Resolution of Orbit Determination Prediction Instabilities at Titan During Cassini's Solstice Mission

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The Cassini-Huygens mission launched in 1997 and the Cassini spacecraft has been in orbit about Saturn since 2004. Exploration of the Saturn system is driven by gravitational flybys of the moon Titan which alter the spacecraft trajectory. The Cassini Navigation Team receives regular updates to the Saturn satellites ephemeris from JPL's Solar System Dynamics group. The difference between subsequent ephemeris deliveries can be hundreds of meters in the position of Titan at the time of a flyby. Errors in Titan's position propagate downstream to the next flyby through the estimated spacecraft trajectory. Prior to 2013, the Cassini Orbit Determination Team estimated the Saturn satellite ephemeris parameters and used the a posteriori states and covariance as a priori inputs to subsequent estimation arcs. Since 2013, the OD Team has only been considering errors in the ephemeris and not estimating a correction to the satellite positions. During the Solstice Mission, the average 3D miss distance at Titan is 0.95 km [1], with many flybys achieving 3D miss distances of less than five hundred meters. However, the T119 Titan flyby exhibited a 3D miss distance of 2.44 km compared to the last control point, shown in Figure 1, at the 5.8σ level. The following T120 flyby yielded a smaller miss of 0.82 km at the 5.7σ error level. These discrepancies between pre-flyby prediction and post-flyby trajectory reconstruction were due to errors in the Titan ephemeris. In order to improve the targeting of Titan in future flybys, the team restarted the satellite ephemeris estimation process for orbit determination solutions. Subsequent flybys had target misses of less than 1 km at the sub-3σ error level. This paper describes the method of scaling the a priori satellite ephemeris covariance in the orbit determination process to allow larger corrections to the system and improve the prediction of Titan's position at the time of spacecraft flybys. The navigation filter also corrects the satellite system GMs as well as the Saturn pole and zonal spherical harmonics to degree eight. Results are shown in terms of filter solutions and trajectory errors mapped to the B-plane at the encounter time.

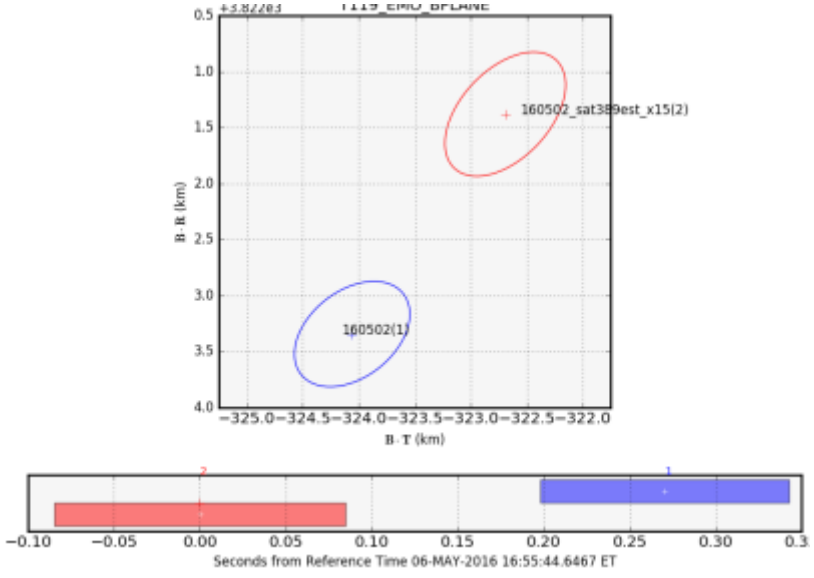

Fig. 1. B-plane differences in T119 Encounter for considering (blue) and estimating (red) satellite ephemeris errors

References

[1] J. Bellerose, S. Nandi, et al. "Cassini Navigation: The Road to Consistent Sub-Kilometer Accuracy Satellite Encounters." AAS 16-142 Breckenridge, Colorado, February 2016.