3.4.3 International VLBI Service (IVS)

IVS Organization and Activities

During 2013, the IVS continued to fulfill its role as a service within the IAG and IAU by providing necessary products for the maintenance of global reference frames: TRF, CRF, and EOP. Some highlights of the IVS organization and activities were:

- A VLBI Training School was held on March 2–5, 2013 in Espoo, Finland.
- The 14th IVS Analysis Workshop was held in Espoo, Finland on March 5, 2013.
- The 21st European VLBI for Geodesy and Astrometry (EVGA) Working Meeting was held in Espoo, Finland from March 6–8, 2013.
- The spring 2013 IVS Directing Board meeting (IVS DB #29) was held on March 8 at Metsähovi Observatory, Finland.
- The 7th IVS Technical Operations Workshop (TOW) was held at Haystack Observatory (USA), May 6–9, 2013.
- The fall 2013 IVS Directing Board meeting (IVS DB #30) was held on September 7, 2013, at GFZ Potsdam, Germany.
- The 2nd International VLBI Technology Workshop was held on October 10–12, 2013, in Seogwipo, Jeju Island, South Korea.
- In the summer of 2013 the IVS published the 2012 Annual Report. Furthermore, three IVS newsletters were published in April, August and December to keep the community informed about IVS activities.

At its 29th meeting at Metsähovi Observatory the IVS Directing Board elected Axel Nothnagel from the University of Bonn to be the chair of the IVS for the next four years, succeeding outgoing chair Harald Schuh. John Gipson replaced Axel Nothnagel as the IVS Analysis Coordinator.

Network Stations

The IVS network operated well for most of 2013. The average single station data loss (scheduled versus correlated) is estimated to have been at the 15% level for stations that participated in 25 or more sessions; this loss number is slightly higher than in the previous year primarily due to scheduled antenna maintenance. The most significant causes of loss identified were scheduled antenna maintenance (accounting for about 40% of the losses), followed by electronics rack problems (20%), miscellaneous problems (9%), receiver problems (8%), and radio frequency interference (6%).

A total of 188 geodetic/astrometric 24-hour sessions were observed during the year 2013. The number of observing sessions coordinated by IVS was about ~3.6 days per week, a slight increase over previous years mostly due to the addition of regional AUSTRAL sessions. The major observing programs during 2013 were:

IVS-R1, IVS-R4 Weekly (Mondays and Thursdays) 24-hour, rapid turnaround measurements of EOP. Databases were available no later than 15 days after each session. The NASA Goddard Space Flight Center (R1) and the U. S. Naval Observatory (R4) coordinated these sessions.

Intensive Daily 1-hour UT1 Intensive measurements were made on five days (Monday through Friday, Int1) on the baseline Wettzell (Germany) to Kokee Park (Hawaii, USA), on weekend days (Saturday and Sunday, Int2) on the baseline Wettzell (Germany) to Tsukuba (Japan), and on Monday mornings (Int3) in the middle of the 36-hour gap between the Int1 and Int2 Intensive series on the network Wettzell (Germany), Ny-Ålesund (Norway), and Tsukuba (Japan). Kokee Park replaced Tsukuba in the Int2 Intensives from May through December during the repair of the antenna base at Tsukuba. Ny-Ålesund replaced Wettzell in the Int1 and Int2 Intensives from mid-July through the end of September while Wettzell was repaired and upgraded, except for Ny-Ålesund's maintenance period in the first two weeks of August during which Svetloe replaced Wettzell.

IVS-T2 Bi-monthly sessions coordinated by the Institute of Geodesy and Geoinformation of the University of Bonn, Germany, with on average 18 stations per session. Seven of these sessions were observed to monitor the TRF with all IVS stations.

IVS-CRF The Celestial Reference Frame (CRF) sessions, coordinated by the U.S. Naval Observatory, provide astrometric observations that are required for improving the current CRF and in extending the CRF by observing 'new' sources. Sixteen sessions were observed for the maintenance of the ICRF in 2013.

VLBA The Very Long Baseline Array (VLBA), operated by the National Radio Astronomy Observatory (NRAO), continued to allocate six observing days for astrometry/geodesy. These sessions included the 10 VLBA stations plus up to 6 geodetic stations, providing state-of-the-art astrometry as well as information for mapping ICRF sources.

Europe The European geodetic network, coordinated by the Institute of Geodesy and Geoinformation of the University of Bonn, continued with six sessions in 2013.

IVS-OHIG The purpose of the IVS-OHIG (Southern Terrestrial Reference Frame) sessions is to tie together optimally the sites in the southern hemisphere. In 2013 six OHIG sessions were observed.

APSG The Asia-Pacific Space Geodynamics (APSG) program operated two sessions in 2013.

AUSTRAL In 2013, 24 Austral sessions were observed. The purpose is to determine the station coordinates and their evolution in the Australia (AuScope) and New Zealand geodetic VLBI network.

JADE The JApanese Dynamic Earth observation by VLBI (JADE) had nine sessions during 2013. These sessions included the dedicated 32-m dish at Tsukuba and are designed to monitor the domestic network within the ITRF.

IVS-R&D Ten research and development sessions were observed in 2013. The goals of the 2013 R&D sessions included the testing of mixed-mode (legacy S/X and broadband) observing, the vetting of sources for the geodetic catalog of good point-like sources, the observation of link sources between *Gaia* and the ICRF2, and the testing of the observing mode for the Continuous VLBI Campaign 2014 (CONT14).

Correlators

The correlator at Haystack Observatory (USA), the correlator at the U.S. Naval Observatory in Washington (USA), the BKG/MPIfR correlator at the Max Planck Institute for Radioastronomy in Bonn (Germany) and the correlator at the Geographical Survey Institute (GSI) in Tsukuba, Japan continued their efficient processing of the data recorded for the IVS. The majority of the 24 hour sessions were processed by the Bonn and Washington correlators. The Bonn correlator used the DiFX software correlator and processed, e.g., the R1, EURO, T2, Int3, and OHIG sessions. The Washington correlator still used the Mark IV hardware correlator and processed, e.g., the R4, Int1, and CRF sessions. The Haystack correlator processed RD sessions and some T2 sessions. The Int2 and JADE sessions were processed at the Tsukuba correlator.

Data Centers

The IVS Data Centers continued to receive databases throughout the year and made them available for analysis within one day of correlation. The Data Centers also continued to receive solutions from Analysis Centers. All data and results holdings are mirrored several times per day among the three primary IVS Data Centers at BKG (Germany), Paris Observatory (France), and Goddard Space Flight Center (USA).

IVS Operational Data Analysis and Combination

The 14th IVS Analysis Workshop was held in Helsinki, Finland on March 5, 2013. In this workshop, the coordination of IVS routine data analysis was discussed as well as a number of individual items concerning geodetic and astrometric data analysis in the framework of the IVS. One of the items that surfaced was the

apparent reversal of time-tags (time-tag of scan A later than the subsequent scan B) in some recent databases that were processed using the DiFX software correlator. This was ultimately traced to the way the DiFX software correlators were handling time-tags: the epoch assigned to all observations in a scan was halfway through the longest observation in the scan. In contrast, the Mark IV correlator used a time-tag which was halfway through the shortest observation in the scan. The DiFX software was modified to conform with the Mark IV hardware correlator convention and the affected databases were reprocessed resulting in slightly improved session fits.

The Combination Center at BKG/DGFI continued to perform the combination of session-based results from the individual Analysis Centers on an operational basis. The combination strategy is based on the combination of normal equations; it is an adaptation of the combination process developed by IGG Bonn.

Technology Development

Most of the activities in improving the VLBI technique was related to the VGOS (VLBI Global Observing System) system, which is the next generation VLBI system based on a broadband observation scheme. Work on developing the VGOS broadband system began in earnest in 2008 when the Eleven Feed was identified as a suitable candidate for use in the next generation VLBI system. As a result of work carried out in the subsequent years, the system is now in a useable state although not completely finalized. Several broadband test sessions were carried out on the ~600 km long baseline between Westford (Massachusetts) and Goddard (Maryland) in the U.S. with the first 24-hour geodetic session having been carried out in late May 2013. The new broadband system required nearly a complete reworking of the legacy S/X system including the frontend, backend, and even the connection between them. There has been significant progress over the past year in a number of areas.

Constituting one of the key technological innovations that makes the new VGOS broadband system possible, active development of the broadband feeds continued in 2013. The workhorse feeds for the Westford/GGAO broadband baseline are Quadridge Feed Horns (QRFH) developed at CalTech. These feeds perform at a high level, are cost effective, and are easy to integrate into cryogenic front ends. So far they are the only broadband feeds that have been successfully deployed in a working VGOS system. Work continued on the integration of the Eleven Feed developed at Chalmers University into a cryogenic front end; a broadband feed developed in Italy is being tested at Noto, and an innovative conical feed that naturally produces circular-polarized output is being proposed for the Spanish/Portuguese RAEGE antennas.

Digital-backend (DBE) development continues in China, Europe, Japan, Russia, and the United States. To help understand the similarities and differences between various DBEs, a document named the VLBI Receiver Back End Comparison, in which the features of all known DBEs are compared in a table, was produced. The document can be found on the IVS Web site. Of the DBEs compared, the ROACH-based DBE (RDBE) and DBBC2010 were the most applicable to the VGOS system.

The Mark 6 data recording system is now ready to enter operational service. It is an excellent fit for VGOS. It can accept data at the VGOS data rate of 16 Gbps, writing it directly into a 30 s RAM buffer and then moving it from the buffer to a (single) disk pack at a sustained rate just under 8 Gbps. With proper care in the development of a schedule it should be easy to ensure that the buffer is ready to be refilled by the time the VGOS antenna has slewed to the next source. This mode of operation opens the possibility of writing a complete 24-hour VGOS session onto a single 32-TByte disk pack that is very efficient for media shipment. The 2nd IVTW was hosted by the Korea Astronomy and Space Science Institute (KASI) at Seogwipo on Jeju Island, South Korea. The workshop focused on four topics: station status reports, e-VLBI/Science, wideband developments, and frequency standards. Attendees at this very well organized workshop were treated to a field trip to the nearby 21-m Tamna radio telescope which is an element in the Korean VLBI Network (KVN).

Training and Education

On March 2–5, 2013, just prior to the 21st EVGA Working Meeting, a geodetic VLBI school was held at Aalto University, Espoo, Finland. The school was sponsored by the IVS, the EGU, Onsala Observatory, the Finnish Geodetic Institute, Aalto University, and RadioNet. It was part of the activities of IVS Working Group 6, “Education and Training”, led by Rüdiger Haas. Lectures and exercises were prepared on a wide range of topics from radio telescopes, feed horns, and receivers to the terrestrial reference frame. It was an opportunity for young participants to get a broad introduction to the field and at the same time for technology experts to learn about analysis and vice versa. Since this was the first running of the school, an important result was the production of learning material on a broad range of topics related to geodetic VLBI. It was agreed that a school of this type should be held roughly every three years.

Dirk Behrend, Axel Nothnagel, Rüdiger Haas