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NASA Thermal Control Technologies for Robotic Spacecraft

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Objective: Technology development is inevitably a dynamic process in search of an elusive goal. It is never truly clear whether the need for a particular technology drives its development, or the existence of a new capability initiates new applications. Technology development for the thermal control of spacecraft presents an excellent example of this situation. Nevertheless, it is imperative to have a basic plan to help guide and focus such an effort. Although this plan will be a living document that changes with time to reflect technological developments, perceived needs, perceived opportunities, and the ever-changing funding environment, it is still a very useful tool. This presentation summarizes the current efforts at NASA/Goddard and NASA/JPL to develop new thermal control technology for future NASA missions.

Observations: NASA's Goddard Space Flight Center and Jet Propulsion Laboratory primarily support the agency's Space Science Enterprise and Earth Science Enterprise. These are robotic, unmanned missions that typically are in Earth orbit, go to a Lagrangian point, or go to another planet. Emerging trends in spacecraft and instrument design are engendering significant thermal control requirements, which require increasingly sophisticated thermal control technology. Major drivers include:

- Dimensional stability of large structures
- Cryogenic heat acquisition and transport
- Tight temperature control (± 1 °C)
- Integrated thermal/mechanical/optical systems
- Common thermal design for fleets of micro/nano spacecraft
- High flux heat acquisition with tight temperature control

- Challenging thermal sink situations, especially for planetary environments
- Minimization of mass and auxiliary power use

Cryogenic structures and other large-scale applications (down to a few Kelvin) are an emerging trend, while stringent optical alignment and sensor needs are requiring ever tighter temperature control and heat flux levels from lasers and other similar devices are increasing. Large, distributed structures such as mirrors will require creative techniques to integrate structural, mechanical alignment, and thermal control functions. Nano and micro spacecraft will also drive the need for new technologies, particularly since such small spacecraft will have low thermal capacitance. This situation, combined with the need for tighter temperature control, will present a challenging situation when such spacecraft/instruments undergo transients. The use of "off-the-shelf" commercial spacecraft buses for science instruments which may have demanding requirements will also present challenges. In general, high performance, low cost, low weight, and high reliability are prime technology drivers.

In response to these perceived needs NASA/Goddard and NASA/JPL are pursuing thermal control technology development efforts to identify and mature, through flight demonstration as appropriate, promising new thermal control technologies. Current efforts include:

- Advanced thermal control coatings such as variable emissive surfaces that permit adaptive intelligent control.
- Cryogenic (3 K to 80 K) heat transport devices (loop heat pipes or capillary pumped loops) for sensor and /or optics cooling which incorporate a diode function.
- Integrated structural, alignment, and thermal control concepts for very large structures.
- Advanced high conductivity materials, such as diamond films, which may be suitable for cryogenic applications.
- Multi-evaporator/multi-condenser two-phase heat transport loops
- Very high heat flux evaporators such as spray cooling techniques

Results: Technology goals and recent efforts towards achieving these goals will be addressed in this paper.