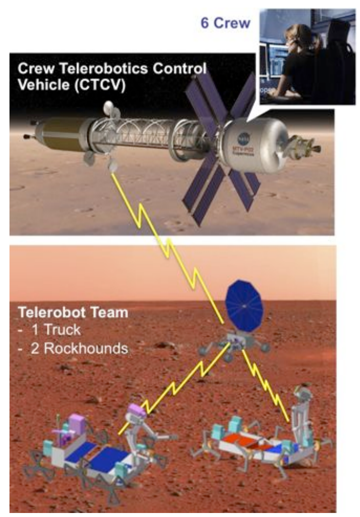
HERRO MISSIONS TO MARS AND VENUS USING TELEROBOTIC SURFACE EXPLORATION FROM ORBIT. G. R. Schmidt[1], G. A. Landis[2], and S. R. Oleson[3], [1]NASA Glenn Research Center, Cleveland, OH 44135 (george.schmidt@nasa.gov), [2]NASA Glenn Research Center, Cleveland, OH 44135 (geoffrey.landis@nasa.gov), [3]NASA Glenn Research Center, Cleveland, OH 44135 (steven.r.oleson@nasa.gov).

Introduction: This paper presents concepts for human missions to the orbits of Mars and Venus that feature direct robotic exploration of the planets' surfaces via teleoperation from orbit. These missions are examples of Human Exploration using Real-time Robotic Operations (HERRO), [1-2] an exploration strategy that refrains from sending humans to the surfaces of planets with large gravity wells. It focuses on sending piloted spacecraft and crews into orbit around exploration targets of interest and conducting exploration of the surfaces using telerobots and remotely controlled systems. The humans are close enough to the surface to eliminate the two-way communication latency that constrains typical robotic space missions, thus allowing real-time command and control of surface operations and experiments by the crew. [3] Through use of state-of-the-art telecommunications and robotics, HERRO could provide the cognitive and decision-making advantages of having humans at the site of study for only a fraction of the cost of conventional human surface missions.

HERRO also avoids the need for complex and expensive man-rated lander/ascent vehicles and surface systems. The propulsive requirements to travel from Low Earth Orbit (LEO) to many destinations with shallow gravity-wells in the inner solar system are quite similar. Thus, a single spacecraft design could perform a variety of missions, including orbit-based surface exploration of the Moon, Mars and Venus, and rendezvous with Near Earth Objects (NEOs), as well as Phobos and Deimos.

The HERRO-Mars mission would entail the crew performing extensive telerobotic exploration of the surface over a period of approximately 1-1/2 year, [4] and the HERRO-Venus mission would use many of the flight systems developed for the Mars mission. [5] Apart from NEOs, the only other destination comparable to Mars in terms of mission velocity and mission duration is Venus. Although this planet has not been seriously considered as a destination for human exploration, the HERRO strategy, with its emphasis on telerobotic exploration, and recent advances in high-temperature electronics [6] and power systems, [7] could make Venus a prime candidate for a human orbital mission.

HERRO-Mars Mission: The goal of the HERRO-Mars is to achieve a level of scientific exploration comparable to that of NASA's most recent architecture for human-landed missions (DRA 5.0) [8] in terms of number of sites explored and the quality of the science gleaned at each site. The architecture features a Crew Telerobotic Center Vehicle (CTCV), very similar to the Mars Transfer Vehicle (MTV) in DRA 5.0. Surface exploration elements include three "Truck" rovers, each of which supports two teleoperated geologist robots, called "Rockhounds." Each of the three Truck/Rockhound groups is launched separately on an Atlas-V or Delta-IV, and is pre-deployed on Mars using an aeroshell-based lander system. Another element that could be included is a sample-return system to bring selected rock and soil samples back to the CTCV, but such a capability was not considered in this study.



Each Truck/Rover group would land in a science location with the ability to traverse a 100-kilometer diameter area. Each Truck would carry the Rockhounds to multiple locations for science activities lasting up to several weeks. The truck is not only responsible for transporting the Rockhounds to these areas, but also for relaying telecontrol and high-resolution communications to/from the Rockhounds and powering/heating the Rockhounds during night and periods of inactivity. The Rockhounds effectively substitute as human geologists by providing an agile robotic platform with real-time control from the crew in the CTCV.

The HERRO-Mars mission begins 26 months before launch of the crew, with deployment of the three Truck/Rover groups. These groups land using proven entry, descent and landing techniques at three different locations around the planet. After these groups are checked out and operational, the CTCV, which requires three heavy-lift (Ares-V or equivalent) launches for assembly and one human crew launch for crew transport, departs Earth and follows the same conjunction-class trajectory to Mars as DRA 5.0. Once it inserts itself into a highly elliptical 12-hr Molniya-like Mars orbit, the CTCV beings to spin at 2.7 rpm to provide Mars g-level artificial gravity. After the astronauts have acclimatized, they begin to operate the Trucks and Rockhounds.

The mission duration entails nearly 500 days in Mars orbit. Once the surface exploration phase of the mission is finished, the CTVC despins and begins the return to Earth. Final return of the crew is performed using the Orion vehicle on a hyperbolic trajectory. After the Orion vehicle has been jettisoned, the CTCV flies by Earth. Sufficient propellant reserves are kept to return the CTCV to the Earth-Moon Lagrange point (L1), where it can be stored and refueled for use in future missions. A total of seven launches are needed to complete each mission.

HERRO-Venus Mission: Conducting one or more HERRO missions to Venus is predicated on the availability of a CTCV, whose capability is extensible to other destinations with comparable mission velocity requirements. It is assumed that HERRO-Venus would take place only as a follow-on to one or more HERRO-Mars missions, which are assumed to occur during the 2030s. HERRO-Venus would follow a nearer-term robotic mission to the surface comparable to the proposed Venus "Flagship" mission, which could occur between 2025 and 2040. Thus, it is reasonable to assume that a HERRO-Venus mission could occur as early as 2040, following a successful HERRO-Mars campaign.

HERRO-Venus employs a CTCV design based on the HERRO-Mars CTCV, but modified for operation in the Venus orbit thermal environment, which is closer to the Sun and incurs greater planet albedo heating. The assumption is to reuse the HERRO Mars CTCV, recovered from parking orbit at the Earth-Moon Lagrange (L1) point, which will be refurbished and refueled for the Venus Mission.

The goal of the HERRO-Venus mission is to achieve a level of scientific exploration comparable to that of HERRO-Mars in terms of number of sites explored and the quality of science gleaned at each site. Surface elements include four pairs of rovers positioned at four sites dispersed across the northern hemisphere of Venus. Each pair works cooperatively and is launched separately on an Atlas-V or Delta-IV. Another element that could be included is a sample-return system to bring selected rock and soil samples back to the CTCV, but such a capability was not considered in this study.

Each rover pair lands in a science location with the ability to traverse approximately a 100-kilometer diameter area over the course of the mission. The approach of splitting robotic functions in an arrangement similar to the Truck and Rockhounds was considered, but was deemed as too challenging and risky for communications relays and autonomous operations needed for energy replenishment.

The HERRO-Venus mission begins in December 2039 with launch and deployment of the four telerobotic pairs. Each transit to Venus lasts about 180 days, but it is assumed that the entire launch and landing of rover groups would take place over a year. These groups land using proven entry, descent and landing techniques at four different locations in the northern hemisphere of the planet.

After these groups are checked out and operational, the CTCV, which has been replenished with propellant and crew over a period of 80 to 90 days, departs Earth and follows a Hohman-class trajectory to Venus. An Earth escape date of 21 December 2040 is assumed, thus yielding a 136-day transit to Venus. Once the CTCV captures into a highly elliptical 24-hr 180 degree orbit, it begins to spin at 2.7 rpm to provide Mars g-level artificial gravity. After the astronauts have acclimatized, they begin to operate the rovers.

The mission entails 472 days in Venus orbit. Once the surface exploration phase of the mission is finished, the CTVC despins and begins the 116-day return to Earth. Final return of the crew is performed using the Orion vehicle on a hyperbolic trajectory. After the Orion vehicle has been jettisoned, the CTCV flies by Earth. Sufficient propellant reserves are kept to return the CTCV to Earth-Moon L1, where it can be stored and refueled for use in future missions. The crewed part of HERRO-Venus is 724 days in duration, 176 days shorter than HERRO-Mars or DRA 5.0.

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