

**MARS SURFACE TRANSPORTATION OPTIONS**

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**ABSTRACT**

As the number of scientific experiments for the surface of Mars grows, the need for effective surface transportation becomes critical. Because of the diversity of the experiments proposed, as well as the desire to explore Mars from the equator to the poles, the optimum surface vehicle configuration is not obvious. Five candidate vehicles are described, with an estimate of their size and performance. In order to maximize the success of a manned Mars mission, it appears that two vehicles should be designed for surface transportation: an advanced long-range rover, and a remotely-piloted airplane.

**INTRODUCTION**

In order to maximize the usefulness of a manned Mars base, surface transportation vehicles are required. These vehicles would transport both men and instrumentation to sites not within walking distance of the landing craft or home base, and also expedite the return of samples. Since a large number of scientific missions are envisioned, several types of vehicles should be considered in an effort to determine the optimum configuration. Consideration must be given to the size and weight of the vehicle, since it must be transported to the Martian surface by a landing craft.

It is assumed that a Mars surface transportation vehicle will be operating from a Mars base located within plus-or-minus 30 degrees latitude from the equator. Scientific experiments will be done in locations ranging from near the Mars base to the nearest pole. The most likely candidates for a Mars surface vehicle are: 1) a lunar-type rover; 2) an advanced rover equipped with a life support tent; 3) a large-scale mobile lab; 4) a robotic walker; and, 5) a remotely-piloted airplane. Following is a description of these vehicles and an estimate of the performance one might expect to obtain from such vehicles. Note that the capabilities and size are rough estimates; no detailed design has been done on any vehicle. Also, these

options do not include quantum advancements in technology which might make another type of vehicle possible.

#### LUNAR-TYPE ROVER

The first option is a two-manned, four-wheeled rover similar to that used in the Apollo program. A direct derivative of the lunar rover could be very effective on Mars, with only minor design changes needed. Such a vehicle would weigh more than the lunar rover because of the requirement to operate in the increased gravitational environment on Mars, perhaps weighing about 600 kg. It could be transported in a container about 3.5-by-2-by-1.2 meters in size, and carry a payload of 680 kg.

Such a vehicle could be expected to have a range of 40 km round-trip, while cruising at a speed of about 7-9 meters per second. An important consideration for any Mars surface vehicle is its ability to operate on the rough terrain without excess maneuvering. The lunar-type rover would be able to drive over a rock with about a .15 meter diameter, and climb a 20 degree grade. This vehicle would satisfy a good deal of the scientific requirements, but would lack the long-range capability needed for polar exploration. Also, each scientific expedition would be necessarily short since the scientists would be restricted to their life support suits. However, this design requires the least amount of technological development; since it is derived directly from a proven vehicle, the design need only be optimized for operation on Mars.

#### ADVANCED LONG-RANGE ROVER

The second option is similar to the lunar rover but includes enhancements to improve its capabilities. This vehicle may be 4- or 6-wheeled, and will be larger than the lunar-type rover. It will include the capability to plug life support suits directly into the rover power supply, thereby increasing the range limit imposed by the life support systems. Also, the rover will carry an inflatable life support tent to be used for sleep periods. The scientists will be able to remove their life support suits for cleaning during this sleep period.

This vehicle will weigh about 770 kg., and will be packaged in a container about 4.5-by-2.5-by-2 meters in size. A range of 125 km round

trip at a speed of 7-9 meters per second can be expected. The rover will be able to carry a payload of about 800 kg., including the life support tent. The rover should have the same terrain capabilities as the lunar-type rover (drive over .15 meter rock, climb a 20 degree slope), but may improve upon this with an advanced design incorporating several wheels and an active control system.

Obviously, this design requires more advanced technology than the lunar-type rover. A better power supply is required to power both the rover and the scientists' life support suits. Weight saving techniques need to be employed in order to reduce the burden on the landing vehicle. Also, the life support tents needed to allow long range need to be developed. This design should significantly improve upon the capabilities of the lunar-type rover without an undue weight penalty or unattainable technological advancements.

#### LARGE-SCALE MOBILE LAB

Given that the Mars base will have a fully-instrumented scientific laboratory, there are two options for lab configurations which include a large-scale vehicle. These configurations are the Mars Autonomous Research Vehicle (MARV), and a complete laboratory on wheels. In either case, the vehicle will be capable of maintaining life support for 5-day scientific excursions. The complete lab on wheels concept is one in which the entire lab module is mobile; the lab is driven to the site of the scientific experiment, and all the analysis is done there. Obviously, this vehicle will be quite large. Only the details of the MARV will be discussed here.

The MARV is a self-contained life support vehicle which has a limited laboratory capability. This vehicle would travel to a desirable site and perform scientific experiments within the scope of the lab's instrumentation. Samples would also be returned to the permanent, complete lab at the Mars base for further, more extensive testing. The MARV would be smaller than the complete lab on wheels; it would be transported to the surface in a 9-by-9-by-3 meter container. Weighing about 4500 kg., it would be capable of carrying a 1800 kg. payload of scientific equipment, life support suits, and so on. At a speed of 7-9 meters per second, its range over the course of a 5-day trip would be about 600 km. As with the two rover con-

cepts, the MARV's terrain capabilities include climbing a 20 degree hill and negotiating a .15-.3 meter rock.

Although the first-cut design of the MARV might resemble a Winnebago, a significant amount of work can be done to optimize a configuration for operation on the surface of Mars. Also, much needs to be done in the area of life support systems in mobile, self-contained vehicles.

#### ROBOTIC WALKER

Because recent experience with walking robots seems to indicate an increasing capability of robotic walking vehicles, it is worthwhile to consider a walker among the possibilities for Mars surface transportation vehicles. Such a vehicle would be smaller than the previously-described vehicles, but its short range capabilities are similar. It would most likely be remotely-piloted (unmanned).

A walker large enough to carry some instrumentation would weigh about 225 kg., but because its 'legs' will fold up significantly, its transportation size would be about 2-by-2-by-2 meters. Because the vehicle lacks a range-constraining life support system, it would likely be able to cover 125 km. at a speed of about 4.5 meters per second. The walker would be able to carry about 225 kg. of payload, and advanced robotics would make up somewhat for the lack of scientific personnel in the operation of experiments. Current walking robots have shown the capability to climb a 45 degree slope, and to walk over a 1 meter rock. This, obviously, is a significant improvement over conventional wheeled vehicles. An effective walking vehicle for use on Mars would depend on significant improvements in remote-control capabilities. Robots have only recently, through the use of on-board computers, been able to negotiate difficult terrain and to master an efficient gait. The most effective load-carrying design is certainly not obvious at this point. Despite the walker's lack of long-range capabilities, its maneuverability suggests it may yet find a place on the Mars base.

#### REMOTELY-PILOTED AIRPLANE

The final concept for consideration as a Mars surface transportation mode is an unmanned, remotely-piloted airplane. This airplane would fly from the Mars base, land occasionally to pick up samples or drop off instrumentation, survey the area traversed, and

return to the base. Since it is assumed that the base will be within 30 degrees latitude of the equator, and it is desired to explore the poles, the airplane must be able to travel from the base to the nearest pole and back without refueling. Although some work has been done on the design of an airplane that is deployed from orbit, the constraints put on the configuration from the reentry phase make a Mars-based vehicle more practical.

The aircraft would be designed to fly at altitudes less than 6 km., and at a speed of about 75 meters per second. The range will be at least 4500 km., in order to reach the nearest pole. It is expected that such an airplane will weigh about 900 kg., and will be packaged in a 6-by-1.5-by-1.5 meter container. The useful load of the airplane will be about 225 kg. Although current technology suggests that a hydrazine engine may be the best power plant, high-density electric batteries or solar cells should also be considered.

The two most significant stumbling blocks to the successful design of a Mars airplane are the aerodynamic configuration and an accurate remote control system. Because of the low air density on Mars, a conventional airplane will necessarily have a large wing span. This presents a problem in efficient storage and transportation. Besides a conventional, fixed wing configuration, others that should be investigated include lighter-than-air, rotary wing, and propulsive lift (vertical takeoff and landing) configurations. Because of the great distance involved, the design of an accurate remote control mechanism may be difficult. Perhaps a satellite in stationary orbit may prove useful in this area.

The remotely-piloted airplane obviously shows some advantages over ground-based transportation modes. It appears to be the only configuration that will achieve the goal of travel to the poles in a timely manner. The only difficulty caused by the rough terrain occurs in takeoff and landing, and this problem may be overcome by vertical takeoff and landing capability. However, because the aircraft will be unmanned, the success of some experiments may be compromised.

## CONCLUSION

A surface transportation vehicle is essential to the success of future manned Mars missions. Although there are several vehicle configurations which will accomplish many of the desired objectives, none will do it all. Because the remotely-piloted airplane is the only vehicle studied which has sufficient range to reach the poles, it should be strongly considered. However, because the airplane may not be as efficient in conducting research near the base, a rover may also be necessary. It appears that an advanced technology rover equipped with a life support tent will successfully fill the need for manned, near-base explorations. It should be emphasized that no detailed design was done; the values given for vehicle size and performance are estimates of what one might expect from such a vehicle.

As a result of this investigation, it is recommended that a detailed design study be undertaken on two Mars surface vehicles. To completely explore the area near the Mars base, a rover should be designed to travel about 125 km. while providing power for two life support suits. Also, a detailed investigation of the feasibility of life support tents should be performed. A Mars-based airplane should be designed to fly at least 4500 km. at an altitude of less than 6 km. As previously mentioned, the configuration studies should not be limited to conventional, fixed-wing designs. The use of these two types of vehicles will make the extensive scientific exploration of Mars a successful program.

SUMMARY TABLE  
MARS SURFACE TRANSPORTATION OPTIONS

VEHICLE	WEIGHT (KG)	PACKING SIZE (METERS)	RANGE (KM)	PAYLOAD (KG)	SPEED (M/S)	SLOPES/TERRAIN CAPABILITIES	TECH. ADVANCEMENTS REQUIRED
Rover	600	3.5x2x1.2	40	680	9	20 deg/.15m. rock	refinements
Advanced Rover	770	4.5x2.5x2	125	800	9	20 deg/.15m. rock	life support tents
Mobile Lab	450	9x3x3	600	1,800	9	20 deg/.15m. rock	life support
Walker	225	2x2x2	125	225	4.5	45 deg/1m. rock	control, load-carrying
Airplane	900	6x1.5x1.5	4,500	225	75	---	RPV control, aero configuration

VEHICLES -	1) Rover	2) Rover w/tent	3) Mobile lab	4) Walker	5) Airplane
	Lunar-type rover	Advanced rover with inflatable life support tent (extended range)	Large scale enclosed, pressurized rover	Small (manned or unmanned) ambulatory robot	Remotely-piloted airplane

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