THE MARS GASHOPPER Robert Zubrin, Pioneer Astronautics, 11111 W. 8th Ave. unit A, Lakewood, CO 80215, zubrin@aol.com

The Mars Gas Hopper, or "gashopper" is a novel concept for propulsion of a robust Mars flight and surface exploration vehicle that utilizes indigenous CO_2 propellant to enable greatly enhanced mobility. The gashopper will first retrieve CO_2 gas from the Martian environment to store it in liquid form at a pressure of about 10 bar. When enough CO_2 is stored to make a substantial flight to another Mars site, a hot pellet bed is heated to ~1000 K and the CO_2 propellant is warmed to ~300 K to pressurize the tank to ~65 bar. A valve is then opened, allowing the liquid CO_2 to pass through the hot pellet bed that heats and gasifies the CO_2 for propulsion. Both ballistic hopper and winged gashopper airplanes are possible, with the former offering greater simplicity and the latter longer range. In the case of winged gashoppers, the hot gas would be piped to a set of thrusters beneath the aircraft, allowing vertical takeoff, after which the gas is shunted off to a primary rearward pointing thruster to generate forward flight speed. The hot gas system is also used for attitude control and main propulsion during landing.

After landing a microrover could be released for local exploration for a period of about a month, during which time the Gashopper would acquire more propellant to enable its next flight. The advantage of the Gashopper aircraft is that it provides Mars exploration with a fully controllable aerial reconnaissance vehicle that can repeatedly land and explore numerous widely separated surface sites as well.

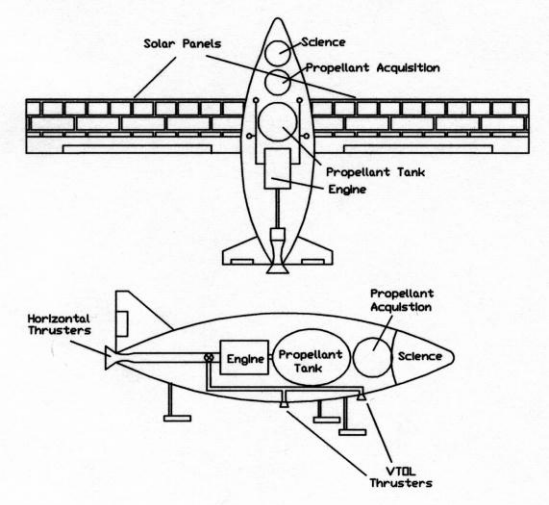

Fig. 1: The Mars gashopper airplane concept

This paper describes work accomplished on gashopper technology in several SBIR programs conducted at Pioneer Astronautics, and presents analysis of potential gashopper mission performance.

Fig. 2: Vertical hover Gashopper flight test

Fig. 3: Gashopper Airplane flight test

Work performed technical analysis on the overall gashopper propulsion system performance, trade studies on thermal bed materials, and design of a full scale gashopper aircraft relative to the size of a Mars vehicle. Analysis showed that practical gashopper airplanes can be built capable of flights of over 100 km per hop on Mars. Phase I demonstrations included successful engine tests to achieve required thrust levels, successful demonstration of a hovering gashopper, flight of a subscale gashopper aircraft, and a successful demonstration of a full scale gashopper airplane in horizontal flight.

Among its other advantages, the Gashopper is uniquely superior to all alternative technologies for finding subsurface Martian water using ground penetrating radar GPR)..Ground rovers are of limited value for GPR missions because they can't travel very far. Orbiters can sweep the planet, but suffer from low spatial resolution and drastic diminution of the strength of radar return signal strength with range, which falls with the *fourth power* of the distance. An aircraft flying at an altitude of 2 km has an eight order of magnitude

advantage in return signal strength compared to that obtained by an orbiter operating at 200 km. Furthermore, the aircraft also would have a two order of magnitude advantage in spatial resolution. In addition, the aircraft would be able to land periodically at selected locations, increasing return radar signal strength by two more orders of magnitude with pin-point resolution, and resolving GPR ambiguities with seismic or EM sounding instruments.

Summary Findings

- Gashopper technology represents a unique capability for Mars exploration.
- Gashopper can repeatedly take off and land, visiting many sites separated by tens to hundreds of kilometers on Mars.
- Both aerial and surface science are multiplied.
- Many sites are visited- Many flights are achieved in 1 mission!
- Unlike rovers, mobility is not impeded by terrain obstacles.
- Vehicle can land in canyon, fly length of canyon, fly out of canyon.
- Context imaging taken from air for surface science to follow.
- Unique Vehicle for GPR mission to find subsurface Water
- Ideal vehicle for demonstrating autonomous hazard avoidance.
- ISRU technology is simplest possible. Gas acquisition only.
- Propulsion technology is simple, safe monopropellant. No new materials are required.
- Gashopper engine built and demonstrated during Phase 1 SBIR program had a specific heat of 1.3 kJ/kg-K. Analysis shows that ballistic gashoppers with such engines would be capable of flying tens of km per hop.
- Based on Phase 1 data, Pioneer has identified practical engine options that could enable gashopper aircraft travel of over 100 km per flight.
- High performance advanced gashoppers can be built using practical structural materials, including stainless steel and titanium.
- High performance advanced gashoppers can be built using practical hot bed materials, including lithium, LiH, Be, B, and aluminum.

References

1. R. Zubrin, et al, “Mars Gashopper,” Final Report on NASA Contract NAS3-00074, delivered to NASA JPL June 8, 2000.
2. R. Zubrin, G. Snyder, D. Harber, K. Johnson, J. Kilgore, and N. Jameson, “Mars Gashopper Airplane,” Final Report on Contract NNL05AB04, Delivered to NASA LaRC, July 25, 2005.
3. R. Zubrin, D. Harber, E. Bostwick White, J. Kilgore, “advanced Gashopper Mobility Technology,: Fanial Report on Contract NNC07QA50P, Delivered to NASA JPL july 23, 2007