



## **COORDINATION OF MARS ORBITING ASSETS TO SUPPORT ENTRY, DESCENT, & LANDING (EDL) ACTIVITIES**

**Joseph Neelon (CA)<sup>1</sup>, Mark Wallace<sup>2</sup>, and Lynn Craig<sup>1</sup>**

<sup>1</sup> Jet Propulsion Laboratory  
California Institute of Technology  
4800 Oak Grove Drive  
Pasadena, CA 91109

<sup>2</sup> University of Texas at Austin  
1 University Station  
Austin, TX 78712

[Joseph.G.Neelon@jpl.nasa.gov](mailto:Joseph.G.Neelon@jpl.nasa.gov)  
(818) 354 – 9571  
(818) 393 – 6388 (fax)

[Lynn.E.Craig@jpl.nasa.gov](mailto:Lynn.E.Craig@jpl.nasa.gov)  
(818) 354 – 4642  
(818) 393 – 9900 (fax)

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# Coordination of Mars Orbiting Assets to Support Entry, Descent, & Landing (EDL) Activities

Joseph Neelon<sup>†</sup>, Mark Mallace<sup>‡</sup>, and Lynn Craig<sup>§</sup>

NASA policy requires continuous telecommunications with missions during the execution of their critical events, which implies constraints on where missions to other planets may land or inject into orbit. JPL is working to establish a telecommunications network at Mars to provide contact with inbound missions to Mars and assets that have landed on the Martian surface, thus reducing the constraints on where critical events may be performed. Coordination of network assets is required to cover an inbound mission's critical event, such as EDL. This paper describes the development of a tool to evaluate EDL coverage capability of Mars network assets over a specified launch date/arrival date space.

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<sup>†</sup> Mission Planner/Engineer, Jet Propulsion Laboratory

<sup>‡</sup> Graduate Student, University of Texas at Austin

<sup>§</sup> Mission Design Engineer, Jet Propulsion Laboratory

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Joseph Neelon<sup>†</sup>, Mark Mallace<sup>‡</sup>, and Lynn Craig<sup>§</sup>

NASA has established a policy for continuous telecommunications with missions during the execution of their critical events, such as entry, descent, and landing (EDL) or orbit insertion (OI). This policy was implemented to provide a source of information for future missions or for analysis of mission anomalies. Up to the current time, only Earth-based telecommunication assets have handled contact during critical events. Using only these Earth-based assets, the policy implies constraints on where missions to other planets may land or inject into orbit.

JPL has been working to establish a telecommunications network at Mars. This network will consist of several orbiters, including Mars Odyssey (ODY), the Mars Reconnaissance Orbiter (MRO), and the Mars Telecomm Orbiter (MTO). These satellites will provide contact with inbound missions to Mars and assets that have landed on the Martian surface. This capability reduces the constraints on where critical events (EDL or MOI) may be performed, but there are other considerations. For instance, a network asset has to be correctly phased within its orbit to be in position to cover the new mission's critical event.

Over the past several months, the Mars Scout missions and the Mars Science Laboratory (MSL) have expressed interest in the EDL coverage capabilities of the Mars network. However, there were no pre-defined arrival dates or landing sites provided for performing this analysis: Scout missions do not want to provide mission details because they are competed projects; and MSL does not intend to select a landing site until one year before launch. For this reason, a more global approach was taken to evaluate the network's capability to cover EDL.

A tool is being developed to evaluate EDL coverage capability of a given orbiter over a specified launch date/arrival date (LD/AD) space. This tool identifies the LD/AD

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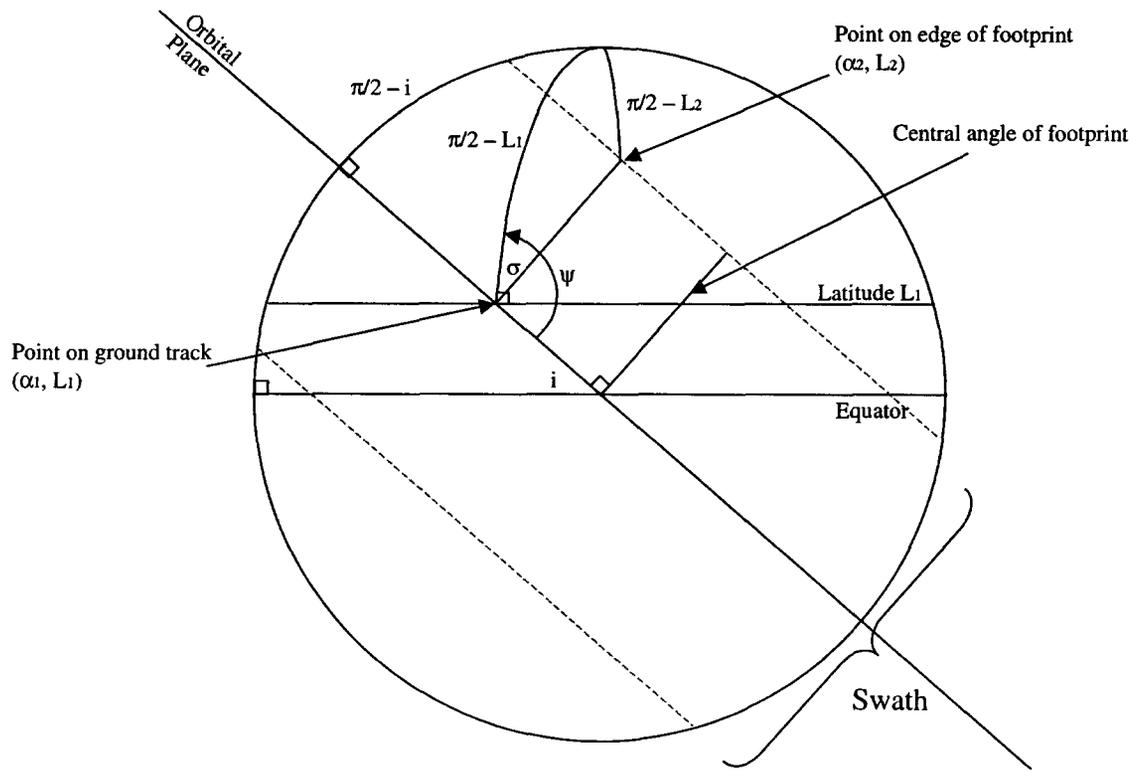
<sup>†</sup> Mission Planner/Engineer, Jet Propulsion Laboratory

<sup>‡</sup> Graduate Student, University of Texas at Austin

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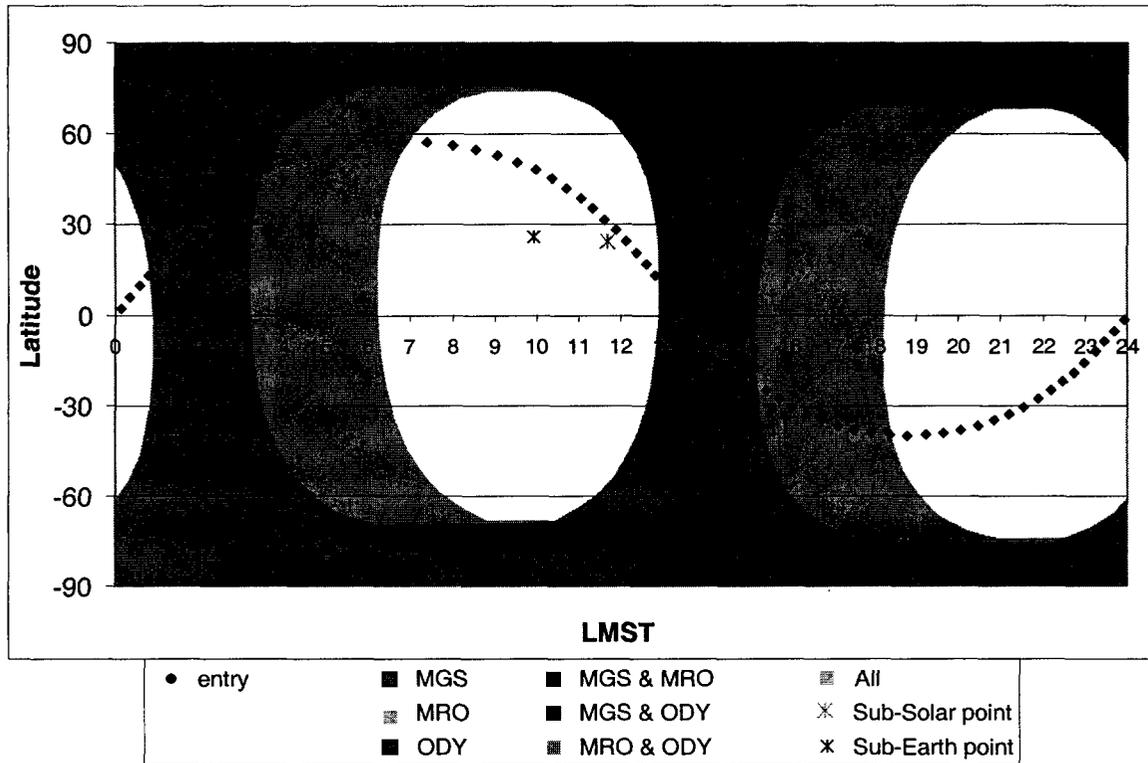
combinations for which the orbiter is capable of covering the lander's EDL and the range of true anomalies the orbiter must be within to provide this coverage.

The first step in developing the tool was to identify the areas of the Martian surface that could be seen by individual satellites in the Mars network. The space used for identifying the visible region is not the latitude/longitude space, but the latitude/local mean solar time (LMST) space. This coordinate space was selected due to the characteristic geometry of EDL; for a given LD/AD combination, a lander can only arrive in a specific range of latitude and LMST based on the approach  $V_{\infty}$  vector and flight path angle (FPA). The initial set of satellites that were evaluated for their surface coverage consisted of the Mars Global Surveyor (MGS), ODY, and MRO. They are all low-altitude, near-circular, Sun-synchronous orbiters that actively control their nodal crossing times to specific LMST values. For this reason, the region of coverage in latitude/LMST space for each satellite is relatively unchanged over time; a single analysis of each orbiter produces a region of coverage that can be used for the lifetime of that mission. The region of coverage is based on the orbital elements of the orbiter and the elevation mask being assumed for the lander. To produce the region, the size of the visibility footprint is calculated over the full range of true anomalies; the size of the footprint is defined as the angle between the center and edge of the footprint as seen from the center of Mars. Using spherical trigonometry, the edges of the region of coverage are identified by calculating points on a normal to the ground track at a distance equal to the footprint size for each point on the ground track. Figure 1 shows a sample of the swath geometry for a circular orbit (central angle of the footprint is constant throughout the orbit).



**Figure 1.** Geometry of Orbiter Swath as seen from Line of Nodes

With the region of coverage identified, the next step is to identify the LD/AD combinations when the landing point can be seen. For a given LD/AD combination and assuming values for FPA and descent angle, loci of entry and landing points are calculated. The locus of landing points is directly compared with a satellite's region of coverage to see what portion of the locus, if any, can be visible to the satellite. Figure 2 shows an example of this comparison for LD/AD of 23 Sept 2007/29 July 2008 using the MGS, ODY, and MRO satellites with a 10-degree elevation mask. Comparing this LD/AD locus with MGS's region of coverage (green, brown, and gray areas), AM landing points between 13N and 48N latitude and PM landing points between 13N and 22S latitude can be visible to MGS. The tool looks at only one latitude for the landing point, specified by user inputs. The landing point-to-region of coverage comparison is automated by inputting a table of the LMST edges of the region by latitude for the specified orbiter. This comparison is used to filter out LD/AD combinations that do not produce a visible landing point from the rest of the analysis, thus reducing run time.



**Figure 2.** Comparison of Landing Locus with Regions of Coverage

For each LD/AD combination where the landing point is visible, the orbiter must be evaluated to find the range of true anomaly for which the entry and landing points are visible at the respective times of each event. Starting from periapsis, the tool locates the true anomaly where the entry point first comes into view. Propagating the orbit forward to the time of landing, the tool evaluates if the landing point is also in view. If the landing point is not in view, the tool steps forward in starting true anomaly and repeats the process. When both points are in view at their respective times (Figure 3), the true anomaly value is saved as the beginning of the true anomaly range. The tool continues to step forward in starting true anomaly until either point is not in view at the appropriate time. The last successful true anomaly value is saved as the end of the true anomaly range. The process is repeated for each LD/AD combination that passed through the landing point filter.



**Figure 3.** Sample of Acceptable Geometry Using MRO and Possible MSL site

Enhancements are planned for simplifying the landing point filter, adding lander's antenna field of view for entry point visibility analysis, and implementing analysis of  $\Delta V$  required for worst case orbit rephasing.