Implementation of the VGOS Trials

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Abstract In February 2014, the VGOS Project Executive Group (VPEG) presented the VGOS Observing Plan, which outlined possible steps on how to go from initial VGOS broadband tests to intermediate observing scenarios to the fully operational VGOS system. The document introduced VGOS trial campaigns as the initial means to accustom the VGOS stations as well as the subsequent component types to the VGOS processing load: scheduling, data taking, data transport, correlation, and analysis. Three different trial campaigns of six to eight weeks each were envisioned. The Coordinating Center—in conjunction with the Observing Program Committee (OPC)—was tasked with their implementation. This paper describes the progress made on implementing the trial campaigns.

Keywords VGOS, trial campaigns, pilot project

1 Introduction

The technical development of the VLBI Global Observing System (VGOS) has made good progress in the past several years. While the progress was not as fast as anticipated, the development has now reached a point where VGOS can gradually be phased into operations. That is, in addition to the activities of the technology development groups, under the supervision of the VGOS Technical Committee (VTC), now other parts of the IVS are getting involved. The VGOS Project Executive Group (VPEG) prepared the VGOS Observing Plan [1] in February 2014 outlining the various phases of the VGOS implementation for operational work. The various stages go from broadband tests, to VGOS trial campaigns, to a pilot project, and eventually to full VGOS operations. In this paper we focus on the implementation of the VGOS trials, but we will also cover the other stages to some degree. The implementation task was given to the Coordinating Center and the Observing Program Committee (OPC). The following summarizes the state of affairs as of early 2016.

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2 VGOS Broadband Test Sessions

Starting in calendar year 2015, test sessions were organized on the baseline Westford to Goddard using the installed broadband signal chains at both sites. These sessions were initially one-hour long and were observed every two weeks. After gaining some experience with and steadily improving the system, the observing time was increased to two hours, then to six hours, and, eventually, to a full 24-hour session. The two-week rhythm was only interrupted to perform necessary repairs at the antennas (e.g., azimuth motor repair at the GGAO12M telescope at GSFC). These test sessions are being continued in 2016; the network will be expanded to include new telescopes as they become available: Kokee Park, Wettzell, Yebes, and Ishioka.

3 VGOS Trial Campaigns

The main purpose of the trial campaigns is to evaluate and improve aspects of VGOS operations [1]. In order to properly assess the sustainability of all as-

pects of operations, each trial will have six observing weeks ensuring the completion of a full operational cycle for *'schedule – acquire – ship/transmit – correlate/process/analyze – ship/transmit'* without backlog. There will be a break of two months between successive trials, which will allow time to compensate for an eventual backlog, to assess performance, to recommend improvements, and to prepare for the subsequent trial [1].

3.1 Observing Scenarios

In the VGOS Observing Plan [1], three trial VGOS campaigns are foreseen to be observed:

- **Trial 1:** *Sustained weekly 24-hour sessions.*
  - all available VGOS stations,
  - optimized for very fast slewing,
  - observe on Sunday (to foster unattended observing),
  - observe UT days (0–24 UT),
  - ship modules.
- **Trial 2:** *Sustained daily VGOS EOP sessions.*
  - all available VGOS stations,
  - optimized for very fast slewing,
  - daily sessions with reduced duty cycle (four one-hour bursts per UT day),
  - observe UT days (0–24 UT),
  - ship modules.
- **Trial 3:** *Sustained daily VGOS EOP sessions with timely transmission of data.*
  - same as Trial 2 but...
  - e-transfer of data as much as possible.

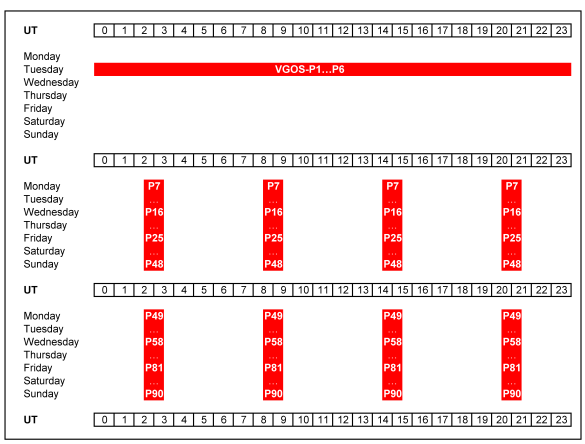

Fig. 1 Observing scenarios of the VGOS trial campaigns: Trial 1 (upper panel), Trial 2 (middle panel), and Trial 3 (lower panel). The naming of the one-hour bursts indicates the grouping of the individual sessions. For instance, session VGOS-P25 consists of four one-hour bursts to be observed on a Friday. It is anticipated that altogether 90 sessions will be observed in the three VGOS trials.

The observing scenarios for all three trials are depicted in Figure 1. Unlike initially planned, Trial 1 will be observed as a UT-day on a weekday (not Sunday) and every two weeks (as opposed to every week) until six 24-hour sessions have been observed.

The move to a weekday is due to the fact that the automation of the observing procedures is not advanced enough to allow for unattended observing. Further, the now planned Tuesday may be changed to Wednesday enabling Westford (and possibly other stations) to participate in the R1 sessions. This allows the VGOS stations to be tied to the existing legacy network.

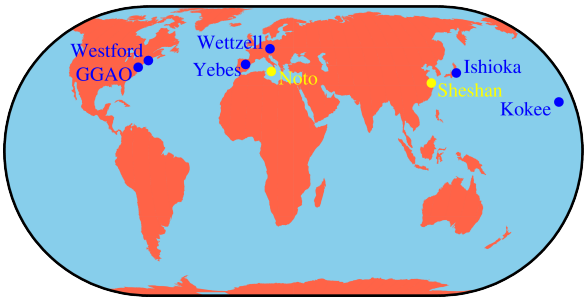

Fig. 2 Network of the VGOS trials. The three trial campaigns will be observed on the network Westford, GGAO, Wettzell, Yebes, Ishioka, and Kokee. The VGOS stations at Noto and Sheshan are not available yet. Other stations may be added if they become available on time (e.g., Santa María or the AuScope stations).

Because of observing only every other week for a total of six sessions, Trial 1 will take twelve weeks (three months) to complete. For the subsequent trial campaigns the decision has not been made on whether weekly or bi-weekly observing will be used. At this point in time, weekly observing is favored, as it is closer to the final VGOS operations.

Trial 2 and Trial 3 observe four hours per day every day of the week. Their only difference lies in the way the data are transmitted from the stations to the correlator: physical shipment of recording modules is replaced as much as possible by electronic data transfer.

3.2 Network

The network for the VGOS trial campaigns was anticipated to consist of eight stations (Figure 2). Two stations (Noto and Sheshan) will not be ready for the first trial campaign and will likely not be ready for the two subsequent ones either.

The VGOS stations currently planned to observe in the trial campaigns are GGAO, Westford, Kokee Park, Wettzell, Yebes, and Ishioka (blue/dark stations in Figure 2). If other stations become available before the end of the trials, they will also be included as much as possible. The trials so far only have stations in the northern hemisphere. However, some southern hemisphere stations (e.g., HartRAO and the AuScope stations) will become available as VGOS sites in subsequent years.

3.3 Timing

All three trials were foreseen to be observed in the calendar year 2015. Figure 3 depicts the spread of the trials over the year with two months of break between the trial campaigns.

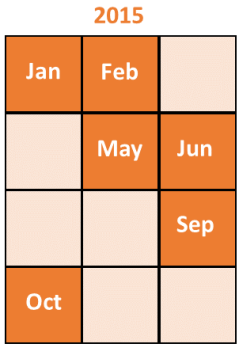

Fig. 3 The original time plan for the three VGOS trial campaigns: Trial 1 in January/February, Trial 2 in May/June, and Trial 3 in September/October.

The planning of the trials was based on information available by February 13, 2014. Since then, several local VGOS projects have slipped in time (e.g., due to delays in getting broadband feeds). For this and other constraints, the trials are currently foreseen to be observed as shown in Figure 4.

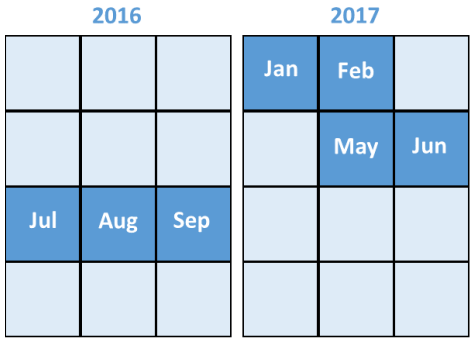

Fig. 4 Current time plan for the three VGOS trial campaigns. The Master Schedule for 2016 has Trial 1 included; that is, the first trial campaign was scheduled. The observing periods for Trial 2 (January/February 2017) and Trial 3 (May/June 2017) are tentative at the point of writing. The two-months observing period for these inherently assumes that the observing will take place on a weekly basis as opposed to a bi-weekly basis.

Hence, the first trial campaign will start 1.5 years later than initially anticipated. The test sessions have shown that a two-week turnaround time is still needed to complete the cycle from observing to correlation to analysis. Thus at least Trial 1 will be kept observation-free every other week.

The observing slots for Trial 2 and Trial 3 are not finalized yet. There will be four one-hour bursts on a daily basis. However, the start and duration (including whether to observe every other week only) still need to be determined.

4 Resource Management

In addition to the station time, the resources necessary for the success of the trials include recording media, data transport, correlation and fringe fitting, and analysis. In order to address these needs, the Coordinating Center has commenced holding monthly teleconferences with the various groups involved in the effort. The teleconferences are also helpful in addressing technical issues that may need to be resolved.

The following provides a brief summary of the resources being discussed:

- **Data transport:** The amount of recorded data is so high that an e-transfer (even for a single station) of the data will easily become too unwieldy. Hence,

the data transport will mostly be physical shipment of recording modules (Mark 6).

- **Mark 6 modules:** A media pool with Mark 6 modules has been started. Each station needs to contribute at least as many modules as required for the trials. The module size is preferably 48 TB in order to fit a single session onto one module (test schedules indicate a need of 37 TB per 24-hour session per station).
- **Correlation and fringe-fitting:** MIT Haystack Observatory is developing the correlation and fringe-fitting capability based on the DiFX software correlator. Haystack will do the correlation/fringe-fitting work.
- **Analysis:** The analysis is based on *vgosDB* as the storage format. The analysis work will be done at Haystack and Goddard using *nuSolve*.

5 Pilot Project

After the successful completion of three trial campaigns, a pilot project can commence. The main purpose of the pilot is to gain experience with the operational mode but without making a full commitment to product delivery [1]. The pilot will be a combination of the observing scenarios of the trials with steadily increasing observing load over time. In order to get to 24/7 observing one of two avenues will be followed: either increasing the burst lengths (Figure 5) or increasing the number of bursts (Figure 6).

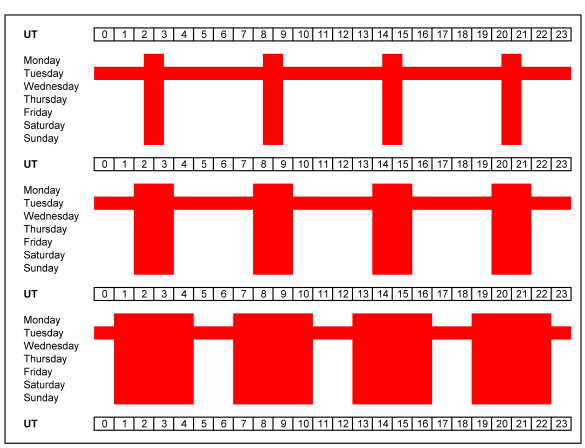

Fig. 5 Pilot project with increasing the burst lengths.

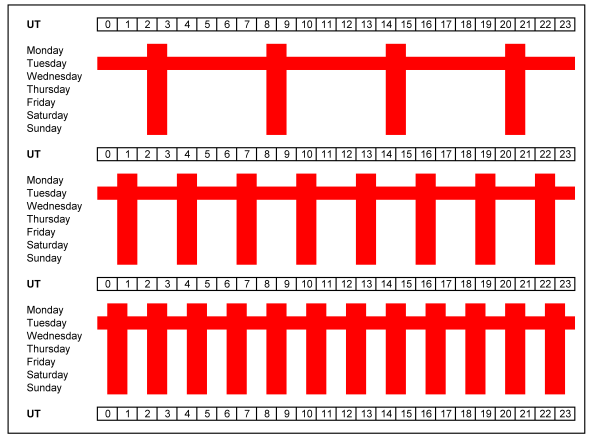

Fig. 6 Pilot project with increasing the number of bursts.

An argument in favor of increasing the number of bursts is that it allows the determination of dUT1 in an Intensive-type approach. However, it has not been decided yet which avenue will be taken. In terms of timing, the pilot project can be scheduled as early as the fourth quarter of 2017 or at the beginning of 2018. This is somewhat dependent on the success of the trial campaigns.

6 Outlook

In the next several years a substantial number of new VGOS antennas will come online. By the year 2018 we expect some 18 VGOS sites altogether. The new stations will be integrated into the trials (if possible) as well as the pilot project. The pilot project will eventually culminate into full VGOS operations by 2020.

References

1. B. Petrachenko, D. Behrend, J. Gipson, H. Hase, C. Ma, D. MacMillan, A. Niell, A. Nothnagel, and X. Zhang. VGOS Observing Plan. *IVS 2014 General Meeting Proceedings 'VGOS: The New VLBI Network'*, edited by D. Behrend, K. D. Baver, and K. L. Armstrong, Science Press (Beijing), ISBN 978-7-03-042974-2, pp. 16–19, 2014.