N87-17785

MARS VEHICLE TCS AND AEROBRAKE TPS

G. Comer
Marshall Space Flight Center
MSFC, AL

ABSTRACT

General design approach, some unique problems and new technology needs for a Mars vehicle manned module Thermal Control System (TCS) and aerobrake Thermal Protection System (TPS) are discussed. The design approach of the TCS will be similar to that of the Space Station. Mars atmospheric dust storms are identified as an unknown that will impact the design of the Mars landing vehicle and base facility. New technology may be needed for thermal control surfaces to functionally survive the dust storms. The TPS for the Mars aerocapture vehicle will be subject to marginal stagnation heating rates for conjunction class missions and very high heating rates for opposition class missions. New technology TPS materials or an ablative heat shield will be required for the high stagnation heating rate trajectories. No significantly new technology is needed for the manned modules that do not descend to the Mars surface.

INTRODUCTION

The Mars vehicle Thermal Control System (TCS) will provide temperature control for the manned modules. This includes temperature and humidity control for the cabin atmosphere, temperature control for the support sub-systems (power and avionics), and temperature control for experiment equipment. This accomodation will be provided during the travel to and from Mars and during the time on the Mars surface.

Before launch, during those periods when the manned modules require cooling, ground support equipment will provide a thermal sink. Similarly, Earth orbit assembly and launch support facilities will provide this accommodation for the orbiting modules until the manned Mars vehicle departs from low Earth orbit.

The aerobrake Thermal Protection System (TPS) will provide protection for the vehicle structure against high aerodynamic heating rates during aerocapture maneuvers at Mars and at Earth.

During interplanetary travel and while at Mars, orbit TCS heat dissipation will be very efficient due to the cold space environment. This condition will set the TCS heat dissipation capability of the orbiting Mission Modules. The Mars Excursion Module (MEM) TCS will be driven by the warmer environment on the Mars surface. The Martian surface environment here will be variable due to the atmospheric dust storms. On clear days heat can be dissipated to both the Mars surface and deep space. Dust storms, however, will block the view to space interfering with radiative heat rejection. Dust particles encountered at high velocity may cause erosion of the shield as well. This will be the worst case design condition for the MEM.

An extended duration Mars base facility would of course be subjected to the same atmospheric condition as the MEM and would have similar heat rejection problems.

The design approach for the Mars vehicle manned modules would be practically the same as that for the Space Station. Both must have extended lifetime capability. The general approach is to provide dual heat transport loops with inflight maintenance capability for replacement of critical components. One probable difference would be design of the radiators. Whereas, on the Space Station, failed heat pipe panels are inflight replaceable, the Mars vehicle radiators would most likely be oversized so that needed heat rejection could be maintained with a number of failed heat pipe panels. This would reduce the inflight maintainance task.

Parametric studies conducted for the Space Station TCS radiators are shown on Figure 1. Radiator size is shown as a function of heat rejection for a deployed radiator, with radiator effective temperature as a parameter. Radiator size as a function of a 14 feet diameter module lenth for a body mounted radiator is also shown, again with effective radiator temperature as a parameter. Radiator sizes will be much smaller than this for the Mars vehicle Mission Modules because of the much colder thermal sink during interplanetary travel and in Mars orbit.

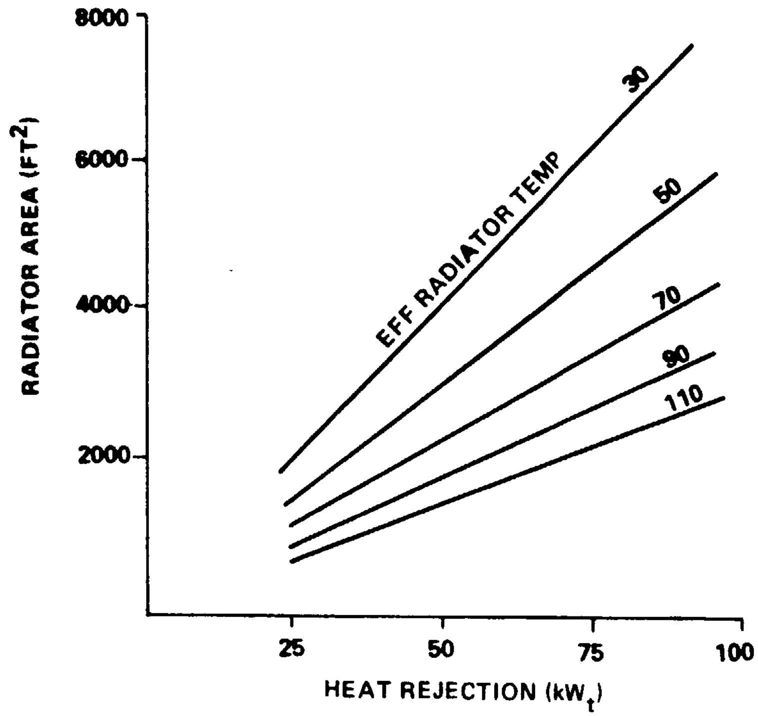
Another subject quite separate from the manned module thermal control is the aerobrake design for aerocapture maneuvers at Mars and Earth. Two categories of missions types are being considered for manned Mars missions: conjunction class and oppositon class. Entry interface speeds at Mars for conjunction class missions range from 17,700 ft/sec to 20,500 ft/sec and result in convective stagnation heating rates of 50 to 150 $BTU/ft^2/sec$. This results in a maximum convective stagnation heating

3559–85

SPACE STATION TCS
RADIATOR PERFORMANCE

DEPLOYED RADIATOR

- $-40\ ^{o}F$ SINK
- AREA INCLUDES BOTH SIDES OF RADIATOR



BODY MOUNTED RADIATOR

- 75% OF SIDEWALL
- $20\ ^{o}F$ SINK

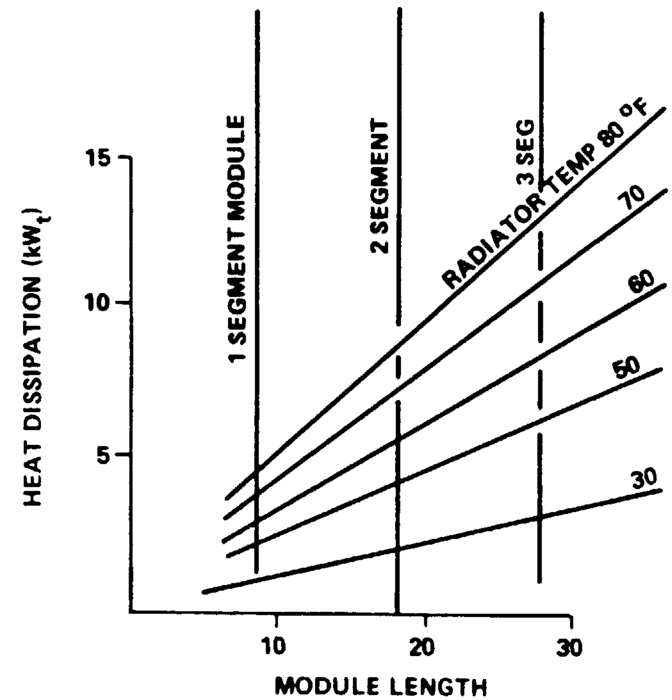


FIGURE 1

rate of 450 BTU/ft^2-sec. These rates are based upon a 1-foot radius sphere.* The TPS requirements for aerocapture maneuvers at Mars are highly mission dependent and should be designed accordingly. Shuttle type reusable TPS may be usable in the lower range but new technology TPS will be required for reusability at the higher end. Ablative heat shields are usable but impose a weight penalty.

The entry interface velocity at Earth for a free-return trajectory from Mars is 38,000 ft/sec and results in a maximum convective stagnation heating rate of 600 BTU/ft^2-sec. A propulsive maneuver near Earth can reduce the entry interface velocity to 33,7800 ft/sec resulting in a maximum convective stagnation heating rate of 390 BTU/ft^2-sec. Heating rates of this magnitude require ablative heat shields, which are heavy, or a new technology TPS.

The physical description or definition of the Mars atmosphere during dust storms is one the greatest unknowns we must deal with. This lack of definition requires that we keep open design options for heat dissipation by the MEM TCS. The most likely candidate for heat dissipation is the conventional fin tube type radiator (either pumped fluid or heat pipe). In the event this is not adequate due to a warm environmental sink condition, a flash evaporator might be used for heat dissipation. Design options for a Mars base facility would not likely include the flash evaporator because of the amount of water required for an extended duration facility. Options for the Mars base facility might include other concepts such as utilization of the soil as a heat sink.

Another concern on the Mars surface is the effect of the dust storms on thermal control sufaces. The abrasive effect will most likely degrade the surface coatings, affecting thermal performance of the radiator and affecting passive temperature control of the MEM structure. Options to deal with surface degradation include: (1) avoidance of solar heating loads by selective orientation of thermal control surfaces, and (2) development of surface maintenance techniques.

Selection of the appropriate option for MEM TCS heat dissipation will depend on the severity of the atmospheric dust storms. Trades could

---

*An approximate rate for a shield of curvature Rm can be obtained by dividing by Rm.

be conducted with two objectives in mind. One study could be for the purpose of determining mission constraints (MEM landing and duration) based on severity of the dust storms. A second study could be for the pupose of defining a TCS that would be acceptable regardless of the dust storm severity.

TECHNOLOGY

Most of the on-going TCS technology is oriented toward efficient accommodation of long duration missions and is appropriate for the Mars mission. On-going TPS technology for atmospheric re-entry is appropriate for the needs of a Mars vehicle aerobrake and design goals are probably adequate for conjunction class missions. However, present design goals are not likely to be adequate for opposition class missions. Heat rates for opposition class Mars missions are expected to be considerably higher than those experienced by vehicles up to this time and new materials will most likely need to be developed.

The convective stagnation heating rates resulting from an aerocapture maneuver at Earth will require an ablative heat shield or new technology TPS. In addition to convective heating, radiative heating must also be considered. More detailed study is required to determine the total heating rates and the requirements for aerocapture maneuvers at Mars and at Earth.

Past studies on the subject of thermal coating contamination during space flight have indicated need for maintenance and have proposed at least two approaches to be pursued: (1) cleaning procedures, and (2) surface coating refurbishment or replacement. A new concern involving thermal coatings on Mars missions is the dust environment on the Mars surface. New technology efforts may be needed to deal with the subject of erosion and contamination of thermal coatings by Martian dust storms.

SUMMARY

The discussion presented here is intended to give some idea of the unique problems, general design approaches and technology needs for a Mars landing vehicle. Mars atmospheric dust storms are identified as an unknown that will probably impact design of the MEM and the Mars base facility. The design approach of the TCS will be similar to that of the

Space Station. The most outstanding new technology requirement may be new materials for the aerobrake TPS. No significantly new technology is needed for the manned module TCS.