

Passive Thermal Control Challenges for Future Exploration Missions

Transformational Space Concepts and Technologies Workshop
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Presented by:

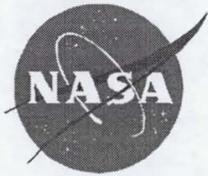
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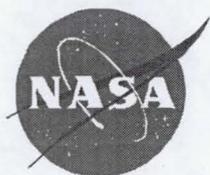
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Presentation Contents

- **Background**
- **Passive Thermal Control Challenges for Exploration**
 - **General**
 - **Electronics**
 - **Environment Characterization**
 - **Analysis**
 - **Testing**
- **Wrap-up**

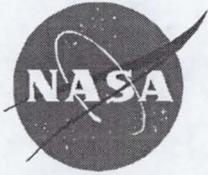
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Background

- **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.



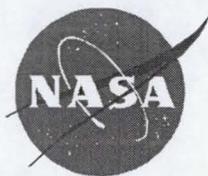
General

• *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 cryogenics 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



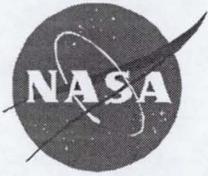
Electronics

•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:*

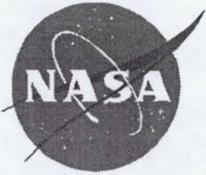
- Gap Fillers;
- Gaskets;
- Improved interface conductance.

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:*

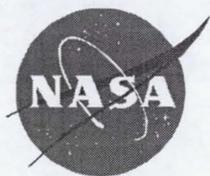
- Atmosphere optical depth and dust storm characteristics;
- Diffuse sky solar and infrared heating components;
- Detailed wind profiles;
- Atmospheric temperature profiles near the surface.



Testing

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

- Solar simulation;
- CO₂ 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.**