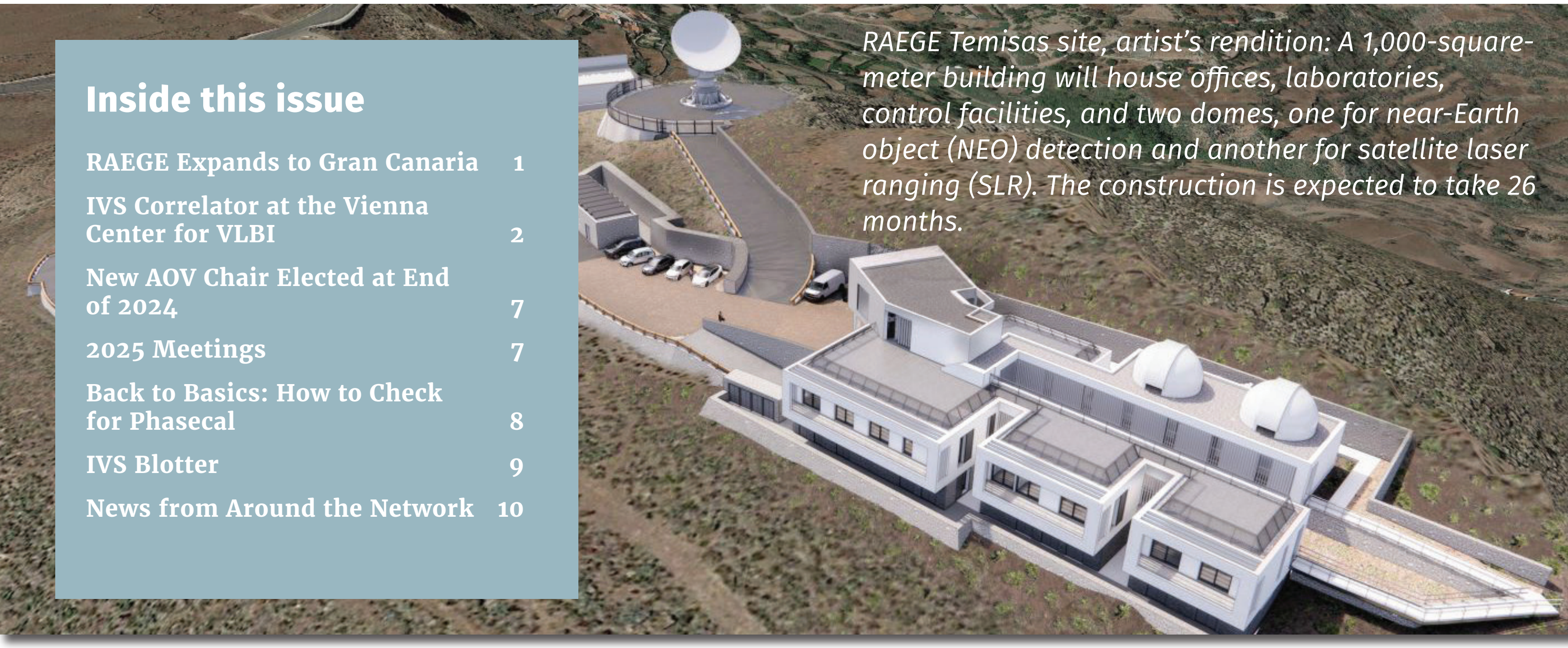

RAEGE Temisas site, artist's rendition: A 1,000-square-meter building will house offices, laboratories, control facilities, and two domes, one for near-Earth object (NEO) detection and another for satellite laser ranging (SLR). The construction is expected to take 26 months.

Inside this issue

RAEGE Expands to Gran Canaria

– José A. ("Pepe") López-Pérez, IGN Spain

The Spanish Ministry of Transport and Sustainable Mobility (MTMS) has commenced the construction of the third RAEGE station in Temisas (Agüimes, Gran Canaria). The site, allocated by the Cabildo of Gran Canaria to the National Geographic Institute (IGN) in March 2023, will enhance RAEGE's contribution to VGOS and global geodetic research.

This facility will complement existing stations in Yebes (Spain) and Santa María (Azores, Portugal), with a fourth planned in Flores (Azores, Portugal). Equipped with a state-of-the-art VGOS radio telescope, GNSS receivers, an atomic clock, gravimeters, and various geophysical instruments, the station will significantly contribute to monitoring Earth's changes and refining terrestrial and celestial reference frames for navigation and positioning.

Groundbreaking ceremony for the RAEGE Temisas site on Gran Canaria on 11 March 2025. The event was attended by several dignitaries from Spain and beyond. Pepe stands to the left of the RAEGE sign.

IVS Correlator at the Vienna Center for VLBI

In September 2018, the Technische Universität (TU) Wien became an official IVS Correlator at the Vienna Center for VLBI led by Johannes Böhm [JB]. A few years later, the organizational footprint was extended and, based on a cooperation agreement from August 2022, the Vienna Correlation Center is now run jointly by the TU Wien and the Federal Agency of Metrology and Surveying in Austria (BEV). Newsletter editor Hayo Hase interviewed the Vienna correlator personnel Jakob Gruber [JG] and Frédéric Jaron [FJ] via email. The following exchange was slightly edited for clarity.

Johannes, what is the story behind Austria not having a radio telescope for geodetic VLBI but running a VLBI correlator?

[JB] At TU Wien, we have been focusing on the analysis of VLBI observations since the start of the IVS in 1999. At that time, and in the years thereafter, it was not possible to contribute to the IVS in a more comprehensive way. In 2012, however, we were granted preferential access to the Vienna Scientific Cluster, allowing us to start with VLBI correlation. We need to acknowledge Jamie McCallum from the University of Tasmania, who introduced us to the world of correlation and helped us a lot in those years. There has always been close cooperation between TU Wien and BEV, not least because of several colleagues with VLBI background moving to BEV. But it was certainly the open and interested president of BEV, Wernher Hoffmann, to see the importance of VLBI correlation for global geodesy and to start correlation together with TU Wien in a joint undertaking.

Jakob and Frédéric at their desk at TU Wien, happy to see a fringe.

Jakob and Frédéric, how did the two of you get involved in VLBI?

[JG] First of all, thank you very much for the invitation to this interview! I'm a big fan of the IVS Newsletter, and I'm very grateful to work and collaborate with so many amazing people worldwide in the field of VLBI.

My journey into VLBI started during my Geodesy and Geoinformation studies at TU Wien, where we had several courses on higher geodesy, even at the bachelor's level. VLBI was introduced at a very high level, and I found the technique absolutely fascinating. On top of that, I really liked the friendly and welcoming atmosphere of the VLBI group at TU Wien.

That initial interest led me to pursue both my bachelor's and master's theses in VLBI. Especially my master's research was a significant step—I had the opportunity to collaborate with the University of Tasmania, which included a three-month research stay. During my time in Hobart, I got hands-on experience as a VLBI station operator. This gave me a fantastic opportunity to understand the intricacies of VLBI operations, and it became a major turning point in my involvement in the field.

[FJ] I got first involved with VLBI in 2007. I was studying physics at the University of Bonn and was hired by Arno Müskens to work at the VLBI correlator of the Max-Planck-Institute for Radio Astronomy as a student assistant. During that time the Bonn correlator transitioned from hardware to software correlation, and I also had the opportunity to be part of a team that worked on the implementation of phase-cal extraction in DiFX. This was a very important step to enable software correlation of geodetic VLBI data and became the subject of my BSc thesis. After completing my PhD in astrophysics in 2016, I was hired by Axel Nothnagel as a postdoc at the University of Bonn to work on a project about VLBI observations of Earth satellites. Since then, I have continuously been working in the field of geodetic VLBI.

Who else is part of the correlator group?

[JG] Since Frédéric joined TU Wien five years ago, we are a small, but powerful two-person team. I think we have a well-balanced division of responsibilities. Frédéric has a strong focus on research, while I handle the operational side of VGOS sessions. This setup allows us to efficiently manage both the scientific advancements in correlation and the day-to-day operational challenges of processing VLBI data. Beyond VGOS operations, I also conduct hands-on research in Genesis and VLBI-to-satellite missions, which is an incredibly exciting field with a lot of potential for the future.

[FJ] Let me add that I correlate VLBI R&D sessions and occasionally regular VGOS sessions. Currently, I use the Vienna Scientific Cluster for the development of a novel method to correct Level 1 data (i.e., the DiFX output) for extended source structure.

What skill sets do you need for establishing a functional correlator?

[JG] A good correlator needs a mix of skills in signal processing, IT, and specific VLBI knowledge. Correlation is a very specialized task that requires dedicated working time, an efficient team, and access to a computing cluster. An often overlooked, but critical skill is managing communication between the stations and the correlator. A VGOS session, for example, requires coordination with up to 13 stations simultaneously. It's not uncommon for a single session to generate over 80 emails! While we aim to be as efficient as possible, gathering raw data from around the world and resolving station issues takes a significant amount of communication and coordination.

Building housing the Vienna Scientific Cluster (maybe not what you expected).

If I had to design a "VLBI Correlator School," it would include courses on (a) Digital Signal Processing, (b) Linux & Programming, and (c) VLBI-specific databases, software, and terminology. From my perspective, if you have a background in signal processing, computing, and programming, you have a solid foundation for correlation work. Adding expertise in VLBI-specific tools and terminology will make you a great correlator. And if you understand the importance of geodetic and astrometric VLBI products, you won't just be a good correlator, you'll also truly enjoy the work.

That said, while you can find excellent resources on signal processing and Linux, learning VLBI correlation itself is much more challenging. Without the guidance of experienced VLBI experts, I wouldn't have been able to reach my current understanding. I'm incredibly grateful to Jamie McCallum, who taught me a lot about VLBI correlation early in my career.

[FJ] I fully agree with Jakob. I would like to add the technical requirements that a facility has to fulfill. To be able to process terabytes of observational VLBI data in a reasonable time, you need to have sufficient computing power and storage capacity. Nowadays, correlation is predominantly carried out with software

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running on high-performance computer clusters. So, you need access to such a machine or purchase one yourself. You also have to make sure that the vast amounts of observational data can be delivered to your facility in a timely fashion. Since electronic data transfer is the preferred method today, you will need a fast network connectivity.

How difficult is it to find fringes and produce good results?

[JG] Phew, that's a tricky question! To make my life easier, I'll go with the classic VLBI answer: it depends—mostly on the quality of raw data from the stations. 😉 That being said, correlators do have quite a few software parameters they can tweak to improve results. Between well-established stations, finding fringes and producing good results is relatively straightforward with the current software solutions, as we already have a solid understanding of the necessary configurations. However, things get more complicated when new or problematic stations are involved. A key factor is having a strong baseline network—good-performing stations help us verify and troubleshoot data from more challenging stations. At the end of the day, there's always a bit of luck involved in which session you get and how well your processing approach aligns with the specific session and stations.

Frédéric playing the piano.

[FJ] That's true. If the observation was carried out as planned, there is a straightforward procedure to correlate the data and obtain fringes. However, in practice a lot can go wrong. Examples for common issues are large deviations from the expected station clock model, problems with the phase-cal signal, or an accidental mix-up of polarization channels in the case of VGOS. Speaking of VGOS, the dual-linear polarization nature of these observations requires additional calibration steps, compared to legacy S/X observations. To maximize the signal-to-noise ratio of VGOS observables, it is crucial to perform this calibration with great rigor. In my opinion, there is the potential to improve and to speed up this step by making appropriate use of calibrator scans, which should be optimized for this purpose.

Which sessions do you correlate and how many?

[JG] Our primary focus is the correlation of operational VGOS sessions. Previously, we processed one session per month, but we now correlate one session every two months. Additionally, we handle a substantial amount of simulated raw data for scientific investigations.

[FJ] In addition, we correlate R&D sessions, if Vienna is involved. We have also been involved in the EU-VGOS project a lot and correlated these sessions here.

How do you troubleshoot correlation problems?

[JG] The IVS community has been incredibly supportive over the years. Help comes in many forms:

- Station experts providing feedback on station issues;
- Lively discussions at DiFX workshops;
- HOPS and nuSolve developers answering all our software-related questions;
- Other correlators sharing their expertise on complex topics.

Portrait of Jakob Gruber.

Correlation was completely new to TU Wien, and it took a lot of effort to navigate the vast amount of unfamiliar terminology, concepts, and software requirements. We had to build a correlator from scratch without any institutional history, which was both challenging and rewarding.

[FJ] The community of VLBI correlators is very cooperative when it comes to helping each other out with problems and issues. A very good forum for the exchange of information is the monthly IVS correlator telecon. In the beginning of operational VGOS observations, we established the EU-VGOS correlation meetings, which really helped to get everyone on the same page and to enable regular processing of VGOS experiments. I am also in good contact with the MPIfR group in Bonn, with which I'm affiliated through a guest contact.

What is so interesting about VLBI correlation? What scientific investigations are being done in that field?

[JG] What I find absolutely mind-blowing is that, as a correlator, you work with the rawest VLBI data possible. Sure, the station hardware filters, down-converts, and samples the signal. But apart from that, the data remains untouched. In other words, every physical effect that influences the signal—from the extragalactic source to the receiver—is contained in the raw data. As VLBI transitions to broadband observations and aims for higher accuracy, many of these physical effects need to be studied not just at the group delay level, but also at the raw data and interferometric phase levels. I expect that in the coming years, there will be exciting developments in raw data processing and many new scientific investigations in this area.

[FJ] Having a background in physics and astronomy, I personally like to work in a field which combines research of astrophysical objects with such a relevant topic as the measurement of our changing Earth. The raw observational data, which are taken at each VLBI station individually, are recordings of pure noise, emitted by quasars many millions of light-years away. It is only through the interference of the recordings of the different stations that information is obtained which is necessary for geodetic and astronomical analysis. The correlator is the place where exactly this happens. Here the data streams are for the first time combined, and at this moment the individual stations participating in a VLBI session form an interferometer.

One important systematic error is the fact that many sources are not point-like but have extended radio structure. In the main project which I'm working on now, we correct the correlator output in such a way that the data of extended sources appear as if they were point sources. Applying this correction right after correlation, very early in the processing chain, has the benefit that any subsequent processing step will not be affected any more by source structure.

Portrait of Frédéric Jaron.

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Jakob rock climbing in Utah.

At the correlator, you have a first look at the quality of the station data. What parameters are you looking at? Do you have any advice for the stations?

[JG] I'll start with two infamous words: Phase Calibration! 😉 This is one of the most important (and sometimes mysterious) parameters we check first. The amplitude and stability of the phase calibration signal give us crucial insights into the station's receiving system and how the software adapts to it.

Next, we examine the Power Density Spectrum for each station channel, where we can detect interference, RFI, and other anomalies.

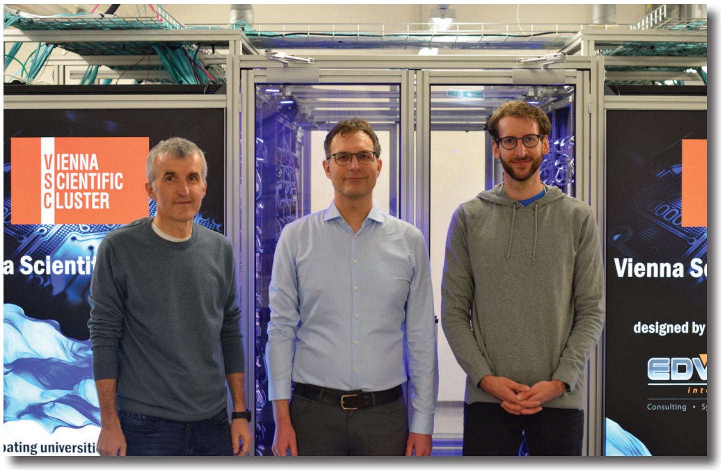
I don't want to be presumptuous giving advice to experienced station operators. But I can say that the observation summaries (sumops.txt) are incredibly helpful for our work. These summaries provide quantitative and qualitative descriptions of station performance, helping us correctly apply calibration parameters, handle errors, and flag data. Expanding observation summaries with additional parameters like system sensitivities would further improve our ability to optimize station data quality.

[FJ] The first parameters that we use to find fringes are the offset and rate of each station clock with respect to GPS time. This information is obtained by analyzing the station log files. In addition, each station has its own "peculiar offset," which reflects additional delays that the source signal experiences on its way from the receiver to the formatter. If there are changes in the station clock or the circuitry, then this typically results in a change of these offsets. If stations let us know when they carry out modifications to their equipment, this would help us a lot in finding fringes and reducing the overall time that we spend investigating these issues.

Finally, after so much cross-correlation, what are your preferred leisure activities?

[FJ] Vienna offers many possibilities both for activities and for relaxing. Especially in the surroundings of the city you can do amazing tours for sightseeing and hiking. In my free time I enjoy making music, like playing the piano.

[JG] After a long day of correlation, I love being active outdoors—ideally in the mountains! You'll usually find me climbing with friends, tackling challenging and aesthetic unclimbed rock formations wherever we can find them. I also love exploring new climbing areas worldwide and learning about their local mountaineering and climbing ethics.



New AOV Chair Elected at End of 2024

– Masafumi Ishigaki,
Geospatial Information Authority of Japan

The Asia-Oceania VLBI Group for Geodesy and Astrometry (AOV) is a subgroup of the IVS organized in 2014 to foster regional collaboration in the Asia-Oceania region. At the end of 2024, elections were held to relieve the outgoing AOV Chair Fengchun Shu and Secretary Lucia McCallum. Fengchun and Lucia have contributed for years to enhance AOV activities and regional sessions. For the latter, mixed-mode correlation was introduced enabling many stations to participate.

At the election event, Lucia McCallum was elected as the new AOV Chair, followed by Masafumi Ishigaki being appointed as the new AOV Secretary. The two appointments (chair and secretary) are for a term of four years each (from January 2025 to December 2028). The new leadership team commenced discussions on several strategic topics, including membership updates, new website (*https://www.spacegeodesy.go.jp/vlbi/AOV/index.html*), regional VGOS sessions, and planning of the next AOV meeting. Stay tuned for updates on future AOV activities!

AOV Chair Lucia McCallum (left) and Secretary Masafumi Ishigaki (right) during a strategy planning meeting.

2025 Meetings

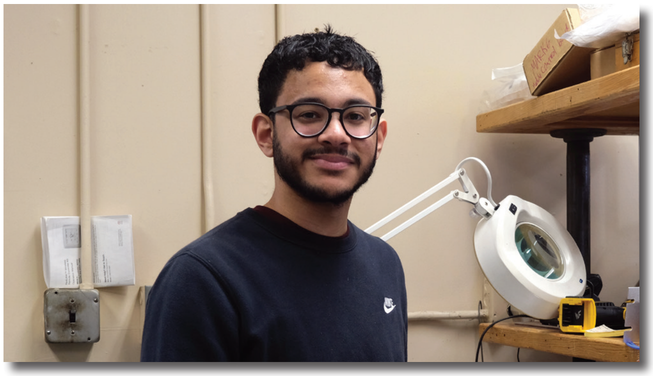
6–11 April	27th EVGA Working Meeting, Matera, Italy
27 April–2 May	EGU General Assembly 2025, Vienna, Austria
4–8 May	Thirteenth IVS Technical Operations Workshop, Haystack Observatory, Westford, MA, USA
26–28 October	5th IVS Training School on VLBI for Geodesy and Astrometry

Back to Basics: How to Check for Phasecal

– Alex Burns, MIT Haystack Observatory

At Westford, it is a year of transition. Mike Poirier retired after 41 years of service to MIT, most of which also happened to be in service to VLBI. With the mantel being passed down, that means another technician (and operator) needed to be added to the Westford team: Welcome Abiel Mendez! That brings up another opportunity to train a new person in the fundamentals of recording good data. It also is a good time to look at the documentation and clarify and simplify the checklist items that the operator has to step through. One problem we had this year required us to check our phasecal amplitude. To check something like phasecal amplitude, it must be determined where in the chain phasecal should be present and at what level. How do we explain where to look, and what you should find?

Checking phasecal in Band D, for example, could mean setting up a spectrum analyzer at 10.5 GHz to measure the phasecal at the RF distributor output. This would be done in the control room. The same frequency setup of the spectrum analyzer could be used at the apex of the Westford dish to measure a point in our high-band path, on the post-dewar electronics plate. But, if your concern is later in the signal chain, you could be measuring the IF, or Intermediate Frequency. What is IF? In order to record the channels and bandwidth we need, we take the RF from the front end and convert it to IF. This is done for 4 bands, which are the 1-GHz-wide selections of IF, that are taken from the full wide-band RF bandwidth "seen" by the sensitive front end. The band is then further cut down into individual channels, 32-MHz wide, that are digitized and recorded onto disk. This is done differently depending on your backend system, but at Westford we have a UDC, which converts RF into IF, followed by the R2DBE. The R2DBE is what takes IF, channelizes and digitizes it, time stamps the packets, and outputs them to the recorder. So, if you are looking for phasecal after a UDC, you need to look between 500×1,500 MHz, no matter what the RF frequency may be. There is a setting on the UDC, called Net LO, that will determine what your band of IF will be. From this Net LO you can also find where in the RF you are looking. So, to find phasecal tones at 10.5 GHz, you would set your Net LO to the VGOS setting of 9672.4 and find your tone in the IF at 828 MHz.

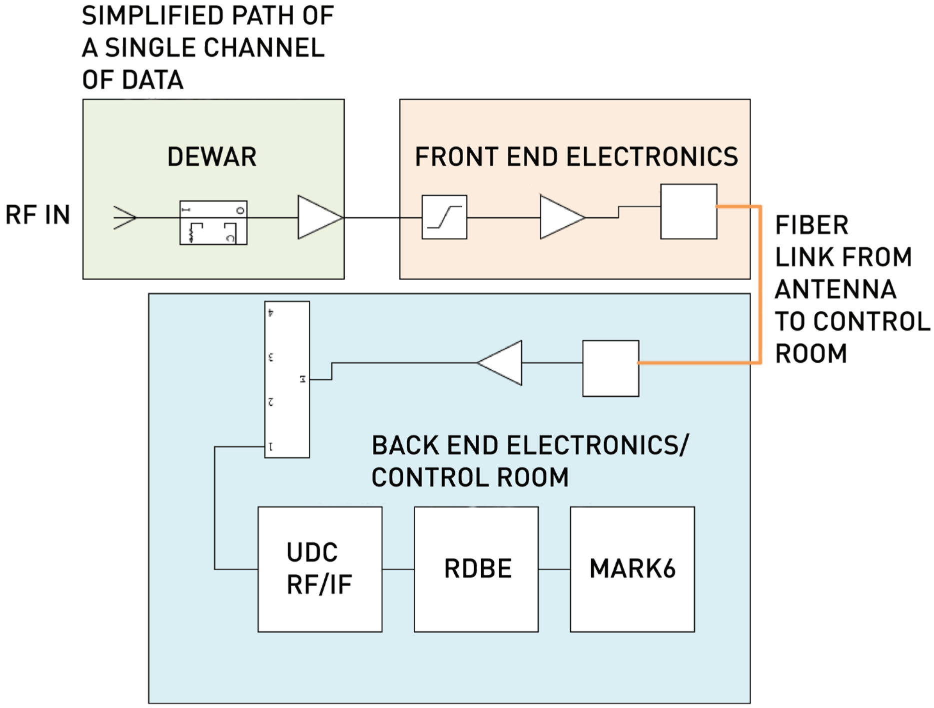


Westford technician Abiel Mendez

Mike Poirier has retired.

Another way you might determine phasecal presence is to look inside the digitizer itself. The final version of R2DBE support will be coming soon to the PCFS, but we can already look inside and take some samples of data to confirm there is phasecal in the IF, as seen by the R2DBE. The correlator can then check in your recorded data.

So, it is with this kind of information that we can look at our signal chain and find phasecal at the various points. With a simple block diagram, we can follow phasecal from its point of origin at the coupler inside of the dewar all the way down to the recorder, and we can test it at each point. This particular block diagram is overly simplified, not a full representation, but knowing these test points will help our new technician become familiar with the site and help him find problems in the future!



IVS Blotter

– Dirk Behrend, NVI

In case you missed it. The December 2024 issue of ***National Geographic*** included a photo of our newly elected Networks Representative Susana García Espada. In an article titled "The New Stars of Polar Science" she is featured in a photo together with the now demolished 20-m antenna at Ny-Ålesund. The photo was taken by Esther Horvarth, a *National Geographic* contributor and photographer for the German Alfred Wegener Institute for Polar and Marine Research. The photographer's work in the polar regions has appeared in *National Geographic* and other publications (e.g., *https://www.spiegel.de/international/world/esther-horvath-photos-of-women-researchers-at-the-edge-of-the-earth-a-99ab502d-ac41-42e4-ac17-b61e06bc0908*).

News from Around the Network

– Alexander Neidhardt, IVS Network Coordinator

Welcome again to the IVS Network Corner. 'Tis the time to point out several of the things that are ongoing in our station network.

General overview. The VGOS network size has grown and is now at 14–16 stations. Hence, there is less time for the correlators to work on failure management or to experiment with data. While the overall network works well together, several stations continue to have a few issues, especially with phase calibration and some of the hardware. The onboarding process with good-quality results becomes increasingly important. Additionally, station personnel should strive to record high-quality data by doing pre-checks and continuous monitoring.

To reach the scientific as well as political goals of continuous observations, discussions must be started to reduce the gaps of observations on holidays. Adding more, well-distributed daily Intensives may be a suitable way of using different baselines.

Activities. We started with the onboarding of the new antenna at Matera. In combination with the technical integration, we started to use Matera as a sample for the registration process, getting CDP and DOMES numbers from NASA and IGN France. This was formerly done by Axel Nothnagel and is now handled by the Network Coordinator.

We also contacted observatory directors to collect information about contacts with national frequency management authorities to support a common attempt to get an item onto the agenda of the World Radiocommunication Conference in 2031. It is necessary that several ITU-R member countries support this attempt. Therefore, please support such attempts and contact your own frequency management authority.

We strongly support the collection of station events and change logs that were started by IVS WG9. A discussion at the upcoming TOW is planned to improve the way we detect events in our products and to tie them to real events at the stations.

As part of increasing professionalism, we have a university project to create web pages and databases for registration, configuration, and logbook management for antennas. It is not yet finished but the process is ongoing.

IVS SADA was moved to a new server. All antenna information was migrated to this new place. The new setup allows geotagging and, hence, the use of world maps to show events in the IVS network. We currently extend the interface with webhooks to enable a simple HTTP-based data injection without bulky SSH calls. This also allows tracking the state of sessions.

The European Space Agency (ESA) has approved the GENESIS mission, which can be described as follows (see also *https://www.esa.int/Applications/Satellite_navigation/Genesis*): "The Genesis satellite will combine the main geodetic techniques (very long baseline interferometry, satellite laser ranging, global navigation satellite systems and possibly DORIS), synchronizing and cross-calibrating the instruments to determine biases inherent to each technic, allowing to correct them for superior precision." ESA GSET WG-3 (VLBI) has commenced work on the preparation and coordination of IVS tasks together with ESA staff. For more detailed planning, we request your help in gathering information for your site about capabilities of satellite tracking, frequency settings, and calibration data. A request email with more details is forthcoming.

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.

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Current and past newsletter issues are available at: *https://ivscc.gsfc.nasa.gov*.

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IVS INTERNATIONAL VLBI SERVICE FOR GEODESY AND ASTROMETRY