Electric Capacitance Volumetric Tomography ECVT for Fuel Gauging Under Zero Gravity

ZeroG Team
University of Wisconsin-Madison
1500 Engineering Dr.
Madison, WI 53706

Principal Investigator
Dr. Manohar Deshpande
Manohr.d.deshpande@nasa.gov

Student Team Contact
Paul Pezzi
Paul.pezzi@gmail.com

Written/Edited By
Benjamin Butler
Btbutler@wisc.edu

Project Summary

To better allow for measurement of liquids, such as propellant, in microgravity, the University of Wisconsin – Madison ZeroG Team conducted an experiment using electric capacitance and volumetric tomography. This procedure allowed for 3D computer imaging of the internal contents of a reservoir to determine the volume of substance inside. For this experiment, polypropylene spheres were used to eliminate the hazards of having fuel inside the cabin of the aircraft. Full analysis of the flight procedures can be seen below.

Experimental Background

Proper measurements of propellants in microgravity were vital to mission optimization. Currently there is not a proven method for accurately measuring the amount of propellant in real time. Because of this, spacecraft must carry extra fuel to compensate for this uncertainty, reducing the payload capacity. One method being studied to determine fuel volume is electric capacitance volumetric tomography (ECVT).

As seen with recent experiments [3], ECVT allows the user to acquire three-dimensional volumetric images. In the case put forth, ECVT has allowed the imaging of dielectric within thermal protection system tiles on the Space Shuttle which can not only tell that there is moisture present that could be potentially harmful but also how much there is and its location, thereby saving money and time as to which tiles need to be replaced.

In other cases, such as mass metering for cryogenic fluids [2], and the TPS case the ECVT technique can be configured to a shape that is helpful to the task at hand. For example, in

measuring the cryogenic fluid, the sensor can fit over the span of the tank and receive the required measurements while the ECVT equipment for the TPS tiles can be fit to match the tile size and square shape to collect the images needed.

ECVT technology shows promising potential for spaceflight applications; not only could ECVT acquire images of rocket fuel or another fluid inside an expensive or dangerous piece of equipment for NASA, but this method could be applied to many other fields where nonintrusive analysis is key, such as medical areas [1]. However, research on this imaging and measuring technique in microgravity has not been extensively studied.

Experimental Description

This experiment investigated the accuracy of the ECVT technology in microgravity. During the flight, polypropylene spheres were placed inside the sensor, and the ECVT sensor took record the dielectric distribution. Polypropylene was been chosen because its dielectric constant is close to that of fuel, and provides a safer alternate to using actual fuel in the experiment. This data was to be outputted to the data acquisition device, and was be processed after the flight to estimate the volume of polypropylene spheres in the sensor by creating a three dimensional image inside the sensor. The volume of the spheres was known, and will be compared to the volume obtained experimentally to determine the accuracy of the ECVT measurement technique. On each flight different sized spheres were used to determine if sphere size affects accuracy.

Structural Verification

This experiment was designed to comply with all NASA and ZeroG Corporation loading configurations. The center of mass of the experiment was found, and then the structure was analyzed under each loading configuration. Four straps provided by the RGO (5000lb rated) will be used to secure the experiment to the floor. Analysis on both the straps and the bolts connecting to the straps to the floor has been performed. This analysis, as well as the analysis performed on other key structural members can be found in the attached appendix.

Electrical Analysis

Schematic

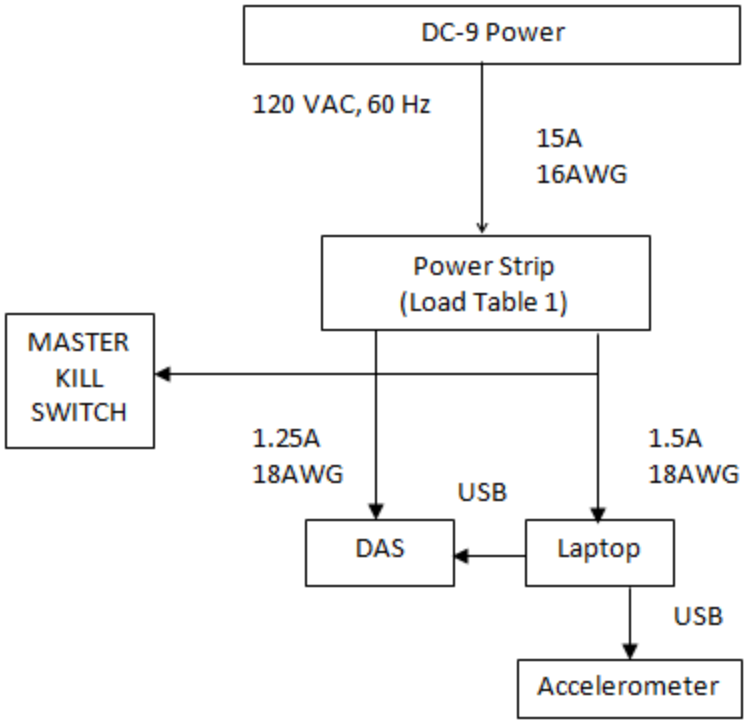

Figure 1: Schematic of electrical system

Team

Fritz, Marcus	Flyer	Fritz, Marcus
Marron, Samuel	Flyer	marron@wisc.edu
Pezzi, Paul	Flyer	paul.pezzi@gmail.com
Weiss, Kevin	Flyer	kjweiss2@wisc.edu
Wong, Nathan	Flyer	nwong@wisc.edu
Bolyard, Craig	Flyer	cbolyard@wisc.edu
Mackstutis, Kevin	Ground Crew	mackstutis@wisc.edu
Bersch, Patrick	Ground Crew	bersch@wisc.edu
Butler, Benjamin	Ground Crew	btbutler@wisc.edu
Kainz, Nathaniel	Ground Crew	nokainz@wisc.edu
Lange, Benjamin	Ground Crew	bjlange@wisc.edu

Experimental Procedures

Equipment Shipment

The experiment was shipped to Ellington Field the week of March 23rd, 2011 so that it will arrive before our arrival in Houston. The experiment came in one package completely assembled and ready for flight.

Ground Operations

Before the flight, it was pertinent to do some standard checks:

1. Check the physical condition of the experiment, and ensure all components were functioning.
2. Check that the Matlab program and other software bing used (i.e. for the accelerometer) were working properly and ready to receive data by performing ground testing.
3. Check all bolts and fasteners to ensure that the experiment was structurally secure.

Loading/Stowing

The experiment required the forklift to be loaded through the side of the airplane. Once loaded, two members moved the experiment into position for the flight.

Pre-Flight

The data acquisition system was calibrated again to account for any environmental changes from previous days of ground testing.

Take-Off/Landing

No special procedures were needed at this time.

In-Flight

The sensor and computer were turned on and prepared for performing the experiment. The accelerometer was activated at this point and recorded data throughout the flight. Data from the ECVT system was recorded in 3 sets; approximately at 10 parabola intervals. These data sets stored in Matlab data files for later analysis.

Off-Loading

A forklift was needed to offload the experiment, and it was shipped back to the University of Wisconsin-Madison.

Supplementary materials and references:

Reference Information

Principal Investigator: Dr. Manohar Deshpande
Contact Information: manohar.d.deshpande@nasa.gov
Experiment Title: Electric Capacitance Volumetric Tomography ECVT for fuel gauging under zero gravity
Work Breakdown Structure (WBS): N/A
Flight Dates: March 31, 2011-April 9, 2011
Overall Assembly Weight (lbs): 40.3lbs.
Assembly Dimensions (L x W x H): 15in. x 15in. x 27in
Equipment Orientation Requests: None, experiment is square.
Proposed Floor Mounting Strategy: Straps
Gas Cylinder Requests: None
Overboard Vent Requests: None
Power Requirements: 120VAC Single Phase
Free Float Experiment: No
Flyer Names for Each Proposed Flight Day:

- Day 1: Paul Pezzi, Kevin Weiss, Nathan Wong
- Day 2: Samuel Marron, Marcus Fritz, Dr. Manohar Deshpande

Camera Pole and/or Video Support: Camera Mount

References

[1] Fan, L (2009) *Electrical Capacitance Volume Tomography.* Columbus, OH: Department of Chemical and Biomolecular Engineering.

[2] Mark A. Nuge, R. Y. (2003, May 4). *Capacitance Based Mass Metering for Cryogenic Fluids.* Retrieved February 8, 2011, from Science Direct: www.elsevier.com/locate/cryogenics

[3] Nurge M. A. (2007). Electrical Capacitance Volume Tomography with High Contrast Dielectrics Using Cuboid Sensor Geometry. *Measurement Science and Technology***,** 1511-1515.