JPL VLBI Analysis Center Report for 2013

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Abstract This report describes the activities of the JPL VLBI Analysis Center for the year 2013. Highlights for the year include the start of operations for the combined NASA-ESA Ka-band network, installation of our Digital Back Ends enabling 1024–2048 Mbps operations, and our first installation of a Ka-band phase calibrator. We continue to support VLBI-based navigation using our combined spacecraft, celestial reference frame, terrestrial reference frame, earth orientation, and planetary ephemeris VLBI systems.

1 General Information

The Jet Propulsion Laboratory (JPL) Analysis Center is in Pasadena, California. Like the rest of JPL, the center is operated by the California Institute of Technology under contract to NASA. JPL has done VLBI analysis since about 1970. We focus on spacecraft navigation, including:

1. Celestial Reference Frame (CRF) and Terrestrial Reference Frame (TRF), which are efforts that provide infrastructure to support spacecraft navigation and Earth orientation measurements.
2. Time and Earth Motion Precision Observations (TEMPO), which measures Earth orientation parameters based on single baseline semi-monthly measurements. These VLBI measurements are then combined with daily GPS measurements as well as other sources of Earth orientation information. The combined product provides Earth orientation for spacecraft navigation.
3. Delta differenced one-way range (ΔDOR), which is a differential VLBI technique that measures the angle between a spacecraft and an angularly nearby extragalactic radio source. This technique thus complements the radial information from spacecraft doppler and range measurements by providing plane-of-sky information for the spacecraft trajectory.

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2 Technical Capabilities

The JPL Analysis Center acquires its own data and supplements it with data from other centers. The data we acquire are taken using NASA's Deep Space Network (DSN).

1. Antennas: Most of our work uses 34-m antennas located near Goldstone (California, USA), Madrid (Spain), and Tidbinbilla (Australia). These include the following Deep Space Stations (DSS): the "High Efficiency" subnet comprised of DSS 15, DSS 45, and DSS 65 which has been the most often used set of JPL antennas for VLBI. More recently, we have been using the DSN's beam waveguide (BWG) antennas: DSS 13, DSS 24, DSS 25, DSS 26, DSS 34, DSS 54, and DSS 55. Less frequent use is made of the DSN's 70-m network (DSS 14, DSS 43, and DSS 63). Typical X-band system temperatures are 35K on the HEF antennas. The 70-m and BWGs are about 20K. Antenna efficiencies are typically well above 50% at X-band.

2. Data acquisition: We use ROACH-based Digital Back Ends with Mark 5C VLBI recorders. These units are now in the field and are expected to become fully operational in 2014. In addition, we have JPL-unique systems called the VLBI Science Recorder (VSR) and the Wideband VSRs (WVSR) which have digital baseband converters and record directly to hard disk. The data are later transferred via network to JPL for processing with our software correlator.
3. Correlators: The JPL VLBI Correlator has been exclusively based on the SOFTC software which handles the ΔDOR, TEMPO, and CRF correlations as well as tests of antenna arraying.
4. Solution types: We run several different types of solutions. For ΔDOR spacecraft tracking we make narrow field ($\approx 10^\circ$) differential solutions. The TEMPO solutions typically have a highly constrained terrestrial (TRF) and celestial frame (CRF) as a foundation for estimating Earth orientation parameters. These reference frames are produced from global solutions which then provide the framework needed for use by TEMPO and ΔDOR.

3 Staff

Our staff are listed below along with areas of concentration. Note that not all of the staff listed work on VLBI exclusively as our group is involved in a number of projects in addition to VLBI.

- Durgadas Bagri: TEMPO and Ka-band phase calibrators.
- James Border: ΔDOR spacecraft tracking.
- Cristina García-Miró: Madrid data acquisition, NASA-ESA southern declination collaboration, and educational outreach.
- Shinji Horiuchi: Canberra data acquisition and NASA-ESA southern declination collaboration.
- Chris Jacobs: NASA-ESA southern declination collaboration, X/Ka CRF, TRF, and S/X CRF.
- Christina King: source stability studies.
- Peter Kroger: ΔDOR spacecraft tracking.
- Gabor Lanyi: MODEST, Fringe fitting and correlation support, ΔDOR, and TRF.
- Steve Lowe: Software correlator, fringe fitting software, and ΔDOR.
- Walid Majid: pulsars, ΔDOR, and VLBA phase referencing.
- Chuck Naudet: NASA-ESA southern declination collaboration and source stability studies.
- Andres Romero-Wolf: ΔDOR, CRF and TRF. MODEST scripts. Source stability studies.
- Lawrence Snedeker: Goldstone data acquisition. NASA-ESA southern declination collaboration.
- Ojars Sovers: S/X, and X/Ka CRFs and TRF. Maintains MODEST analysis code.
- Alan Steppe: TEMPO and TRF.

4 Current Status and Activities

The TEMPO task's EOP measurements continue. Our S/X CRF work is being downsized in favor of X/Ka-band (8.4/32 GHz) CRF which continues to make major strides forward. In particular, in 2013, ESA's Malargüe, Argentina antenna became a regular part of our Ka-band network adding much needed southern coverage, and DSN operations moved to 1024 to 2048 Mbps.

VLBI spacecraft tracking continues to provide measurements of angular position in support of mission navigation and planetary ephemeris development. The New Horizons trajectory toward Pluto was verified with a series of Delta-DOR measurements in June-August 2013. Delta-DOR data were used to assure the Earth-flyby targeting for Juno in October 2013. Dawn is being supported with Delta-DOR during its low thrust cruise from Vesta to Ceres. Monthly Delta-DOR measurements of MRO and Mars Odyssey continue to improve the ephemeris of Mars. Delta-DOR measurements have begun on both the NASA mission Maven and the ISRO mission MOM to support navigation during their cruise to Mars.

5 Future Plans

In 2014, we hope to improve our VLBI system by making our Digital Back End, the DVP, compatible with the JIVE and DiFX correlators, thereby enabling broader calibrations. We hope to deploy operational Ka-band phase calibrators at our overseas sites. We expect the combined NASA-ESA deep space network to reach sub-nanoradian (200 μas) Ka-band CRF results over the south polar cap ($-90^\circ < \delta < -45^\circ$). On the spacecraft front, we plan to continue supporting a number of operational missions while further improving techniques for using VLBI for spacecraft tracking.

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