

Mars Relay Spacecraft: A Low-cost Approach

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The next phase of Mars exploration will utilize numerous globally distributed, small, low-cost devices, including landers, penetrators, microrovers and balloons. Direct-to-Earth communications links, if required for these landers, will drive the lander design for two reasons: a) mass and complexity needed for a steerable high-gain antenna and b) power requirements for a high-power amplifier (i.e., solar panel and battery mass). Total mass of the direct link hardware for several recent small-lander designs exceeded the mass of the scientific payload.

Alternatively, if communications are via a Mars-orbiting relay spacecraft, resource requirements for the local UHF communication link are comparatively trivial: a simple whip antenna and less than 1 Watt power. Clearly, using a Mars relay spacecraft (MRS) is the preferred option if the MRS mission can be accomplished in an affordable and robust way.

Our paper describes a point design for such a mission launched in the 2001 or 2003 opportunity. We have asked the following question: What is the least-cost MRS mission design for relaying scientific data from stations on the Martian surface to Earth as well as for commanding these stations? Specifically, requirements for our MRS study were based on the latest International Mars Exploration Working Group (IMEWG) mission model for the post-2001 era. The assumed aggregate data return is 65 Mbit/sol total from six landers to be relayed in one 4-hour DSN contact using a 34-m subnet.

The mission design assumes the MRS is launched on a NASA small expendable launch vehicle to LEO parking orbit. A small spin-stabilized upper stage (Star-27) injects the spacecraft to the Mars transfer orbit. The injection capability of this configuration is 98 kg (to C3 = 10.2 kg²/m²). The spacecraft provides all propulsion after injection: trajectory corrections, Mars orbit insertion and orbit maintenance, and attitude control. The simple blowdown monopropellant hydrazine system has Δv capability of 1850 m/sec.

The spacecraft is spin-stabilized, with the high-gain antenna pointing towards Earth. The solar panel is behind an optically-transparent (mesh) antenna and is sized for continuous transmitter operation under the worst-case conditions. All of the highly-integrated electronics are contained in a single unit with the exception of RF hardware and attitude sensors. Attitude determination is performed with simple V-slit star and sun crossing sensors. A standard X-band small deep-space transponder (SDST) is used for DSN communications and UHF transceiver is used for the in-situ communications at 400 MHz. No antenna switching nor reconfiguration is required. The only active thermal control components are the hydrazine heaters. Estimated spacecraft dry mass is 42 kg with 20% margin. The power requirement is 23 W for spacecraft housekeeping and 17-40 W DC for high-power transmitter, depending on orbit geometry.

This MRS point design requires no post-launch deployments, has no moving parts, and its full functional redundancy and expendable budget is compatible with five year lifetime in Mars relay orbit. The estimated life-cycle cost of this mission is less than \$50M (including launch vehicle and mission operations).

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