SCIENTIFIC RESEARCH ON THE LOW TEMPERATURE MICROGRAVITY PHYSICS FACILITY ON ISS

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Abstract: A hallmark for fundamental physics research at low temperature is the ultra-high measurement precision. Recent advancements in measurement techniques have reached the extent that gravity is the only limiting factor in many areas of research at low temperature. Thus the Low Temperature Microgravity Physics Facility (LTMPF) on the ISS will expand the frontier, and provide scientists an unique research opportunity. The LTMPF is a state-of-the-art facility for long duration science investigations whose objectives can only be achieved in microgravity and at low temperature. It is a self contained, reusable, cryogenic facility that will accommodate a series of low temperature experiments to be conducted on the Japanese Experiment Module Exposed Facility (JEM-EF) of the ISS, with a cryogen lifetime exceeding five months. This paper will describe areas of research planned for early missions of LTMPF, as well as LTMPF science requirements, design capabilities and current status. Opportunities for utilization and collaboration will also be discussed.

Fundamental Physics Research at low temperature *and* in the microgravity environment were pioneered by three highly-successful NASA sponsored experiments on the Space Shuttle (STS): the Superfluid Helium Experiment (SHE) in 1985, the Lambda Point Experiment (LPE) in 1992 and the Confined Helium Experiment (CHeX) in 1997. A low temperature facility on the ISS would provide much longer duration for scientists to perform high-precision measurements. Given the constraints of mass and volume on a JEM-EF payload and from launch carriers, current dewar technology promises 5-6 months cryogen lifetime, which is much longer than the nominal two weeks available on STS. In 1994, the National Research Council (NRC) Space Studies Board recommended that a low temperature facility be constructed for the ISS. Later in 1995, the Low Temperature Science Steering Group (LTSSG, now the Discipline Working Group, DWG), reiterated the same recommendations. As a result, the LTMPF is now being designed and developed by the Jet Propulsion Lab (JPL) in collaboration with industrial partner Ball Aerospace and Technology Co.

The objectives of LTMPF are to provide more frequent access to space, increased sensor capabilities allowing for more diverse science opportunities, and longer experiment operation time in the microgravity environment. The LTMPF, as currently designed, is a complete low temperature laboratory that can be re-flown for at least 5 missions. The current project baseline is capable of supporting two experiments in the same flight. The key feature of each facility is a superfluid helium dewar with the capability to reach and maintain a base temperature of at least 1.6 Kelvin for a period of 5 months. This dewar will house the scientific instrument consisting of the experiment specific hardware of the Principle Investigators (PIs), integrated into a highly stable thermo-mechanical platform. There is a large degree of technical inheritance from the past LPE and CheX experience.

The NASA Research Announcement (NRA) science selection process for flight and ground based investigations occurs on an average of once every two years and the experiments are selected through peer review based on scientific merit and need for microgravity. There are currently two experiments selected to fly on the first mission (M1) of LTMPF, and two experiments selected for the M2 Mission. They are the Critical Dynamics in Microgravity (DYNAMX), the Microgravity Scaling Theory Experiment (MISTE), Boundary Effects on the Superfluid Transition (BEST), and the Superconducting Microwave Oscillator

(SUMO). The first three experiments are condensed matter experiments performed using liquid helium samples (^3He and ^4He) and make use of high precision, SQUID-based thermometry which was originally developed for LPE. The SUMO experiment represents a class of experiments exploring gravitational and relativistic physics in a low temperature microgravity environment. The Principal Investigators (PIs) for these experiments are from the University of New Mexico, JPL, the University of California at Santa Barbara, and Stanford University. There are also co-investigators from France and Germany.

The PIs, at their home institutions, conduct ground-based low temperature fundamental physics research, define their flight experiments, and develop that part of their apparatus which is specific to their investigations. The PIs may also develop and prove new technologies necessary to perform their experiments in space. The low temperature facility includes a cryogenic dewar, electronics, mechanical and thermal support structures, and structures necessary to interface with the ISS and launch vehicles. JPL, in addition to constructing the thermo-mechanical probe structure and to performing key software tasks, is responsible for the overall project definition, management, implementation, as well as the final flight integration and tests.

Input from scientists currently working in fields which may benefit from access to a low temperature environment in microgravity was actively sought to design a facility useful for cutting edge science. A Science Requirements Envelope Document (SRED), finalized in September 1999, was created to capture this input. Particular attention was given to the current flight PIs, who are in the process of developing their own individual science requirements specific to their experiments. The goal of the SRED is to "envelope" the needs of each of the flight definition experiments, capturing the common needs of all the experiments while at the same time insuring that PI specific items were not excluded by an evolving conceptual design for the facility. Inputs from previous flight experimentPIs, participants of fundamental physics workshops, and fundamental physics ground PIs were also incorporated into the SRED.

In addition to the requirements generated by consideration of the needs of the science community, there are many other sources of constraints which affect the design of LTMPF. Such sources include the ISS, the STS, the JEM EF, and the launch carriers. Requirements derived from operating in space environments, such as the survivability of electrical components in space, must also be considered in the development of the facility. These requirements, as well as those derived from the SRED, are combined into a System Functional Requirements Document (FRD) which guides the engineering design of LTMPF.

To support the scientific instruments located inside the dewar, an extensive system of electronic and mechanical equipment, as well as thermal, electrical and magnetic shielding, and mechanical structures is located within the facility. Electronics being designed and built for the facility include Superconducting Quantum Interference Devices (SQUIDs) used to make precision temperature and pressure measurements, resistance thermometry and precision heaters for thermal control and experiment operation, and other electronics specific to each individual experiment. The overall design of the facility electronics is modular and flexible to meet the needs of future experimenters. A modular system for handling gas supplies for experiment control and sample supply, as well as optical access capability to the instrument area is available. An onboard flight computer controls all facility and instrument electronics, command, telemetry, and data storage during on-orbit operations.

Most candidate experiments are sensitive to random vibrations, charged particles, and stray magnetic fields. LTMPF is constructed with a passive vibration isolation system attenuating vibration levels coming from the ISS to below 700 μg rms at the instrument. Several layers of magnetic shielding are built into the instrument probe to protect the experiments from on-orbit variations in the magnetic field environment. The vibration and radiation levels will be monitored and real time data will be provided to experimenters. The facility is built with the mechanical and thermal structures necessary for survival in the environments encountered from launch and attachment to the ISS, through return and landing of LTMPF on the Space Shuttle.

Once the facility and the two flight experiments are built and tested by their developers, the hardware is shipped to JPL for final integration and testing. After integration, the entire facility is shipped to the launch site cold. The facility is manifested for its first launch April, 2005. It may take one to two weeks before the LTMPF is docked on its JEM-EF site and is ready for science data acquisition. The experiments simultaneously take data for four and a half months. After cryogen depletion, LTMPF may continue to monitor environments on board the ISS while it awaits return by the Space Shuttle. While one of the facilities is docked on the ISS taking data, the next set of flight experiments are prepared for flight.

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