Trajectory Options for a Mars Mission Combining Orbiting Science, Relay and a Sample Return Rendezvous Demonstration

Joseph R. Guinn[(1)], Stuart J. Kerridge[(2)], and Roby S. Wilson[(3)]
[(1)]*Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109*
818-354-0425, Joseph.R.Guinn@jpl.nasa.gov
[(2)]*Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109*
818-354-0899, Stuart.J.Kerridge@jpl.nasa.gov
[(3)]*Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109*
818-393-5301, Roby.S.Wilson@jpl.nasa.gov

Keywords: *Mars, Sample Return, Relay Orbit, Surface Operations*

ABSTRACT

The progression of Mars Sample Return mission architectures has converged on a multiple mission concept that retires risky elements through early demonstrations and relies on both orbiters and landers to ultimately return samples that maximize science objectives. With missions such as the Mars Exploration Rovers, Phoenix and the Mars Science Laboratory, safe landing and sample collection are considered proven elements, while, demonstration are still needed for launch to low Mars orbit and Orbiting Sample Detection, Rendezvous And Capture (OSDRAC).

Ideally, all elements would be verified prior to the first sample return campaign. Looking forward to the 2018 Earth to Mars opportunity, combining an OSDRAC demonstration with an orbiting science mission would be a cost effective way to retire that element. In addition, the orbiter can serve as an *in-situ* communications relay for surface assets. Trajectory options are presented in this paper to accomplish the combination of these functions in a single mission.

NASA recently decided to cancel participation in the ExoMars/Trace Gas Orbiter (TGO) mission with the European Space Agency (ESA). The mission was to launch in January 2016 and take approximately 9 months to travel to Mars. The TGO spacecraft would then do an orbit insertion burn to capture into a 4 Martian day (sol) orbit followed by a series of maneuvers to target the desired inclination and reduce the apoapsis to a 1 sol orbit. The spacecraft would spend the next 6 to 9 months aerobraking to further reduce the orbit altitude. The end of aerobraking would conclude with a series of maneuvers that target the desired science orbit.

The initial requirements for the TGO mission described the science orbit as circular with a 400 km altitude and 74 degree inclination. This orbit is compatible with performing an OSDRAC demonstration. The 74 degree inclination orbit would not impose a severe propellant penalty for the launch element of the future sample return campaign and possibly be preferable since it may enable a wider span of Earth return trajectory options. This science orbit would also provide significant surface coverage as a relay asset.

To optimize communications relay capabilities for surface assets, there exists a family of low inclination orbit options that are optimal for tactical surface operations cadence used by the

MER, Phoenix and MSL missions. For 2018, following Mars Orbit Insertion, the orbiter can be placed temporarily in one of these optimal relay orbits or possibly deploy a dedicated cubesat to extend the overall Mars relay infrastructure.

Recent Mars lander surface operations use a morning relay orbiter pass to receive instructions for the upcoming sol's activities. In the afternoon another relay pass is used to transmit science and engineering data collected before configuring the lander into a low power or sleep mode for the night. There exist families of relay orbits that maintain regular morning and afternoon overflight geometries. They are derived by matching the sum of the line of apsides and nodal rates to the planets orbital rate around the sun. By selecting an orbital period that is an integer fraction of the planets spin rate the periapsis locations remains fixed over any selected meridian. Designing the periapsis to be over the lander at noon minimizes the slant range of the combined AM and PM passes. Figure 1. shows one such orbit with a period of 1/3 of a sol, inclined 15 degrees and a periapsis altitude of about 1000 km. The combination of repeating AM/PM pass times, long durations at relatively short slant ranges (<8000 km) provides for regular high data volume relay opportunities.

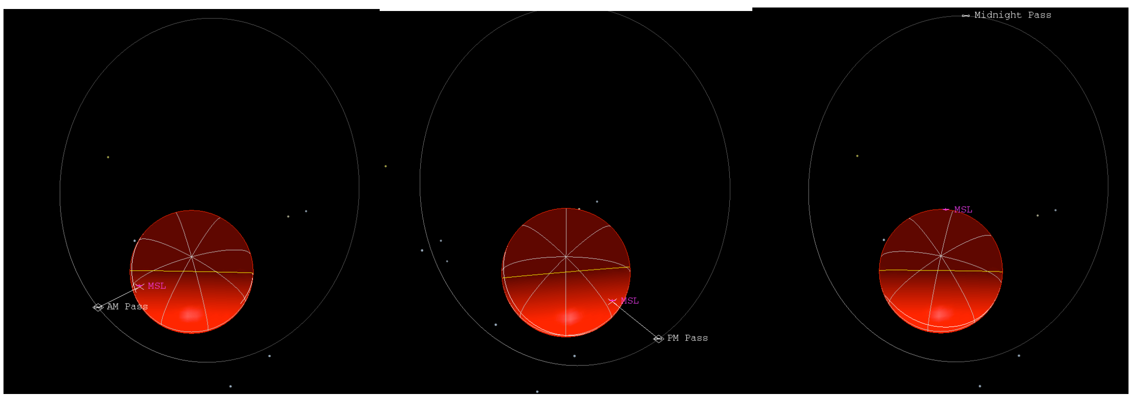

Figure 1 – Optimal relay orbit for near equatorial surface operations

Combining science, communications relay and orbiting sample detection, rendezvous and capture into a single mission provides a cost effective way to continue high priority science recommended by the National Research Council's recommendations set forth in the recent decadal survey for planetary missions.