3.4.3 International VLBI Service (IVS)

IVS Organization and Activities

During 2007, 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. Two IVS Directing Board meetings were held, one in February at the Geodetic Observatory Wettzell, Germany, and the other in September at the University of Bonn, Germany. At the Wettzell meeting, the Board elected Harald Schuh from Vienna University of Technology, Vienna, Austria as the new chair of the IVS replacing the outgoing chair Wolfgang Schlüter, BKG Germany.

The eighth *IVS Analysis Workshop* was held at the Vienna University of Technology, Vienna, Austria, on April 14, 2007, in connection with the 18th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting. In April/May 2007 the fourth IVS *Technical Operations Workshop (TOW)* took place at MIT Haystack Observatory, Westford, MA, USA. The sixth *International e-VLBI Workshop* was held at Max-Planck-Institute for Radio Astronomy (MPIfR), Bonn, Germany in September 2007.

IVS published its 2006 Annual Report in April 2007 and three newsletter issues which keep the community informed about IVS activities. In June 2007 a Special Issue on Very Long Baseline Interferometry (<http://www.springerlink.com/content/v760312v657v/>) of the Journal of Geodesy was published. At the 18th Directing Board meeting held in September 2007 at Bonn University, IVS Working Group 4 on VLBI Data Structures was formed. The Working Group will examine the data structure currently used in VLBI data processing and investigate what data structure is likely to be needed in the future. It will design a data structure that meets current and anticipated requirements for individual VLBI sessions including a cataloging, archiving and distribution system. Further, it will prepare the transition capability through conversion of the current data structure as well as cataloging and archiving software to the new system.

Network Stations

A total of 1185 station days were used in 168 geodetic/astrometric sessions during the year. Observing sessions coordinated by IVS remained at an average of ~3.5 days per week, similar to previous years. The major observing programs during 2007 were:

IVS-R1, IVS-R4

Weekly (Mondays and Thursdays) 24-hour, rapid turnaround measurements of EOP. Data bases are available no later than 15 days after each session. These sessions are coordinated by NASA Goddard Space Flight Center (R1) and the U. S. Naval Observatory (R4).

Intensive Daily 1-hour UT1 Intensive measurements are made on five days (Monday through Friday, Int1) on the baseline Wettzell (Germany) to Kokee Park (Hawaii, USA) and on weekend days (Saturday and Sunday, Int2) on the baseline Wettzell (Germany) to Tsukuba (Japan). The daily sessions are recorded using Mark 5 (Wettzell-Kokee) and K5 (Wettzell-Tsukuba) technology. In August 2007 a third Intensive series (Int3) was started to fill the 36-hour gap in the data series between the Int1 and Int2 Intensive sessions and to take full advantage of the electronic transfer capabilities available at the participating stations of Ny-Ålesund, Tsukuba, and Wettzell as well as at the correlator at MPIfR Bonn. Through a careful setup of operating steps and strong endeavors of the staff, UT1–UTC from these sessions is available within 24 hours after the observations, most often already within 8 hours.

IVS-T2 Bi-monthly sessions coordinated by the Institute of Geodesy and Geoinformation of the University of Bonn with 12 stations per session. These sessions were observed to monitor the TRF with all IVS stations scheduled at least 3–4 times during the year.

IVS-CRF, IVS-CRMS, IVS-CRD The Celestial Reference Frame (CRF) sessions, the CRF median-south (CRMS), and the CRF deep-south (CRD) sessions, all coordinated by the U.S. Naval Observatory, provide astrometric observations that are required for improving the current CRF and extending the CRF by observing “new” sources. Seventeen sessions were observed for the maintenance of the ICRF in 2007 primarily in the southern hemisphere. Seven of them were scheduled with emphasis on the far southern hemisphere (CRD) and three with emphasis on the median south (CRMS).

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 7 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 2007.

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

JADE The JApanese Dynamic Earth observation by VLBI (JADE) had 12 sessions. 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 2007. Four of them were scheduled using Gbit/s recording rates to demonstrate the highest data rate available today and five of them were scheduled to test 512 Mbps recording modes for possible usage in the continuous VLBI campaign 2008 (CONT08). The last session was dedicated to the determination of receiver polarization leakage effects on the geodetic VLBI measurables.

The Network Coordinator's data base of station performance showed a data loss of 11.4%, slightly better (2%) compared to 2006. The most significant causes of data loss were antenna reliability (35%), receiver problems (15%), data acquisition system problems (11%), and RFI (10%).

Correlators

The correlators at Haystack Observatory (USA), the U.S. Naval Observatory (USA), and at Max-Planck-Institute for Radioastronomy (Germany) further increased their efficiency in processing data recorded on Mark 5 disk media. Several 24-hour sessions can now be correlated in less than a day. The correlator at MPIfR Bonn had been connected at 1 Gbps in the later part of 2006 and production use of this connection started in 2007. Electronic data transfer (e-transfer) was routinely used between connected network stations and the MPIfR correlator. Initial steps have been taken to also connect the USNO correlator.

Data Centers

The IVS Data Centers continued to receive data bases 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.

Analysis Coordinator

On January 1, 2007, a new combination process for the two IVS EOP series (rapid and quarterly solutions) was made operational. Routine combinations of IVS are now being made exclusively on the basis of datum-free normal equations in SINEX format. In 2007, five IVS Analysis Centers (BKG, DGFI, GSFC, IAA and USNO) contributed to the IVS combined products by providing input in the correct format. The rapid solutions contain only R1 and R4 sessions and new data points are added twice a week as soon as the SINEX files of the five IVS Analysis Centers are available. The SINEX file submissions should not be later than 48 hours after the correlation is completed. A Web page is automatically updated which states the timeliness of the latest submissions of the R1 and R4 ses-

sions. As can be seen on this Web page, the timeliness requirement has been missed quite often, mostly due to logistical and personnel issues.

For the quarterly solution, updated every three months, almost all available data of 24-hour sessions from 1984 onwards are used. Since this series is designed for EOP determinations, those sessions are excluded which are observed with networks of limited extension or which are scheduled for a different purpose like radio source monitoring.

The advantage of the new combination strategy is that one common terrestrial reference frame (e.g. ITRF2005) is applied after the combined datum-free normal matrix is generated. Thus, it is guaranteed that an identical datum is used in the combination process for all input series. After datum definition the combined system of normal equations is solved (inverted) and the full set of EOP (pole components, UT1–UTC, and their time derivatives as well as two nutation offsets in $d\psi$, $d\varepsilon$ w.r.t. the IAU2000A model) are extracted. These results are added to the two EOP time series in the IVS EOP Exchange format, the rapid solution file (e.g., ivs07r1e.eops) and the quarterly solution file (e.g., ivs07q4e.eops). Companion files containing the nutation offsets in the X, Y paradigm are routinely generated through a standard transformation process (i.e., ivs07r1X.eops, ivs07q4X.eops). The weighted RMS differences between the individual IVS Analysis Centers and the combined products have been reduced over the last two years from roughly 80–100 μas to 50–60 μas in all components, which can mostly be attributed to the proper usage of models and conventions. On the IVS Analysis Coordinator's Web page additional information about the series, the residuals of the individual contributions w.r.t. the combined solution as well as comparisons with IGS and IERS EOP results are provided routinely.

At the same time the combined SINEX files (datum-free normal equations) are also available on the Web for further combination with other techniques. At present, this is done on an experimental basis only, but the IERS Analysis Coordinator is strongly pushing towards such a routine process.

Technology Development

Routine use of high-speed optical fiber connections continued to grow. MPIfR conducted regular e-transfers of data for which the Bonn correlator is the correlation target. This included data from Tsukuba, Kashima, Onsala, Ny-Ålesund, and Wettzell. All data recorded on K5 systems at Tsukuba and Kashima were transferred either to MPIfR or Haystack depending on the target correlator. Syowa (Antarctica) K5 data was physically shipped to Japan and electronically transferred to Haystack or MPIfR. All of Wettzell's daily UT1 Intensive data was e-transferred, either directly to the

correlator at the Geographical Survey Institute (GSI), Tsukuba, Japan (Saturday–Sunday) or to a site near USNO in Washington, D.C. (Monday–Friday), where it was picked up and taken to USNO for correlation (so-called 'sneaker-net'). All data of the newly established Int3 Intensive sessions with Wettzell, Tsukuba, and Ny-Ålesund was e-transferred to MPIfR.

The four network stations at Kashima, Metsähovi, Onsala, and Tsukuba commenced a study on ultra-rapid Intensives using e-VLBI (e-transfer of data with near real-time correlation). Intensive-type sessions of 1-hour length were observed on two almost parallel baselines between Europe and Japan (Onsala–Tsukuba and Metsähovi–Kashima). The sessions were processed in near real-time by making use of the high-speed optical fiber connections of the four stations and the software correlators at Kashima (NICT) and Tsukuba (GSI). The work will be continued in 2008. Once the procedure (from observation to final product) has been proven to be robust and reliable, it can be employed to improve the IVS observing program, e.g., by reducing the latency for results of the Int1 or Int2 sessions. The results from the two parallel baselines will allow the investigation of systematic errors in dUT1 estimation.

The VLBI2010 Committee continued its work on designing and implementing the next generation VLBI system. The work concentrated on Monte Carlo simulations to investigate the performance of network configurations, schedules and observing scenarios, and on the broadband delay approach. The broadband approach involves the use of broadband feeds (2–15 GHz) and multiple IF channels to reliably resolve RF phase, even at low signal-to-noise ratios. It will enable extremely precise delay measurements to be made while using comparatively small and cost effective 12-m class antennas. The lower cost of these antennas will make replacement of existing, old antennas and the addition of new stations more affordable. On November 19, 2007, the combined effort and hard work of a group of scientists and engineers working on experimentally demonstrating the VLBI2010 concept came to fruition. On that day first fringes were found with the proof-of-concept hardware that has been installed at the MV-3 antenna at Goddard's Geophysical and Astronomical Observatory (GGAO).

Dirk Behrend, Axel Nothnagel