LASER-POWERED MARTIAN ROVER

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by W. E. Meador

Two rover concepts were considered: an unpressurized skeleton vehicle having available 4.5 kW of electrical power and limited to a range of about 10 km from a temporary Martian base and a much larger surface exploration vehicle (SEV) operating on a maximum 75-kW power level and essentially unrestricted in range or mission. The only baseline reference system was a battery-operated skeleton vehicle with very limited mission capability and range and which would repeatedly return to its temporary base for battery recharging. It was quickly concluded that laser powering would be an uneconomical overkill for this concept.

The SEV, on the other hand, is a new rover concept that is especially suited for powering by orbiting solar or electrically pumped lasers. Such vehicles are visualized as mobile habitats with full life-support systems onboard, having unlimited range over the Martian surface, and having extensive mission capability (e.g., core drilling and sampling, construction of shelters for protection from solar flares and dust storms, etc.). Laser power beaming to SEV's was shown to have the following advantages: (1) continuous energy supply by three orbiting lasers at 2000 km (no storage requirements as during Martian night with direct solar powering); (2) long-term supply without replacement; (3) very high power available (MW level possible); (4) greatly enhanced mission enabling capability beyond anything currently conceived. Pointing and tracking of rovers are not problems for laser power stations at 2000 km altitudes, nor are the sizes of transmitter and receiver dishes (3 m and 1 m diameters, respectively). An electrically pumped laser diode array, with the sun as the prime energy source, was selected for special study. The total LEO mass, including OTV and fuel, for a 192-kW laser array is 7.5×10^6g. By far the largest contributor to the mass of the photovoltaic converter (to 75 kW electric on the rover) of the laser beam is the 240 kg radiator for rejection of waste heat. Some of these weights can no doubt be alleviated by novel engineering schemes, including use of waste converter energy to run Stirling engines and use of energy stored in the blackbody collector on the laser system for propulsion. Moreover, cooling by the constant Martian winds might be more effective than presently contemplated.

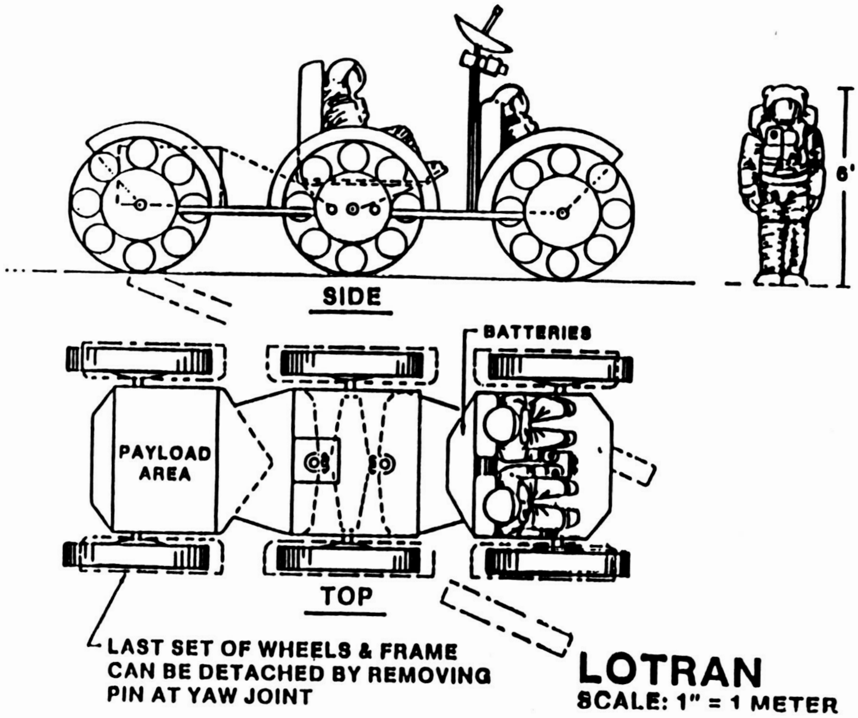
In summary, laser power beaming to large Martian rovers is a potentially revolutionary new concept for enhancing mission capability, removing range limitations, and generally and very significantly broadening the scope of mission planning.

CONTENTS

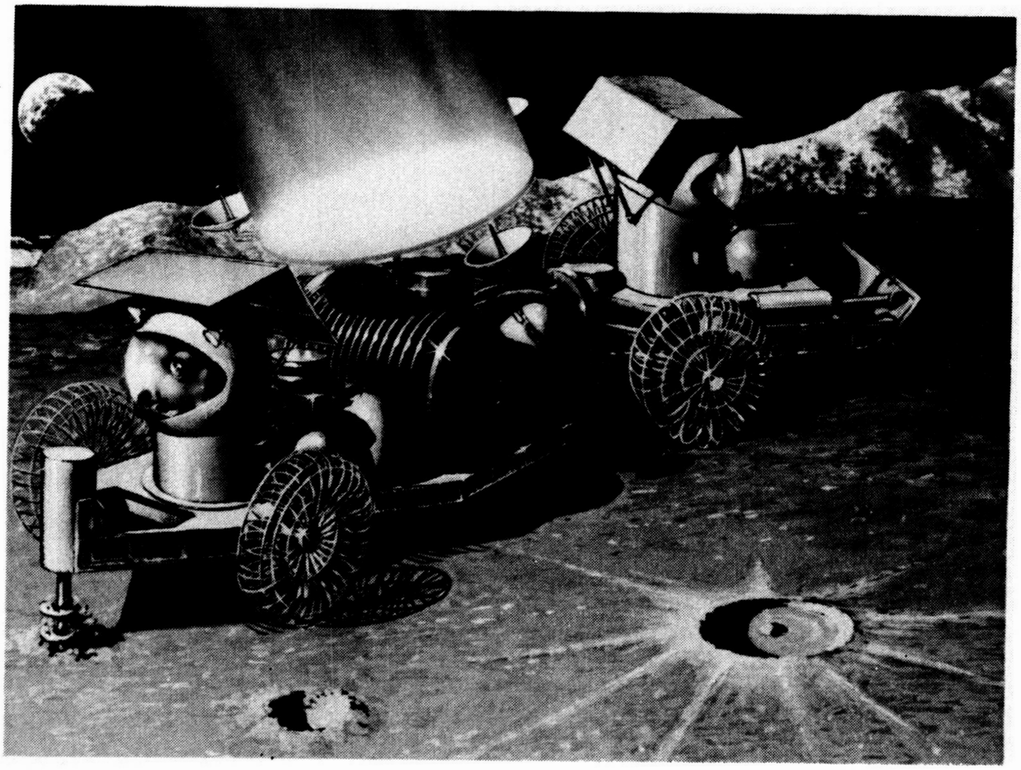
- Advantages of power beaming
- Rover concepts: unpressurized skeleton; Winnebago
- Power beaming alternatives
- Pointing and tracking
- Laser satellite
- Masses to LEO
- PV conversion; heat use (e.g., Stirling engine at 500° K; decrease radiator size) and rejection

POWER BEAMING ADVANTAGES

- Primary OEXP Issue: How to power rover
  - Batteries, fuel cells run down; need gas stations
- Laser power beaming to rover
  - Long life without replacement
  - Unlimited range from base; Winnebago rover is moving habitat
  - Very high power available
  - Greatly enhanced mission enabling capability; rover becomes mobile power source.



HIGH POWERED MARTIAN ROVER



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SPECIFICATION FOR MARS SURFACE EXPLORATION VEHICLE

Total Weight	8000 (Kg) inc 25% for power system
Crew	5 persons
Speed	10 Km/hr.
Slope climbing	30° for 50 Km

	POWER REQUIREMENTS	(KW)
1	Rolling resistance at 10 Km/hr;	10.5
2	Hill climbing 30° at 10 Km/hr:	37
3	Housekeeping requirements	4.5
4	Externally mounted core drill	10
5	External power tools	2
	Max. power (1 + 2 + 3)	52
	Need ~ 50% reserve	
	Max. power including reserve	75

SIZE OF TRANSMITTING AND RECEIVING DISHES DIFFRACTION LIMITED

D_t = diameter transmitter dish

D_r = diameter receiver dish

λ = wavelength of signal = 1 μm

z = distance apart

$$D_t D_r = \frac{4}{\pi} \lambda z = 1.27 \times 10^{-6} z$$

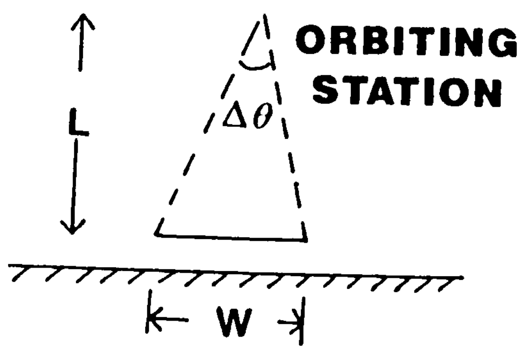
e.g., if $z = 2 \times 10^7$m-geosynchronous orbit on Mars, and D_r = 2m, then D_t = 13m

If $z = 2 \times 10^6$m, and D_r = 1m, then $D_t \approx 3$m

PROVIDING POWER TO A MARS ROVER

	METHOD	ADVANTAGES	DISADVANTAGES
Directly from orbiting satellite via laser beam	1. Nuclear-electric-laser 2. Direct solar-pumped laser 3. Solar panel-diode laser 4. Solar concentrator-solar panel-diode laser	a) 4 satellites cover most of Mars b) energy storage not required c) unlimited range	
From orbiting satellite to ground station. Energy stored, rover returns to recharge	1-4 above - store energy	d) large receiving dishes secure on ground	f) limited range ~ 100 Km for rover, g) need storage at ground station and on rover.
Ground station collects directly from sun. Energy stored, rover returns to recharge.	5. Solar panel - store energy 6. Solar concentrator - solar panel - store energy	(d) above e) eliminates laser	(f), (g) above h) collects for only 6 hrs. a day.

POINTING TO A STATIONARY VEHICLE ON MARS



$\Delta\theta \leq W/L$

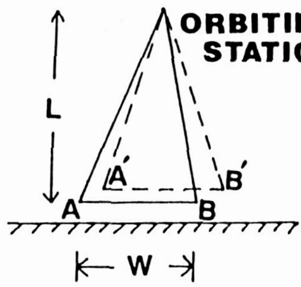
Maximum attainable accuracy $\Delta\theta = 0.2"$ arc $= 10^{-6}$ radian

If W = 2m, and $L = 2 \times 10^7$m-geosynchronous orbit

$\Delta\theta = 10^{-7}$radians--impossible

Reduce L to 2×10^6 m or 2000 Km--then possible

TRACKING A MOVING VEHICLE ON SURFACE OF MARS



Vehicle motion random—cannot anticipate. Signal from position AB takes time $t = L/c$ to station. Laser beam takes similar time; total = $2L/c$, c = velocity of light.

Vehicle with vel υ moves $2L\upsilon/c$ in this time.

Require $2\,L\upsilon/c < BB' = \alpha\,W$; α is precision factor

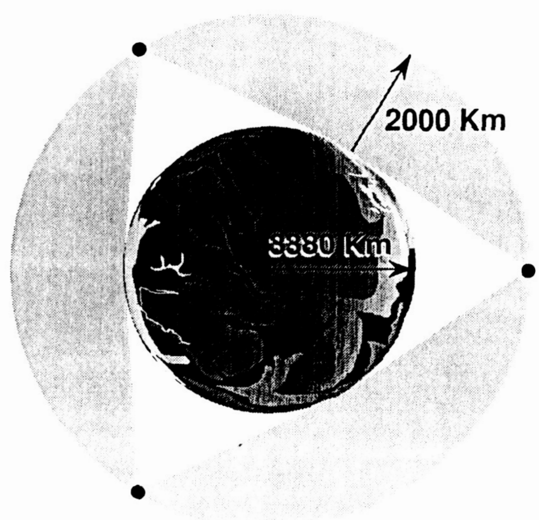
If $\upsilon = 10$ Km/hr = $2.8\ ms^{-1}$, $c = 3 \times 10^{8}\ ms^{-1}$, $\alpha = 0.1$, $W = 2m$

For $L = 2 \times 10^{7}m$, geosynchronous orbit

$2L\upsilon/c = 0.37m$; $\alpha\,W = 0.2$ - not satisifed.

Would be satisfied for $L = 2 \times 10^{6}m$ or 2000 Km.

MARTIAN ORBIT DATA
Surface area covered 55.76%



Orbit height	**2000 Km**	**View time**	**56 min 39.8 sec**
Period	**3 hrs 19 min 40.8 sec**	**Dead time**	**9 min 53.8 sec**
Velocity	**2821.47 m/sec**		

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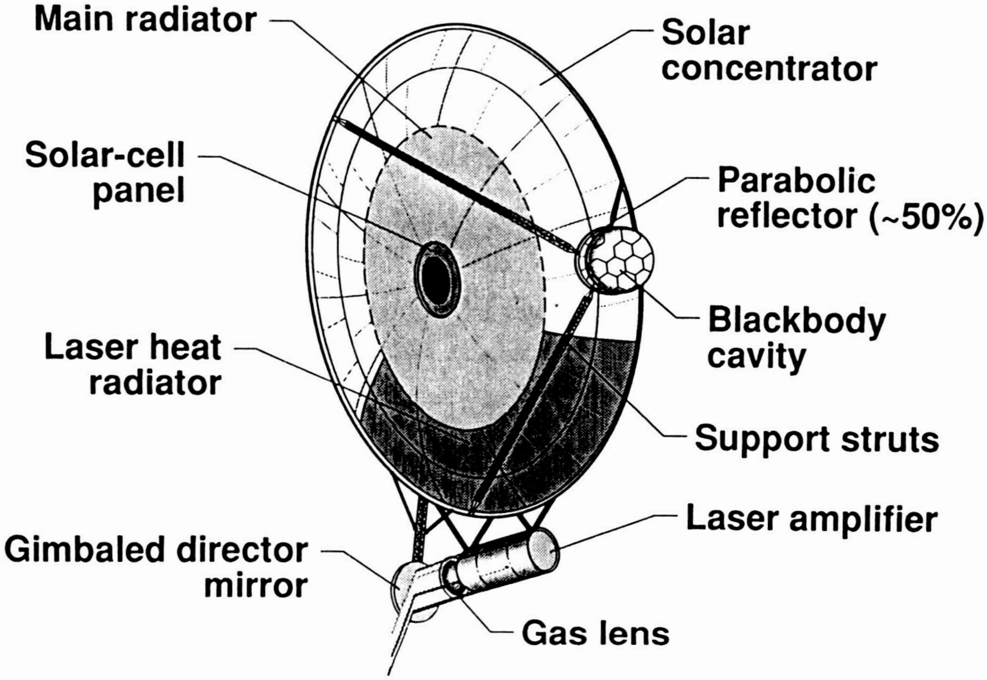
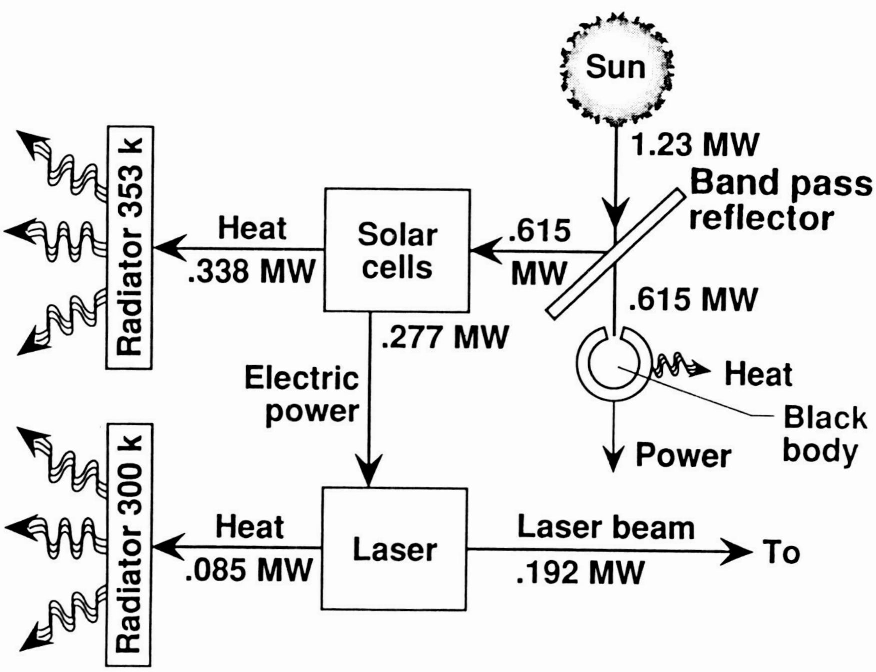
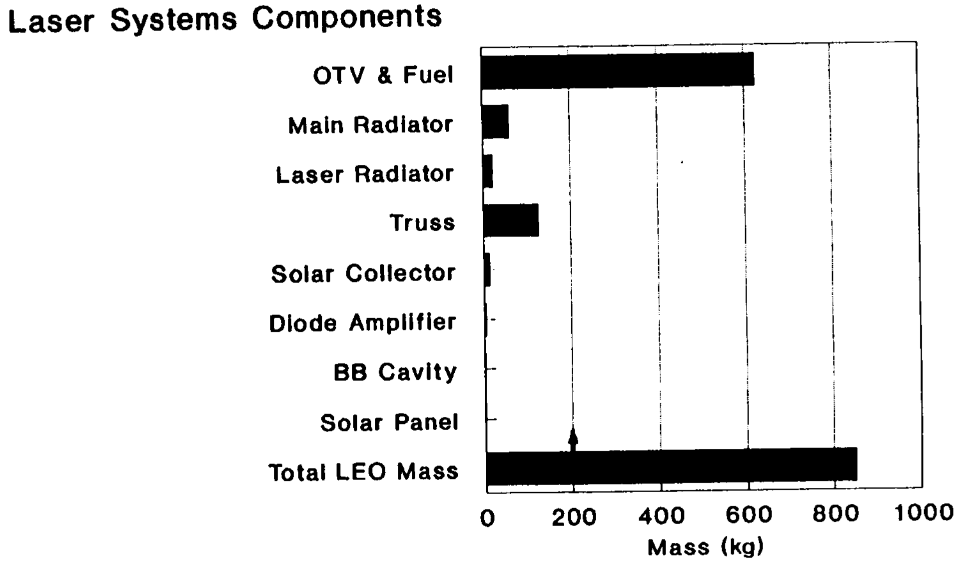
DIODE LASER SATELLITE



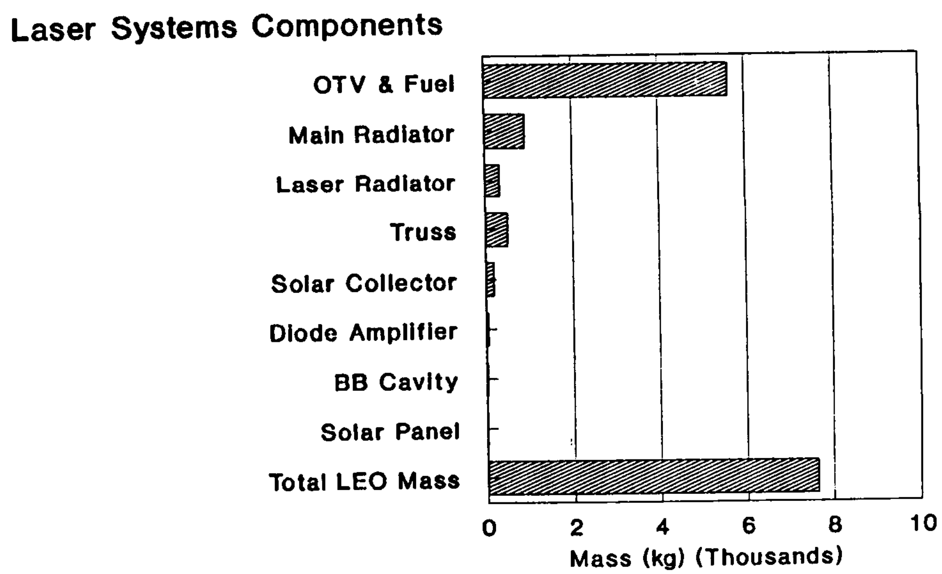
MARTIAN SATELLITE POWER FLOW



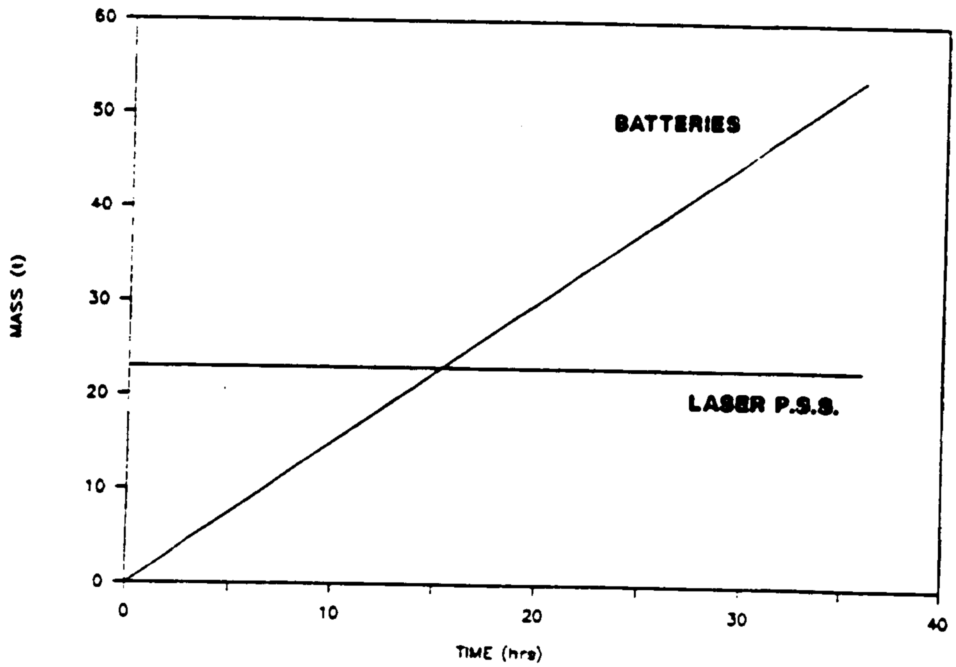
Laser Diode Array For Mars Rover
12.3 kW Laser Output



Laser Diode Array For Mars Rover
192 kW Laser Output



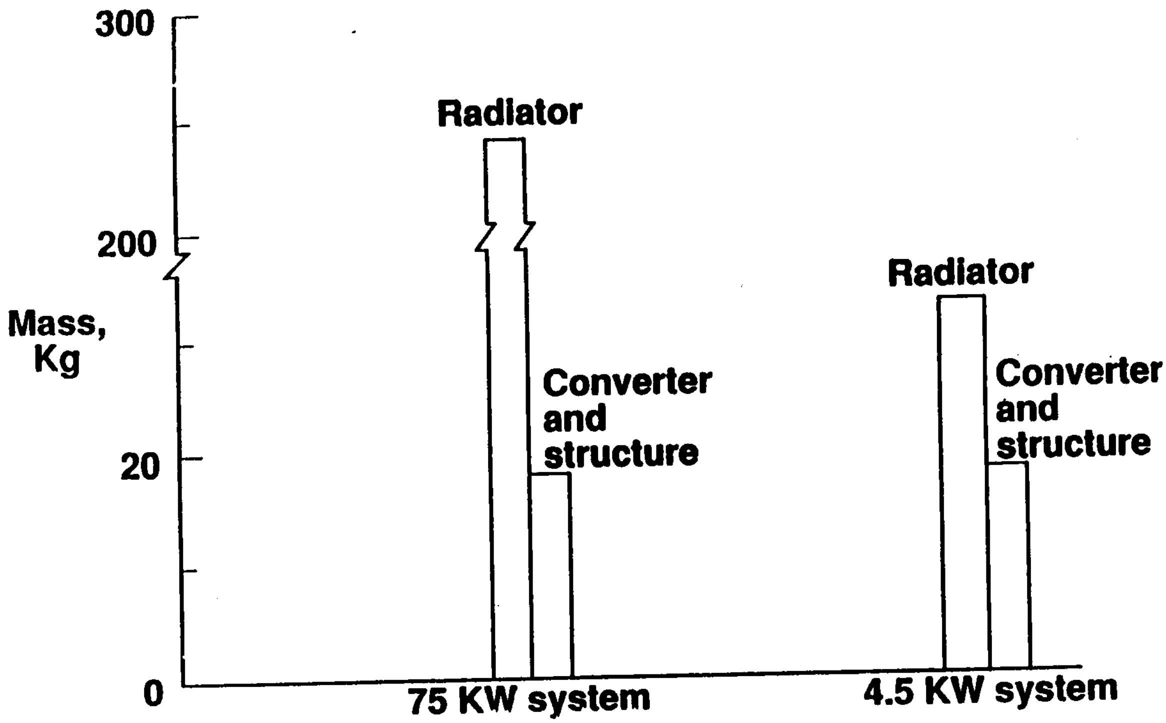
ROVER POWER SYSTEM MASSES



PHOTOVOLTAIC CONVERTER FOR MARS ROVER

- Diode laser (0.85μm)
- $Ga_{.971}$ $Al_{.029}$ As converter
- 75 KW_e system
- 4.5 KW_e system

PHOTOVOLTAIC CONVERTER FOR MARS ROVER



CONCLUSIONS

- Laser power beaming overkill for skeleton rover with limited range and mission capability.
- Laser power beaming to Winnebago rovers potentially revolutionary new concept.
  - Mission enabling
  - Unlimited range; circumnavigation
  - No pointing or tracking problems for lasers at 2000 km altitude
  - Reasonable weights, with substantial reduction possible via novel uses of waste energy