Strategies for Improving the IVS-INT01 UT1 Estimates: Preliminary Results of RD0907 through RD0910

K. D. Baver[1], J.M. Gipson[1], and D. S. MacMillan[1]

[1] NVI, Inc., Code 698, NASA Goddard Space Flight Center, Greenbelt MD, 20771

1. Introduction

The primary purpose of the IVS-INT01 sessions is the estimation of UT1. Improving the accuracy and precision of the UT1 estimates is an important goal in the scheduling of these sessions.

In 2009 the GSFC VLBI Analysis Center requested and received the use of four IVS R&D sessions, RD0907 through RD0910, for the evaluation of a new strategy for scheduling the IVS-INT01 sessions.

In this poster we present some preliminary results from our analysis of these sessions, and we discuss future work.

2. Labeling the Intensives

USNO vs. TEST vs. STND

In this study we are studying several different kinds of 1-hour sessions, and we need to distinguish them. We will refer to the operational Intensives scheduled by USNO as USNO Intensives, or **USNO** for short. These sessions use a restricted source list. In our experiments, we scheduled two kinds of 1-hour sessions. The first kind used the same sources used by USNO. We will refer to these as Standard Intensives or **STND** for short. The second kind used an enlarged source list consisting of all sources that are mutually visible at Kokee and Wettzell. We refer to this set as **TEST** Intensives.

Greenwich Sidereal Time

Because the standard Intensive sessions are usually single baseline and of short duration, they only sample a small part of the sky. This changes depending on the date and time of the Intensive. Hence Intensives scheduled on the same date, but at different times can see very different parts of the sky. It is useful to have something that unambiguously is associated with the visible part of the sky. The Greenwich Sidereal Time (GST) serves this function. Sessions which start at the same GST on different dates will sample the same part of the sky.

3. Experiment Design

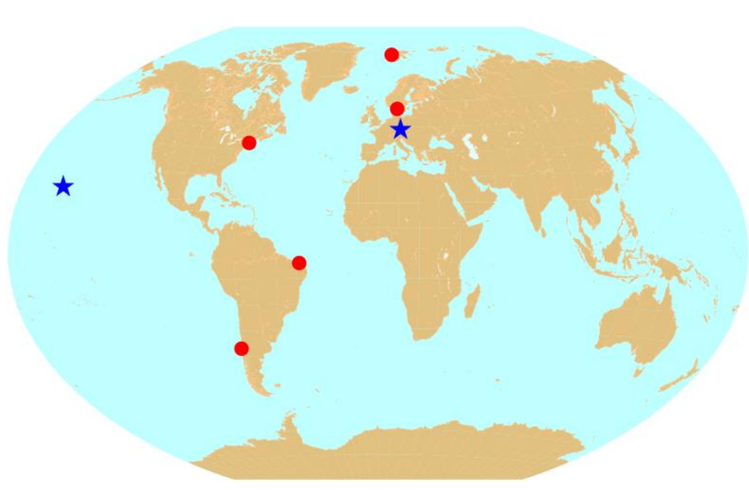

Figure 1. Typical R&D network. Kokee & Wettzell (★) are used in the Intensive network.

We divided the R&D network into two parts—the single baseline Kokee-Wettzell network, and a remaining network consisting of ~5 stations. Each network was scheduled independently. The primary purpose of the larger network was to serve as an independent check on UT1.

Because Kokee-Wettzell are used in the operational Intensives, they were not available for the 2 hour period immediately prior to, during and after the operational Intensives. Hence we had use of them for 22 hours in each R&D. We used this time to schedule a series of one-hour Intensives, alternating between the STND strategy and the TEST strategy. On the first R&D the antenna became available at 19:45, following the end of the operational Intensive. The first session we scheduled began at 20:00 UT. **We adjusted the start time of the Intensive series in the remaining R&Ds so that we sampled the same part of the sky.** All of the STND Intensives start close to the even hours in GST, while all of the TEST Intensives start close to the odd hours GST.

RD0910, which has not yet been correlated, is not included in this analysis.

Table 1 lists the 4 R&Ds covered in this study. The top of the table displays the name and date of the R&D session. The start time is specified in both UT and Greenwich Sidereal Time.

Following this are the start times of the alternating Intensives in each session. The first column indicates the scheduling strategy—STND or TEST– and the remaining columns give the start time in UT and GST. Rows are organized to clearly indicate the correspondence in GST across the sessions. We indicate the first Intensive in each session by **bold face red.** The remaining Intensives are found by reading down to 23:00 GST, and then starting at the top.

Table 1. Intensive Study R&D Sessions

Date	RD0907 2009Jul08 UT	GST	RD0908 2009Sep23 UT	GST	RD0909 2009Oct06 UT	GST	RD0910 2009Dec16 UT	GST
Start	**18:00**	**13:07**	**18:00**	**18:10**	**17:30**	**18:32**	**18:00**	**23:42**
	Alternating Intensives							
STND	5:00	0:09	0:00	0:11	23:10	0:12	INTENSIVE	
TEST	6:00	1:09	1:00	1:11	0:10	1:13	**19:30**	**1:12**
STND	7:00	2:09	2:00	2:12	1:10	2:13	20:30	2:12
TEST	8:00	3:09	3:00	3:12	2:10	3:13	21:30	3:12
STND	9:00	4:09	4:00	4:12	3:10	4:13	22:30	4:12
TEST	10:00	5:09	5:00	5:12	4:10	5:13	23:30	5:12
STND	11:00	6:10	6:00	6:12	5:10	6:13	0:30	6:13
TEST	12:00	7:10	7:00	7:12	6:10	7:14	1:30	7:13
STND	13:00	8:10	8:00	8:13	7:10	8:14	2:30	8:13
TEST	14:00	9:10	9:00	9:13	8:10	9:14	3:30	9:13
STND	15:00	10:10	10:00	10:13	9:10	10:14	4:30	10:13
TEST	16:00	11:10	11:00	11:13	10:10	11:14	5:30	11:13
STND	17:00	12:11	12:00	12:13	11:10	12:14	6:30	12:14
TEST	NORMAL		13:00	13:13	12:10	13:15	7:30	13:14
STND	INTENSIVE		14:00	14:14	13:10	14:15	8:30	14:14
TEST	**20:00**	**15:07**	15:00	15:14	14:10	15:15	9:30	15:14
STND	21:00	16:07	16:00	16:14	15:10	16:15	10:30	16:14
TEST	22:00	17:07	17:00	17:14	16:10	17:15	11:30	17:14
STND	23:00	18:08	NORMAL		NORMAL		12:30	18:15
TEST	0:00	19:08	INTENSIVE		INTENSIVE		13:30	19:15
STND	1:00	20:08	**20:00**	**20:11**	**19:10**	**20:12**	14:30	20:15
TEST	2:00	21:08	21:00	21:11	20:10	21:12	15:30	21:15
STND	3:00	22:08	22:00	22:11	21:10	22:12	16:30	22:15
TEST	4:00	23:08	23:00	23:11	22:10	23:12	NORMAL	
Yellow blocks are periods when Kokee & Wettzell participated in a normal Intensive and were not available for the R&D.								
	USNO Intensives on R&D Days							
	I09189		I09266		I09279		I09350	
Start	18:30	13:37	18:30	18:40	17:30	18:32	18:00	23:42

4. Comparison of Test and Standard

In Table 2 we summarize various statistics for the 3 processed R&D sessions. In general the STND strategy has more observations because it uses stronger sources. The TEST strategy uses more, but weaker sources. Because of this it has fewer observations, but the sky distribution is better.

Table 2. Summary of Results

	STND		TEST	
Typical Sky Distribution	GST 011110		GST 011110	
Average # of observations	28.3	✓	23.2	
Average # of sources	10.6		18.5	✓
Source strength	better	✓	worse	
Sky coverage	narrower		wider	✓
Comparison of techniques (✓ = better for the UT1 estimate)				

5. Current Strategy and Source Dropouts

Better sky coverage is empirically linked with improved precision and accuracy of the UT1 estimates. The current USNO strategy uses only the strongest sources. Because strong sources are unevenly distributed, at some times of the year there are only a few available, which can potentially result in poor sky distribution. Furthermore, because the number of scheduled sources is small, the current USNO strategy tends to schedule sources many times in one session. The loss of a single source can lead to dramatic changes in sky coverage, which in turn has a large effect on the formal errors of UT1.

We looked at the effect of losing a single source on the operational Intensives. These results are summarized below. Depending on the particular session and its sky coverage, the effect ranges from minimal (10% degradation in sigma) to doubling the formal error.

Table 3. Effect of Losing a Source on Formal Errors of UT1

Sky Coverage	When	Charts	
Good	GST 07:12 April 1-5	$08APR01XU; 26 obs 10.23 us	minus 0059+581; 24 obs 11.52 us
Intermediate	GST 17:11 Sep 1-5	$09SEP01XU; 24 obs 22.19 us	minus 0059+581; 21 obs 35.39 us
Bad	GST 19:12 Oct 1-4	$08OCT01XU; 27 obs 16.41 us	minus 1418+546; 21 obs 32.08 us

5. Robustness and Accuracy of the UT1 Estimates from the USNO and Test Schedules

Sessions are prone to lose observations. Ideally, we would like the estimated parameters to be insensitive to this loss. A session is robust if the parameters do not change very much with the loss of a single source.

To compare the robustness of the techniques, we selected four USNO Intensives with varying levels of sky coverage ranging from good to bad, and paired these with TEST Intensives. For each session we ran a set of solutions in which we suppressed a single source and estimated UT1. We did this for all sources in the session, and then computed the scatter of the estimates. These results are summarized below.

Table 4. RMS Scatter in Estimates of UT1 after Deletion of Sources

Sky Coverage	GST	USNO	RMS	TEST	RMS
Good	07:12	GST 071210	5.3	GST 071210	4.4
Intermediate	11:12	GST 111250	12.2	GST 111250	7.4
Intermediate	17:11	GST 171150	13.2	GST 171150	2.9
Bad	19:12	GST 191210	21.6	GST 191210	4.4
Average RMS			**13.1**		**4.8**

The TEST Intensives are much more robust than the USNO Intensives because their sky coverage is better and they use more sources. Hence the loss of a single source does not change the sky coverage as much as in the USNO Intensives.

We are still investigating ways of verifying the accuracy of the UT1 estimates from the TEST Intensives.

6. Comparison of Test and USNO

Because the Intensives are sensitive to the part of the sky they sample, it is important in comparisons to use sessions that start at the same GST.

We purposefully designed our experiment so that the TEST sessions would sample the same part of the sky as other TEST sessions, and similarly for the STND sessions. This has the advantage that, for a particular GST, we have more sessions of a given kind. It has the disadvantage that it makes it difficult to directly compare the TEST and STND sessions.

One way around this is to compare the TEST sessions with USNO sessions. The advantage of doing so is that you can ensure that you are sampling the same part of the sky. The disadvantage is that the weather, which influences the noise, will be different, since these sessions are at different times of the year.

Our TEST sessions sample 12 parts of the sky. We looked at all USNO Intensives from 2007-2009 that started at the same GST as the TEST sessions. For each set of Intensives and strategy, we calculated the average formal error and session fit. The TEST strategy generally has lower formal errors. Examination of the exceptions indicates that the TEST strategy can introduce weaker sources that drive up the session fit and in turn the UT1 formal errors. If the USNO scheduled has especially good sky coverage, the TEST schedule may suffer in comparison. It may be possible to compensate for this by excluding weaker sources in the TEST schedules.

Table 5. Sky Coverage, UT1 Formal Errors and Session Fit

GST	USNO Typical Sky Chart	USNO σ (μs)	USNO Fit (ps)	USNO # Sess	TEST Typical Sky Chart	TEST σ (μs)	TEST Fit (ps)	TEST # Sess.
01:11	GST 011110	12.3	45.8	2	GST 011110	9.5	55.4	3
03:11	GST 031130	20.0	48.2	4	GST 031130	6.8	40.5	3
05:11	GST 051150	26.2	40.4	3	GST 051150	13.5	64.4	3
07:12	GST 071210	12.1	58.3	7	GST 071210	16.2	87.5	3
09:12	GST 091230	9.7	35.7	4	GST 091230	10.8	50.5	3
11:12	GST 111250	11.6	35.4	3	GST 111250	16.7	68.8	3
13:13	GST 131300	13.0	50.3	7	GST 131300	9.0	48.5	2
15:11	GST 151130	11.	50.0	3	GST 151130	10.8	49.0	3
17:11	GST 171150	17.3	68.9	3	GST 171150	8.6	44.1	3
19:12	GST 191210	16.7	37.9	7	GST 191210	13.6	58.9	1
21:10	GST 211030	10.3	51.0	1	GST 211030	8.7	45.6	3
23:10	GST 231050	13.0	48.2	4	GST 231050	7.1	38.4	3
Avg		14.5	47.5	4		10.9	54.3	
StdDev		4.8	9.7	2		3.3	13.9	

Shaded blocks indicate which strategy has better formal errors.

7. Conclusions and Future Work

The results of the TEST strategy for the Intensives are very encouraging. The TEST strategy yields schedules which are more robust than the USNO Intensives. On average the UT1 formal errors are 30% better for the TEST sessions. In cases where the TEST formal errors are worse, changing a parameter of the TEST algorithm might compensate. Much of the improvement in the TEST schedules compared to USNO is due to scheduling more sources and better sky coverage.

RD1001 and RD1002 are two more sessions in this series, and we plan on requesting two more. In these new sessions the TEST and STND series will sample the parts of the sky they didn't in RD0907 through RD0910. This will allow us to directly compare the TEST and STND strategies.

2010 IVS General Meeting in Hobart, Tasmania, Australia

Email: karen.d.baver@nasa.gov;john.m.gipson@nasa.gov