

## Recent Progress and Future Perspectives of the International VLBI Service for Geodesy and Astrometry (IVS)

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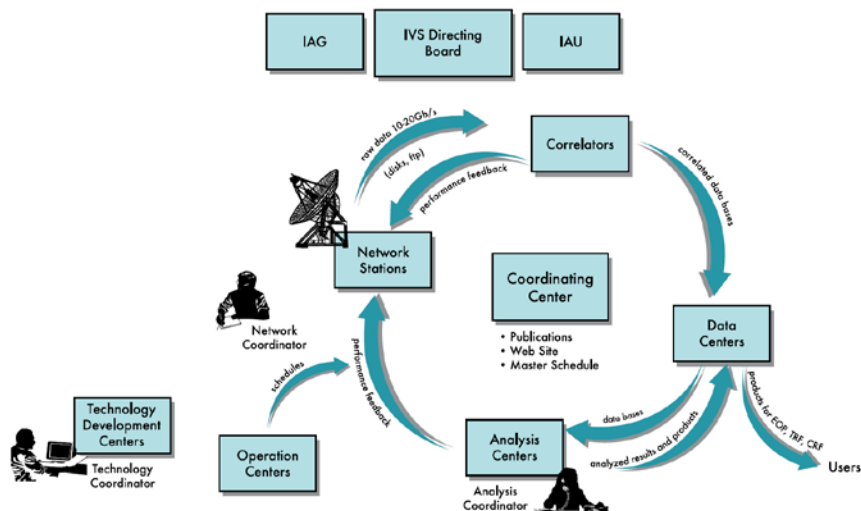
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**Abstract.** *The International VLBI Service for Geodesy and Astrometry (IVS) was established in 1999 to operate or support Very Long Baseline Interferometry (VLBI) components.*

*In recent months, IVS has made enormous progress advancing towards the realization of the VLBI Global Observing System (VGOS). The key issues of the new generation IVS installations are fast rotating radio telescopes capable of receiving broadband quasar radiation between 2 and 14 GHz in a continuous frequency band. A number of new telescopes have been built or are approved providing a good basis for a thorough refurbishing of the IVS network as a whole. Together with addressing a number of other technique-specific issues, the IVS is on a good path to fulfill the requirements of the Global Geodetic Observing System (GGOS).*

### Introduction

The International VLBI Service for Geodesy and Astrometry (IVS) is an international organization established in 1999 as a service of the International Association of Geodesy (IAG) and of the International Astronomical Union (IAU) to collaborate with geodetic and astrometric organizations on Very Long Baseline Interferometry (VLBI). As of 2013, the IVS consists of 83 Permanent Components representing 43 institutions in 21 countries. The IVS Components working in VLBI data flow are 33 Network Stations acquiring high performance VLBI data, 7 Correlators processing raw VLBI data, 6 Data Centers storing and archiving data and products, 27 Analysis Centers analyzing the data and producing the results and products. Additionally 3 Operation Centers coordinate the routine operations and generate observing schedules for Network Stations, 6 Technology Development Centers develop new VLBI technology, and a Coordinating Center is responsible for coordinating daily and long term activities of IVS (Figure 1).



**Figure 1.** The organization of International VLBI Service for Geodesy and Astrometry.

## Next generation VLBI System

VLBI has played an important role in providing high-precision geodetic data, as one of the multi space geodetic techniques together with the Satellite Laser Ranging (SLR), Global Navigation Satellite System (GNSS), and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS). However, the existing worldwide VLBI system, though being continually upgraded, has now nearly reached the limits of its capabilities and requires major renewal in order to provide the 1 mm accuracies demanding in the coming years. In 2003, the IVS Working Group 3 (WG3) started to examine current and future requirement for geodetic VLBI, including all components from antenna to analysis, and to create recommendations for a new generation of VLBI system called VLBI2010. In September 2005, its final report entitled "VLBI2010: Current and Future Requirements for Geodetic VLBI Systems" was compiled (Niell et al., 2006). The goals of the new system described in this report are to achieve:

- 1 mm position and 0.1 mm/year velocity accuracy on global scales,
- continuous measurements for time series of station positions and Earth orientation parameters,
- turnaround time to initial geodetic results of less than 24 hours, preferably in near real-time.

The report proposed strategies to move toward the unprecedented 1mm position accuracy target and broad recommendations for a next generation system based on the use of smaller (~12 m) fast-slewing automated antennas. In order to encourage the implementation of the WG3 recommendations, IVS established the VLBI2010 Committee (V2C) in September 2005. The work of the committee through the end of 2008 was summarized in the progress report (Petrachenko et al., 2009).

Table 1 shows the specifications of the VLBI2010 system compared with the current VLBI system. Several simulation studies showed that shortening the source-switching interval is an effective means for improvement in station position accuracy. In order to approach the VLBI2010 1-mm position accuracy, the source-switching interval must be about 30 sec. An antenna must track a source until adequate SNR in a very short integration period, and slew to another source quickly within 30 sec. Thus, an antenna with 12 deg/s azimuth slew rate and higher recording rate is required. As for data transport, previously the way to transport raw VLBI data has mainly been media shipping. For 24-hour session, it has taken at least 1 to 2 weeks to complete its data processing and to get an initial geodetic result. A more desirable way of data transport is electric transmission of data ("e-VLBI"), which would drastically reduce processing turnaround time and allow fully automated station operation.

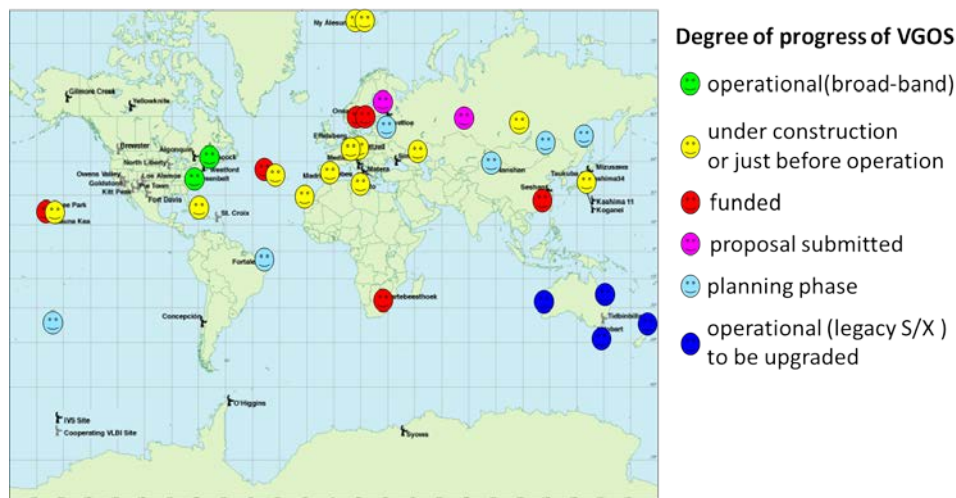
**Table 1.** Specifications of the current VLBI system and the VLBI2010 system.

Parameter	Current VLBI system	VLBI2010 system
Antenna diameter	5–100 m dish	~ 12 m dish
Slew speed	~ 0.3–3 deg/sec	≥ 12 deg/sec
Sensitivity (SEFD)	200–15000 Jy	≤ 2500 Jy
Frequency range	S/X-band	~ 2–14 GHz
Recording rate	~ 128, 256 Mbps	8–32 Gbps
Data transport	Usually disk shipping some e-transfer	e-transfer, e-VLBI disk shipping when required

The IVS named such a next generation VLBI system “VLBI Global Observing System (VGOS)”. It is, of course, a pun for the “Global Geodetic Observing System (GGOS)” promoted by the International Association of Geodesy (IAG).

## New VGOS stations in the world

A number of new telescopes have been built or are under construction in the world (Figure 2).



**Figure 2.** Degree of progress of VGOS World. It is based on available information as of September 2013 by V2PEG (Hase et al., 2011)

In the United States two VGOS telescopes (GGAO in Maryland and Westford in Massachusetts) are already in operation with broadband feeds for the Proof-of-concept demonstration of NASA and MIT. German station Wettzell (BKG) installed two clone 13.2-m telescopes called "Twin Telescope Wettzell (TTW)" inaugurated in April 2013. The IGN Spain is building four VGOS telescopes that constitute a VGOS network on North Atlantic Ocean. The IAA in Russia is constructing two VGOS telescopes in Badary and Zelenchukskaya. Ny-Alesund in Norway and Onsala in Sweden are each planning to build twin telescope VGOS station too. Other than that there are some ongoing VGOS projects in the world (e.g. China, South Africa).

## VGOS Project in Japan

In Japan, the Geospatial Information Authority of Japan (GSI) has been involved in the IVS geodetic VLBI sessions for a long time. GSI decided to build a new VGOS station in 2011. After about two years of planning and consideration for its specification, construction work began in July 2013 at the top of a small hill in Ishioka City, Ibaraki Prefecture (Figure 3). The Ishioka VGOS station consists of a radio telescope with a 13.2-m dish, three exchangeable broadband front-end systems, a flexible up-down convertor, a set of the digital back-ends (DBE), and a pair of hydrogen masers. By mid-March 2014, the construction will be completed.



**Figure 3.** Ishioka VGOS telescope (pedestal) under construction.

## **Toward GGOS**

Currently the IVS is on a good path to fulfill the requirements of GGOS. One of the requirements for the GGOS core site is co-located multi space geodetic facilities; VLBI, SLR, GNSS, and DORIS. One thing to be considered for VLBI in such a GGOS core site is radio frequency interference (RFI) from other facilities. Due to the broadband frequency range of VGOS telescope, DORIS beacon at 2GHz and aircraft avoidance radar for SLR at 9GHz can be serious intra-site RFI source on the VGOS broadband operation. IVS investigates the use of physical barriers, notch filters, or interlocking operational schedule for SLR/VLBI. Or, other techniques for aircraft avoidance for Laser Ranging should be considered.

## **References**

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