Title of Investigation:

Development of Cryogenic Accelerometers for 4 Kelvin

Principal Investigator:

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Initiation Year:

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FY 2004 Authorized Funding:

In-house, $15,000

Actual or Expected Expenditure of FY 2004 Funding:

In-house, $15,000

Status of Investigation at End of FY 2004:

To be continued into FY 2005 with funds remaining from FY 2004.

Expected Completion Date:

January 2005

Purpose of Investigation:

The main goal of this investigation was providing scientists and engineers with a new capability for measuring the structural performance of their flight hardware while subjected to temperatures near 4 Kelvin (K). Being able to do this will help us to improve the structural design of our components and significantly improve the performance of our hardware.

To carry out the investigation, we had two requirements. First, we needed an accelerometer, which is used to measure acceleration of a component during vibration testing, to operate under dynamic loads at cryogenic temperatures. Second, the accelerometer had to be small (<0.5" cube), with little mass, because we did not want to alter the structural characteristics of the component that we were testing.

The intent of this study was to find a commercial, off-the-shelf (COTS) accelerometer(s) that met, or came as close as possible to meeting, the requirements and then to perform verification tests on the accelerometer(s). An additional goal was determining the best method for attaching an accelerometer to the hardware. At low temperatures, differences in property between the hardware and the adhesive material can cause an accelerometer to separate from the test item, producing invalid data and possibly damaging the hardware. Therefore, this investigation also had to determine which attachment methods (bolting and various bonding adhesives) would best mount the instrument.

FY 2004 Accomplishments:

We began our investigation by searching for possible COTS instrumentation that would meet the basic requirements of being small, lightweight, and accurate at a temperature of 4 K. We found no accelerometers that completely met the requirements. The accelerometer that came closest to meeting the requirements was a model 8730A, manufactured by the Kistler Instrument Corporation. It is 0.64” tall and 0.28” in diameter, weighs 1.9 grams, and is rated for operation down to 77 K. For size comparison, the accelerometer model currently being used at the Goddard Space Flight Center for cryogenic temperatures is the Endevco model 2272, which is 0.8” tall and 0.625” in diameter, weighs 27 grams, and is rated for operation down to 77 K. Several Kistler model 8730A accelerometers were purchased and six tests were performed to determine whether the Kistler accelerometers would properly function at temperatures below 77 K. The following tests were performed: two ambient temperature vibration tests; two 4-6 K temperature (liquid Helium (LHe)) vibration tests; one 77-80 K temperature (liquid Nitrogen (LN2)) vibration test; and one 4-6K temperature cool down. The ambient temperature vibration tests were performed to verify that the accelerometer operated under rated conditions and to verify that the accelerometers were not damaged after being subjected to cryogenic temperatures. The LHe temperature vibration tests were the main verification tests of the accelerometers and the mounting techniques. The LHe temperature cool down test was performed to more closely monitor the temperature of the accelerometers during cool down and determine at what temperature the accelerometers would no longer function properly.

All cryogenic temperature vibration tests were performed using a small vibrating dewar. This dewar is approximately 18” tall and 16” in diameter. The dewar cold plate, where our accelerometers are mounted, is approximately 9” in diameter. The dewar is capable of maintaining a small component-to-cryogenic temperature for 2-4 hours while subjected to structural vibration loading. Temperature sensors were mounted to the dewar cold plate and to the Kistler accelerometers to monitor the temperatures. Figure 1 shows the sensors mounted to the accelerometers. The dewar bulkhead connector plate accommodates three accelerometer signals. For each test, two Kistler 8730A accelerometers and one Endevco 2272 accelerometer were being monitored. The Endevco was the standard to which the Kistler accelerometer responses were compared.

The accelerometers were subjected to the highest structural loading possible without overstressing the dewar. The structural loading applied to the accelerometers was low-level sine sweep, sine burst, and random vibration. This loading was applied to the axial direction of the dewar and accelerometers. The structural loading is shown in Table 1.

Table 1. Structural Loading Applied to Accelerometers

Applied Loading	Level
Low Level Sine Sweep	0.1 G, 10-1000 Hz, 4 oct/min
Sine Burst	25 G, 6 cycles, at 25 Hz
Random Vibration	8.93 Grms, 60 seconds duration

Various mounting configurations were investigated for attaching the Kistler accelerometers to the cold plate of the dewar. These mounting configurations included: (1) bolting the accelerometer to a G-10 isolator, which was then bolted to the AL dewar cold plate; (2) bonding the accelerometer to the dewar cold plate using Scotchweld 2216 gray adhesive and AL tape; and (3) bonding AL blocks that weighed the same as an accelerometer using Superglue or 3M#966 Acrylic Adhesive

Transfer Film. Figures 2 and 3 show the accelerometers mounted for vibration testing using various mounting configurations.

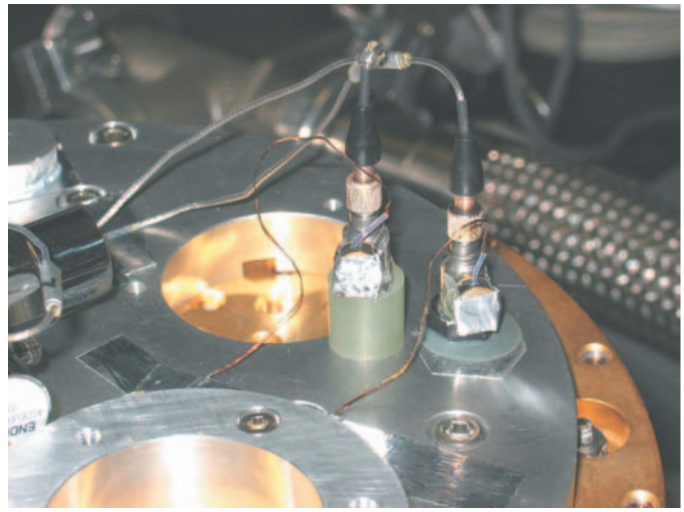

Figure 1. Close view of the Kistler accelerometers with temperature sensors

The results of all testing showed that the Kistler accelerometers functioned at temperatures below 77 K, but only down to approximately 30 K. Below 30 K, the accelerometers do not function reliably. It should be mentioned that these temperatures are the temperatures of the accelerometer case and not the cold plate. One feature of the Kistler 8730A accelerometers is that they have integrated electronics to convert the charge output to a voltage signal. The electronics require a 10-20 V, 4 mA power supply. This applied power generates heat in the accelerometer. This heat is good for the accelerometer functionality because it can warm the accelerometer up to above 30 K. This was the case with the accelerometer that was mounted on the G-10 spacer. During the 4-6 K tests, the 8730A accelerometers did not immediately respond when first connected to the power supply, but after a short time under power, the accelerometer on the G-10 spacer started responding and worked fine throughout the test. The accelerometer that was bonded did not always warm up enough to start responding. Though the G-10 spacer was initially used as an electrical isolation mechanism to eliminate ground loop noise in the accelerometer signal, it is actually beneficial thermal isolation between the cold plate and the accelerometer that keeps the accelerometer at a warmer temperature when powered. It should be noted that the generated heat could be detrimental to any hardware being tested. This issue must be considered before using these accelerometers. The results show that the accelerometers either worked fine or did not work at all. All of the collected data showed good agreement between the Kistler 8730A accelerometer signals and the Endevco 2272 accelerometer signal as long as the accelerometers were responding. Figure 4 is an example of a comparison of the response data.

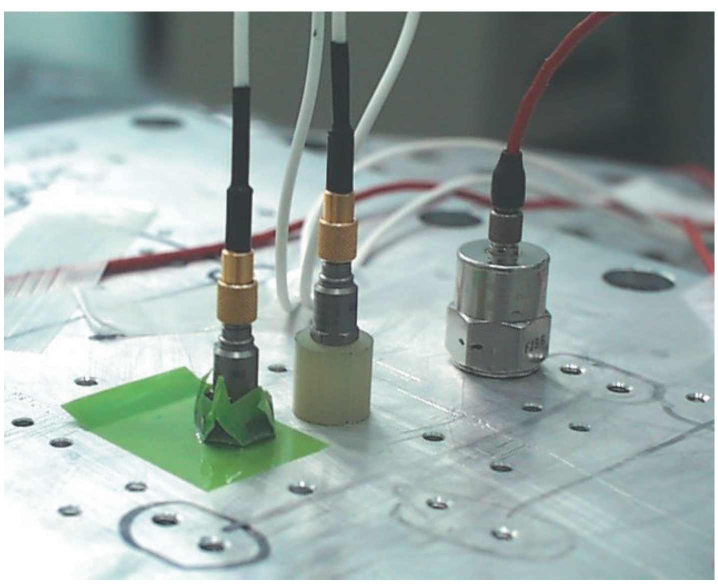

Figure 2. Kistler accelerometers (on left) mounted to the shaker table for ambient vibration testing

The results of the mounting technique tests show that Scotchweld 2216, Superglue, and Acrylic Adhesive Transfer Film, all successfully mount the accelerometers or AL blocks without them coming loose or moving while subjected to LHe temperatures and structural loading.

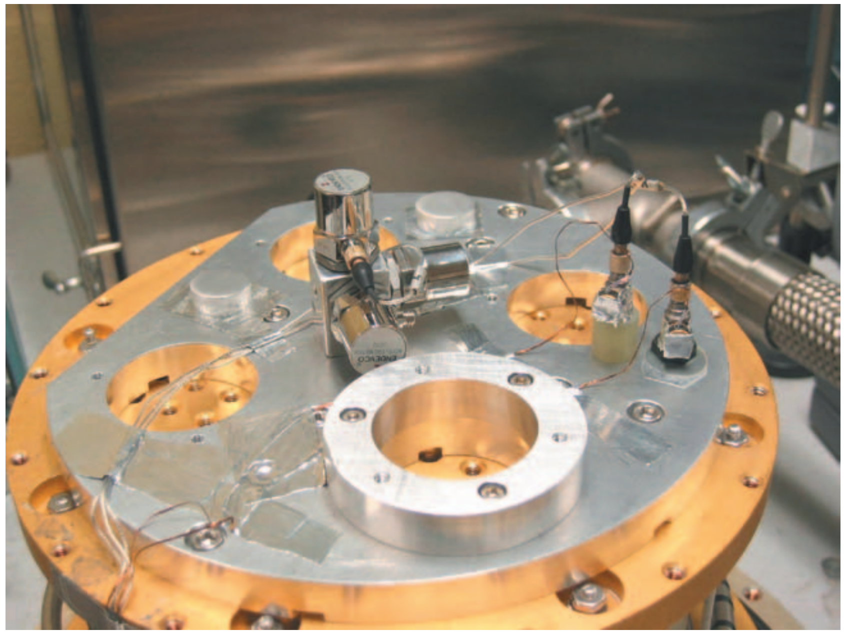

Figure 3. Dewar cold plate configuration

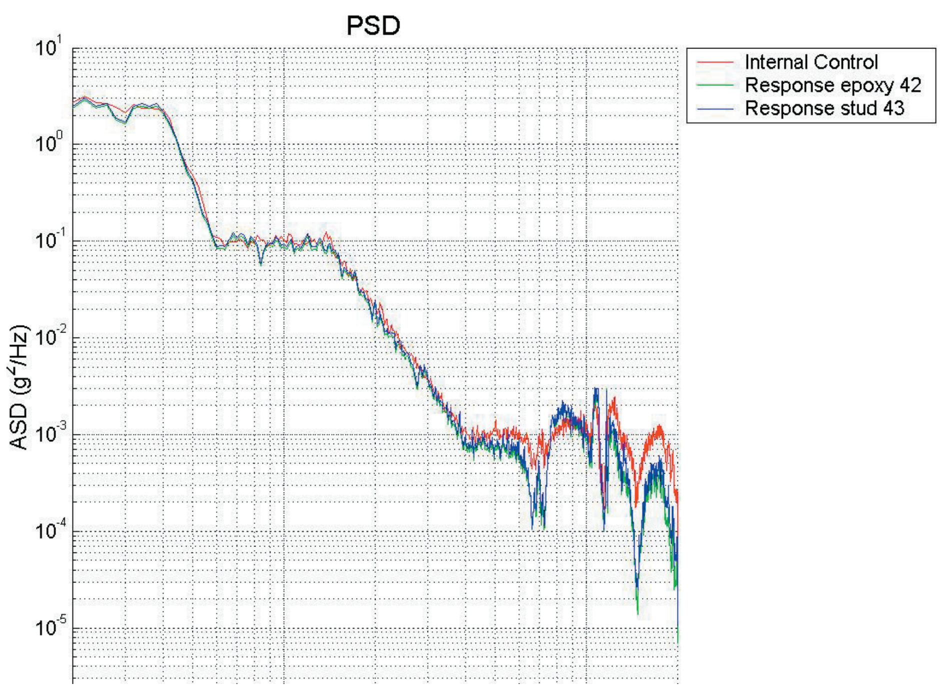

Figure 4. Random Vibration Response Data of Endevco (Internal Control) Accelerometer Compared to Bonded and Bolted Kistler Accelerometers

Planned Future Work:

Testing so far has included only a single axis accelerometer configuration, applying only axial loading. Additional cryogenic temperature vibration tests are planned to demonstrate that accelerometers mounted in a three-axis configuration can sustain not only axial, but also lateral loading when the three-axis configuration is bonded to the dewar cold plate. In addition, results of all testing will be discussed with the Kistler Instrument Corporation to investigate the possibility of developing accelerometers that operate at LHe temperature when they are bonded to the tested hardware.

Summary:

We obtained and tested small, lightweight, cryogenic accelerometers. It was uncertain when we purchased them whether they would work at LHe temperature. Our research effort would be considered a success if the accelerometers could accurately measure structural performance, while subjected to both LHe temperature and structural vibration loading using various mounting configurations. We discovered that the accelerometers that were bolted with an isolator to the dewar's cold plate performed properly at the LHe temperature of about 4 K. However, the accelerometers that were bonded without an isolator to the cold plate performed only as long as the accelerometer's temperature remained above 30 K. It was determined that these particular accelerometers required thermal isolation to operate in a 4 K environment. When isolation was used, the accelerometers worked properly and provided useful information. Using the accelerometers in this way has provided a new capability for the Goddard Space Flight Center's vibration facility because they are small, lightweight and can operate in a 4 K environment. We now are able to properly instrument small components for cryogenic testing. This capability will allow us to design more efficient, lightweight components as well as reduce development time that would have been increased with additional ambient temperature testing.