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JPL Advanced Thermal Control Technology Roadmap 2003

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JPL Advanced Thermal Technology Team

Pradeep Bhandari:	Pumped Fluid Loops, Long-Life Pumps
Gaj Birur:	Pumps, Fluid Loops, LHP,etc
Gani Ganapathi:	MER Heat Rejection System
Keith Novak:	Loop Heat Pipe and MER Heat Switch
Tony Paris:	MEMS based Pumped Liquid Loop
Mike Pauken:	Loop Heat Pipe and MER Heat Switch
Jose Rodriguez:	Loop Heat Pipes
Eric Sunada:	MER Heat Switch
Glenn Tsuyuki:	Light Weight Insulation,

JPL OUTLINE

- **Background**
- **Future JPL Missions**
- **JPL Thermal Control Technology Roadmap**
- **Conclusions**

JPL Advanced Thermal Control Technologies

- Future NASA deep space science missions will be complex and diverse in terms of thermal environments and requirements
- Current thermal control technologies are not be able to meet the science objectives of these missions
- Advanced thermal technologies and architectures are needed to meet the cost, mass, volume, and capability requirements of future missions
- JPL is developing several advanced spacecraft thermal control technologies working with other organizations

JPL Future Space Science Missions at JPL

- **Mars Missions**
  - Mars missions - landers, rovers, in-situ production experiments, and robotic support for human colonization missions, Mars Micro Missions. MER (2003), MRO(2005), Mars Scout (2007), and Mars Science Laboratory (2009)
- **Other Deep Space Missions**
  - Missions to comets/asteroids - e.g., Comet Nucleus Sample Return, asteroid exploration & sample return
  - Missions to other Planets - Europa orbiter/lander, Venus Surface Sample Mission, Jupiter Multiprobe, Titan In-Situ Mission, Saturn Ring Observer, Neptune Orbiter
- **Other Missions** - Earth orbiting spacecraft/science payload, space telescopes, space interferometer missions, and science instruments

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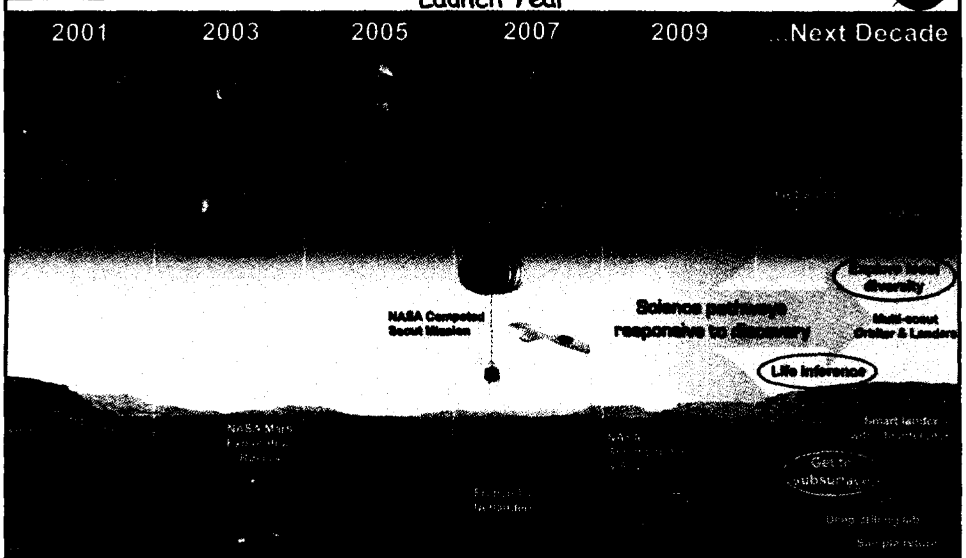
JPL Mars Exploration Program

Launch Year



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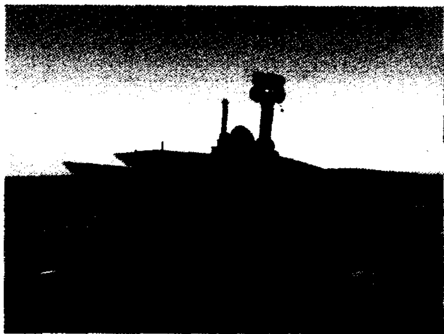
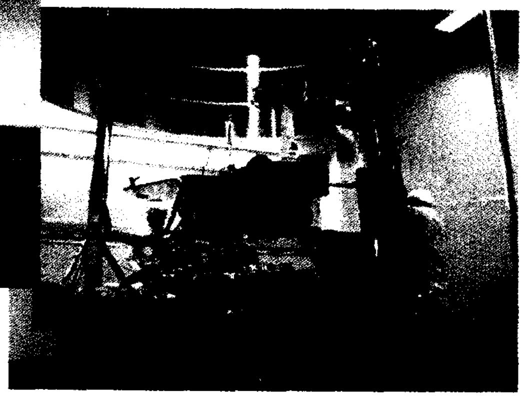
Mars Exploration Rover





Rover test in December 2003

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Mars Rovers - Past, Present, and Future

MSL ('09), ~ 750 kg
Pumped cooling loop

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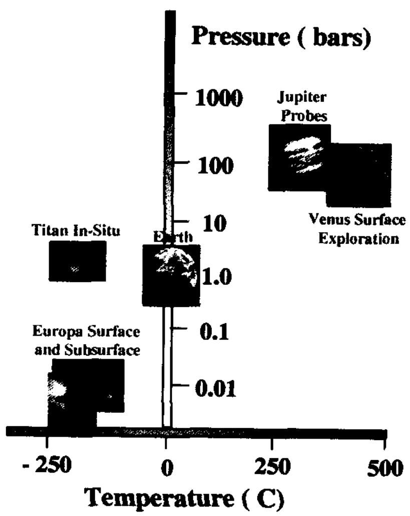
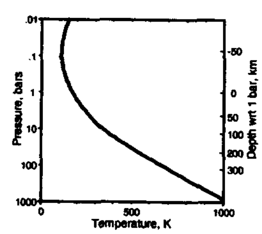
Extreme Environments in Future Space Missions

Mission	Low Temp. C	High Temp., C	High Radiation Levels	High Pressure	Other Environmental Conditions
Venus Surface Exploration and Sample Return		460		90 bar	Sulphuric acid clouds at 50 km 97% CO2 at the surface
Giant Planets Deep Probes	-140	380		100 bar	
Comets Nucleus Sample Return	-140				Dust
Titan In-Situ	- 180			1.5 bar	2-10% Methane Clouds Solid/liquid surface
Europa Surface and Subsurface	-160		5 MRad		

Extreme Environment





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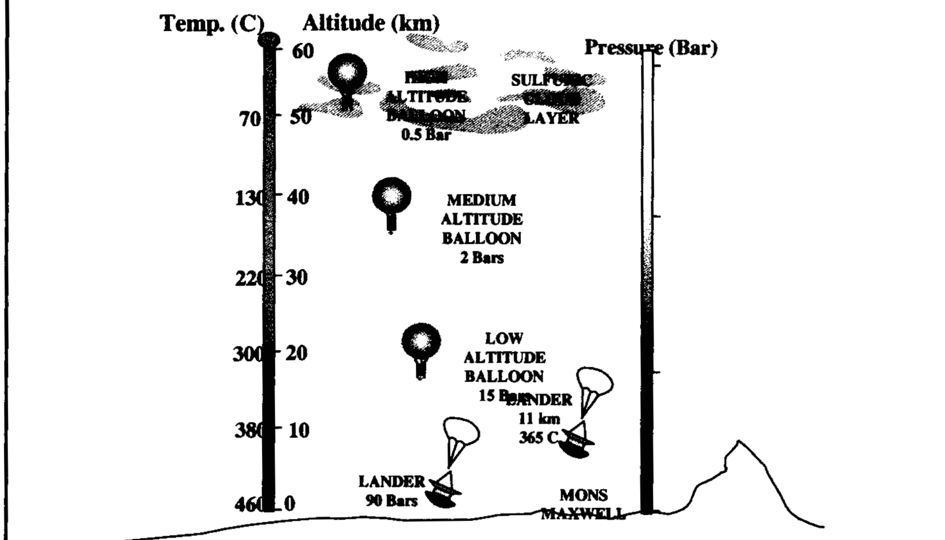
Mars Environment



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Titan in-situ and Comet Environment

Thermal technology needed to protect the science and engineering equipment to survive and operate in Titan/Comets low temperature (- 180 to - 140 C) environment:

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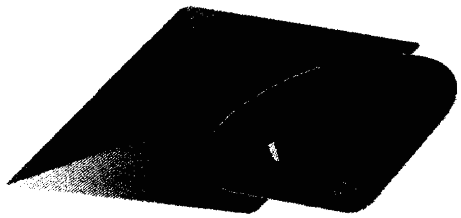
JPL Space Interferometer Missions

- Space Interferometer Missions, Terrestrial Planet Finder, future space telescopes need Picometer accuracy, 100 micro-Kelvin temperature stability

Infrared Interferometer based on formation flying telescopes



Visible light Coronagraph Concept for Terrestrial Planet Finder

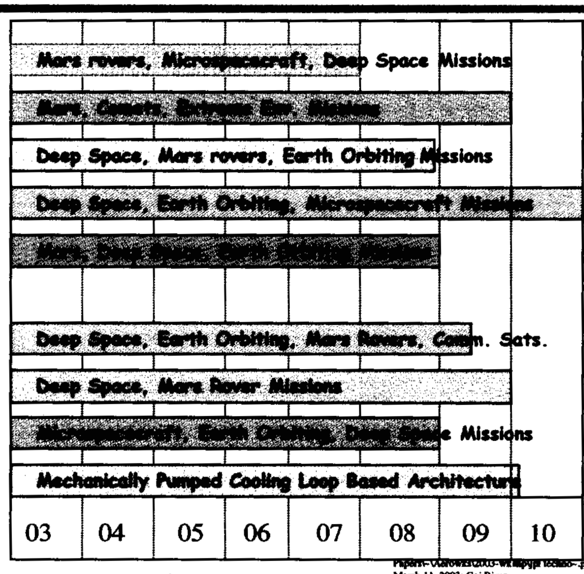
JPL JPL Thermal Control Technology Roadmap

PASSIVE TECHNOLOGIES

- Loop Heat Pipe
- PCM Thermal Storage
- Heat Switches
- Variable Emitt. Devices
- Passive Loop Arch.

ACTIVE TEHNOLOGIES

- Long life pumps
- High-temp.loops
- Active Micro-cooling Sys
- Active Loop Architecture



Loop Heat Pipe Technology

(Small Size/Capacity LHPs)

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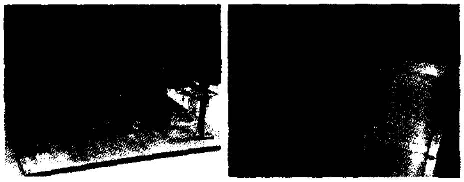

Miniature loop heat pipe for Mars Thermal Control

Dual Evaporator Miniature LHP

Technical Description

- A versatile thermal control device: transfers heat, controls source temperature, and acts as a heat switch (all in one)
- Light weight (< 200 gms to transfer 60 W) device compared to other thermal control hardware performing the same function
- Enormous flexibility in locating heat sources and sinks on the spacecraft

Participants & Facilities

- JPL is investigating this technology for Mars rover & microspacecraft applications
- Tests performed at JPL and Goddard during FY00-02 for evaluating miniature multiple evaporator loop heat pipe
- Dynatherm Corp (Swales) designed and fabricated a miniature loop heat pipe

EOS-TES Loop Heat Pipes

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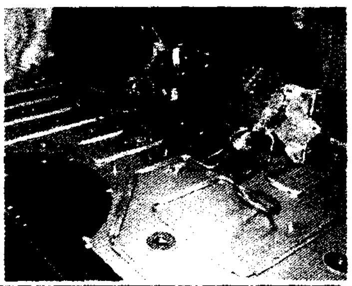
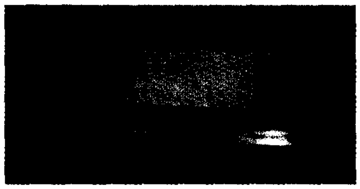


- **EOS-TES is using five LHPs in its thermal design (Jose Rodriguez)**
- **Propylene LHPs in the 75 to 150 W range**
- **Instrument level tests successfully completed in early 2003**
- **TES to be integrated on EOS spacecraft for system level tests**

JPL Phase Change Material (PCM) Thermal Storage Technology

Dodecane PCM Thermal Storage Unit (Melting point, -10.5 C)



Hexadecane PCM Thermal Storage (Melting Point temperature 18 C)

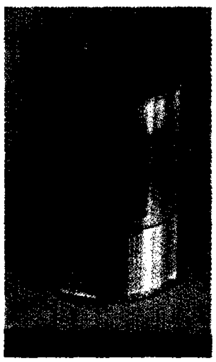
Description

- Phase change material (PCM) utilizes latent heat to protect equipment against temp. extremes by increasing thermal capacity
- PCM stores excess heat when available and releases when needed
- The technology is simple, reliable, and mass efficient

Current Status

- A dodecane (MP -10.5 C) PCM capsule (ESLI, San Diego) was integrated with miniature LHP and tested for Mars rover battery thermal control
- A Hexadecane (MP, 18 C) PCM from ESLI is being evaluated for Mars rover battery thermal control at JPL

JPL Heat Switch for Space & Mars Surface Applications



Lightweight Heat Switch

Description

- Wax actuated heat switch for Mars with target performance of 0.4 W/C, switch ratio of 30 in 8 torr CO_2, weighing less than 120 gms
- A miniature lightweight high performance heat switch using phase change material actuator (FY99 -0.12 W/C with open/close ratio of 18 weighs 8 gms; FY02 - 0.348 W/C, 8 gms)

Participants & Facilities

- Wax actuated heat switch for MER was developed by Starsys. in Boulder, CO
- Miniature heat switch development is conducted by ESLI under NASA SBIR II

Variable Emittance Devices (Electrochromic)

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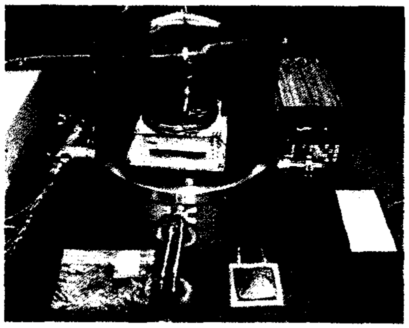

Electrochromic Device Testing at JPL

Description

- A change of surface emissivity in the range of 0.2 to 0.8 by an external electric field of ~ 1V dc
- Provides a low mass device(400 gm/sq m) to vary heat rejection capacity on th spacecraft

Participants & Facilities

- JPL is investigating this technology along with GSFC and AFRL for Spacecraft applications
- Conducting polymer based devices made by Ashwin-Usha
- Space endurance testing underway for UV, radiation, thermal vacuum, & micrometeroid environment at JPL and NASA GSFC

Mechanically Pumped Cooling Loop

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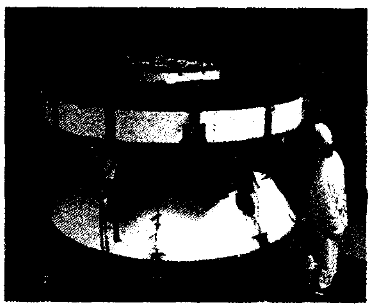


Mars Pathfinder MPL (1996)

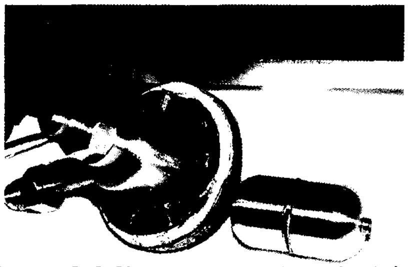
Description

- Mechanically pumped single-phase cooling loop used on Mars Pathfinder (1996) and MER (2003) for thermal control
- A pump assembly of 7 kg uses CFC-11 to remove ~160 W from spacecraft to external radiator

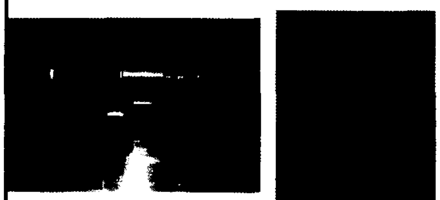
Participants & Facilities

- JPL is investigating this technology for future Mars and deep space missions
- Pacific Design Technology built the pump assembly for MER Mission
- An engineering pump unit under life test at JPL for the last eight months

JPL Long-Life Mechanical Pumps



NASA SBIR Ph II Prototype Pump (2002)



NASA SBIR Ph I Prototype Pump (2000)

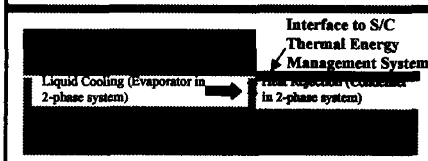
Description

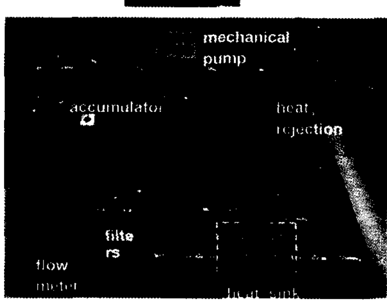
- The bearing and seal-free pump uses a floating rotor and no seals; promises high reliability for long-term operation
- Light weight device compared to state of the art mechanical pumps (Mars Pathfinder pump) has large clearances

Participants & Facilities

- JPL is investigating this technology for mechanically pumped cooling loops for space applications (Mars rover, µS/C)
- Long-life testing completed (5000 hours) on Phase I pump at JPL in 2001
- Advanced Bionics Inc., in Minnesota is developing this pump for heart bypass and heart replacement functions

JPL Active Micro-Cooling Systems





Description

- To develop MEMS based liquid pumped cooling system for high density electronics and sensors for future micro/nano Sciencecraft
- Single-phase liquid is circulated in microchannels with a mechanical pump

Participants & Facilities

- JPL is investigating this technology for high power density heat removal in microspacecraft and large spacecraft
- Other participants Stanford University and SAIC
- A miccooling test bed used for evaluation of microchannels and micropumps

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Conclusions

- The thermal control challenges posed by future NASA science missions can only be met by advanced thermal control technologies
- Both passive and active thermal control technologies are needed to enable/enhance future missions
- Both near/far term missions and large/micro spacecraft require advanced thermal technologies
- JPL is actively working with several organizations in the development of these technologies

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Presenter's Introduction

- Gaj Birur -
  - Gaj is a Task Manager in the Thermal and Propulsion Engineering Section at JPL where he has been working for the last twenty-four years. His current areas of interest are spacecraft thermal control design, thermal hardware implementation, and advanced thermal control technologies for future interplanetary spacecraft and Mars landers and rovers. He manages the operations of an advanced thermal technology laboratory at JPL