THE FUTURE GLOBAL VLBI2010 NETWORK OF THE IVS

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ABSTRACT. The VLBI2010 concept was developed by the International VLBI Service for Geodesy and Astrometry (IVS) in order to create the next generation VLBI system needed to meet the goals of the Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG). Global measurement goals of 1 mm position error and 0.1 mm/year site velocity error require new radio telescope designs, new VLBI receiving and recording systems, new concepts for data transmission and correlation, as well as updated software for scheduling, data analysis, and archiving. In December 2010, the IVS VLBI2010 Project Executive Group (V2PEG) conducted a survey among existing IVS network stations to measure awareness of VLBI2010 and to learn about modernization plans towards VLBI2010; the results of this survey indicate that most of the IVS network stations are already planning the transition to VLBI2010 capabilities. The survey indicated that up to 20 new radio telescopes at 17 sites with VLBI2010 compliance could become operational by 2017; a sufficient number of VLBI2010-compatible radio telescopes should be available by 2014–15 to support initial VLBI2010 operations.

1. INTRODUCTION

The Directing Board (DB) of the International VLBI Service for Geodesy and Astrometry (IVS) established the VLBI2010 Project Executive Group (V2PEG) in early 2009 to provide strategic leadership to the VLBI2010 project and guide the transition from the VLBI2010 development phase to the VLBI2010 implementation phase. V2PEG is also the primary point of contact for VLBI2010-related questions from institutions that are interested either to upgrade existing VLBI operations to VLBI2010 compatibility or to build new compatible systems. The V2PEG has also been involved at different levels to help expedite administrative processes concerning the setup of VLBI2010 radio telescope projects, including the proof-of-concept project.

In 2010, V2PEG conducted a survey among existing IVS network stations in order to:

- gather information about individual VLBI2010 plans,
- trigger VLBI2010 discussion at the network station level,

- solicit input on what the V2PEG can do to provide the best support to individual VLBI2010 projects.

The survey addressed 31 IVS network stations, all of which replied. Subsequently, the survey results were re-distributed back to the IVS network stations in January 2011, which are also available at the IVS Web site (Hase et al., 2011).

2. VLBI2010

In the first decade of this millennium the IVS established two working groups to define the outline of VLBI2010. Working Group 2 "Product Specifications and Observing Programs" got the task to define the VLBI2010 measurement goals and to propose corresponding observing programs. The Working Group 2 report (Schuh et al., 2003) was completed in 2002, describing the future demands of the service products. Several products, such as station coordinates, episodic events, Earth rotation velocity, rotational pole position, nutational parameters, as well as geophysical properties of the ionosphere and troposphere, demand continuous seven days per week observation. The follow-up IVS Working Group 3 "VLBI 2010" was created in September 2003. It examined current and future requirements for VLBI geodetic systems, including all components from antenna to analysis, and published a report with recommendations for a new generation of systems. The final report was presented in 2005 (Niell et al, 2005). The main characteristics of the future VLBI2010 system can be identified as follows:

- continuous observations in 30 s slew-track cycles,
- fast radio telescopes of $\geq$ 12-meter reflector class with kinematic parameters of either a single 12-meter diameter antenna with very high slew rates, e.g. 12 deg/s in azimuth, or a pair of 12-meter diameter antennas, each with more moderate slew rates, e.g. 5 deg/s in azimuth (Petrachenko et al., 2009),
- wideband feed, 2–14 GHz (later 2–18 GHz),
- digital baseband converter,
- high-data-rate sampling data acquisition, $\geq$ 8 Gbps,
- broadband connectivity for e-transfer and e-VLBI,
- distributed remote controlled continuous operation of the VLBI network,
- software correlator,
- automated production process including analysis.

3. GLOBAL GEODETIC OBSERVING SYSTEM

The International Association of Geodesy (IAG), within the International Union of Geodesy and Geophysics (IUGG), contributes with the Global Geodetic Observing System (GGOS) to the Global Earth Observing System of Systems (GEOSS). GEOSS is an outcome of the Group on Earth Observation (GEO) which is composed of 87 nations plus the European Commission and 64 participating organizations (as of December 2011). The envisaged goals of GGOS are:

- 1 mm position accuracy, 0.1 mm/year velocity accuracy,
- continuous observations for time series of station positions and Earth orientation parameters,
- turnaround time to initial geodetic products of less than 24 hours.

The realization of GGOS calls on the IVS community to improve its performance to VLBI2010 standards.

4. IVS NETWORK STATION SURVEY

The survey consisted of six questions (see detailed questions in the analysis report Hase et al., 2011):

1. Specify plan to upgrade your site to full VLBI2010 capability.
2. Do you plan to acquire a new radio telescope that fully meets the VLBI2010 recommendations?
3. Do you plan to continue operating your existing legacy radio telescope in the future?
4. What is the best estimate of the year in which your VLBI2010 capability will become operational?
5. At what stage are you in the planning process?
6. What support do you need from the IVS?

The answers received were, of course, based on best estimates of the availability of resources to build new systems. However, the average of optimistic and pessimistic estimates gives a first clue to the future development of the VLBI2010 network. Summarizing the results:

- By 2013, a sufficient number of VLBI2010 compatible radio telescopes will be available for significant, but not full-time, VLBI2010 operations (Figure 1).
- By 2017, approximately 20 new radio telescopes at 17 sites operated by IVS network station institutions will be available for full-time VLBI2010 observations (Figure 2). Additional new stations may also join if approved and constructed.
- Even in 2017, the American/Pacific region will still lack presence of VLBI2010 network stations, though a 10-station NASA network covering some of this area may eventually be built.
- Through at least 2015, observations by a large number of legacy S/X-band telescopes will still be supported for data continuity, astrometry and space applications (Figure 3).
- Many network stations need technical consultation about VLBI2010, as well as support letters to be successful with the administration and funding level.

Table 1 shows detailed IVS station-by-station projections through 2017 according to survey results. The stations marked with an asterisk (*) are planning very fast radio telescopes that are compliant with the proposed VLBI2010 slewing rate and observation mode. Stations marked with two asterisks (**) will follow the twin telescope concept, which consists of two VLBI2010 radio telescopes at one location. Stations marked with a plus (+) will be VLBI2010 compliant except that only a single antenna with a $\sim$5 deg/sec azimuth slew rate is currently planned. Legacy stations upgrading to VLBI2010 receivers and data systems are unmarked. Stations marked with a minus (-) will continue to operate with S/X-band only. The indicated year is an estimate for operational capability for the IVS.

The upgrade list according to Table 1 constitutes a snaphot as of January 2011. In order to capture changes in plans and to be more concise, the V2PEG intends to contact the IVS network stations again about a year after the original survey requesting updated information. In early March 2012 a VLBI2010 workshop about technical specifications of the station hardware will be held in Wettzell, Germany. Station managers and technical staff are encouraged to participate in this workshop in order to advance the effort to establish a more powerful global VLBI network.

5. CONCLUSION

A highly capable VLBI2010 network will be implemented within this decade; new broadband 2–14 GHz observation modes will come into regular operation from 2014/2015 onwards with full operation by about 2017. The current S/X operation mode will be maintained in parallel at a number of legacy stations for data continuity, astrometry and space applications.

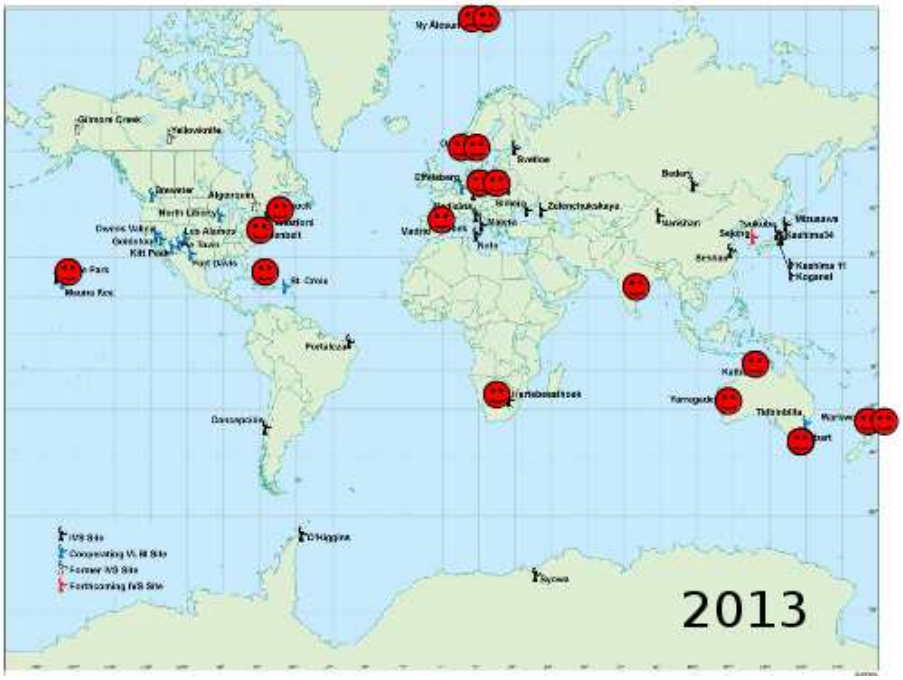

Figure 1: Prediction for 2013: Approximately 13 stations will be available, allowing significant, but not full-time, VLBI2010 observations.

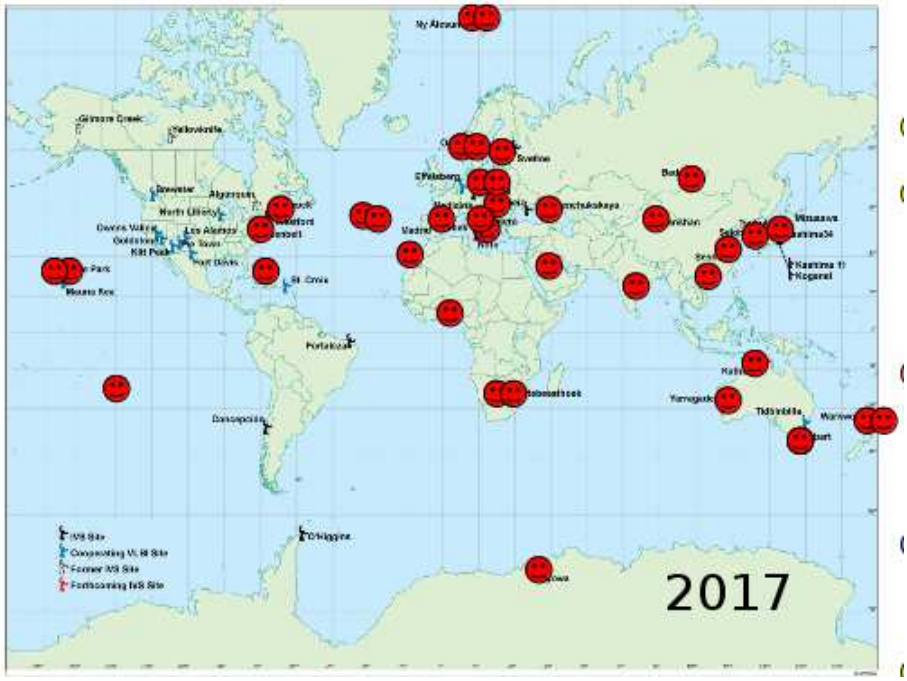

Figure 2: Prediction for VLBI2010 observations in 2017: Approximately 20 stations will be available for full-time observations. Additional sites in Tahiti, Nigeria, Saudi-Arabia and India may join the IVS network if funding is approved.

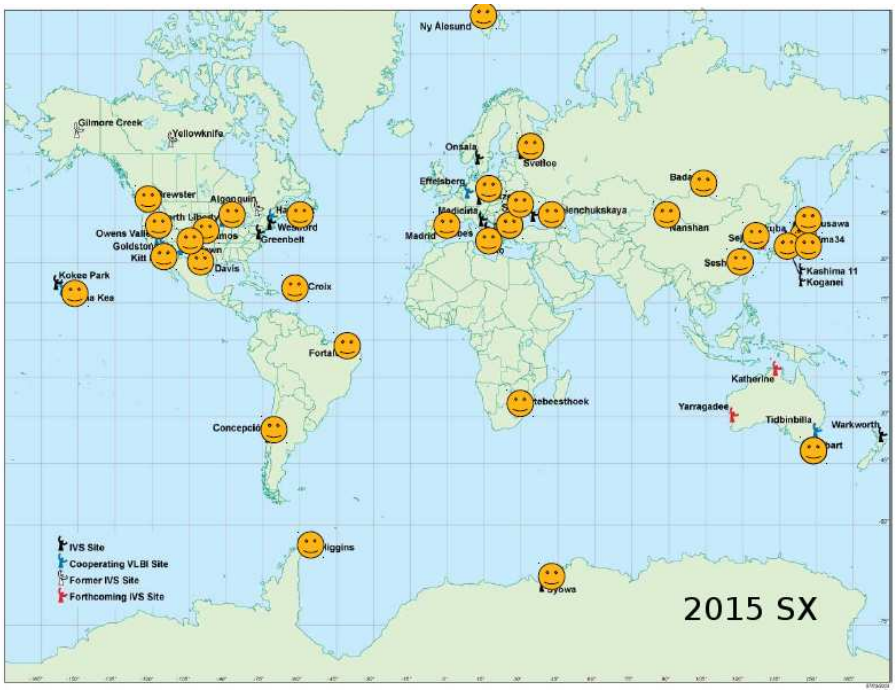

Figure 3: Prediction for S/X observations in 2015: IVS will still utilize existing global S/X network stations for some time to support data continuity, astrometry and space applications.

6. REFERENCES

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network station	country	year	project name
Hobart+	Australia	2010	AuScope
Warkworth+	New Zealand	2010	
Yarragadee+	Australia	2011	AuScope
Katherine+	Australia	2011	AuScope
Wettzell**	Germany	2011	TTW
Westford+	U.S.A.	2011	POC
Greenbelt+	U.S.A.	2011	POC
Kashima34	Japan	2013	
Koganei11	Japan	2013	
Yebes*	Spain	2013	RAEGE
Onsala**	Sweden	2013	
Badary*	Russia	2014	
Zelenchukskaya+	Russia	2014	
Matera*	Italy	2014	
Santa Maria*	Portugal	2014	RAEGE
Fortaleza	Brazil	2014	
Kokee Park*	U.S.A.	2014	
Sejong22	Korea	2015	
Gran Canaria*	Spain	2015	RAEGE
Hartebeesthoek*	South Africa	2015	
Tsukuba32	Japan	2016	
Tsukuba*	Japan	2016	
Sheshan*	China	2016	
Hainan*	China	2016	
Flores*	Portugal	2016	RAEGE
Ny Ålesund**	Norway	2017	
Arecibo+	Puerto Rico	2017?	
VERA-	Japan	n.a.	
Simeiz	Ukraine	n.a.	
Svetloe	Russia	n.a.	
Medicina	Italy	n.a.	
Noto	Italy	n.a.	
Syowa	Antarctica	n.a.	
O'Higgins	Antarctica	n.a.	
TIGO	Chile	n.a.	
VLBA-	U.S.A.	n.a.	

Table 1: Details of the projected schedule of VLBI2010-station construction through 2017 (see text for details).