



# DSN Network e-VLBI Calibration of Earth Orientation

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# Summary



- Background: TEMPO
  - JPL navigation drives requirement of UT1 knowledge
  - Current tape-based TEMPO meets NAV requirement (5 day latency with 1 cm UT1 uncertainty)
- e-VLBI TEMPO R&D tests
  - Wide-band VLBI Science Receiver (WVSR) digital recording
  - DSN T1-line (3Mbits/s) data transfer
  - Software correlation
  - Performed ~ 10 successful tests
  - UT1 calibration of 1.5 day latency, ~ 1.5 cm uncertainty
  - Test limitation
- Conclusion: performance to improve
  - Coming T3-line (45Mb/s)
  - Additional WVSR
  - Platform upgrade and software automation



# Background: TEMPO

- Earth Orientation UTPM
  - GPS constellation provides continuous polar motion tracking
  - VLBI remains the best method of calibrating UT1
  - Deep space network Goldstone-Madrid baseline suited for measuring UT1
  - JPL Time/Earth Motion Precision Observation (TEMPO) bi-weekly VLBI performed on this baseline
  - JPL deep space navigation drives requirement of real time UT1 knowledge (30 cm)
  - TEMPO designed to meet this requirement
  - TEMPO is tape-based



# Background: TEMPO

- Facts about current operational TEMPO
  - TEMPO accurately measures UT1, to  $\sim 1$  cm, at the time of calibration
  - But latency causes calibration to be less valuable
    - Tape transit time, total turnaround can be up to 5 days
    - UT1 real time knowledge error grows  $\sim 1$  cm / day
  - Latency is key to improve UT1 real time knowledge
    - Less accurate but quicker turnaround calibration can be better
  - Recent e-VLBI TEMPO test is designed to leverage existing Delta-e-VLBI (DDOR) infrastructure to obtain EOP data



# Background: UT1 Knowledge Error



- Current data latency enables  $\sim 5$  cm UT1 real time knowledge error (at time of delivery)
- Example: a 2 cm calibration accuracy with 1 day latency enables  $\sim 3$  cm UT1 real time knowledge error

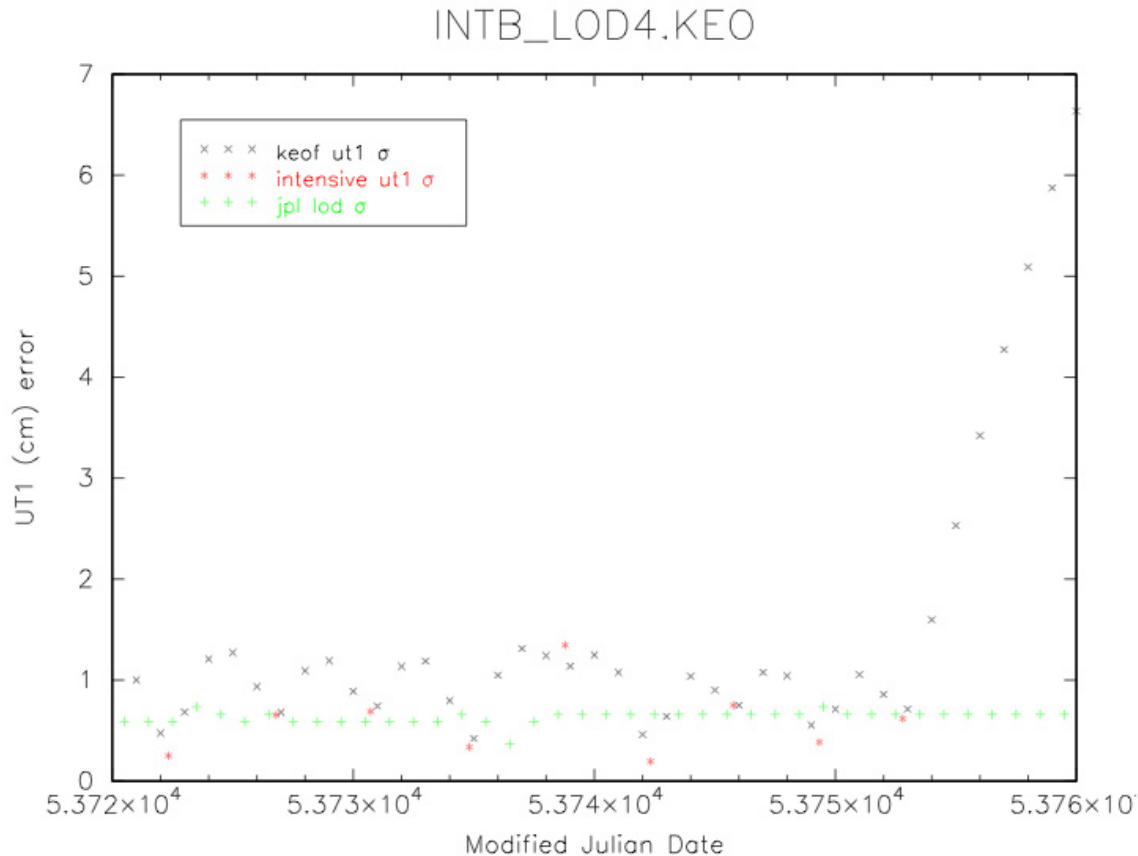


Figure: UT1 error predicted by Kalman Earth Orientation Filter (KEOF). The error grows approximately  $\sim 1$  cm per day. At 5 day latency, the knowledge error is  $\sim 5$  cm. (Courtesy of Richard Gross)



# e-VLBI: WVSR TEMPO Overview

- Observation sequence design
  - Similar or shorter than TEMPO
- Digital Recording Instrument
  - JPL VLBI Science Receiver (VSR)
  - VSR bandwidth < 100 MHz
  - Wide-band VSR (WVSR) bandwidth ~ 400 MHz
  - VSR for S-band, WVSR for X-band recording
- DSN T1-line (3Mbits/s) data transfer
- Software correlation on simple Solaris platform (4 processors)
- Fringe fitting (standard JPL 'Fit' code)
- MODEST analysis
- Obtain 2-component UTPM calibration
- Use an equivalent UT1 measurement error  $\sigma$  as performance metric



# e-VLBI: WVSR TEMPO Turnaround

- WVSR TEMPO R&D test turnaround time

Number of Scans	Experiment Duration (h)	T1 Data Transfer (h)	4-Processor Parallel Processing (h)	Fringe Fit & MODEST (h)	Total Turnaround (day)
20 - 30	3	~ 20	< 10	< 3	< 1.5
40 - 50	4 - 5	~ 36	< 17	< 3	~ 2.5



# e-VLBI: WWSR TEMPO R&D Tests

- List of WWSR TEMPO tests recently performed

Exp Type	Exp Date	# of Scans	UT1 Meas. Error (cm)
WWSR TEMPO	06-057	19	1.37
TEMPO piggyback	06-072	24	1.05
TEMPO piggyback	06-106	25	1.15
WWSR TEMPO	06-162	23	1.87
WWSR TEMPO	06-174	26	1.70
WWSR TEMPO	06-177	43	1.21
WWSR TEMPO	06-180	44	1.05
WWSR TEMPO	06-181	50	1.11
WWSR TEMPO	06-193	28	1.33
WWSR TEMPO	06-234	44	1.37





# WVSR TEMPO Test Conclusion

- R&D Test Initial Conclusion
  - 20 - 30 scan observation
  - 1.5 day latency (T1 line)
  - UT1 measurement error - 1.52 cm (uncertainty  $\sim 1/\sqrt{\text{\# of scans}}$ )
- Compare tape TEMPO: WVSR TEMPO accuracy slightly degraded  $\sim 20\%$ , cause:
  - VSR S-band bandwidth limitation - 25 MHz, etc.
- But: e-VLBI has much quicker turnaround: 2 days vs. 5
- Performance WVSR-TEMPO better than tape-TEMPO
  - better meets NAV requirement with latency improvement



# Conclusion



- Current e-VLBI TEMPO limitation
  - DSN network transfer speed - 3 Mbits/s
  - VSR instrument bandwidth
  - # of processors for software correlation
  - Processing is not automated
- Coming improvements
  - DSN T3 line installed - 45 Mbits/s
  - Additional WVSR to be installed
  - Platform enhancement
    - (Beowolf cluster bought, can add # of processors)
  - Software automation planned
- Future Prospect
  - Expect 1 cm accuracy and < 1 day turnaround