JPL Advanced Thermal Control Technology Roadmap 2002

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Advanced Thermal Technology Team

Pradeep Bhandari:	Bearing and Seal-Free Pump
Siina Haapanen:	Loop Heat Pipe and Electrochromics
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
Eric Sunada:	MER Heat Switch
Glenn Tsuyuki:	Light weight Insulation for Mars

OUTLINE

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

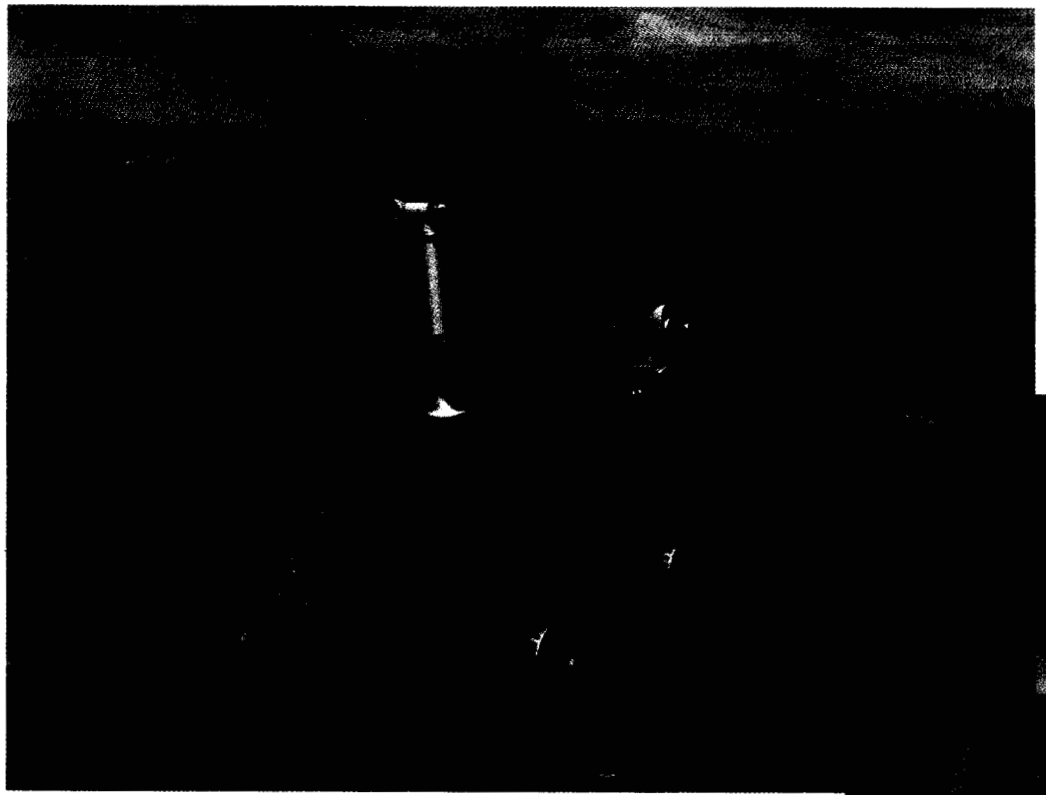
Advanced Thermal Technology at JPL

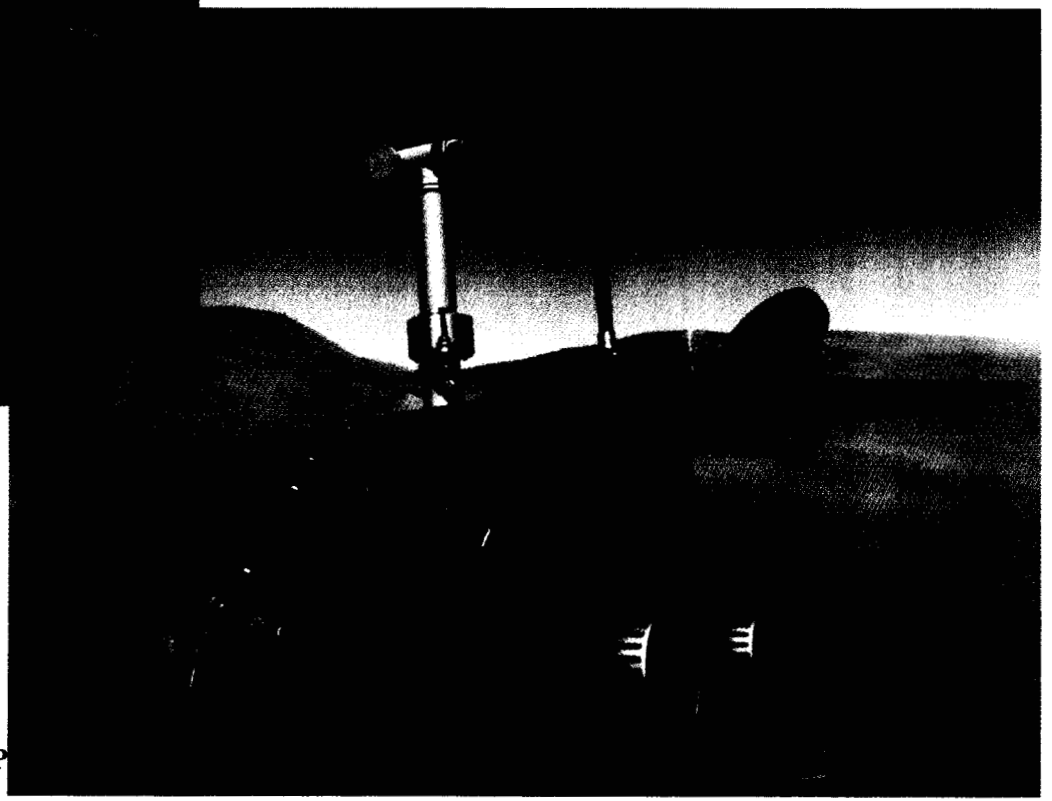
- Advanced thermal technology insertion into S/C at JPL seriously started in mid 90's
- Mars Pathfinder was the first one to insert advanced technologies in a big way - mechanical pumped loop, aerogel isulation
- Mission complexity and the need to make the S/C lighter, cheaper and more capable is the driver
- Managers are more willing to take risks to achieve higher performance

Deep Space Missions

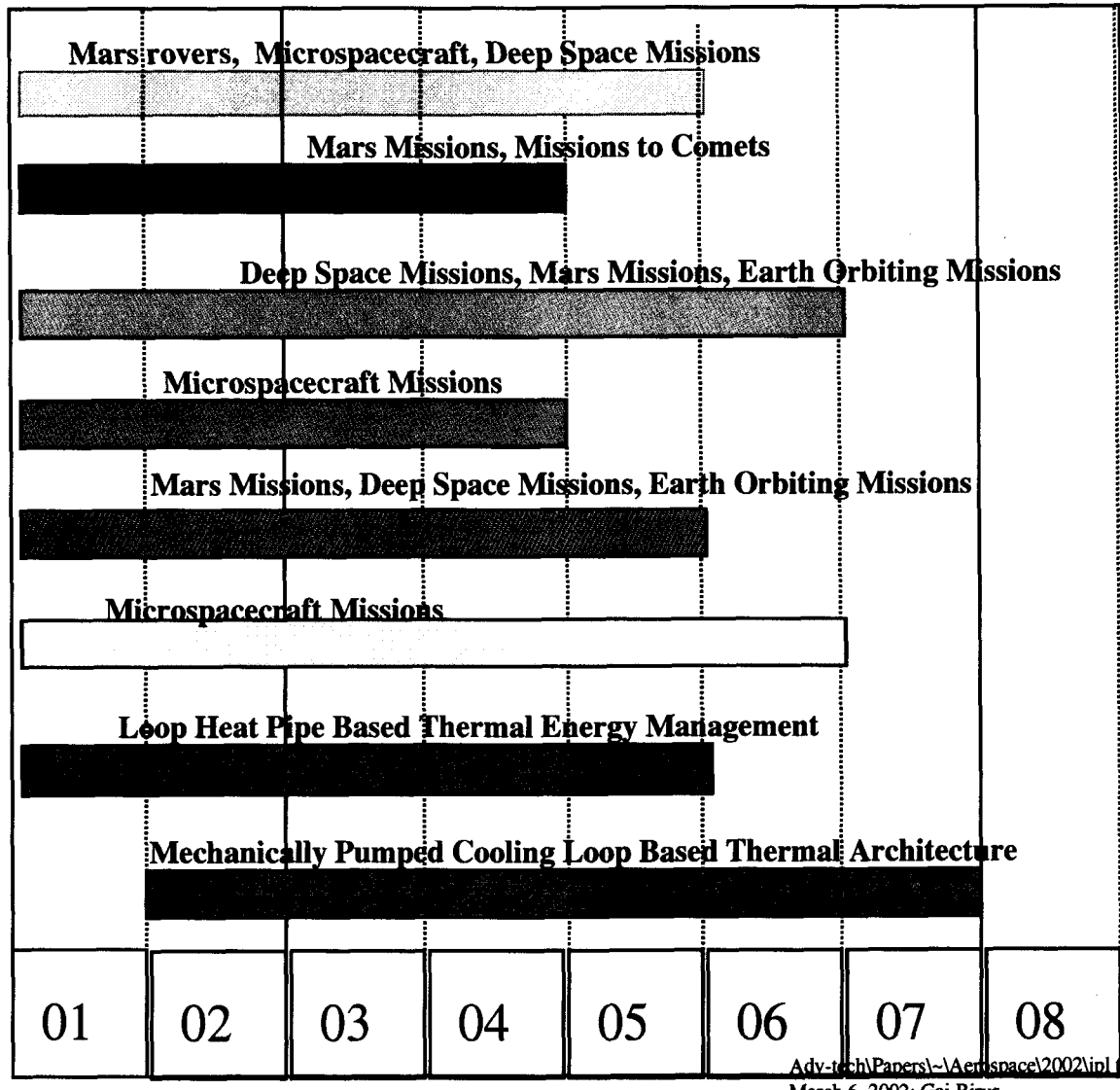
- **Mars Missions**
  - Mars missions - landers, rovers, in-situ production experiments, and robotic support for human colonization missions, Mars Micro Missions. MER (2003), Mars '05 Orbiter (2005), Mars '07 Mega Lander (2007)
- **Other Deep Space Misssions**
  - Missions to comets/asteroids - e.g., Comet Nucleus Sample Return, asteroid exploration & sample return
  - Missions to other Planets - Europa orbiter/lander, Saturn Ring Observer, Neptune Orbiter
- **Other Missions - Earth orbiting spacecraft/science payload, space telescopes, instruments**
- **Microspacecraft Missions**

Mars Exploration Rover Conceptual View

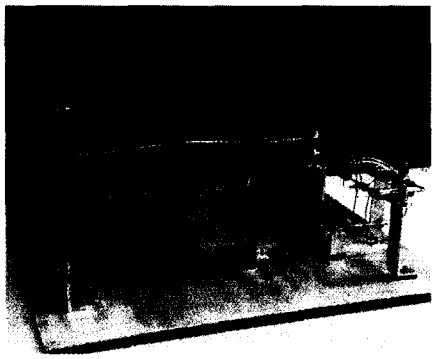




JPL Thermal Control Technology Roadmap



Loop Heat Pipe Technology



Miniature loop heat pipe for Mars Thermal Control

Technical Description

- A versatile thermal control device: transfers heat, controls source temperature, and acts as a heat switch (all in one)
- Light weight (less than 150 gms to transfer 50 W) device compared to other thermal control hardware performing the same function
- Enormous flexibility in locating heat sources and sinks on the spacecraft

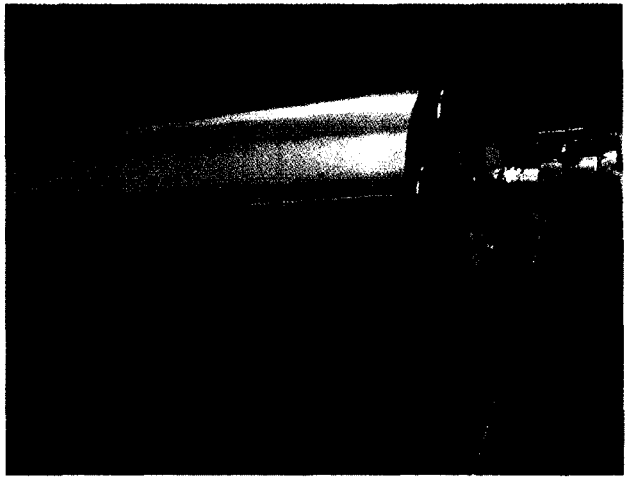
Participants & Facilities

- JPL is investigating this technology for space applications (Mars rover/lander, micro S/C)
- Tests to be performed at JPL and Goddard during FY00 for evaluating miniature multiple evaporator loop heat pipe
- Dynatherm Corporation has designed and fabricated a miniature loop heat pipe for Mars Rover battery thermal control concept

Mission Impact & Future Applications

- This technology reduces S/C thermal control mass and provides enormous flexibility
- This is a key technology for enabling Integrated Thermal Energy Management System
- This technology is applicable to small & large S/C and planetary vehicles thermal control

Phase Change Thermal Storage Technology insert new PCM storage



Dodecane PCM Capsule

Description:

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

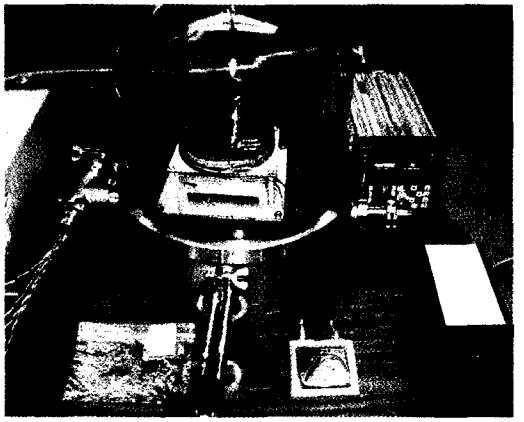
Current Status:

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

Future Development:

- Investigate PCM materials with low and high temperature MP for operations
- Develop and qualify low mass system for thermal energy management on Mars landers, in-situ experiments and Microspacecraft missions

Variable Emittance Devices (Electrochromic)



Electrochromic device from Ashwin-Usha under test

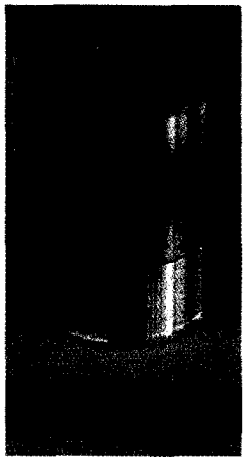
Description

- A change of surface emissivity in the range of 0.3 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 the spacecraft
- Conducting polymer material used as electrochromic material
- Devices based on similar materials used for auto and building energy conservation

Status & Future Applications

- Significant work by EIC labs, LBL Berkeley, ASHWIN-USHAS, NASA GSFC
- JPL, GSFC & AFRL investigating for S/C use
- Excellent candidate for JPL's Integrated Thermal Energy Management (ITEM) systems for future spacecraft
- Space endurance testing underway for UV, radiation, thermal vacuum, and micrometeroid environment at JPL and NASA GSFC
- A sample device will be flown on New Millennium ST-5 flight for validation by NASA GSFC
- Device failure mechanisms in space applications need to be understood

Heat Switch for Space and Mars Surface Applications



- Heat Switches for MER battery thermal control

Technical 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 goal- 0.8 W/C, 2 gms)

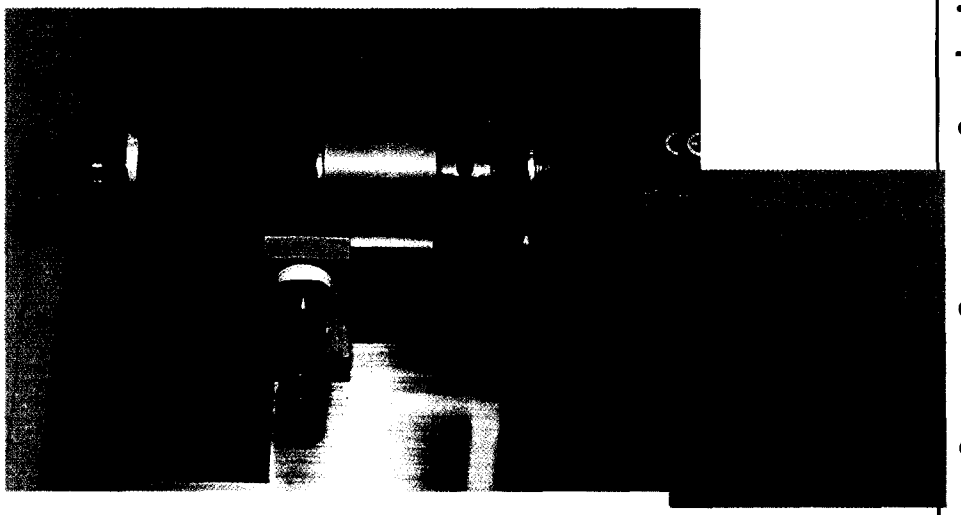
Participants & Facilities

- JPL is investigating this technology for space applications (Microspacecraft and Mars rover
- Miniature heat switch development is conducted by ESLI under NASA Phase II SBIR
- Wax actuated heat switch for Mars rover application is being developed by Starsys, in Boulder, Colorado

Mission Impact & Future Applications

- This is a key technology for the survival of rovers and lander batteries on Martian surface
- This technology reduces Mars rover nighttime thermal control heater needs significantly
- The miniature heat switch is one of the enabling thermal technology for future microspacecraft missions

Bearing and Seal-Free Mechanical Pump for Spacecraft Thermal Control



Technical 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)
- Various working fluids can be used in this pump

Participants & Facilities

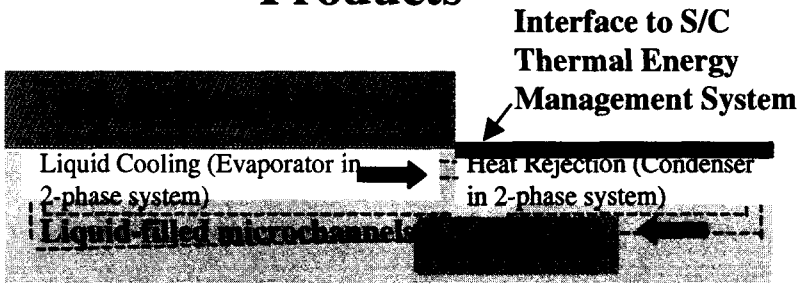
- JPL is investigating this technology for mechanically pumped cooling loops for space applications (Mars rover/lander, micro S/C)
- Tests at JPL during FY01for evaluating long-life performance (5000 hours completed)
- Advanced Bionics Inc., in Minnesota is developing this pump for heart bypass and heart replacement functions

Mission Impact & Future Applications

- This technology is a key part of the cooling loop which reduces S/C system level mass and allows locating heat sources and sinks on S/C and lowers overall I&T
- This is a key technology for the survival of rovers and landers on Martian surface
- This technology is applicable to thermal control of small & large planetary vehicles

MEMS Pumped Liquid Cooling System

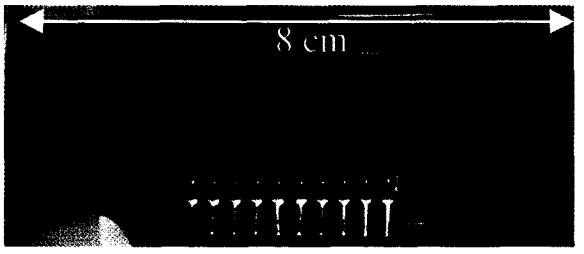
Products



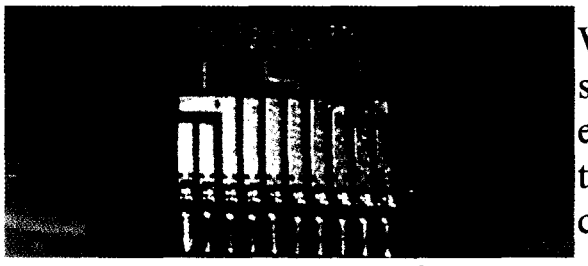
- Microchannels, Micropumps, and
- Integrated microcooling system

Overview

- To develop MEMS based liquid pumped cooling system for high density electronics and sensors for future micro/nano Sciencecraft
- FY00 and FY01: Microchannel design and evaluation of micropump technology
- FY02: Design, fabrication and testing of complete cooling system; TRL 3



Silicon wafer showing the μ-channel side



Wafer backside showing the embedded heater thermistors & connector

Microchannels on a silicon wafer with a connector for heaters and temperature sensors (JPL Micro Device Lab)

Participants:

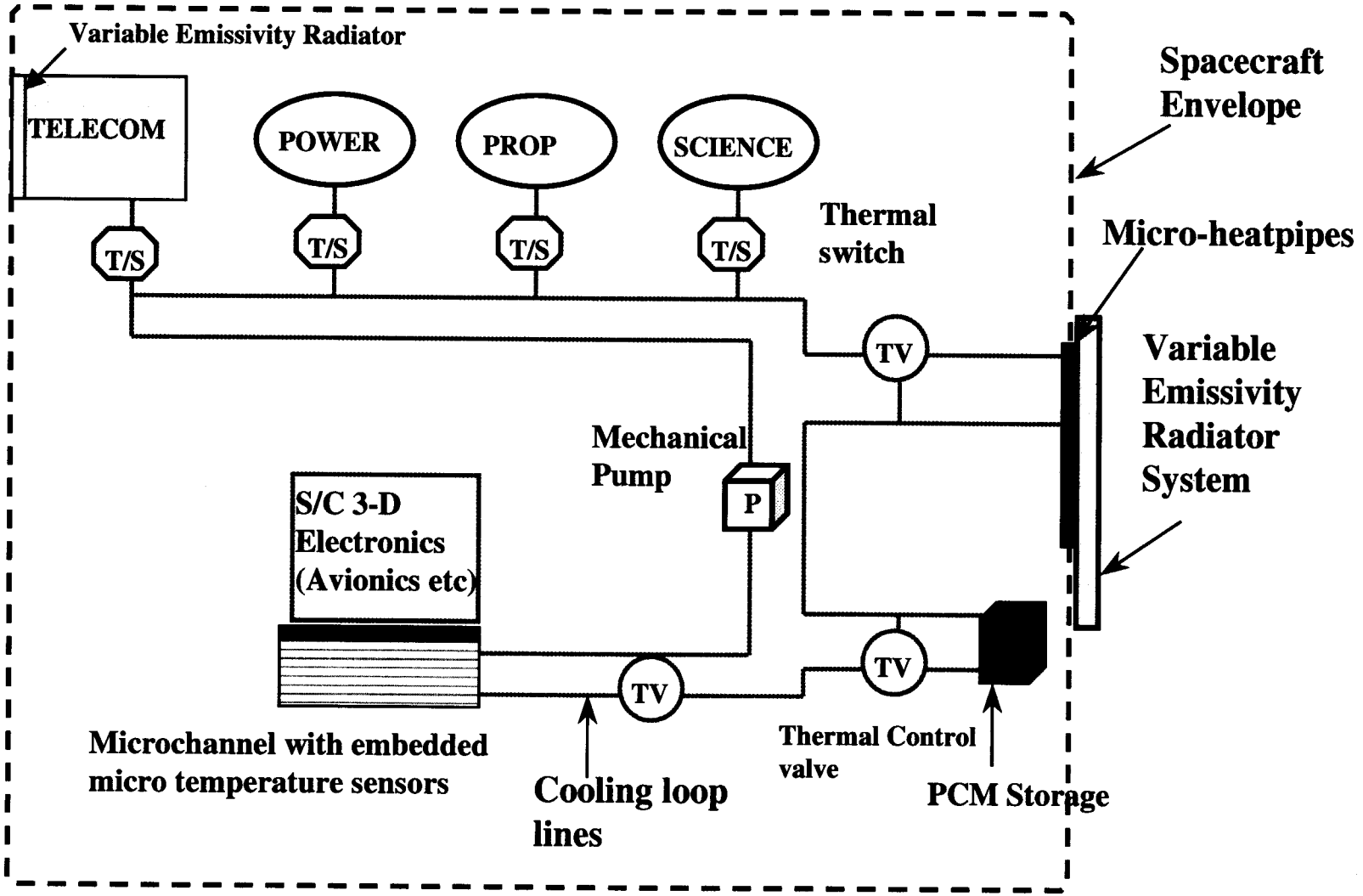
- Jet Propulsion Lab – Dr. Gaj Birur (PI)
- SAIC, San Diego - Dr. Tricia Sur
- Micro Device Labs (MDL) at JPL & Stanford and Thermal Flight Systems & Technology Lab at JPL

Customers:

- Primary Enterprise Customer: Code S, Solar System Exploration missions to Mars & other planets, SEC missions (GSFC)
- Secondary Enterprise Customer: Code Y, advanced sensors, high power density payload

Advanced Thermal Architecture

Based on Active Integrated Thermal Energy Management System (ITEMS)



Conclusions

- JPL is actively investigating advanced thermal control technologies for future deep space missions
- The advanced technologies investigated include: passive and active, enabling and enhancing technologies
- These technologies span both near/far term missions and large/micro spacecraft
- JPL is actively collaborating with other organizations in the development of these technologies