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Performing LabVIEW-Based Data Acquisition Onboard a NASA Aircraft

NIWeek Paper Finalist

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The Challenge: Acquiring video-synchronized acceleration and temperature data in zero gravity aboard a NASA research aircraft.

The Solution: Using LabVIEW and a DAQ card in a ruggedized portable PC to read time codes and acquire analog voltages.

A LabVIEW-based test system was recently carried aloft in a NASA DC-9 "Vomit Comet" that flew parabolic trajectories to acquire time-tagged data and video on how super-fluid liquid helium behaves in zero gravity.

The purpose of this experiment was to gather empirical data needed to validate and refine computer models of how the helium responds to small perturbations when weightless. The most direct applications of these models involve spacecraft design. Some spacecraft need to keep heat-sensitive parts extremely cold – superfluid helium offers unique properties that make it ideal for this purpose. A good example of such use is maintaining uniform, cold mirror temperatures in space-based infrared telescopes.

The LabVIEW software and data acquisition products operated with the rugged PC without a single problem; the system was regarded by the science team as the best part of the system

The problem is that even at absolute zero, superfluid helium is still a fluid, and fluids slosh around when disturbed. Superfluid helium is one of the worst offenders because it has very little viscosity or surface tension. As a result, a significant risk of causing instability exists when maneuvering such a spacecraft, especially a small one, unless this sloshing can be accounted for in the attitude control system.

Flight operations personnel from the Reduced Gravity Office at NASA's Lewis Research Center manage the Float Package as it drifts in zero gravity.

The author floats over the Data Acquisition Rack as LabVIEW automates the capture of experiment data in zero gravity.

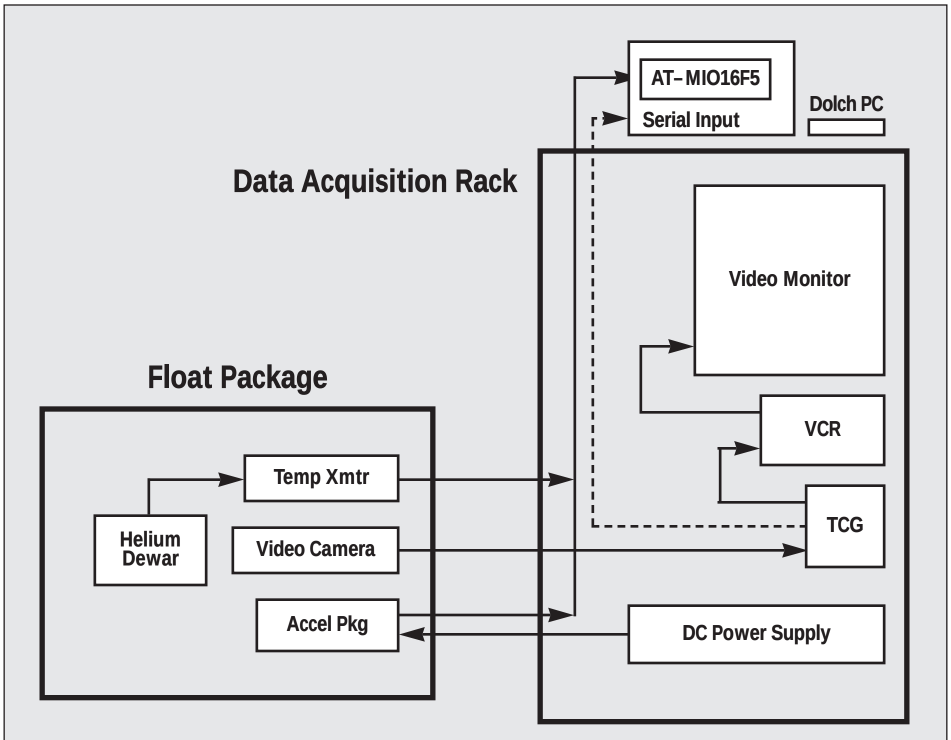
Simply generating a computer model of the physics of sloshing is not sufficient; an experiment was required to verify the correctness of the model and make refinements. This involved acquiring acceleration data and videotaping a flask of superfluid liquid helium while suspended in zero gravity – certainly not an easy task!

The Cryogenic Float Package

I was approached by the Low-Temperature Physics group at JPL to build the data acquisition (DAQ) system for this experiment. The equipment consisted of two units, a tubular steel float package and a DAQ rack. The focus of the float package was a small, cylindrical dewar of liquid helium with a window on one end and a translucent grid on the other. This flask was submerged in a larger steel dewar of liquid nitrogen to minimize heat transfer to the helium, ensuring sufficient time to perform the experiment before the helium completely evaporated. The outer dewar was fitted with a corresponding pair of windows, with a lamp mounted on one side and a video camera on the other. The camera recorded the image of the helium bubble as it drifted against the background grid. A three-axis accelerometer mounted on the outer dewar measured the small g-forces acting on the helium as it sloshed. A vacuum pump and a pair of Lake Shore cryogenic temperature probes monitored the transition to superfluidity as the helium was evaporatively cooled from 4.2 kelvins down to 1.4 kelvins during the experiment.

The second unit, the DAQ rack, was a half-height 19 in. instrument rack bolted securely to the deck of the aircraft, a modified DC-9 cargo jet. The rack contained a Hewlett-Packard dual DC power supply for the accelerometers, a Sony professional VHS video tape recorder, a Horita time code generator module, a video monitor, and the control computer, which was mounted on the top of the rack. The control computer was a 100 MHz Pentium-based ruggedized "lunch box" portable computer made by Dolch, running LabVIEW 3.1.1 under Windows 3.1. A National Instruments AT-MIO-16F-5 multifunction DAQ board occupied one of the six full-size EISA/PCI slots in the computer. A Cirque touchpad took the place of a mouse or trackball, neither of which could be used in zero gravity.

The two units were connected by a bundled set of cables providing power to the float package and returning data and video signals to the DAQ rack. Power for the entire system was provided to the rack from the aircraft power supply on two 15-Amp 120 VAC lines.



System Block Diagram

DAQ Software Design

The major design issue for this project involved the synchronization between the video frames recorded by the VCR and the data acquired by the control computer. This was required so that investigators could later associate the g-forces on the helium bubble with its visual behavior. Because the video was recording 30 images/s, the DAQ system needed to cycle at the same rate.

Timing for the main loop was provided by the Horita time code generator. Every 33 ms, the device transmitted a stream of 10 bytes, encoding the time and frame number to the PC serial port. This data was read with Serial Read VI but not decoded. Immediately afterwards, the software read an array of seven analog voltages from the MIO card. All data were stored in RAM in buffers to minimize overhead. Typical acquisition time for each parabola was 40 seconds (1,200 samples), bracketing a 20-second period of weightlessness. The operator was responsible for starting and stopping data acquisition by pressing the Enter key on the keyboard. The operator interface was kept as simple as possible, both to minimize processing overhead and to relieve the operator of any additional stress of operating the system. After acquisition stopped, the software translated the time codes from packed BCD format to time strings, translated the data acquired using the array to spreadsheet string VI, and wrote the resulting ASCII data to disk file.

We developed the entire DAQ system within two months, just meeting its very tight schedule and budget.

Each parabola resulted in a separate data file being written to disk to maximize data security, another important design issue. To reduce chances of mistakes, an automatic file and directory generator was developed to maintain date and time-tagged files. Each flight resulted in 45 files being written to that day's directory. We backed up data to floppy disk during the flight back to the airport each day. Between flights, we read the data into a spreadsheet program for further manipulation and critiquing of the experiment.

Experiment Results

The four days of flights were very successful, producing four video tapes and 180 files of time-tagged acceleration and temperature data. We developed the entire DAQ system within two months, just meeting its very tight schedule and budget. The LabVIEW software and data acquisition products operated with the rugged PC without a single problem; the DAQ system was regarded by the science team as the best part of the project. Preliminary analysis of the video and recorded data indicates that several useful sequences were captured and will be incorporated in the physics models under development.

Ted Brunzie produces turnkey data acquisition, analysis, and control systems at Caltech's Jet Propulsion Laboratory, providing support for various NASA and industry research projects. His current position as part of the JPL Measurement Technology Center follows an nine-year career in the Deep Space Network developing automated signal processing equipment.

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