Passive Thermal Control Challenges for Future Exploration Missions

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Background

•The President's recently announced vision refocuses attention to exploration;

•Emphasis shifts *from* Earth orbit operations *to* travel to the Moon, establishing a lunar base, and an eventual journey to Mars;

•Humans went to the Moon during Apollo, but only for short stays – a different set of challenges arises when we consider going to the Moon to stay for extended periods;

•Humans have yet to visit Mars but work on advanced programs has identified some key challenges associated with sending humans to Mars.

NOTE: This presentation will focus only on passive thermal control – thermal protection (entry-related technologies) will be covered in a separate presentation.

General

- *Improved Thermo-optical Coatings:*
  - **Low solar absorptance to infrared emittance ratio (α/ε) – potential use on radiators;**
  - **Inexpensive – some current low α/ε coatings are very expensive;**
  - **Easy to apply;**
  - **Resistance to property changes (due to ultra-violet radiation);**
  - **Resistance to atomic oxygen;**
  - **Long lifetime with stable properties;**
  - **Can be easily maintained (in lunar- or martian-dust environment);**
  - **Variable/user specified optical properties.**

- *Thermal Instrumentation:*
  - **Inexpensive;**
  - **Reliable;**
  - **Robust.**

General (Continued)

- *Cryogenic Boil-Off:*
  - **Improved storage of cryogens for prolonged periods.**

- *Insulation/Isolation Technologies:*
  - **Vacuum panels;**
  - **Use of aerogels;**
  - **Multi-Layer Insulations (MLI);**
  - **Thermal Compartments;**
  - **Thermal Switches.**

- *Lunar Day/Night Survival:*
  - **Lunar days and nights each last ~two weeks;**
  - **Extreme temperatures during lunar day (> +250 deg F);**
  - **Lunar soil reaching high temperatures in prolonged sunlight;**
  - **Lunar nighttime produces surface temperatures < -300 deg F**

Electronics

•With further miniaturization of electronics components, power density and the associated challenges of electronics heat dissipation will provide new challenges -- Potential needs include power reductions that keep pace with electronics miniaturization;

•Improved means of heat transfer from electronics components:

- **•Gap Fillers;**
- **•Gaskets;**
- **•Improved interface conductance.**

Involvement by the thermal community is critical early in the development process.

Analysis

- *Improved modeling of systems;*

- *Potential for large model sizes*

- *Improved modeling of electronics components;*

- *Improved thermal environment characterization;*
    - **Planet/moon surface environments, atmospheric extinction, diffuse sky heating components;**
    - **Improved convective heat transfer calculations for Mars surface;**

- *Improved compatibility with concurrent engineering tools:*
    - **Thermal → Structural;**
    - **CFD → Thermal;**
    - **Orbit → Thermal;**
    - **Etc.**

- *Thermal Analysis of Inflatable Structures*

Environment Characterization

•*Lunar and Martian Orbit Environments:*

- •Lunar albedo and infrared emission;
- •Martian albedo and infrared emission.

•*Mars Surface Environments:*

- •Atmosphere optical depth and dust storm characteristics;
- •Diffuse sky solar and infrared heating components;
- •Detailed wind profiles;
- •Atmospheric temperature profiles near the surface.

Testing

•*Facilities to support large-scale thermal-vacuum testing for lunar- and martian surface environments are needed:*

- **Solar simulation;**
- **CO_2 environment at low pressure (for martian surface simulation);**
- **Lunar and Mars surface simulation.**

Wrap-up

- **Expect additional technical challenges to arise as an architecture for exploration matures;**

- **Key aspects of passive thermal control arise as a consequence of spacecraft integration:**
    - **Utilizing waste heat from one system to accommodate the needs of another system;**
    - **The entire system must function successfully as a unit.**