Title: Early Mission Orbit Determination Error Analysis Results for Low-Earth Orbiting Missions using TDRSS Differenced One-Way Doppler Tracking Data

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Condensed Abstract:

Differencing multiple, simultaneous Tracking and Data Relay Satellite System (TDRSS) one-way Doppler passes can yield metric tracking data usable for orbit determination for (low-cost) spacecraft which do not have TDRSS transponders or local oscillators stable enough to allow the one-way TDRSS Doppler tracking data to be used for early mission orbit determination. Orbit determination error analysis results are provided for low Earth orbiting spacecraft for various early mission tracking scenarios.

Extended Abstract:

Differencing multiple, simultaneous Tracking and Data Relay Satellite System (TDRSS) one-way Doppler passes can yield metric tracking data usable for orbit determination for (low-cost) spacecraft which do not have TDRSS transponders or local oscillators stable enough to allow the one-way TDRSS Doppler tracking data to be used for early mission orbit determination. The paper "Tracking and Data Relay Satellite System (TDRSS) Support of User Spacecraft Without TDRSS Transponders" (AAS 95-443, Michael Maher, Greg Marr, and James Jackson) proposed the use of TDRSS to provide telemetry, tracking, and command support of spacecraft without TDRSS transponders which had not previously been considered candidates for TDRSS support. The paper documented early mission orbit determination results for the NOAA-J mission using TDRSS differenced one-way Doppler tracking data but did not include orbit determination error analysis results.

Using the NASA Goddard Space Flight Center's Orbit Determination Error Analysis System (ODEAS), orbit determination error analysis results are presented for early mission orbit determination for the low inclination low Earth orbiting Galaxy Evolution Explorer (GALEX) spacecraft to be launched from Cape Canaveral Air Force Station by a Pegasus launch vehicle. A nominal GALEX separation state vector with a semi major axis of 7069 km and an inclination of 29 degrees was used for this analysis. The analysis assumed three geostationary Tracking and Data Relay Satellites (TDRS's) would be available to support GALEX (TDRS-6 at 47.0 degrees West longitude, TDRS-7 at 171.0 degrees West longitude, and TDRS-3 at 275.0 degrees West longitude). Three tracking scenarios were analyzed for Galex using short arcs of TDRSS differenced one-way Doppler (DOWD) of different overall durations and pass lengths to obtain an initial orbit solution. Consistent with the UARS and NOAA-J TDRSS differenced one-way Doppler tracking data analyzed in AAS 95-443, a noise value of value of 0.03 Hz and a bias of zero were used in this analysis. The GALEX scenarios analyzed are summarized in Table 1.

Table 1, GALEX Early Mission Orbit Determination Error Analysis Scenarios

Scenario Number	Number of TDRSS DOWD Passes	Pass Durations (Minutes)	Tracking Arc (Minutes from Separation)
1	2	23, 32	12-74
2	3	23, 32, 15	12-137
3	3	5, 5, 5	12-127

Scenario three is a reduced tracking scenario which demonstrates the results that can be obtained in an environment with tight scheduling constraints where passes might be scheduled on a non-interference basis. A summary of selected GALEX early mission OD error analysis results obtained in the analysis of scenarios one, two and three follows in Table 2.

Table 2, GALEX Early Mission Orbit Determination Error Analysis Results (3 Sigma)

Scenario Number	Predicted OD Position Error (Separation+12 hours)	Predicted OD Position Error (Separation+24 hours)
1	896 meters	1887 meters
2	163 meters	466 meters
3	1012 meters	2595 meters

The analysis indicated convergence (in batch mode) would be expected for all three of the early mission GALEX scenarios above. All three scenarios result in orbit solutions with sufficient accuracy to allow continued acquisition by TDRSS or ground stations for a period of more than 24 hours. Early mission orbit solutions could be used to update the state vector used by the ground stations to acquire the satellite allowing for continued acquisition during the critical early mission phase. Longer arcs of TDRSS differenced one-way Doppler produce better early mission orbit determination results for a given pass duration, and additional results using longer arcs will be included in the paper.

Early mission orbit determination error analysis results for a high inclination low Earth orbiting spacecraft with a launch from the Western Range (WR) will also be presented in the paper. However, the scenario three results demonstrated the viability of a solution with short pass durations.

TDRSS differenced one-way Doppler tracking data allows high quality tracking data to be obtained for inexpensive user spacecraft with S-band transmitters. This tracking data can be used to obtain critical early mission orbit determination solutions. The use of ODEAS allows the TDRSS tracking schedule to be refined to avoid wasting TDRSS resources or to confirm that a given tracking schedule constructed on a non-interference basis would be expected to be sufficient (or insufficient) to obtain early mission orbit determination solutions at specific epochs.