Prioritized Technology: Low Temperature Actuators and Mechanisms – Lubrication

Technical Goal

1. Advanced Dry lubricants: Lubricant materials that can operate in cryogenic conditions, and that can survive -240˚C to 125˚C temperature cycling and operate at -240˚C
2. Materials that do not require lubricants, survive survive -240˚C to 125˚C temperature cycling and operate at -240˚C
3. Lubricant life testing and -240˚C to 125˚C temperature cycling

Technical Status

Many of the current technology can survive -190˚C, but for very short time or few cycles.

- Dry lube: PGM-HT (PTFE, Glass fiber & Molybdenum), Sputtered Molybdenum Disulfide, Carbon nanotubes, graphite, Ion plated type (Europeans have good success with Ion Implanted gold, lead or other metals)
- Non-lubricated system:
  - TRL3: JPL Bulk Metallic Glass system
  - GSFC: hybrid combinations VIM-CRU20 with –Silicon Nitride, titanium carbide. (Steel PMGHT). Steel with hybrid balls. Hybrid combination changes with thermal mismatch that needs to be addressed. Material data at those temperature
  - New combination to identified other
- Life testing data: need to get a lot of data on life test in extreme environment of various dry lubes (existing or new ones). Look also at material properties at those temperature…

Mission Applications

1. Europa [Near Term] robotic arm, gimballed antenna and camera requires a range of capabilities (lubrication, bearings, actuators and gearboxes).
2. Titan landers [Mid/Far term] pin point landing enabled. If capability realized, mission duration will be extended
3. Ice penetration and sampling on Ocean Worlds in the Mid/Far Term on missions would be extended from a couple weeks to few months.
4. Enabling this low temperature technology will allow us to reduce mass, power consumption (no heaters), and thermal losses (less cables) which ultimately, extends mission life. If actuators need not need heaters to operate, more power would be available for instrument operation and would extend the mission life. e.g. M2020, it could take up to 3 hours with energy as high as ~400Wh in order to warm up one of the arm actuators from -100C to -30C. Having actuators that operate at -240 would save energy and warm up time, which would increase science operating time and extend mission life. Thermal leaks will be reduced with no heater, PRT and control cables. The heat loss for a 1 meter 20AWG copper that links cold sink at -240˚C to hot source at 10KC is ~0.2W. Reducing the number of wire from 20 wires to 10, would save about 2W power. Fewer heaters also help reduce thermal contamination of the area of interest. Although heaters, PRTs, and thermostat are low mass, savings from no MLI could be considerable as the typical A142 20-layer MLI is 1kg/m2. Required MLI is highly dependent mission architecture but baseline area for MSL type mission is about 3-4 m2.
5. Another improvement very much needed is to increase target lifetime low temp cycles of operation from 500-1000 cycles to a few million cycles for the actuators. For Mars2020, the requirement for MOXIE is to run 3000rpm for 10 hours; translating to about 4 million cycles testing needed (2X life). In addition, percussion actuators requirement is 25Hz for 30 hours (or 5.4 million cycles if tested at 2X life).
6. Enabling these lower temperature technologies will enable science in Europa, Titan, and other ocean worlds.