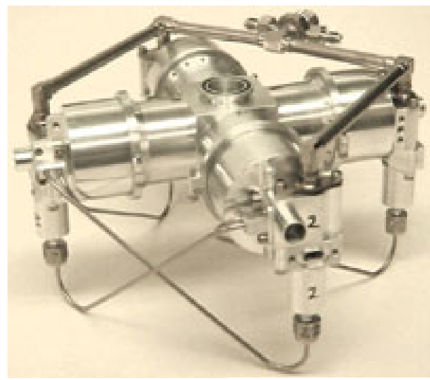
Base Technology > Low-Cost Mission Technologies

Task: Lightweight Leaktight Quad Pump for Mars Access

Description:



Enlarge

LLNL is developing and testing a lightweight propulsion component for low-cost Mars missions. A leaktight, reliable propellant pump will lead to small, high-performance propulsion stages. Potential applications include Mars ascent and descent, Earth return from Mars orbit, and possibly outbound trips to Mars using small spacecraft launched from Earth as secondary payloads.

Mars Sample Return (MSR) has been unaffordable, largely because existing rocket technology does not offer the straightforward development of a sufficiently small and practical Mars Ascent Vehicle (MAV).

Considering the requirement for a high velocity change (~4300 m/s) at significant acceleration (roughly Earth g), ascending from Mars to orbit is more technically challenging than any propulsive maneuver achieved to date except Earth launch. The latter is done using 100 ton vehicles, but low-cost MSR needs a 100-kg MAV. The total mass landed on Mars influences mission cost to the tune of a million dollars per kilogram, so potentially hundreds of millions of dollars could be saved by a 100-kg MAV.

Launching from either Earth or Mars requires propulsion stages having a much higher propellant mass fraction (85-90%) and a much smaller inert fraction (10-15%) than spacecraft attain. Miniaturizing launch vehicle technology to the scale of 100 kg is therefore seen as a key step toward affordable MSR.

Earth-launch vehicles minimize hardware mass by using thin-walled low pressure tanks and compact high-pressure thrust chambers. Just a few percent of the propellant energy is used to drive high-performance pumps. This approach can be taken on a tiny scale also, but turbopumps as used on launch vehicles for high-pressure delivery cannot be scaled down without losing efficiency and sacrificing their power-to-weight ratio.

Reciprocating pumps developed and tested at LLNL in the past were sufficiently small and lightweight to meet the need for MAV's. However, the original LLNL piston pump of 1990-1994 was inefficient due to warm gas leakage. Circa 2001, liquid-cooled soft seals were shown to eliminate the warm gas leakage, but that first low-leakage implementation was heavier by 2-3 times relative to volume flow.

During 2004-2005, this Mars Technology Program task completed the design, fabrication, and initial testing of a lightweight, leaktight four-chamber piston pump. Performance was characterized better than for any previous version of the design, including measurements of the power-to-weight ratio, volumetric efficiency, and the quantity of high-pressure gas required to power the pump. The test pump was powered by both helium and decomposed nontoxic hydrogen peroxide (i.e. mostly steam), while pumping water to simplify iterative benchtop testing. Operating lifetime sufficient for Mars ascent was demonstrated with helium power at room temperature.

Testing at elevated temperatures exceeding 1000 F validated the liquid cooling scheme for the warm gas seals on the power pistons, and for the power cylinder wall and head end. However, it became evident that the gas intake-exhaust valves reach tempertures near that of the gas itself, which limited their reliability and operating cycle life. During 2006, several design iterations of the gas valves were tested, resulting in a vast improvement over the initial configuration. As funding was expended, the final outcome of this technology deveopment task was a demonstrated operating lifetime for the valves exceeding 3/4 of that needed for a conceptual Mars Ascent Vehicle.

Pending a future funding opportunity, follow-on work would test the pump with rocket propellants. Leaktight operation is expected to enable oxidizer pumps, as well as fuel pumps, to be powered efficiently by decomposed hydrazine. Based on test results to date, only 2 percent of the total propellant in a miniature rocket stage would be needed to power both the fuel and oxidizer pumps.

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