NAVIGATION CHALLENGES IN THE MAVEN SCIENCE PHASE

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ABSTRACT

The Mars Atmosphere and Volatile EvolutioN Mission (MAVEN) is a future NASA Mars orbiting spacecraft. The mission is managed by Goddard Space Flight Center (GSFC), with Lockheed Martin (LM) building the spacecraft and the Jet Propulsion Laboratory (JPL) performing the navigation. At first glance, the navigation might appear to be standard compared to the previous Mars orbiters. However, there are several unique features of the mission design which make navigation particularly challenging in the science phase. This paper describes the science phase navigation requirements, the differences between this orbiter and previous NASA Mars orbiters and the resulting challenges.

MAVEN will explore the planet’s upper atmosphere, ionosphere and interactions with the sun and solar wind. It will launch in November of 2013 and will be in the science phase in late October 2014. The primary science phase will last one (Earth) year, during which the spacecraft will be in an elliptical 4.5 hour orbit at an inclination of 75 degrees. The 75 degree inclination results in the orbit periapsis oscillating between ±80 degrees latitude, thus naturally covering most Mars latitudes during the primary mission. The orbit will be controlled via maneuvers so that the maximum orbit density remains in one of two density corridors. The nominal corridor is 0.05 kg/km^3 to 0.15 kg/km^3. This results in a periapsis altitude around 160 km. However, the altitude will vary significantly based on the latitude, Mars season and actual atmosphere behavior observed. Five times during the science phase, MAVEN will maneuver to a higher density corridor (2 kg/km^3 to 3.5 kg/km^3) to perform science for five days.

The MAVEN primary science phase may be described as a light aerobraking phase. Thus the Mars atmosphere will impart a significant drag **Δ**V perturbation on each spacecraft orbit. The DSN coverage for MAVEN, in terms of the Navigation 2-way Doppler data, will be approximately 5 hours per day. This is minimal compared to the continuous coverage standard for aerobraking phases of Mars missions (MGS, ODY, MRO). In fact, MAVEN's DSN coverage will be significantly less than that for the higher orbits of the MGS, ODY and MRO primary science phases. This will result in significantly reduced accuracies in the reconstructed trajectories. However, they are acceptable for the suite of science experiments on the MAVEN spacecraft. The biggest challenge is to meet the accuracy requirements on the predicted trajectories.

A typical aerobraking phase has relatively loose accuracy requirements: its purpose is to change the spacecraft orbit, not to support science. The requirement is expressed in terms of a loose error in a single direction – the orbit down-track direction, or orbit timing. This is good since the large atmosphere uncertainties will quickly degrade any predict. On the other hand, the purpose of the MAVEN "light aerobraking" orbit is to support science. Thus it has much more stringent accuracy requirements – and for all six components of the spacecraft state. On MAVEN the state accuracy requirements are specified in terms of the six orbital elements. The error on five of the orbital elements do not grow rapidly: they can be met over a 9 day period (2.5 days during the deep-dips). The accuracy of the sixth orbital element, mean anomaly or orbit timing, will degrade quickly. Once a predicted ephemeris is uploaded on the spacecraft, the LM Periapse Timing Estimator algorithm, along with the underlying design of the sequence, will allow this sixth orbital element error to be controlled to within 20 seconds. The need to upload the predicted ephemeris within a 20 second timing error, along with the limited DSN schedule and operations teams processes, determines the required timelines for predict deliveries to the project. The limited DSN schedule means that MAVEN is much more susceptible to sporadic DSN problems. Thus contingency processes will be much more important on MAVEN. The contingency processes are driven by both the 20 second requirement and the accuracy requirements on the other five orbital elements. Furthermore, it will be difficult to derive quality models for the predicted trajectories since only limited recent information can be derived from the limited DSN Doppler data.

In summary, MAVEN is another Mars orbiter, but will have unique navigation challenges as a result of its primary science phase being in a light aerobraking type orbit with limited DSN tracking.