# LESSONS LEARNED FROM THE FLIGHT OF THE NASA IN-STEP CRYO SYSTEM EXPERIMENT

## (Category D.4 Cryogenic integration Technologies)

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## Extended Abstract

The Cryo System Experiment (CSE), a NASA In-Space Technology Experiments Program (IN-STEP) Flight Experiment, was developed by Hughes Aircraft Company under contract to the Jet Propulsion Laboratory (JPL) to validate in near zero-g space a 65 K cryogenic system for focal planes, optics, instruments, or other equipment (gamma-ray spectrometers, and infrared and submillimeter imaging instruments) that require continuous cryogenic cooling. Two key cryogenic technologies designed to improve performance of systems for scientific, commercial and defense applications in space were successfully demonstrated on NASA's recent shuttle mission, Discovery (STS 63), launched on February 3- 11, 1995. The eight-day mission enabled CSE to validate the zero-g operation of a Hughes 65 K Improved Standard Spacecraft Cryocooler (ISSC) built to cool space-based optics in conjunction with future long-duration missions requiring a low-vibration, long-life cryogenic cooling source; and a Hughes diode oxygen heat pipe thermal switch that enables physical separation and on-off switching between the cooling source and heat load.

CSE achieved 100 percent of its objectives, demonstrating the ruggedness to withstand the space shuttle launch vibrations, and characterizing the performance of both thermal management technologies. It's successful operation validated the on-orbit cooling performance required by space-borne infrared and gamma-ray sensors to reduce the background noise inherent in sensors operating at room temperature. In addition to the flight performance data, an important result of the experiment was the establishment of flight-heritage data that thoroughly demonstrates the system's flight qualification status and compliance with launch vehicle safety and cryosystem integration constraints.

A key value of this flight experiment has been the opportunity for Hughes and the JPL to identify and resolve cooler and imaging-instrumentation integration issues that will be encountered when these enabling thermal management technologies are integrated in future space cryogenic cooling systems. The CSE thermal management technologies are strong candidates for use in future NASA and DoD cryogenic subsystems associated with precision space-science instruments being designed for 5- to 10-year lifetimes. A key focus of this low-cost, high-payback experiment has been to understand and resolve integration issues such as: 1) achieving acceptably low thermal parasitic while simultaneously providing structural support of cryogenic elements, 2) achieving cryogenic cooldown of the experiment's sizable thermal inertia prior to the end of the one-week shuttle flight time, 3) achieving high thermal conductance and low weight between cryogenic elements, and 4) achieving acceptable reliability through the optimal selection and configuration of redundant elements.

A number of valuable lessons were derived from the system integration of cryocoolers and heat pipe technologies as well as from the flight experiment. Presented are lessons learned such as: the effectiveness of launch-vibration restraints for the expander cold-tips, the effectiveness of a high-compliance thermal strap to minimize side loads on the expander, system operations/software considerations, physical location of electrical components, probability of single-event upsets, and the value of on-orbit diagnostics (compressor and expander hysteresis test capability) to check status of the ISSC.

The low-vibration, lightweight cooler, which provided 1.2 watts of cooling during the flight experiment, is an improved version of the 65 K Standard Spacecraft Cryocooler developed by Hughes under Air Force Phillips Laboratory/Ballistic Missile Defense Organization (AFPL/BMDO) sponsorship. It is the first U.S.-built long-life Stirling cooler to operate in space. Its continuous performance over the course of the eight-day mission equaled its performance during ground testing. The experiment is complemented by a ground-based life-test program, funded by the Hughes Brilliant Eyes Program Office, that includes two ISSCs each having approximately 1.8 years of continuous operating time. These life tests are anticipated to continue for the next several years.

The second cryogenic component successfully demonstrated was an oxygen diode heat pipe. The cryogenic heat pipe is designed to provide a high-conductance path between the cryogenic load and the cryocooler, when operating. The diode nature of the heat pipe limits heat conduction in the reverse direction when the cooler is turned off. The shuttle based experiment showed that a cooler can be switched off to conserve power, and also resolved a key technical concern by demonstrating that the diode oxygen heat pipe does work in the near-zero gravity of space. Additionally, due to an unexpected test result in which the diode heatpipe once failed to easily turn off, further tests were conducted. These additional tests confirmed that the radiation shield cooler vibration level, which is much higher than the ISSC vibration level, apparently acts to enhance wicking in the heat pipe. This is an important heretofore unobserved zero-g effect, which has implications for space use of both diode heat pipes and conventional heat pipes.

The work was performed by Hughes under contract to JPL through NASA's Office of Space Access and Technology which provides investigators a rapid, low-cost opportunity to validate the performance of new technologies in the space environment. The CSE illustrates an important type of NASA space-flight experiment in which an enabling technology is validated to provide the option for subsequent application in near-future space system developments.