**International Operations Test Plan for VSOP**

**Version 2.0**

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## 1.0 INTRODUCTION

This document outlines the VSOP test plan for international operations. It generally gives only the description of the tests that involve more than one organization, but tests internal to JPL or ISAS are occasionally listed when they may be related to tests involving other organizations. Each mission element also must develop its own test plan to meet the requirements of the test plan for international operations, but these tests within a single mission element are not included in the present document.

The plan concentrates on the exchange of data and information according to international interfaces, as well as joint international mission operations. For data related to tracking stations, many data interfaces have been formally specified within the International Mission Operations Group (IMOG) for space VLBI. For data related to ground radio telescopes, few interfaces specific to the VSOP mission have yet been defined. However, since many of the interfaces will follow commonly accepted practices for ground-only VLBI, it is hoped that these can be defined quickly (perhaps informally) by the technical working group of the Global VLBI Working Group.

Most of the dates given in Version 1.0 of this document have slipped considerably, partly because the plan was overly ambitious and partly because there was no coordinated attempt to meet the original schedule. In view of the upcoming VSOP launch, planned for September 1996, it is necessary to make a more consistent effort to perform the pre-launch tests on schedule. Performance of the tests described here is being coordinated by the VSOP Science Operations Group (VSOG). Within the VSOG, P. Edwards is leading the effort related to ground radio telescopes, while J. Ulvestad and Y. Murata are leading the effort related to tracking stations.

## 2.0 GENERAL CATEGORIES OF TESTS

There are a number of general categories of tests that can be defined. In order for coherent VSOP operations to be possible, the different types of tests should take place as part of an overall plan rather than as independent activities. In this document, we separate the tests according to the following groups:

(1) Files to be exchanged between tracking stations and VSOG
(2) Files to be exchanged between VSOG and VLBI correlators
(3) Navigation-related data to be exchanged
(4) Data to be exchanged with ground radio telescopes
(5) Test observations and correlations
(6) Tracking-station compatibility tests

(7) Status reports
(8) Tape management
(9) Complete operations tests

## 3.0 TRACKING STATION/VSOG FILE EXCHANGES

There are seven types of files related to individual tracking sessions that must be exchanged between tracking stations and the VSOG. All files will be exchanged via standard ftp (file-transfer protocol) methods. The file types are listed below:

(1) Space Radio Telescope (SRT) Schedule Files from VSOG
(2) Telemetry header files from tracking stations
(3) Time correction files from tracking stations
(4) VLBA correlator log input files from tracking stations
(5) S2 correlator log input files from tracking stations
(6) Phase calibration files from tracking stations
(7) Performance reports from tracking stations

### *3.1 SRT Schedule Files*

The SRT Schedule Files will be used to specify all activities that must be performed by tracking stations in order to operate in conjunction with the VSOP spacecraft. The specification for these files is "SRT Schedule File, Version 3.0," by Ulvestad *et al.* (September 15, 1995), which has been formally approved by the IMOG and the VSOG. Each file made available by the VSOG must cover the complete activities for one week of tracking. The first test file was made available in September 1995, but a revised version will be supplied in December 1995. It is the responsibility of the JPL Project and the Green Bank Earth Station to retrieve this test file and perform whatever actions they need to interpret it and ensure that it can be used by their tracking stations.

### *3.2 Telemetry Header Files*

Tracking stations must make VSOP downlink telemetry header files available to the VSOG as soon as possible after reception. The specification for the file exchange is in "VSOP Science Header Data Format," by Y. Murata (September 1, 1995), which has been formally approved by the IMOG and the VSOG. The first test files should be made available to the VSOG by the Green Bank Earth Station and the JPL Project by the middle of March 1996. A preliminary test file from the Green Bank Earth Station was produced in late August.

### *3.3 Time Correction Files*

The time correction files from U.S. tracking stations must be made available to the VSOG, which will also provide a similar file from the Usuda station for application at the necessary correlators. The specification for this file is in "Time Corrections File Interface, Revision E," by D'Addario and Langston (April 24, 1995). Formal approval of this interface occurred in September 1995. Files from the Green Bank Earth Station and the JPL Project must be made available by the middle of March 1996.

### *3.4 VLBA Correlator Log Input File*

The VSOG will create final space radio telescope log input files for the VSOP, VLBA, and S2 correlators. In order to do so, they must receive log input files from the tracking stations for each tracking pass. The current specification for log input files to the VLBA correlator is "Alternative Log Input to the VLBA Correlator for Space VLBI Observations," by J. Romney (September 15, 1995). This log input file will include a variety of flags; a preliminary definition is available in "Flag Dictionary for Space Radio Telescope Logs," by Ulvestad *et al.* (October 4, 1995). Revisions of both specifications are expected soon, and final adoption is required by the end of 1995. The tracking stations actually will provide a subset of the log information, with the remainder to be supplied by the VSOG from spacecraft downlink data. Input logs for VLBA tapes going to the VSOP correlator will follow the VLBA specifications, and will be converted to a VSOP correlator log input format as part of the tape-copy process at the VSOP correlator. Data to be supplied to the VSOP correlator from the Usuda tracking station will use the VSOP log format internal to Japan, so this data flow is not a subject of the international test plan. The first log input files from tracking stations intended for supply to the VLBA correlator must be made available by the middle of March 1996.

### *3.5 S2 Correlator Log Input File*

The VSOG also must create log files for the Canadian S2 correlator, or for translation from S2 to VSOP format, as for the VLBA format. The specification of the format is due by the end of January 1996. The current draft is Version 1.2 of "SVLBI Space Radio Telescope Log Input to the Canadian (S2) Correlator," by Carlson *et al.* (November 29, 1995).

### *3.6 Phase Calibration Data*

Phase calibration data must be supplied to the VSOG by all tracking stations. A draft specification of the format was given in the September 15, 1995 version of "Alternative Log Input to the VLBA Correlator for Space VLBI Observations." However, the description of the phase calibration data will be removed from this specification and given separately as a format independent of correlator type. The first draft of that specification is due by the end of December 1995, with the final adoption due by the end of January 1996. Data should be supplied to the VSOG by the middle of March 1996.

### *3.7 Performance Reports*

Each tracking station will make a performance report available to the VSOG after the completion of each tracking pass. These performance reports supply information about tracking-station and (perhaps) spacecraft activities, and will not be passed on to correlation facilities. The current draft specification for the NRAO and DSN stations is "Spacecraft/Station Performance Log Interface," by L. D'Addario (November 21, 1995). The Usuda station will use a format internal to ISAS. The performance report for the DSN tracking stations will include a subset of the data items defined in the interface, as discussed with the VSOP Project. In addition, the DSN will provide access to more detailed monitor data that the VSOG may use to help check the performance of the Usuda tracking station. Agreement on the common specification is expected by the end of December 1995. Performance report files should be made available to the VSOG by mid-March 1996.

## 4.0 VSOG/CORRELATOR FILE EXCHANGES

Several types of files must be made available to the VLBI correlators by the VSOG in order to enable correlation and calibration of data from the Space Radio Telescope. These files follow directly from the tracking-station output files, sometimes with information added or with several files concatenated to one. The files to be provided are as follows:

(1) Time Correction File
(2) Correlator Log Input File
(3) Phase Calibration File
(4) Amplitude Calibration File
(5) SRT Gain Curve

### *4.1 Time Correction File*

The time correction file for the correlators follows directly from the files supplied by the tracking stations, and follows the specification referenced in Section 3.3. A sample file will be provided to the VLBA, VSOP, and S2 correlators by the end of March 1996. It is the responsibility of the correlators to properly read and interpret this sample file.

### *4.2 Correlator Log Input File from SRT*

The correlator log input file from the space radio telescope (SRT) will be generated from the log input files provided by the individual tracking stations, with additional information coming from downlink telemetry headers and data directly available through the link with the Kagoshima command station. The format for the VLBA correlator will follow the specification referenced in Section 3.4, the format for the S2 correlator will follow the specification referenced in Section 3.5, and the format for the VSOP correlator is an internal matter within Japan. The test versions of these files will be made available to the correlators by the VSOG during April 1996.

### *4.3 Phase Calibration File*

The phase calibration file to be provided to the end user will be passed to the correlators according to the specification mentioned in Section 3.6. Test files should be provided to the correlators by the middle of April 1996.

### *4.4 Amplitude Calibration File*

The end user must be supplied with amplitude calibration files in order to properly interpret correlator output data. The information required is in the downlink telemetry headers and (possibly) in the results of pre-launch and post-launch calibration tests. There is not yet any specification for the contents or format of these files. The schedule for supplying the files is the same as for the phase calibration files.

### *4.5 SRT Gain Curve*

VSOP data cannot be calibrated without a gain curve (versus Sun angle?) for the Space Radio Telescope. This must be provided by the VSOG to the correlation facilities, to be used as part of a telescope data base at the correlators (see Section 6.0). A preliminary gain curve should be made available during March 1996.

## 5.0 NAVIGATION DATA

Many types of navigation data must be exchanged internationally. They include the following:

(1) Predicted sequence of SRT pointing for JPL Navigation team (JPL NAV)
(2) Predicted orbits for tracking station pointing and frequency predictions
(3) Doppler data exchange between JPL NAV and ISAS NAV
(4) State vector exchange between JPL NAV and ISAS NAV
(5) Reconstructed orbits from JPL NAV to ISAS NAV
(6) S-band range data from ISAS NAV to JPL NAV
(7) GPS data from ISAS NAV to JPL NAV
(8) Reconstructed orbit from JPL NAV to VLBA and S2 correlators
(9) Reconstructed orbit from ISAS NAV to VSOP correlator
(10) Executed sequence of events from ISAS NAV to JPL NAV

### *5.1 Predicted SRT Pointing Sequence*

The predicted pointing sequence for the SRT is given in the SRT schedule file. As stated in Section 3.1, a new version of this file will be made available by the end of 1995; it will be provided to JPL NAV for their interpretation at that time.

### *5.2 Predicted Orbits for Tracking Stations*

Predicted orbits from JPL NAV for Green Bank will be supplied in the SPICE format of the Navigation Ancillary Information Facility (NAIF). Such orbits already have been delivered and used to track the SURFSAT spacecraft. Predicted orbits for DSN stations, in an internal format, have been delivered by JPL NAV and used to track SURFSAT. Predicted orbits for the Usuda tracking station have been delivered by ISAS NAV.

### *5.3 Interfaces Between ISAS NAV and JPL NAV*

Several types of data must be exchanged between ISAS NAV and JPL NAV, as listed in items (3)–(7) of Section 5.0. Test deliveries of all these data types are due by the end of January 1996.

### *5.4 Reconstructed Orbit to VLBA and S2 Correlators*

The reconstructed orbit will be delivered from JPL NAV in SPICE format, and made available to the VLBA correlator and to the Canadian S2 correlator via ftp. A sample orbit has already been delivered and processed by the VLBA correlator. Delivery to the S2 correlator is due in March 1996.

### *5.5 Reconstructed Orbit to VSOP Correlator*

Reconstructed orbits for the VSOP correlator will be delivered by ISAS NAV in a standard ISAS SCEF (Spacecraft Ephemeris File) format. However, there will also be the possibility for

ISAS NAV to convert a reconstructed orbit delivered by JPL NAV from SPICE format to the ISAS format. Test delivery of an internally generated ISAS orbit will take place during January 1996, while test delivery of an orbit converted from the JPL SPICE format will take place by the end of the same month.

### *5.6 Executed Sequence of Events*

The executed sequence of events for the VSOP spacecraft must be delivered to JPL NAV for use in orbit modelling. A preliminary date for the first test delivery is the end of January 1996, although this depends on a software design process that is not yet very far advanced.

## 6.0 DATA EXCHANGE WITH GROUND RADIO TELESCOPES

Several types of data must be exchanged with ground radio telescopes (GRTs). Most of these exchanges will be exercised in GRT test observations to be made in VSOP observing mode. The first test observations are planned for February 13, 1996. All data types to be supplied by the GRTs will be exercised using the observations made on that date. Schedule files (in DRUDG format) must be supplied by the VSOG by January 17, 1996, in order to support the test observations. Required data types are as follows:

(1) GRT schedule files supplied by VSOG
(2) GRT log files supplied to VSOG
(3) GRT logs and tapes supplied to VLBA correlator for correlation
(4) GRT logs and tapes to VSOP (Mitaka) correlator for translation and correlation
(5) GRT tape information supplied to international management system (TRACK)

In addition to the data related to specific experiments, the ground correlation facilities also will need up-to-date data bases for the GRTs and SRT. For the GRTs, this requires items such as telescope locations and gain curves. Data bases with some different information are required by the VSOG in order to conduct a coherent scheduling and telescope-allocation process for VSOP. The final information for these data bases should be supplied by the middle of January 1996.

## 7.0 GRT TEST OBSERVATIONS AND CORRELATION

The first GRT test observations will take place in February 1996. The data from these observations will be sent first to the VLBA correlator and then to the Mitaka correlator. One of the functions of the observations will be to test the many file exchanges listed in Section 6.0. Observations will be done in the international VSOP mode (two 16-MHz channels with 2-bit sampling) according to a schedule distributed by the VSOG. Correlation should be complete by the end of March 1996 in Socorro, and by the end of April in Mitaka. Additional test observations are scheduled for June 1996, and should be correlated during July 1996. The latter tests should be done in conjunction with end-to-end operations tests described in Section 11.0.

## 8.0 TRACKING STATION COMPATIBILITY

Tests of U.S. tracking-station compatibility with VSOP afford an opportunity to test some of the data interfaces as well as the hardware. Specifically, this provides the chance to use a VSOP satellite simulator to generate VLBI data that can be recorded on wideband tape via the standard path for space VLBI data. The reading and interpretation of the tapes at correlation facilities then can be tested. The compatibility tests also may provide the opportunity for tracking stations to generate real output files that can later be passed to the VSOG in the proper format. These compatibility tests are scheduled to take place in February 1996.

## 9.0 STATUS REPORTS

The VSOG desires a weekly status report from all mission elements, but many elements have been reluctant to supply such a status report because of a fear that it would create an extra workload. One simple way to provide a status report with minimal work is to create a "forms" interface under "html" (hyper-text markup language), enabling mission elements to fill in a simple form and submit it to the VSOG. A test form was completed in September 1995. However, the GRTs apparently prefer an unformatted e-mail message. If this preference is followed, there is little to test; this approach presumably will be tried during the GRT experiment in February 1996. The idea of a general status report by the VSOP project has been discussed, but no consensus has yet been reached.

## 10.0 TAPE MANAGEMENT SYSTEM

It is necessary for the VSOP operations to use a global tape management system. For VLBA tapes, this will be the TRACK system currently in use by the VLBA and other observatories worldwide. The VSOG, GRTs, and tracking stations must provide information to the common system and be able to retrieve information from that system. A means of allocating tapes from a common pool also is required. During the ground observatory test in February 1996, real tape information should be entered in the global pool as specified in Section 6.0. Information from tracking stations that have received new VLBA tapes should be entered in the TRACK system by the end of February 1996. Finally, using the first real long-term observing schedule generated in March (?) 1996, a hypothetical plan for distribution of tapes during the first three months of observations should be generated by the end of April 1996.

## 11.0 ONE DAY/ONE WEEK OPERATIONS TESTS

It is highly desirable to perform complete end-to-end tests of at least a week in the life of VSOP. The minimum requirement seems to be several tests of one day of operations, and a full 1-week test of operations before launch. These tests must include distribution of schedules and output files as well as operation of as many mission elements as possible. Prior to VSOP launch, these tests may be performed by having ground telescopes observe a radio source, while tracking stations and navigation groups operate in conjunction with the SURFSAT satellite. It appears that coordinated tests will not be possible during the GRT test in February 1996, but coordinated operations are highly desirable during the second GRT test observations, scheduled for June 1996.

The 1-week (or longer) test will simulate a period of at least one week of observations. However, it will require a longer period of operational activities, since it will include distribution of schedule files well in advance, generation of predicted orbits several days in advance, operation of mission elements during the simulated observation period, and processing and distribution of a variety of data over a period of weeks. The 1-week test should take place during July 1996.

## 12.0 TEST SUMMARY BY CATEGORY

This section provides a summary of the deadlines for the operational tests, by category.

### *12.1 Tracking Station/VSOG File Exchanges*

| | |
|---|---|
| SRT schedule file specification | Complete |
| Downlink header file specification | Complete |
| Time correction file specification | Complete |
| SRT schedule file VSOG→TS | 12/31/95 |
| VLBA correlator log file specification | 12/31/95 |
| Flag dictionary specification | 12/31/95 |
| Performance report specification | 12/31/95 |
| Phase calibration specification | 1/31/96 |
| S2 correlator log file specification | 1/31/96 |
| Downlink header files TS→VSOG | 3/15/96 |
| Time correction files TS→VSOG | 3/15/96 |
| VLBA correlator log input TS→VSOG | 3/15/96 |
| S2 correlator log input TS→VSOG | 3/15/96 |
| Phase calibration files TS→VSOG | 3/15/96 |
| Performance reports TS→VSOG | 3/15/96 |

### *12.2 VSOG/Correlator File Exchanges*

| | |
|---|---|
| Amplitude calibration file specification | 1/31/96 |
| SRT gain curve VSOG→CORR | 3/15/96 |
| Time correction files VSOG→CORR | 3/31/96 |
| Correlator log input VSOG→CORR | 4/15/96 |
| Phase calibration files VSOG→CORR | 4/15/96 |
| Amplitude calibration files VSOG→CORR | 4/15/96 |

### *12.3 Navigation Data*

| | |
|---|---|
| Orbit predictions ISAS→USUDA | Complete |
| Orbit predictions JPL→GB | Complete |
| Orbit predictions JPL→DSN | Complete |
| Reconstructed orbit JPL→VLBA | Complete |
| SRT pointing sequence VSOG→JPL | 12/31/95 |
| Reconstructed orbit ISAS→MITAKA | 1/15/96 |
| Executed SOE ISAS→JPL | 1/31/96 |
| Doppler JPL↔ISAS | 1/31/96 |
| State vector JPL↔ISAS | 1/31/96 |
| Reconstructed orbit JPL→ISAS | 1/31/96 |
| S-band range ISAS→JPL | 1/31/96 |
| GPS data ISAS→JPL | 1/31/96 |
| Reconstructed orbit JPL→ISAS→VSOP | 1/31/96 |
| Reconstructed orbit JPL→S2 | 3/31/96 |

*12.4 Data Exchange with GRTs*

| | |
|---|---|
| GRT DB specification for scheduling | 1/15/96 |
| GRT correlator data base completion | 1/15/96 |
| GRT schedule files VSOG→GRT | 1/17/96 |
| GRT log files→VSOG | 2/13/96 |
| GRT logs and tapes→VLBA | 2/13/96 |
| GRT tape information→TRACK | 2/13/96 |
| GRT logs and tapes→MITAKA | 3/31/96 |

*12.5 GRT Test Observations and Correlation*

| | |
|---|---|
| 1st test GRT observation | 2/13/96 |
| Correlation of 1st GRT test→VLBA | 3/31/96 |
| Correlation of 1st GRT test→MITAKA | 4/30/96 |
| 2nd test GRT observation | 6/15/96 |
| Correlation of 2nd GRT test→VLBA | 7/15/96 |
| Correlation of 2nd GRT test→MITAKA | 7/15/96 |

*12.6 Tracking-Station Compatibility*

| | |
|---|---|
| TS hardware compatibility | 2/15/96 |
| TS tape interpretation | 2/29/96 |

*12.7 Status Reports*

| | |
|---|---|
| Draft html status interface | Complete |
| Testing of status interface | 2/13/96 |
| Final status interface specification | 3/15/96 |

*12.8 Tape Management System*

| | |
|---|---|
| TS tape information→TRACK | 2/29/96 |
| 1st tape allocation plan | 4/30/96 |

*12.9 Full Operations Tests*

| | |
|---|---|
| 1-day operations test | 4/15/96 |
| 1-day operations test | 6/15/96 |
| Schedule for long-term operations test | 6/15/96 |
| Long-term operations test | 7/15/96 |

## 13.0 CHRONOLOGICAL SUMMARY

This section contains a summary of all the items from section 12, rearranged in chronological order:

### *13.1 Completed Activities*

| | |
|---|---|
| SRT schedule file specification | Complete |
| Downlink header file specification | Complete |
| Time correction file specification | Complete |
| Orbit predictions ISAS→USUDA | Complete |
| Orbit predictions JPL→GB | Complete |
| Orbit predictions JPL→DSN | Complete |
| Reconstructed orbit JPL→VLBA | Complete |
| Draft html status interface | Complete |

### *13.2 December 1995*

| | |
|---|---|
| SRT schedule file VSOG→TS | 12/31/95 |
| VLBA correlator log file specification | 12/31/95 |
| Flag dictionary specification | 12/31/95 |
| Performance report specification | 12/31/95 |
| SRT pointing sequence VSOG→JPL | 12/31/95 |

### *13.3 January 1996*

| | |
|---|---|
| Reconstructed orbit ISAS→MITAKA | 1/15/96 |
| GRT DB specification for scheduling | 1/15/96 |
| GRT correlator data base completion | 1/15/96 |
| GRT schedule files VSOG→GRT | 1/17/96 |
| S2 correlator log file specification | 1/31/96 |
| Phase calibration file specification | 1/31/96 |
| Amplitude calibration file specification | 1/31/96 |
| Executed SOE ISAS→JPL | 1/31/96 |
| Doppler JPL↔ISAS | 1/31/96 |
| State vector JPL↔ISAS | 1/31/96 |
| Reconstructed orbit JPL→ISAS | 1/31/96 |
| S-band range ISAS→JPL | 1/31/96 |
| GPS data ISAS→JPL | 1/31/96 |
| Reconstructed orbit JPL→ISAS→VSOP | 1/31/96 |

### *13.4 February 1996*

| | |
|---|---|
| 1st test GRT observation | 2/13/96 |
| GRT log files→VSOG | 2/13/96 |
| GRT logs and tapes→VLBA | 2/13/96 |
| GRT tape information→TRACK | 2/13/96 |
| Testing of status interface | 2/13/96 |
| TS hardware compatibility | 2/15/96 |
| TS tape interpretation | 2/29/96 |
| TS tape information→TRACK | 2/29/96 |

### *13.5 March 1996*

| | |
|---|---|
| Downlink header files TS→VSOG | 3/15/96 |
| Time correction files TS→VSOG | 3/15/96 |
| VLBA correlator log input TS→VSOG | 3/15/96 |
| S2 correlator log input TS→VSOG | 3/15/96 |
| Phase calibration files TS→VSOG | 3/15/96 |
| Performance reports TS→VSOG | 3/15/96 |
| SRT gain curve VSOG→CORR | 3/15/96 |
| Final status interface specification | 3/15/96 |
| Reconstructed orbit JPL→S2 | 3/31/96 |
| Time correction files VSOG→CORR | 3/31/96 |
| Correlation of 1st GRT test→VLBA | 3/31/96 |
| GRT logs and tapes→MITAKA | 3/31/96 |

### *13.6 April 1996*

| | |
|---|---|
| Correlator log input VSOG→CORR | 4/15/96 |
| Phase calibration files VSOG→CORR | 4/15/96 |
| Amplitude calibration files VSOG→CORR | 4/15/96 |
| 1-day operations test | 4/15/96 |
| Correlation of 1st GRT test→MITAKA | 4/30/96 |
| 1st tape allocation plan | 4/30/96 |

### *13.7 May 1996*

| | |
|---|---|
| No items currently due | 5/31/96 |

*13.8 June 1996*

| | |
|---|---|
| 2nd test GRT observation | 6/15/96 |
| 1-day operations test | 6/15/96 |
| Schedule for long-term operations test | 6/15/96 |

*13.9 July 1996*

| | |
|---|---|
| Correlation of 2nd GRT test→VLBA | 7/15/96 |
| Correlation of 2nd GRT test→MITAKA | 7/15/96 |
| Long-term operations test | 7/15/96 |

*13.10 August 1996*

| | |
|---|---|
| Contingency | 8/31/96 |

*13.11 September 1996*

| | |
|---|---|
| **VSOP LAUNCH** | **9/15/96** |