LabVIEW Data Acquisition onboard a NASA Microgravity Research Aircraft

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Abstract

A LabVIEW-based system was recently carried aloft in a NASA DC-9 "Vomit Comet" while flying parabolic trajectories to acquire ti~ne-tagged data and video on how superfluid liquid helium behaves in zero gravity. Built quickly and inexpensively, the system performed flawlessly in capturing nearly 200 data sets during four days of flights.

The Challenge:

Acquiring video-sy]?cl~ro~~ized 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.

Introduction

A LabVIEW-based system was recently carried aloft in a NASA DC-9 "Vomit Comet" while flying parabolic trajectories to acquire time-tagged data and video on how superfluid 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, and 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 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, since it has very little viscosity or surface tension. As a result, there is a significant risk of causing instability when maneuvering such a spacecraft, especially a small one, unless this sloshing can be accounted for in the attitude control system. Simply generating a computer mode] of the physics of sloshing is not sufficient; an experiment must be carried out to verify the correctness of the model and make refinements. This involves 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 system for this experiment. The equipment consisted of two units, a tubular steel Float Package and a Data Acquisition Rack. The focus of the Float Package was a small cylindrical dewar of liquid helium having 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 Data Acquisition Rack, was a half-height 19" 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, 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-16F5 multi-function data acquisition card occupied one of the Dolch's six full-size EISA/PCI slots. 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 Data Acquisition Rack. Power for the entire system was provided to rack from the aircraft power supply on two 15-amp 120 VAC lines.

Data Acquisition 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 the investigator could later associate the g-forces on the helium bubble with its visual behavior. Since the video was recording images 30 times per second, the data acquisition system needed to cycle at the same rate.

Timing for the main loop was provided by the Horita time code generator. Every 33 milliseconds 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 afterward, the software read an array of seven analog voltages from the MIO card. All data were stored in RAM in pre-allocated buffers to minimize overhead. Typical acquisition time for each parabola was 40 seconds (1200 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 was stopped, the time codes were translated from packed BCD format to time strings, the data acquired was translated using the array to spreadsheet string VI, and the resulting ASCII data written to disk file.

Each parabola resulted in a separate data file being written to disk to maximize data security, a major 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 clay's directory. Data was backed up to floppy disk during the flight back to the airport each clay. Between flights, the data was read 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. The entire system was developed within two months, just meeting its very tight schedule and budget. The LabVIEW software and NI data acquisition products operated with the rugged PC without a single problem, ant] was regarded by the science team as the best part of the system. Preliminary analysis of the video and recorded data indicates several useful sequences were captured a net will be incorporated in the physics models being developed.

Acknowledgments:

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About the Author:

Ted Brunzie produces turn-key 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 eight-year career in the Deep Space Network developing automated signal processing equipment.

Figure Captions:

Block Diagram: The block diagram of the JPL Low-Temperature Microgravity Flight Facility illustrates the connection of signal paths between system elements. (BLOCKDIA.FH4)

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

Data Acquisition Rack **Photo**: The author floats over the Data Acquisition Rack as LabVIEW automates the capture of experiment data in zero gravity. (DATARACK.JPG)

Packages Used to Create the Artwork:

Block Diagram: (BLOCKDIA.FH4)

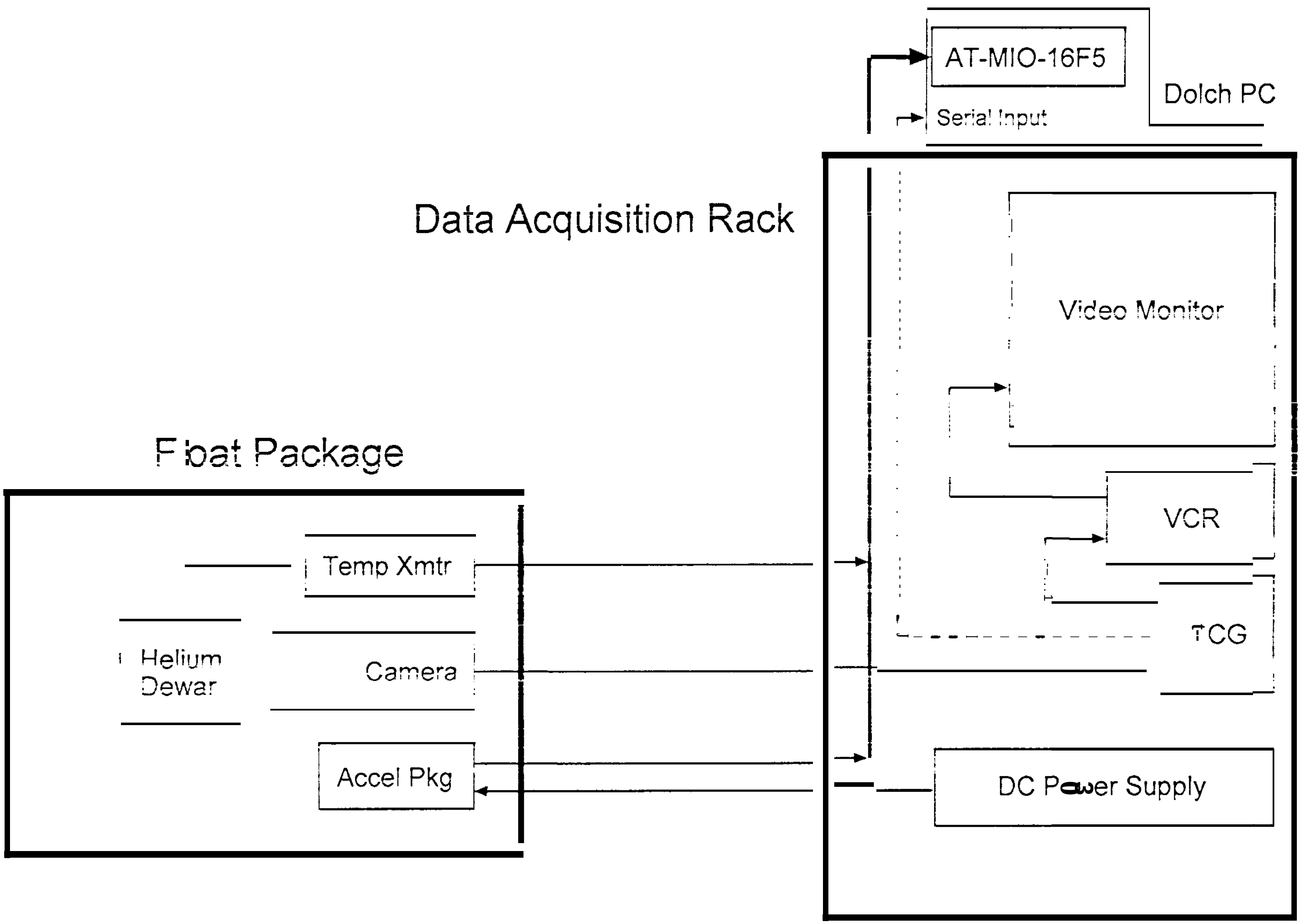
Freehand v4.0 for Windows

Float Package Photo: (FLOATPKG.JPG)

Microsoft Imager 1.0 to crop, reduce, and convert a scanned photograph

Data Acquisition Rack Photo: (DATARACK.JPG)

Microsoft Imager 1.0 to crop, reduce, and convert a scanned photograph


Float Package
Temp Xmtr
Helium Dewar
Camera
Accel Pkg
Data Acquisition Rack
AT-MIO-16F5
Serial Input
Dolch PC
Video Monitor
VCR
TCG
DC Power Supply