46th INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SYSTEMS
ICES 2016

Mars Sample Thermal Control During Mars Ascent and Orbit

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Pre-Decisional Information – For Planning and Discussion Purposes Only

Agenda

- Possible Architecture for Mars Sample Return
- Thermal Problem Statement
- Thermal Challenges for Orbiting Sample (OS) During Ascent from Mars
- Options Studied for Thermal Control of OS During Ascent from Mars
  - Using Thermal Mass of OS
  - Phase Change Materials (PCM)
  - Additional Radiation Heat Loss Area
  - OS covered with Thermal Protection System (TPS)
  - Fairing or Shroud covering OS
- OS Thermal Control During Orbit
- Summary & Conclusions
- Acknowledgements

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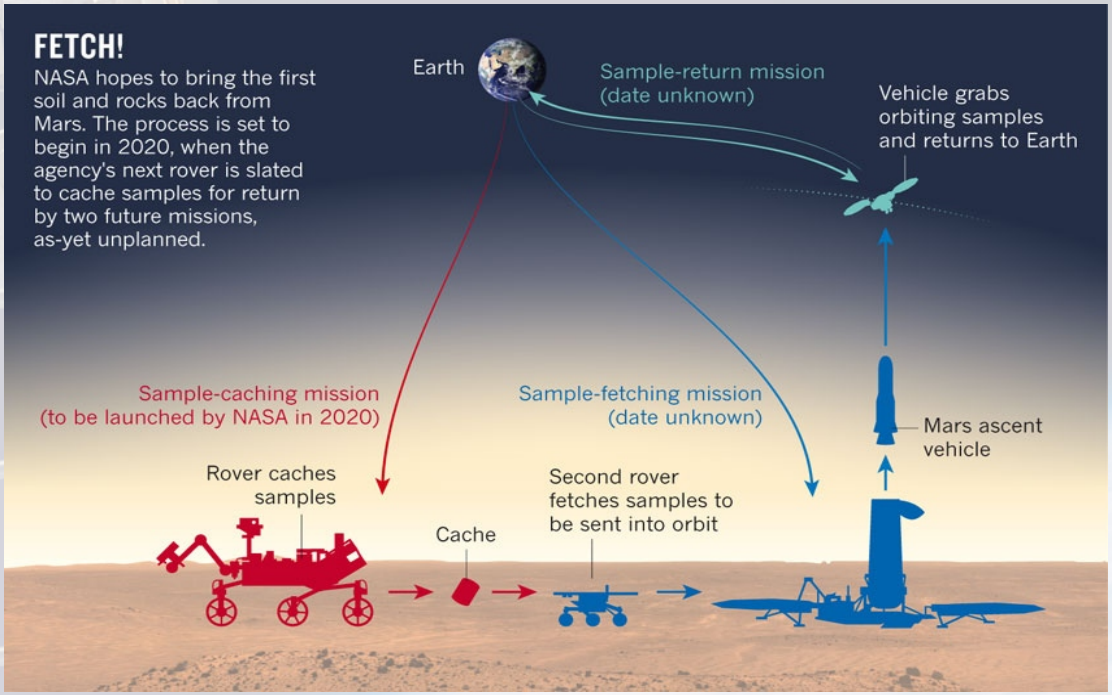
Possible Architecture for Mars Sample Return

- No official NASA plan at this time for Mars Sample Return (MSR)
- This study is part of Mars exploration Program formulation office mission concept studies for MSR
- Mars sample tube could be on Martian surface for several years
  - Up to 10 years
- Then once in orbit, could be there for several more years before return to Earth
  - Up to 10 years



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Thermal Problem Statement

- The Martian samples would have substantial scientific value
- Their thermal Integrity has to maintained to preserve them
- Allowable temperature limits:
  - ~ -125/+60 C
- Mars sample tubes contained in Orbiting Sample (OS) sphere container
- During ascent from Mars, sample container subjected to substantial aero-thermal heating
- During orbit (Mars or Sun), subjected to thermal loading from Mars/Sun & heat loss to Space

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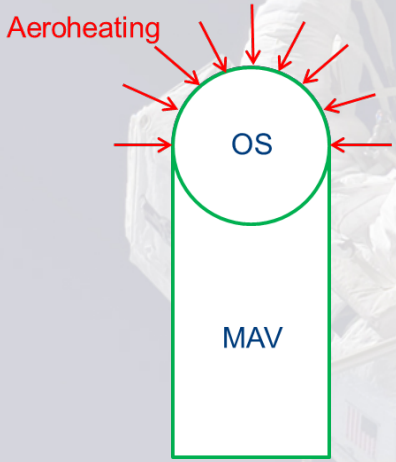
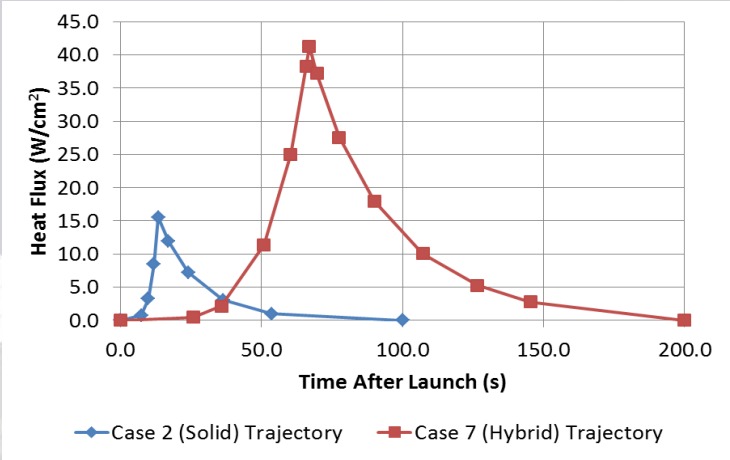
Aero-Heating During Ascent from Mars

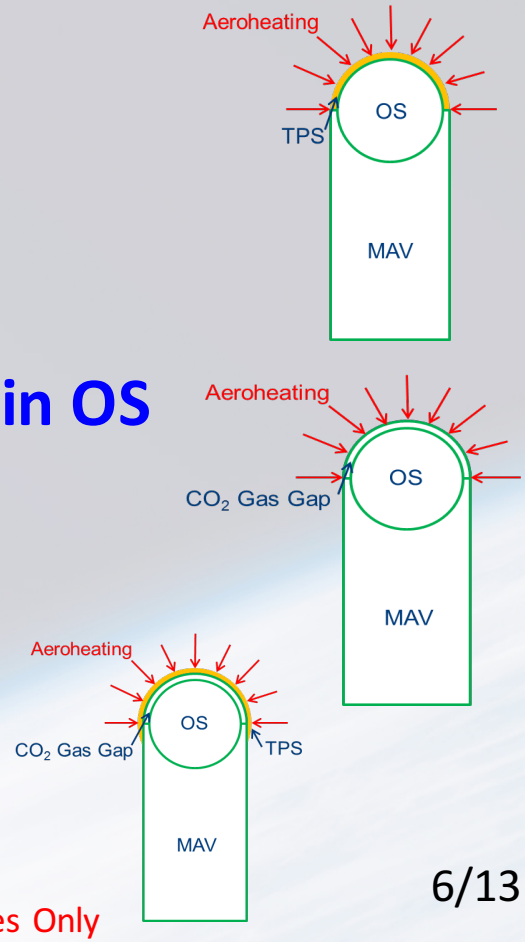




- **OS ~20 cm diameter sphere**
  - **5-10 kg mass**
- **Peak Fluxes of ~ 15 – 40 W/cm^2**
  - **Integrated Energy: ~ 0.25 – 1.5 kJ/cm^2**
  - **Translates to > 1000 kJ of energy on 10 cm nose cone radius sphere**
- **Need to arrive thermal control schemes to prevent overheating**

Options Studied for Thermal Protection of OS During Ascent from Mars

- Using Thermal Mass of OS
- Phase Change Materials in OS
- Additional Radiation Heat Loss Area in OS
- OS covered with Thermal Protection System (TPS)
- Fairing or Shroud covering OS



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Non-TPS, Non-Fairing Schemes for OS

- **Rely only on Thermal Mass of OS**
  - Thermal mass too small
  - Would rise by ~150 - 400 C
  - Not viable
- **Augment OS Thermal Mass by PCM**
  - Would need 1-1.5 kg additional mass (excessive)
  - Additionally, PCM have very low thermal conductivity
    - Very large temp. gradients → Very hot exterior of PCM
  - Not viable
- **Add Additional Radiation Area on OS to increase heat loss**
  - Heat loss by radiation very small due to low max temps. (σT^4)
  - Increase in radiation area also increase heat input
  - Not viable

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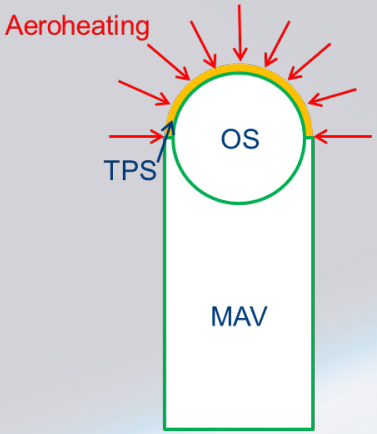
OS Covered with TPS

- OS needs to be tracked in Orbit
  - Optical tracking
    - Requires high solar reflectance
      - Partial or full White/Shiny surface
  - Radio beacon
    - Narrow survival temp. (-40/+50 C)
      - Electronics or Battery

- TPS with low thermal conductivity
  - HRSI, FRCI-12 (Shuttle tiles) – low k and ρ
  - But typically black to increase IR emissivity
    - Black would compromise optical tracking
    - White would compromise heat flux capability
  - Compromise could be ½ black, ½ white



- TPS made of Ablative Materials
  - SIRCA, SLA-561, PICA have high heat flux capability compared to Shuttle tiles
  - Shuttle Tile, SIRCA, SLA-561: ~0.3 kg mass, ~1 cm thick (ROM)
  - PICA has much larger k, so need to be much thicker, heavier
  - SIRCA, SLA-561, PICA may char
  - But hybrid ½ black (nose cone, TPS), ½ white (anti-nose cone, no TPS) could work

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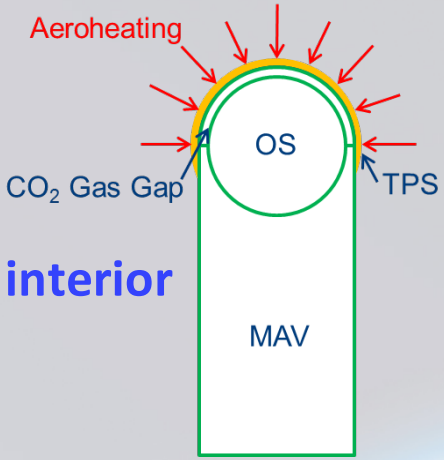
Fairing/Shroud Covered with TPS

- OS could be protected by covering with Fairing/Shroud
  - Fairing would be clamshell, released after ascent
  - Shroud is door-based opening
  - Fairing & Shroud are similar thermally
- The main feature is a gap between OS & Fairing/Shroud & interior of F/S low emissivity
  - Gap would fill up with Martian CO2 gas
  - Provides thermal isolation between them
- Metallic shroud not viable because it would overheat (~500 C) & may not be viable structurally
- TPS on F/S provides the same advantages as TPS on OS
  - Also provides additional thermal isolation due to gap
  - Additional TPS mass affects MAV, not OS, so lighter OS

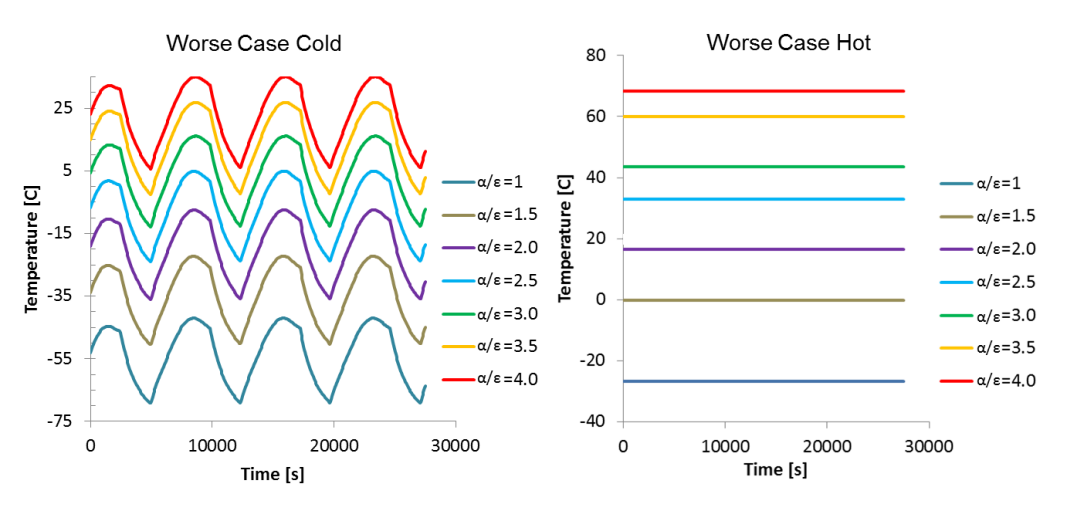


OS During Orbit

Case	Altitude	Orbit Beta Angle	Solar Irradiation	A.U.
Worst Case Hot	500 km	90°	720 W/m^2	1.381
Worst Case Cold	500 km	0°	495 W/m^2	1.665

- Once OS released from MAV nose cone, it orbits Mars or Sun, waiting for rendezvous with Earth Return Vehicle
  - Needs to be have surface partially reflective in solar spectrum to be optically trackable
  - But if radio beacon employed, needs to be maintained in narrow temperature range (-40/+50 C) for electronics/battery integrity
- Passive design for long duration (several years)

OS During Orbit



- White paint would have low α, but has high ε and leads to low temps.
  - Not desirable for Radio beacon
  - But desirable for optical tracking

- α/ε of 2-2.5 most desirable to meet narrow temp range (-40/+30 C) during hottest & coldest conditions
  - Suitable for either tracking methods
  - Could be achieved by "zebra-striping" or ½ & ½ combination of different coatings on two hemispheres

Summary & Conclusions

- Maintaining Thermal Integrity of Martian samples in the OS during ascent from Mars & orbit phases is a challenging problem
- Several options to achieve this were studied
  - Some discarded, some useful for further study
- TPS on OS or Fairing/Shroud are attractive for ascent protection
- OS coated with combinations of solar reflective material and & TPS would be attractive for tracking in orbit & protection during ascent from Mars
- These are only conceptual studies & significant additional considerations need to be taken into account for a mature design

Acknowledgements

- **The work described in this paper was performed at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.**