VGOS Observing Plan

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Abstract Over the past several years, the VGOS broadband system has been under development; it is currently undergoing advanced testing. At the same time, commitments were made for a number of antenna projects with as many as 30 stations expected for VGOS observing by 2019. In order to focus activities into the future, a proposal was made by the VPEG for an observing plan with the long term goal of guiding the transition from S/X operations to VGOS operations. The plan anticipates that by the end of 2014 as many as eight antennas will be capable of broadband observing. These antennas will participate in a series of test campaigns during 2015 followed by a VGOS pilot project throughout 2016. Full operations with as many as 16 stations are expected to begin in 2017. The observing plan places a priority on early improvement in the quality of daily products. As a result, the pilot project involves a single weekly 24-hour session with reduced duty cycle sessions on each of the remaining days of the week. Correlator and data transmission requirements for the plan are currently being assessed.

Keywords VGOS, VLBI Global Observing System, Observing Plan, VPEG

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1 Introduction

In 2003, the IVS Directing Board recognized the need for a complete revision of geodetic VLBI infrastructure including antennas, systems, and processes [1, 2]. Bold goals for the new vision included 1-mm position accuracy, 24/7 operations, and the release of initial products within 24 hours of taking data. At the core of the new concept is a network of fast slewing antennas, a new broadband observing system, enhanced automation, and increased use of electronic networks to transmit data. When conceived, the new vision was called VLBI2010. Today the realization of the new network is being referred to as the VLBI Global Observing System (VGOS).

Over the past decade, technical development for the new system was coordinated by the VGOS Technical Committee (VTC, formerly the VLBI2010 Committee), and strategic leadership was provided by the VGOS Project Executive Group (VPEG, formerly the VLBI2010 Project Executive Group). About a year ago, it became apparent to the VPEG that system development and network expansion were sufficiently advanced that a roadmap was required to guide the transition from current style observations with the legacy S/X system to the operational realization of the new vision. To satisfy this need, the VPEG began to develop the VGOS Operations Plan.

The first priority of the plan is to deliver consistent daily products of high and uniform quality, especially Earth orientation parameters (EOP), as soon after observing as possible. A previous attempt to build up a 24/7 geodetic VLBI capability involved the addition of 24-hour sessions until all seven days of the week were filled. Each session would have used a different network as operational capacity increased. Unfortunately, the process ended with the scheduling of only two 24-hour sessions per week, R1 and R4, with the remaining days bridged by UT1 Intensive sessions typically involving a single baseline observing for only one hour per day. Scientifically, this mode of operation is suffering from inconsistent data quality through the week. Furthermore, staggered UT start times of the VLBI sessions has led to irregular reference epochs for the EOP results which hamper combination efforts with those of the other space geodetic techniques.

To avoid these problems, the VGOS operations plan takes a different philosophy for its ramp-up to full 24/7 operations. Since it is recognized that operational capacity for continuous observing will not be available at the outset, the initial years of the plan involve daily sessions using the complete available network but with a reduced duty cycle. In other words, instead of observing continuously 24 hours per day, sessions will consist of four equally spaced one-hour bursts at 3, 9, 15, and 21 UT. These four bursts will then be analyzed together to produce all EOP with as many as four UT1 values per day. Furthermore, the four bursts can be centered on the reference epoch of 12 UT, which is consistent with the reference epochs of the other space geodetic techniques. As operational capacity increases, stations can be scheduled to observe a larger number of one-hour bursts per day until each day is filled.

The first draft of the observing plan was completed in the summer of 2013. The plan was then circulated to the IVS Observing Program Committee (OPC) for comment, resulting in a significantly improved concept and a rewritten draft. It was realized that a full operations plan should also include estimates of correlator, data transmission, and analysis requirements and not just a schedule for the increase of observations. In the end it was decided, however, that the community needed to be informed as soon as possible of the planned roll out of observations and that the other requirements documents could be completed and released later. The title of the document was then changed from the VGOS Operations Plan to the VGOS Observing Plan [3]. It was accepted by the IVS Directing Board in February 2014.

2 Summary of the VGOS Observing Plan

The VGOS Observing Plan covers the five-year interval from 2015 through 2019, culminating in full 24/7 VGOS operations in 2020. It deals almost entirely with broadband observations, although it is recognized that an important part of the transition will also involve mixed-mode observing in which VGOS broadband antennas participate in S/X sessions. These are required to establish a strong tie between the new VGOS antennas and the legacy S/X network.

During the remainder of 2014, IVS technology development focuses on ensuring that VGOS systems and processes are ready for the first test campaigns to be carried out in 2015. The VGOS observing plan begins with a series of three test campaigns in 2015 with as many as eight sites expected to participate. Each of the three campaigns introduces a different aspect of the new VGOS mode of operation so that by 2016 the IVS will be ready to begin a VGOS Pilot Project. All campaigns will be roughly six weeks in duration to exercise the full "schedule-to-final-products" operational chain in a sustained format:

- The first campaign focuses on automation of processes unique to broadband operations and consists of a single 24-hour session. This has the benefit of allowing six days per week to prepare for the next session. Data will be recorded and shipped after each session (Figure 1).

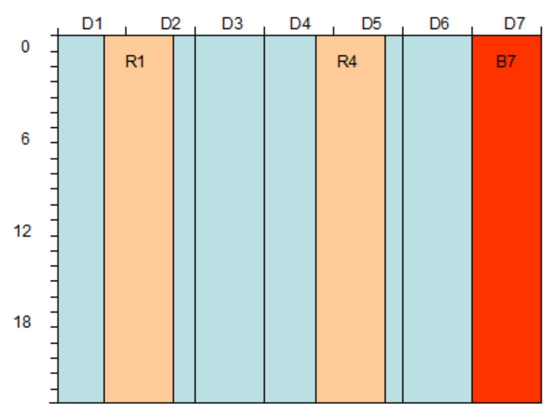

Fig. 1 Trial campaign 1: Sustained weekly 24-hour sessions, January–February 2015. The VGOS Day 7 broadband session (B7) is represented in red (dark gray).

- The second campaign focuses on producing a full set of EOP products on a daily basis. It involves observing four hours per day in equispaced one-hour bursts. As with the first campaign, data will be recorded and shipped once per week (Figure 2).
- The final campaign focuses on producing initial EOP products within 24 hours. Observationally it will be identical to the second campaign but the data will be e-transferred instead of being shipped (Figure 2).

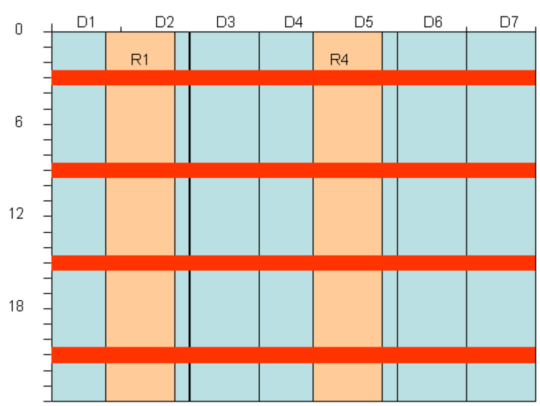

Fig. 2 Trial campaigns 2 and 3: Sustained daily VGOS EOP sessions, May–June 2015 and September–October 2015. The daily hour-long VGOS bursts are represented in red (dark gray).

The VGOS Pilot Project will be carried out throughout 2016. The project will imitate operations but without a full commitment to product delivery. As with the second and third trial campaigns of 2015, there will be four one-hour EOP sessions each day of the week along with a single 24-hour session per week (Figure 3). It is expected that perhaps one or two additional stations will come on-line during 2016.

By the end of the pilot project, VGOS will be ready to commit to product delivery. Daily EOP sessions and weekly 24-hour sessions will continue as in the pilot project, but the number of one-hour bursts in the daily sessions will increase as operational capacity increases. By the end of 2017, as many as 16 VGOS broadband stations are expected to be on-line, and by the end of 2019 the number of stations could be as large as 30. By 2020 it is expected that all or most stations will be observing nearly continuously, with sufficient time scheduled for maintenance.

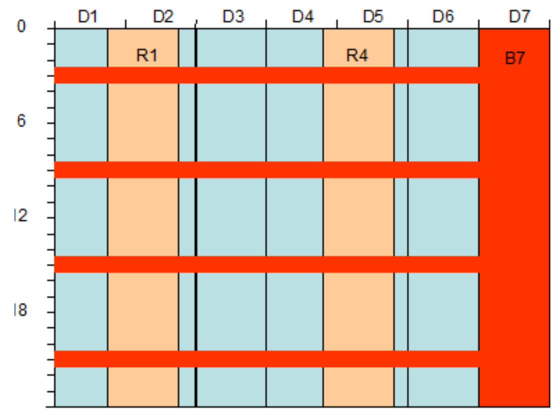

Fig. 3 VGOS Pilot Project: One 24-hour VGOS session and six daily VGOS EOP sessions per week during 2016. VGOS observing is represented in red (dark gray).

3 Simulated Performance

An attempt was made to predict performance for three scenarios from the VGOS Observing Plan (Table 1). The scenarios are: eight stations observing in four equally spaced one-hour bursts (2015–4h); 16 stations observing in eight equally spaced one-hour bursts (2017–8h), and 30 stations observing continuously for 24 hours (2019–24h). Performance was compared to that of the R1, R4, and CONT11 networks. To ensure a level basis for comparison, all performance estimates, including those for the R1, R4, and CONT11 networks, were derived using Monte Carlo simulations.

Table 1 Simulated performance for a number of observing scenarios.

	Observations [#/hr/stn]	UT1 [μs]	X-pole [μas]	Y-pole [μas]	Scale [ppb]
R1	10.8	3.0	71	58	0.47
R4	14.6	3.7	65	105	0.45
CONT11	15.8	2.0	34	27	0.35
2015–4h	87.5	2.0	83	96	0.41
2017–8h	52.3	1.4	38	43	0.26
2019–24h	58.2	0.4	9	9	0.08

The observing schedules for the R1, R4, and CONT11 simulations were taken from real sessions, while those for the VGOS predictions were generated using SKED assuming real antenna sensitivities and slew rates. In Table 1, it can be seen that, as expected, the number of observations/hour/station is significantly greater for the VGOS schedules than for the R1, R4, and CONT11 schedules. However, the VGOS schedules still fall significantly short of the VGOS target density of 120 observations/hour/station. For the 2015–4h schedule, this can be attributed to the inclusion of two slower legacy antennas in the network. However, the even greater shortfall for 2017–8h and 2019–24h is harder to understand. As a result, work continues towards improving scheduling algorithms for VGOS. Needless to say, performance for the VGOS simulations is expected to improve when observation densities are increased towards the 120-observations/hour/station target.

Generally speaking, the performance of the VGOS 2015–4h scenario is near that of the R1 and R4 scenarios, and VGOS 2017–8h is near that of CONT11, with UT1 and scale tending to be better in the VGOS simulations and X-pole and Y-pole being worse. Even considering the sub-optimal schedules used for the 2019–24h simulations, the predicted EOP and scale performance for this scenario is better than anything experienced to date.

4 Next Steps

- All relevant VGOS broadband processes, systems, and stations need to be completed in advance of the test campaigns scheduled for 2015.
- Requirements documents for correlation, data transmission, and analysis need to be completed to ensure that appropriate resources are available for all steps of the VGOS Observing Plan.
- Network expansion needs to remain a priority. Specifically, more Southern Hemisphere stations are required to support ICRF definition, and, in general, a more uniform global distribution of stations is required to support ITRF definition.

5 Conclusions

The VGOS Observing Plan provides a reasonable guideline for the IVS and for all observatories that are gearing up for the next generation of geodetic and astrometric VLBI observations. For the new radio telescopes yet to be installed, the operational requirements within VGOS are clear from the very beginning. In this respect, the operations of the VGOS network can evolve in a product-oriented fashion with very good results from the beginning. With more radio telescopes to participate in later years, the quality, stability, and redundancy of the VLBI results will define a new state of the art in space-geodetic EOP and reference frame results.

References

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