Shadow Navigation Support at JPL for the Rosetta Landing on Comet 67P/Churyumov-Gerasimenko

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On September 30, 2016, the Rosetta spacecraft ended its 12-year mission when it landed on the surface of comet 67P/Churyumov-Gerasimenko (C-G). For the preceding 26 months, the spacecraft had characterized the environment of C-G in unprecedented detail from a series of orbits and other nearby trajectories. Throughout the mission, the primary navigation responsibility for the mission was handled by the ESA Flight Dynamics team at the European Space Operations Center (ESOC-FD) in Darmstadt, Germany. In order to maximize the probability of a successful landing, ESOC-FD invited a team from the Jet Propulsion Laboratory (JPL) in Pasadena, California, USA to provide independent navigation solutions during the last two months of the mission. We will describe the experiences and results from this JPL "shadow navigation" team.

The JPL support team had two main functions: optical navigation (OpNav) and orbit determination (OD). The OpNav team created an independent topographic map of C-G and identified landmarks on that topographic map in imagery from the spacecraft. The OD team modelled the dynamical environment around C-G, estimated the parameters of that model, and predicted the future trajectory of the spacecraft. Though the OpNav and OD teams had distinct responsibilities, their activities were mutually dependent. The interface and work flow between these two teams will be presented.

JPL provided a similar support task in 2014, starting at Rosetta's initial approach to C-G and ending with the release of the Philae lander [1,2]. That experience was invaluable, as it allowed us to prepare to support this extremely complex navigation challenge in a short period of time. The first step in the preparation for our 2016 support was to update the 2014 topographic model of the comet based on some of the images that had been collected since then. This turned out to be more challenging than expected because the rotation rate of the comet was changing over time. Our next major activity was to revitalize and improve the OD models and configuration based on lessons learned from 2014. Some of our improvements were technical (e.g., we included a topography model scale factor in the filter) and others were process oriented (e.g., we implemented an automated system to process the data deliveries from ESOC).

We began delivering OD solutions for the consideration of the ESOC team on August 4, about 2 months before the landing. For most the remaining mission, Rosetta was in a 3-day eccentric orbit with a beta angle of about 70 deg. Over time, the radius at periapsis (which was always above the lit side of the comet) decreased steadily from about 7.5 to 4.1 km (C-G's maximum radius is about 2 km). As the periapsis altitude decreased, the effects of the very non-spherical gravity of C-G became increasingly pronounced. Initially this was very challenging for OD, but as data was accrued it allowed us to solve for the gravity field of C-G up to 5th order with reasonable accuracy, significantly improved our trajectory predictions. We will present our estimated values of the various parameters of the C-G environment, including gravity, rotation rate, and spin pole.

The most critical support provided by the JPL team was on the final approach to the landing. Fortunately, all activities leading up to the landing went nominally and the touchdown location was very close to the targeted location. The final trajectory predictions of the ESOC and JPL teams differed by less than 20 m and by a comparable amount relative to the actual landing site (analysis pending). The end of the Rosetta mission was an unqualified success, and we were very happy to play a minor role in such a historic achievement.

References

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