NASA/TM–2013-217373

Zero G and Other Microgravity Simulations
Summary Report

Human Health and Performance Directorate
Human Systems Engineering and Development

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

January 2013

THE NASA STI PROGRAM OFFICE . . . IN PROFILE

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at http://www.sti.nasa.gov

- E-mail your question via the internet to help@sti.nasa.gov

- Fax your question to the NASA Access Help Desk at (301) 621-0134

- Telephone the NASA Access Help Desk at (301) 621-0390

- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7115 Standard
  Hanover, MD 21076-1320

NASA/TM–2013-217373

Zero G and Other Microgravity Simulations
Summary Report

Human Health and Performance Directorate
Human Systems Engineering and Development

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

January 2013

PREFACE

This document represents a summary of medical and scientific evaluations conducted on board the Zero G and other NASA sponsored aircraft from June 2011 to June 2012. A general overview of investigations manifested and coordinated by the Human Adaptation and Countermeasures Division is included. A collection of brief reports that describe tests conducted on board the NASA sponsored aircraft follows the overview. Principal investigators and test engineers contributed significantly to the content of the report describing their particular experiment or hardware evaluation. Although this document follows general guidelines, each report format may vary to accommodate differences in experiment design and procedures. This document concludes with an appendix that provides background information concerning the Reduced Gravity Program.

Acknowledgments

The Space Life Sciences Directorate gratefully acknowledges the work of Jacqueline M. Reeves, and Elisabeth Spector for their outstanding editing support and contributions to the overall quality of this annual summary report.

Available from:

NASA Center for AeroSpace Information
7115 Standard Drive
Hanover, MD 21076-1320
301-621-0390

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
703-605-6000

This report is also available in electronic form at http://ston.jsc.nasa.gov/collections/TRS/

Zero G and Other Microgravity Simulations
Summary Report – September 30, 2012

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center

Prepared by: Wanda L. Thompson 11/16/12

Wanda L. Thompson, RN, BC, NMCC
Coordinator
JES Tech, LLC

Date

Approved by: 10/30/12

Michelle Frieling
Space Medicine Group Manager
Human Performance & Engineering Division
Science, Technology & Engineering Group

Approved by: Todd T. Schlegel 11/16/12

Todd T. Schlegel, MD
Technical Monitor
Human Health and Performance Directorate
Reduced Gravity Program
NASA Johnson Space Center

Date

Table of Contents

Overview of Reduced Gravity Flight Activities 1
Gravitational Modulation of Calcium Signaling in Bone 3
Plant Viability for a NanoRack Food Growth Chamber 15
Water Purification and Ion Removal Through Low Pressure Distillation 21
Effect of Microgravity on Spinal Expansion 28
Hydrofuge Alpha and Bravo Plant Chambers 37
Aquaponics 44
Flying an Egg in Space 48
Background Information about NASA's Reduced Gravity Program 51

Overview of Reduced Gravity Flight Activities
Sponsored by the Human Adaptation and Countermeasures Division

As a summary for the year, 4 weeks were specifically reserved for flights sponsored from June 2011 to May 2012. A total of 8 flights with approximately 32 parabolas per flight were completed. The average duration of each flight was 2.1 hours. The Reduced Gravity Program coordinator assisted principal investigators and test engineers of 7 different experiments and hardware evaluations in meeting the necessary requirements for flying aboard the C-9 or other NASA sponsored aircraft and in obtaining the required seating and floor space. Support was provided to the Education Outreach Program and High School Students United with NASA to Create Hardware (HUNCH) during weeks in June and April. A large ground crew from the respective academic institutions supported the in-flight experiments. The reports that were received from all groups are included in this publication. The data following does not represent the total who actually participated. The number of seats supported and number of different tests flown by flight week are provided below:

Flight Week	Seats	No. Tests Flown	Sponsor
June 9, 2012	12	1	HUNCH
April 24–25, 2012	12	6	HUNCH

Additional flights will be added throughout the remainder of calendar year 2012 to accommodate customers as needs arise.

Medical and Scientific Evaluations during Parabolic Flights

TITLE

2011 Microgravity University –Gravitational Modulation of Calcium Signaling in Bone

FLIGHT DATE

June 9, 2011

PRINCIPAL INVESTIGATORS

Benjamin Davis; Department of Biological Sciences, Boise State University, Boise, ID
Jake Forsberg; College of Engineering, Boise State University, Boise, ID
David Connolly; College of Engineering, Boise State University, Boise, ID
Stephanie Frahs; Department of Chemistry & Biochemistry, Boise State University, Boise, ID
Ron Pierce; College of Engineering, Boise State University, Boise, ID
Dawn Mikelonis; Depart. of Biological Sciences, Boise State University, Boise, ID

CO-INVESTIGATORS

Dr. Brian Crucian; Johnson Space Center's Immunology Lab
Kami Faust; Johnson Space Center's Immunology Lab
Dr. Tom Glass; Sapidyne Instruments, Boise, ID
Dr. Robert Hay; College of Engineering, Boise State University, Boise, ID
Mayra Nelman; Johnson Space Center's Immunology Lab
Alex Miller; Transform Solar, Boise, ID
Dr. Sondra M. Miller; College of Engineering, Boise State University, Boise, ID
Barbara R. Morgan; Distinguished Educator in Residence, Boise State University, Boise, ID
Dr. Julia T. Oxford; Depart. of Biological Sciences, Boise State University, Boise, ID
Heather Quiriarte; Johnson Space Center's Immunology Lab
Dr. Clarence Sams; Johnson Space Center's Immunology Lab

GOAL

This goal of this experiment was to acquire baseline data on the effects of the oscillating gravitational accelerations produced by parabolic flight on intracellular free calcium concentrations in bone cell cultures. We expected these to show the extent to which calcium flux events correlate with alternating gravitational conditions (hyper- and microgravity) and the extent to which these events remain consistent over time and cyclical exposure to conditions representing opposing departures from the resting (1-G) gravitational environment.

OBJECTIVES

1. Expose osteocyte cultures to gravitational oscillations produced in parabolic flight.
2. Monitor and record changes in cytosolic calcium concentrations in real-time as indicated by calcium responsive fluorescent dyes via portable ratiometric fluorometry and flow cytometry systems.
3. Collect environmental data at regular high-resolution time intervals to associate with fluorescence data via 3-axis accelerometer.
4. Establish correlations between fluorescence data and in-flight environmental conditions.
5. Fixate cellular samples at regular time intervals for postflight analysis of calcium-dependent activation of cell signaling intermediates via immunofluorescent flow cytometry and microscopy assays.
6. Perform in-fight tests in steady 1-G environment to obtain experimental control data.
7. Construct potential qualitative relationships between gravity-induced calcium mobilization and mechanotransduction pathways to direct future testing.

METHODS AND MATERIALS

Experimental Approach

The experimental approach consisted of environmental data collection, fluorescent calcium monitoring, and cellular fixation. Real-time data were collected in flight for gravitational acceleration via a 3-axis accelerometer and for calcium flux through ratiometric fluorometry and flow cytometry. A chronological set of fixated cellular samples was generated for postflight assessment of calcium-sensitive signaling activation by flow cytometry and microscopy. All data sets were temporally correlated.

Environmental Monitoring

Gravitational acceleration data were collected with corresponding time stamps at approximately 10 Hz to generate a precise map of the gravitational conditions encountered by cell samples. Ratiometric and flow cytometric fluorescence data, as well as fixation time points, were correlated to this acceleration data set via timestamps recorded from the same clock. The cell culture sample wells were maintained at a physiologic temperature of 37°C during flight by the temperature control subsystem of the ratiometric fluorometer. A commercial USB-to-serial temperature probe from Quality Thermistor, Inc., interfaced with the flight software and monitored the underside of the aluminum warming plate to allow real-time temperature measurements in the LabVIEW software. A pulse-width modulated proportional integral derivative (PID) control loop triggered the active duty cycle of four 3-Ohm resistor modules mounted to the bottom of the warming plate surface to maintain the desired temperature setpoint. Temperature measurements made for control loop feedback were stored as a time-stamped data set to correlate temperature variations to any observed changes in calcium concentration.

Cell Samples

Samples were composed of MLO-Y4 immortalized osteocytes loaded with fluorescent calcium detecting dyes Indo-1 (flight 1) and Mag-Indo-1 (flight 2) at 10 µM. The cells were adhered to Cytopore-2 microcarrier beads (200,000 cells/mg). Before flight, cell lines were maintained by the staff of the Johnson Space Center's (JSC) Immunology Laboratory using standard cell-culture protocols. Cells were seeded onto microcarrier beads 24 hours before flight and infused with fluorescent dye 1 hour before flight. Microcarriers were suspended at 10 mg/mL in Minimal Essential Media-alpha growth medium with 5% fetal bovine serum, 5% calf serum, penicillin and streptomycin, 25mM HEPES buffer (4-[2-hydroxyethyl]-1-piperazineethanesulfonic acid), and 0.1% low-melting-point agarose to prevent sample shifting during flight. Three experimental samples per flight had the previously described basic composition, while two other samples contained additional control reagents.

The sample herein referred to as the negative control contained 8 mm ethylene glycol tetraacetic acid (EGTA), a calcium chelator that out-competes fluorescent dye for calcium binding thus buffering against ratio shifts, and ideally represented a maximum unbound fluorescent dye signal. The sample herein referred to as the positive control contained 1 µg/mL ionomycin, an ionophore that nonspecifically permeabilizes cellular membranes to calcium ion flow with the anticipated effect of releasing all intracellular calcium stores for a maximum bound fluorescent dye signal. All samples were contained within 6-mL optical glass cuvettes (Starna).

Ratiometric Fluorometry

The team developed a synchronous, dual emission fluorometry system to monitor ratiometric calcium indicators with high temporal resolution. This required several subsystems including the samples themselves, sample containment, temperature control (requisite to maintain a physiologic environment for sample viability), excitation and detection optics, electronics, and software to facilitate data acquisition and analysis. The finalized fluorometer with integrated subsystems is shown in Figure 1.

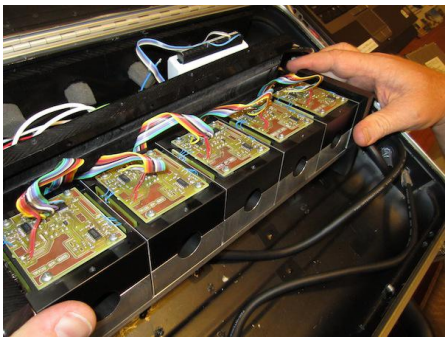


Figure 1. Synchronous, dual emission fluorometer assembled for microgravity flight testing.

Optics

The optical design of the ratiometric fluorometer revolved around the requirement of exciting the Indo-1 dye at its responsive peak in the ultraviolet range, 355 nm, and simultaneously detecting the two emission peaks of the dye at 405 nm and 485 nm. A diagram of the Indo-1 excitation and emission spectral response curves is provided in Figure 3. The most direct method of separating out these desired wavelengths from a broad-spectrum source was by using optical filters. A large amount of design time was spent in selecting the optimized filter set for these purposes, and the optical filters also comprised a large fraction of the cost of the total fluorometer system.

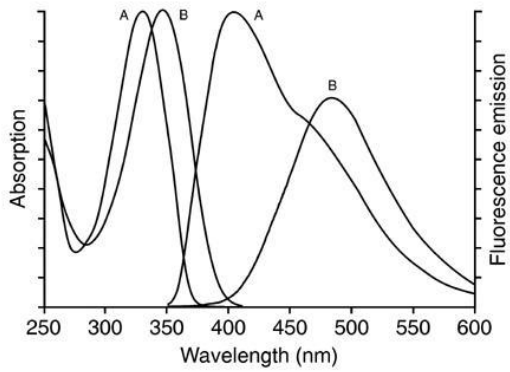


Figure 2. Excitation and fluorescent emission spectra of Indo-1 dye. Measurements are represented by high calcium concentrations and *B* calcium-free solutions.

Three different narrow-band-pass optical filters were used for each of the five constructed fluorometer modules. Each filter was tuned to pass a particular wavelength at peak transmittance, and the full-width at half-maximum transmission window for most of the filters used was 15 nm. The narrow pass-band of the excitation filter was primarily required to keep the very bright excitation light-emitting diodes (LEDs) from coupling into the photodiode detectors and saturating out the comparatively dimmer Indo-1 dye fluorescence signal. The remaining two filters were each placed ahead of the photodiodes to detect the 405 nm and 485 nm emission spectral peaks, respectively. The narrow pass-band of the two detection filters removed any remaining transmitted light in the 355 nm range, and also blocked out any signal from the other dye emission mode so that each detector should only observe the light generated by the particular emission mode of the dye.

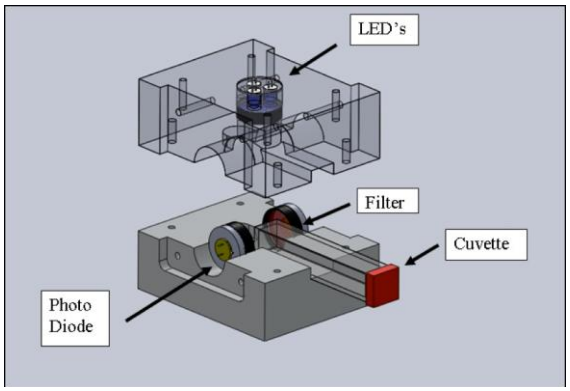


Figure 3. Synchronous, dual emission module schematic.

The rest of the sample holder well in each fluorometer module was made to minimize stray light admittance into the interior where it might affect measurements, although an electronic noise cancelling solution was also used to mitigate any effects from that potential situation. Figure 3 provides a schematic of the primary optical components in each fluorometer module.

Electronics

The fluorometer was powered by two identical 12-volt power supplies, separated to limit noise between the emission and detection circuits. The electronics in this system cycle ultraviolet (UV) LEDs on and off at an approximately 1 kHz rate with a 50% duty cycle. This allows for running the LEDs at a higher current than they can continuously endure, keeping them from overheating while exposing the cell samples to as much UV radiation as possible in the 355 nm range. Photodiodes were placed on either side of the cell sample, with optical filters blocking out all but the 405 nm spectrum on one side and the 485 nm spectrum on the other. The photodiodes absorbed the light emitted by the dye as it fluoresced and converted the light to a very small electric current. This current was then amplified by a three-stage amplifier to get a strong enough signal to be read by the Data Acquisition (DAQ) system. The DAQ then converted the voltages obtained to digital values that were passed to the LabVIEW software.

The system was powered by the 115V AC electrical service of the aircraft. All power from the supply cord passed through an emergency kill switch that would instantly de-energize the experiment apparatus in the event of an emergency. From the kill switch, power was routed to a power strip where the laptop and DC power supplies for the fluorometer were connected. An overview diagram of the electrical system is shown in Figure 4.

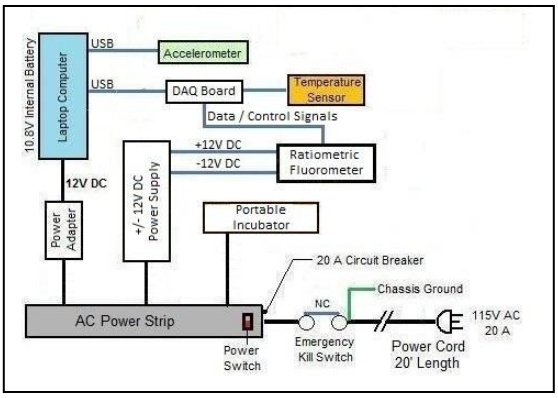


Figure 4. High-level schematic of experiment electrical system.

Software

The experiment software was developed as a LabVIEW Virtual Instrument (VI) and performed synchronous analog and digital IO on the fluorometer device through a National Instruments DAQ module. The architecture of the experiment software for in-flight fluorometry was implemented as five main components that execute in parallel for hardware control and data storage. The overarching software system design is illustrated in Figure 5.

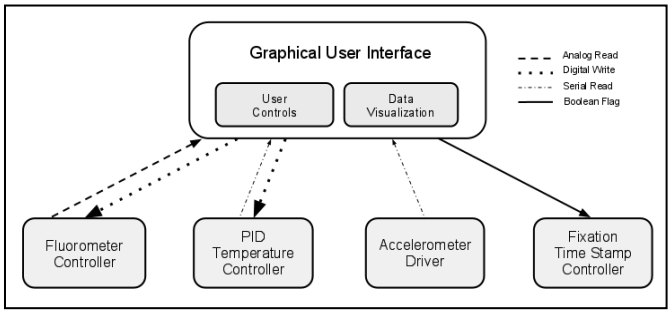


Figure 5. High-level diagram of the flight software system design and data paths.

The application provided a graphical user interface (GUI) for simplified user control and visualization of experiment data in real-time during ground and flight operation. An image of the in-flight experiment VI is shown in Figure 6. The GUI was the primary device through which acceleration, temperature, and fluorescence data were synchronized and displayed.

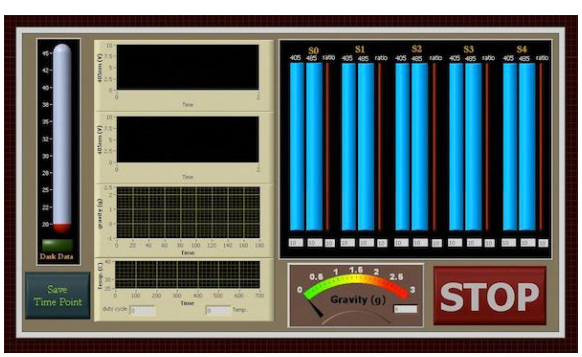


Figure 6. In-flight fluorometry graphical user interface VI.

The fluorometer was controlled through the National Instruments DAQmx driver, which provided synchronization of analog and digital devices through high-level API calls. Dual emission fluorescence measurements were made on the five-analog output pins at approximately 50 Hz through a software-initialized clock. The bound and unbound channel outputs were multiplexed by a digital DAQ output line. Each dual fluorescence measurement required an analog read of the first channel, a digital MUX select,

an adequate settling time delay, and an analog read of the second channel. Digital logic in the control loop alternated the first channel read on each iteration. The dual fluorescence measurement control sequence is provided in Figure 7.

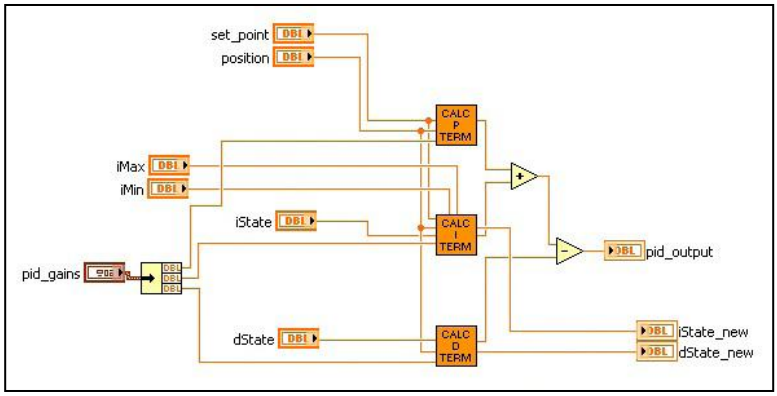


Figure 7. Software control sequence diagram for synchronous dual emission measurements.

The UV excitation source can be pulsed or made inactive by a digital software switch. Every 60 seconds the excitation source was turned off and a dual-emission measurement recorded. These “dark data” were stored as a separate data set for postflight analysis of dark current drift.

Acceleration data were collected during flight by a serial-to-USB 3-axis accelerometer. This device ran continuously in parallel with the fluorometer controller as a separate execution thread and stored acceleration changes in a time-stamped file at approximately 60Hz.

A pulse-width modulated PID controller was implemented and tuned for precise temperature control of the device. The control loop triggered the active duty cycle of four 3-Ohm resistor modules mounted to the bottom of the warming plate surface to maintain the desired temperature setpoint. The control logic for combining calculated PID terms is shown in the block diagram of Figure 8.

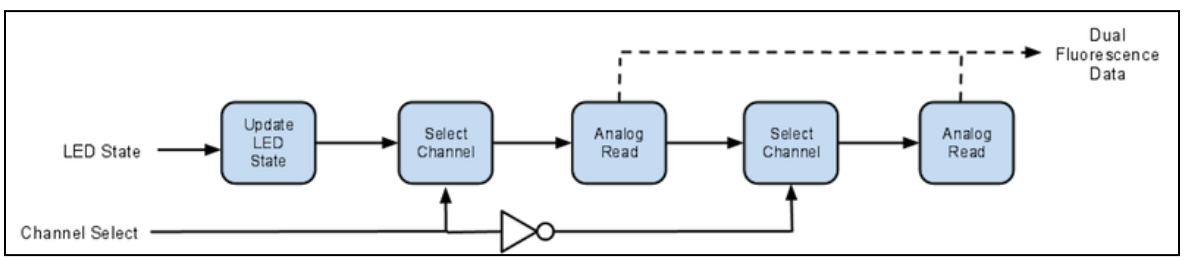


Figure 8. Update PID controller block diagram.

The duty cycle is updated on each control loop iteration by calculating the P, I, and D terms as

Pterm = (S - T) x *Pgain*
Iterm = [(S - T) + Istate] x *Igain*
Dterm = (T - Dstate) x *Dgain*

Where:
S = desired temperature setpoint
T = actual temperature measured

To correlate fixation samples with experiment duration, a time-stamped data set was collected during microgravity flight. The experiment operator pushed the 'Save Time Point' graphical button on the user interface simultaneously with manual sample collection, which flagged the fixation time stamp controller to retrieve the current time from the system clock and append it to the fixation time stamp file. Fixative samples were labeled and collected in numerical order to correspond with saved time points.

Flow Cytometry

To evaluate the performance of the custom fluorometer system, a portable flow cytometry system developed by the JSC's Immunology Laboratory, was used to collect fluorescent data on calcium flux.

Cell Fixation

Cellular samples were fixed using whole blood staining devices (WBSDs), also developed by the JSC's Immunology laboratory for collection of biological samples on board the International Space Station. WBSDs provided sterile containment of ~5 mL of fluid. Three-fixative conditions were employed for subsequent analysis by flow cytometry (2% paraformaldehyde), fluorescent microscopy (4 mm EGTA, 6% formaldehyde), and electron microscopy (4% gluteraldehyde, 6% formaldehyde). Seven sets of the three conditions were collected at different times during each flight for a total of 21 samples per flight. The schematic in Figure 9 represents the reduced gravity aircraft flight path. Three cellular samples were fixated at each time point indicated (1-7). Sample 1 was taken before flight take-off, sample 2 at altitude before beginning parabolic maneuvers. sample 3 during the first set of parabolas, sample 4 during turnaround, sample 5 during the second set of parabolas, and sample 6 at the conclusion of parabolic maneuvers. Sample 7 was taken following landing and completion of aircraft taxi.

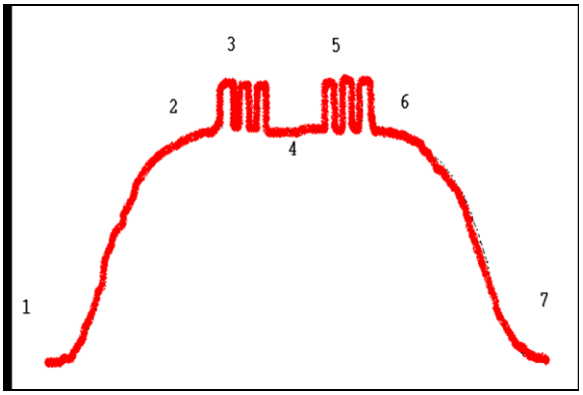


Figure 9. Flight path with planned time points for cellular fixation.

RESULTS

At the time of this report such ground testing of the ratiometric fluorometer had not taken place because of obstacles encountered in system function upon return from JSC. Observed fluctuations in signal ratios during flight must be interpreted using results from ground-based runs, as these control for all variables except for parabolic flight. In the absence of such data, ratio changes in parabolic flight have been compared to signal activity before take-off and after landing.

Results for the two flights varied considerably and this was interpreted as a consequence of the different dyes used for the different flights. For the first flight, the standard Indo-1 was used as this was identified as the most common ratiometric calcium indicator in the literature. For the second flight, Mag-Indo-1 was chosen to explore the consequences of altered affinity on calcium flux observation in parabolic flight. Mag-Indo-1 has considerably lower binding affinity for calcium ions than standard Indo-1 (Kd ~35 nm versus 230 nm). Increased Kd decreased the likelihood of calcium flux buffering by dye and increased the chance of observing rapidly changing events.

Fluorometric Experimental Samples

Results for the first flight were generally inconclusive with little change in ratio observed in association with parabolic flight. All samples showed a steady increase in ratio over the course of the experiment in flight 1. This was consistent in flight 2 with the exception of sample 3 (Figure 10 D), which showed a steady decrease in ratio over time. The ratio represents the signal, in volts, from the 485 nm channel divided by that from the 405 nm channel; therefore, it can be thought of as unbound over bound. In this way, a positive slope indicates a relative increase in unbound dye and by extension a decrease in free calcium. It appears that free calcium decreased over time. However, if nonbiological factors (electronic performance for example) led to either an increase in signal from 485 nm channels, a decrease in signal from the 405 nm channels, or some combination of the two, the ratio would have increased. Ground testing for comparable periods to flight testing (~2 hours) should help shed light on this question.

Examination of ratio response during parabolic maneuvering as compared to measurements obtained on the ground and during nonparabolic periods of the flight suggests that gravitationally sensitive calcium flux was observed on the second flight using Mag-Indo-1 (Figure 10, C-E). As is evident in Figure 10, ratios consistently increased immediately following the initiation of microgravity periods, while ratios consistently decreased immediately following initiation of hyper-gravity periods. This would suggest that free calcium decreased in response to microgravity and increased in response to hyper-gravity. Ignoring overall changes in slope, this behavior remained relatively consistent throughout the entire 32 parabolas. Taking the results of flight 2 into account, calcium flux did appear to occur in response to parabolic flight, but did not appear to show regulative behavior over the time course of this experiment.

Fluorometric Control Samples

In the first flight, the control sample results did not behave significantly different than experimental samples 1 and 2. It was anticipated that the ratios would remain relatively constant, with the negative control maintaining a higher ratio value due to its anticipated increase in the proportion of unbound dye. In the second flight the positive control still behaved like the experimental samples (with the exception of an opposite overall slope to sample 3). In contrast, the negative control sample did seem to maintain a relatively stable, although low, ratio even in the presence of lower-affinity dye. The results of the negative control in flight 2 (Figure 10 A and B) are encouraging in that the experiment functioned as anticipated while the results from the positive control are less supportive of this interpretation. The positive condition required use of a reagent with which the team did not have any prior experience and thus the possibility that the reagent was not properly prepared or delivered is an area of consideration in future sample preparation optimization exercises.

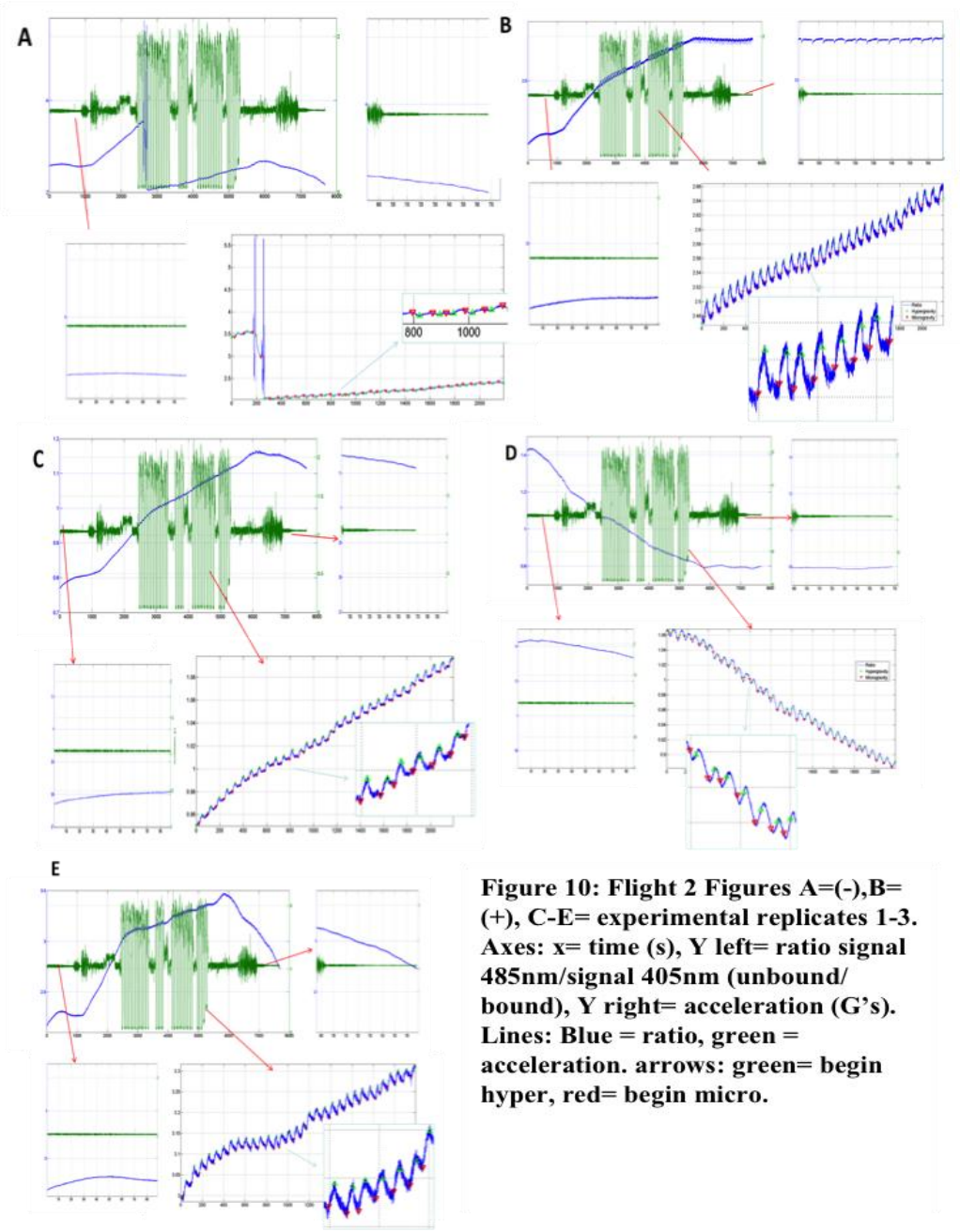


Figure 10: Flight 2 Figures A=(-),B=(+), C-E= experimental replicates 1-3. Axes: x= time (s), Y left= ratio signal 485nm/signal 405nm (unbound/bound), Y right= acceleration (G's). Lines: Blue = ratio, green = acceleration. arrows: green= begin hyper, red= begin micro.

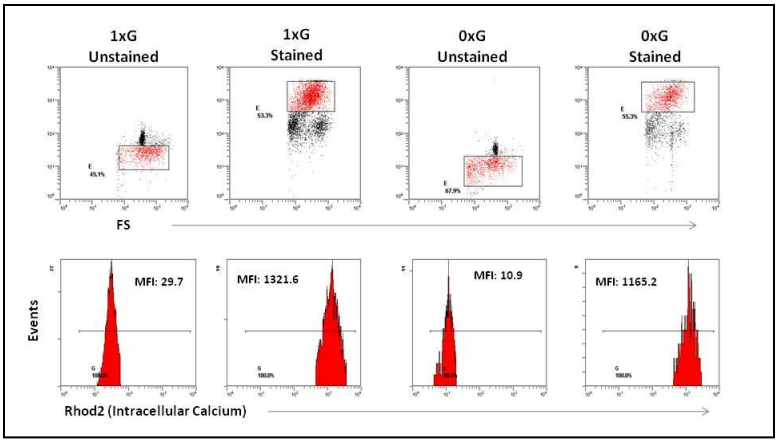


Figure 11. Scatter plot analysis of portable flow cytometry in microgravity.

Portable Flow Cytometry

Flow cytometry demonstrated a decrease in free calcium in microgravity relative to 1 G with mean fluorescence units (MFI) going from 1321.6 in to 1165.2 in Rhod-2 stained cells. These measurements are in accordance with flight 2 fluorometry results and support the notion that the calcium flux suggested by ratio shifts in Mag-Indo-1 signals are not artifactual.

Fixation

At the time of this report, samples fixed for analysis by microscopy and cytometry have not been processed.

DISCUSSION

The encouraging results from the flight, along with the significant increase in familiarity with concepts and skills required to complete this investigation, set the stage for increased chance of success in the event of follow up flights. Several limitations were identified in the current instrument and experimental procedures; aspects of the experimental system were considered to be inadequate.

Mag-Indo-1 will be used for all future flights. Samples may be changed to osteocyte-osteoblast co-cultures to create a more biologically relevant system. Consideration will be given to transitioning from photodiode-based, modular detection to a lens-based system in which a single CCD could monitor a larger area covering multiple samples. This could increase sample capacity and reduce variability observed across replicates that is likely due to a lack of uniformity across modules. Flexibility in optics geometry would accommodate standard sample containers such as microplates with well inserts to increase uniformity and sample number, and decrease the amount of material per sample (~6 mL versus ~200 µL). These changes may make it possible to increase the number of variables to identify underlying molecular mechanisms of gravitationally induced calcium flux. Examples include treatments in calcium-free media to evaluate the contribution of influx of extracellular calcium as well as the inclusion of inhibitors (siRNA, receptor binding antibodies) and stimulators (pharmaceuticals) of specific mediators of calcium flux to determine which pathway constituents are involved.

Data acquisition software will be refined for easy transfer and a comprehensive data analysis script will be prepared before a follow-up flight so that results can be immediately evaluated postflight and any

necessary adjustments can be made between flights. The temperature control system needs improvement as the current placement of the sensor loop on the exterior of the aluminum block produces readings that are generally lower than actual sample port temperatures due to exposure to the ambient environment.

Variable gain control will be implemented. The current system requires gain to be adjusted in solid state through changing of resistors etc., thus hampering sample preparation optimization. Currently, to evaluate minimal dye concentration and incubation periods, one must re-solder PCBs every time the signals are decreased. A more flexible system would allow adjustment of the instrument to samples, rather than having to adjust samples to the instrument. Iteration toward the ideal testing conditions would be considerably aided.

Problems with humidity and with static damage were encountered. Solder flux paste, used during the board soldering process, became slightly conductive with moisture and created undesirable current flow in the sensor circuit. Use of pre-coated PCBs in future designs will mitigate this problem.

CONCLUSION

Astronauts can lose bone mass at rates that make long-term missions to destinations such as the moon, Mars, and beyond unfeasible. Additionally, astronauts experience damage to their immune systems, musculature, vasculature, and even nerve tissues. Much work remains to be done to identify effective strategies for mitigation of the negative health consequences of exposure to nonhomeostatic gravitational environments. This project and the technologies produce can be of use in evaluating any number of tissue types and biomolecular activities.

ACKNOWLEDGEMENTS

This research supported by grants from NIH/NCRR (P20RR016454), Idaho State Board of Education funding for the Musculoskeletal Research Institute, NASA/EPSCoR NNX10AN29A, Boise State University Office of Research, and the Idaho Space Grant Consortium (ISGC) Travel Grant.

The osteocytes used in this study were generously donated by Dr. Linda Bonewald and her laboratory at the University of Kansas City, Missouri.

We would like to thank the JSC's Immunology Laboratory team for use of their facilities and their invaluable technical assistance. We would also like to thank Barbara Jibben, Raquel Brown, and Diane Smith at the Boise State University Biomolecular Research Center, as well as Kim Long and Linda Georgiev at the Boise State University College of Engineering for their support. Special thanks to Dr. Vidya Nandikolla, Kameryn Williams, Jason Griswold, Chris Barbie, Dr. Ken Cornell, Dr. Roy Langton, and Kellen Moore for their collaboration.

REFERENCES

1. Ingber D. 1999. How cells (might) sense microgravity. FASEB J, 13(Suppl.):3-15.
2. Liedert A, Kaspar D, Blakytny R, Claes L, Ignatius A. 2006. Signal transduction pathways involved in mechanotransduction in bone cells. Biochem Biophys Res Comm, 349:1-5.
3. Zhang P, Hamamura K, Yokota H. 2008. A brief review of bone adaptation to unloading. Geno Prot Bioinfo, 6(1):4-7.

4. Turner CH. 2006. Bone strength: current concepts. Ann N.Y. Acad Sci, 1068:429-446.
5. LeBlanc AD, Spector ER, Evans HJ, Sibonga JD. 2007. Skeletal responses to space flight and the bed rest analog: a review. J Musculoskelet Neuronal Interact, 7(1):33-47.
6. Kufhal RH, Saha S. 1990. A theoretical model for stress-generated fluid flow in canaliculilacunae network in bone tissue. J Biomech, 23(2):171-180.
7. Kurpinski K, Park J, Thakar RG, Li S. 2006. Regulation of vascular smooth muscle cells and mesenchymal stem cells by mechanical strain. MCB, 3(1):21-34.

CONTACT INFORMATION

Benjamin Davis
Department of Biological Sciences
Boise State University
1910 University Drive
Boise, ID 83725
208.426.2455
E-mail: Benjamindavis1@u.boisestate.edu

TITLE

Plant Viability for a NanoRack Food Growth Chamber

FLIGHT DATES

April 24 and 25, 2012

PRINCIPAL INVESTIGATOR

Alli Westover

CO-INVESTIGATORS

NASA Engineering Design and Development HUNCH Course

The Clear Springs High School Flight Team and Astronaut at Ellington Field

GOAL

Our goal was to design a plant growth chamber that can sustain long-term plant growth in a 0-G environment and fly on board the International Space Station (ISS) in a NanoLab.

OBJECTIVES

The experiment was flown as part of the High School Students United with NASA to Create Hardware (HUNCH) program from a Project Lead the Way (PLTW) school. It was designed by the students of the Engineering Design and Development (EDD) course at Clear Springs High School in League City, Texas. This experiment was meant to test an effective system for growing plants for food in microgravity, such as on a space station or long-duration flight. This research would allow NASA to expand on the idea for setting up a greenhouse for large-scale production of food and carbon dioxide filtration.

The plant growth chamber was designed to grow legumes that were supported by our artificial biome. A plant growth chamber has been developed to reduce the need for food re-supply in space, especially for long-duration missions. The experiment tested plant viability of the *Medicago truncatula*, because it was easy and fast to grow, which is ideal for multiple trials. The experimentation included sensors that measured the plant's overall condition and environmental factors. This experiment needed to fit in 1 or 2-unit NanoLabs. The testing included the use of light-emitting diode (LED) lights, water distributor, Gore-Tex®, rock wool, and cameras, as well as sensors that measured hydration, temperature, and relative humidity.

RESULTS

In the next version of this chamber, it would be beneficial to remove the plate that the plant growth tray sits on in favor of a lip on which the tray can sit. This would allow for a much better seal to be sure that water will not escape the system. Additionally, there were some issues with the channel being too small for the wires to the pump to run through. This would be changed by creating a larger channel or some other means of passing the wires past the plant tray without drilling through the chamber. On the next version of our system, we will also be able to have a surface-mounted camera that would drastically increase the amount of space available for the growth of the plants by decreasing the size of our electronics suite. Also, work still needs to be done to make the watering dependent on the water levels as measured by the moisture sensor. This addition would make the system fully autonomous, with the exception for the need for additional water after a certain amount of time. These design changes are illustrated in the following two figures. Figure 1 shows the plant chamber that flew on the Zero G plane. Figure 2 shows the design changes that next year's EDD class will implement.

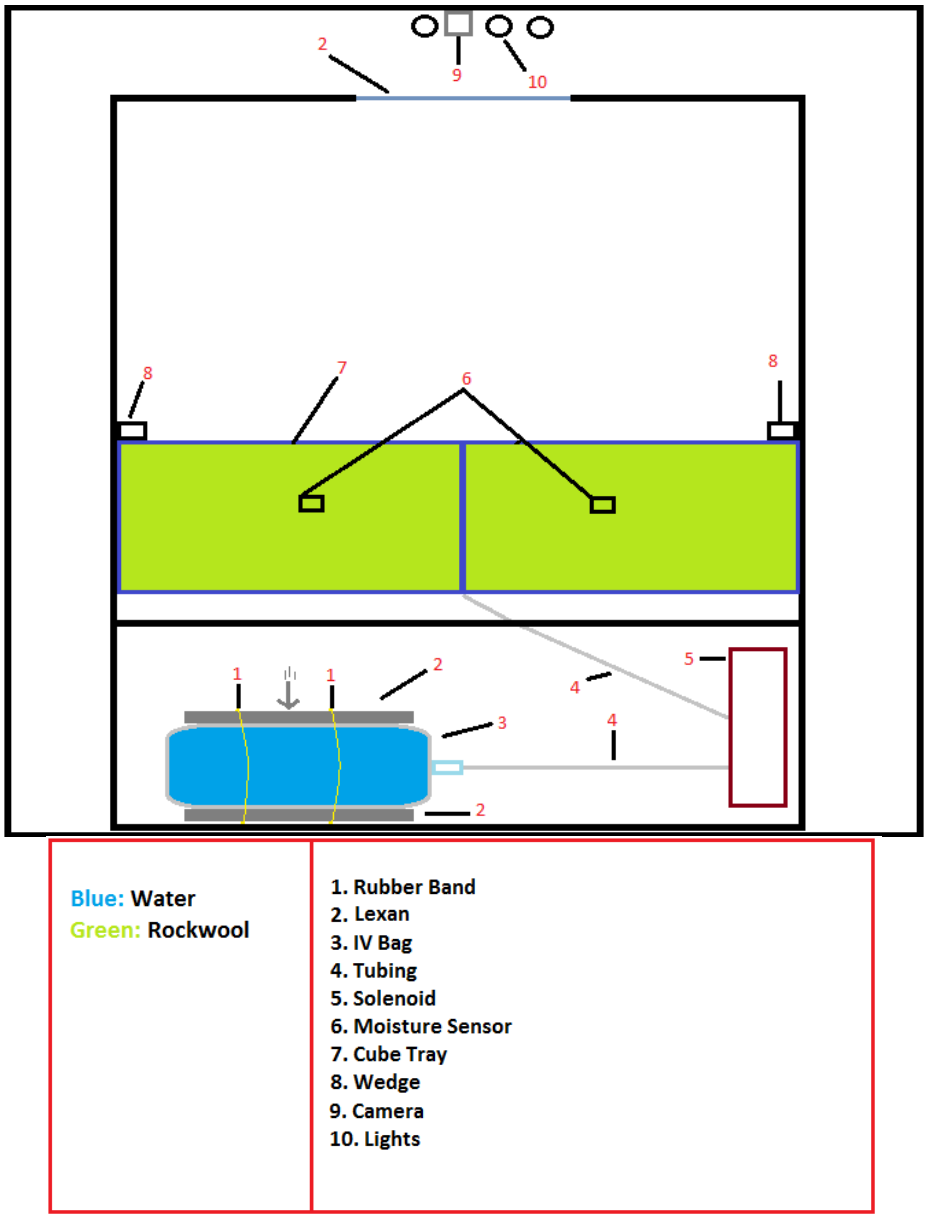


Figure 1. Design for the zero-gravity flight of the plant chamber.

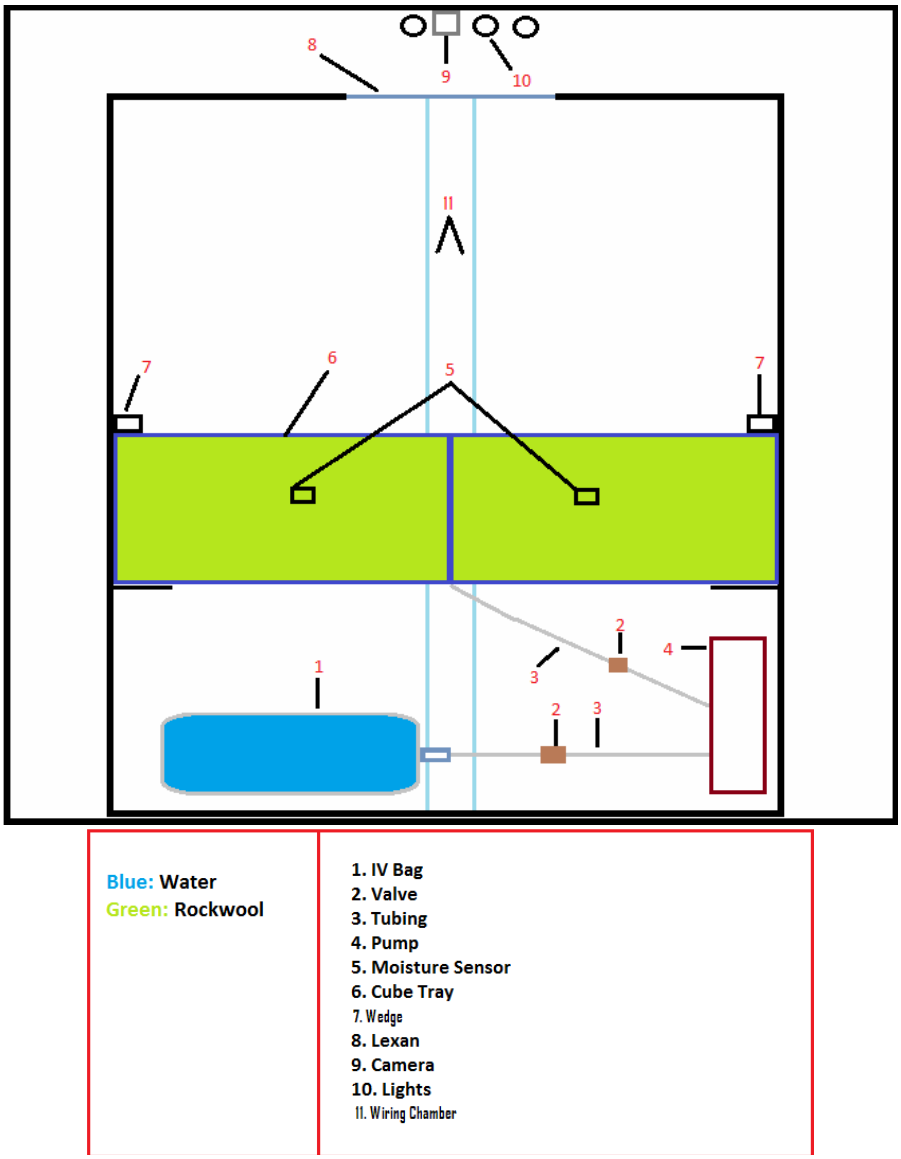


Figure 2. Design for next year's plant growth chamber.

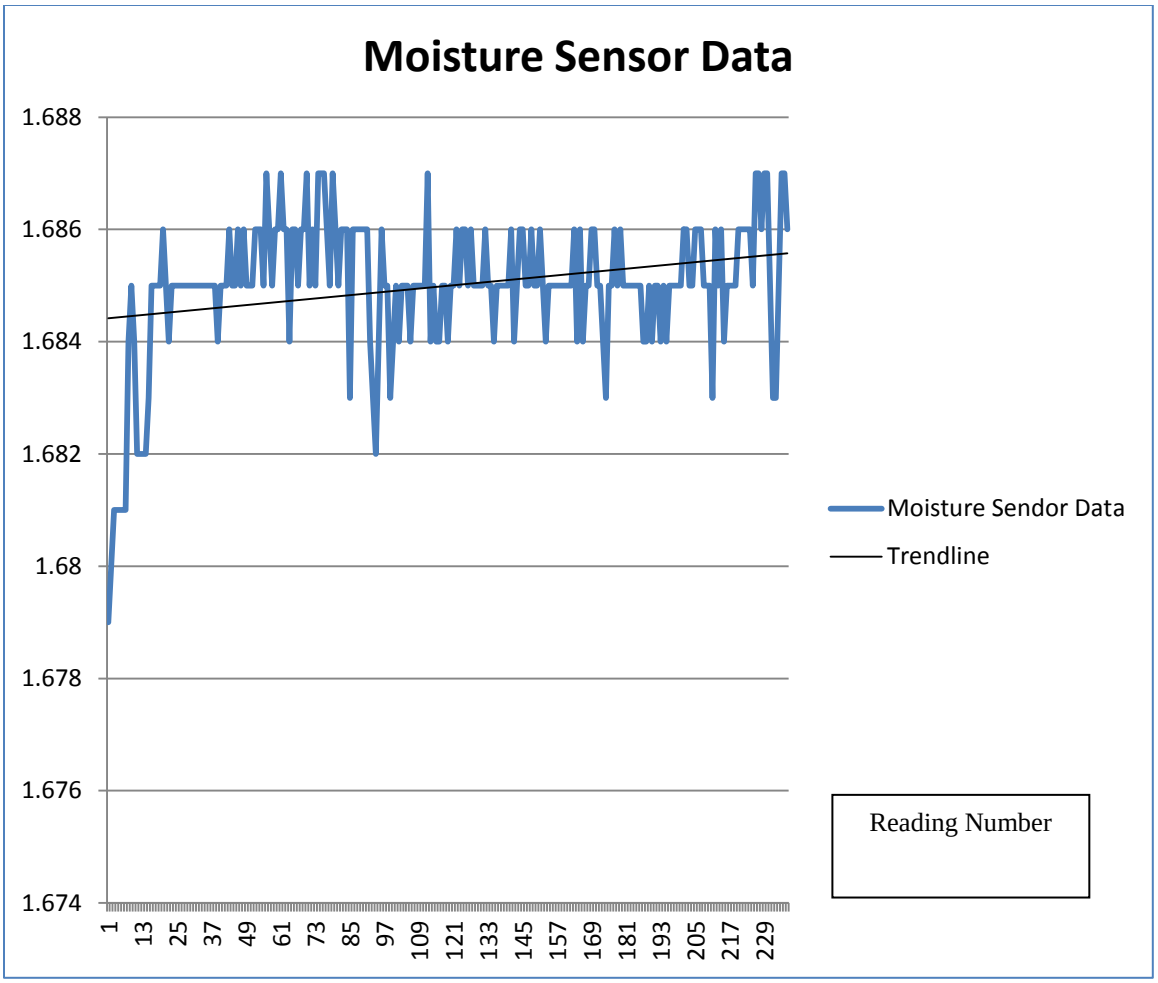


Figure 3. Moisture Sensor Data.

DISCUSSION

Figure 3 shows an increase in the water measured by the moisture sensor, proving that it did work as we expected. The moisture sensor measured the voltage across the two leads and saved the reading to a micro SD card. If there was a higher voltage, it meant there was more water in the Rockwool due to water's natural conductivity. A lower voltage meant there was little water in the Rockwool. Using these readings, we could tell when to water the plant, and how much water was necessary to keep the plants healthy. The water delivery system worked. We found that we needed to use higher gage wire for the moisture sensor. We found problems with the box that created leakage. There was some slight water leakage between the shelf that holds the tray and the tray itself due to an indirect seal. We plan to fix this by replacing the shelf with a lip that will allow us to directly seal the Levin tube to the tray.

CONCLUSION

There will need to be changes before our design is ready to fly on the ISS. We need to change some design features of the box. There is also a lot of work to be done on the microcontroller to make it self-sufficient on the ISS. The microcontroller will allow the experiment to be fully automated, with the exception of refilling the water bag when necessary. In addition, the microcontroller will be able to give

us much more accurate readings, as well as let us get a real-time look at the plant and conditions on the experiment from the ISS. We would changes the wires of the moisture sensor and program the microcontroller to handle cameras. We also need to change the delivery method of the water to a dose-metered pump instead of the rubber bands. The pump will be better than the rubber bands because it will give a constant amount of water whenever needed. The pump will also help us take out the guesswork when trying to give the right amount of water.

REFERENCES

http://www.theleeco.com/LEEWEB2.NSF
http://nanoracks.com/

CONTACT INFORMATION

Alli Westover:
Work: 281.284.1300
Cell: 832.876.5724
E-mail: awestove@ccisd.net

TITLE

The O-Zone ***WILD***

Water purification and Ion removal through Low pressure Distillation

FLIGHT DATE

April 25, 2012

PRINCIPAL INVESTIGATOR

John Frost PhD, Overland High School, Cherry Creek School District, Aurora, CO

CO-INVESTIGATORS

Jacob Donohoue
Jericho Oviedo
Cynthia Turcios
Megan Cassidy
Richard Charles, MS
Jennifer Nass-Fukai, PhD

GOAL

The goal of this experiment was to assess and quantify the performance of commercial waterproof "breathable" fabrics to act as liquid-gas phase separators.

OBJECTIVES

The objective of this experiment was to assess and quantify the performance of commercial waterproof "breathable" fabrics to act as liquid-gas phase separators.

Water is one of the most vital factors necessary for support of life, research, and commercialization of extraterrestrial environments. However, traditional water purification and filtration systems used at 1 G are often difficult or impossible to use in a microgravity environment. The current Environmental Control and Life Support System (ECLSS) used on board the International Space Station (ISS) relies on the generation of artificial gravity by rotating the distillation assembly. Though current techniques are effective at producing high quality water, the reliance on moving parts make this system vulnerable to mechanical failure. Additionally, rotating the distillation assembly requires power that could be used elsewhere on the system. Our initial objective was to develop an innovative new method to effectively and efficiently purify water in a microgravity environment without the reliance on generating artificial gravity.

Recently there has been an explosion in the number and type of "breathable" waterproof fabrics, such as Gore-Tex® and coated Cordua® nylons. These fabrics are impermeable to liquid water but allow water vapor to freely pass. The best of these fabrics are capable of allowing more than 830 g of water vapor to pass per square-meter per hour at atmospheric pressure. These fabrics can be used to keep the wastewater within the container without the need to generate an artificial gravity environment. We investigated their potential use as phase separators in a low-pressure distillation apparatus.

METHODS AND MATERIALS

The experimental layout is shown in Figure 1. A small quantity of water (3 mL) was added along with five marble boiling chips to a polycarbonate water chamber. The water chamber was sealed at one end using another piece of polycarbonate solvent welded to the end of the tube. The other end was sealed using a one-hole rubber stopper that had a piece of the fabric being tested affixed to the top using rubber cement. This fabric was one of two commercially available "breathable" waterproof fabrics: 1000-denier-coated Cordura® nylon and a 2-Layer Gore-Tex®. This assembly was placed inside the vacuum chamber, a slightly larger version of the water chamber, also made out of polycarbonate tubing. The top of the vacuum chamber was fitted with a three-hole rubber stopper. The first hole was fitted to a Vernier Gas Pressure Sensor, the second to an exhaust valve, and the third to the vapor trap and vacuum pump. The vapor trap was a polycarbonate tube with isolation valves on both ends and filled with indicating silica gel desiccant. The pump, donated by KNF labs, was a model N920AP diaphragm pump capable of achieving the low pressures necessary for this experiment. The exhaust valve was used to return the vacuum chamber to atmospheric pressure between microgravity data sets. Ground-based testing revealed that without this exhaust valve, the pressure in the vacuum chamber would remain below the vapor pressure of water. After the isolation valves on the vapor trap were closed, water continued to boil and caused condensation on the inside of the vacuum chamber, thus causing inaccuracies in the timing of the experiment.

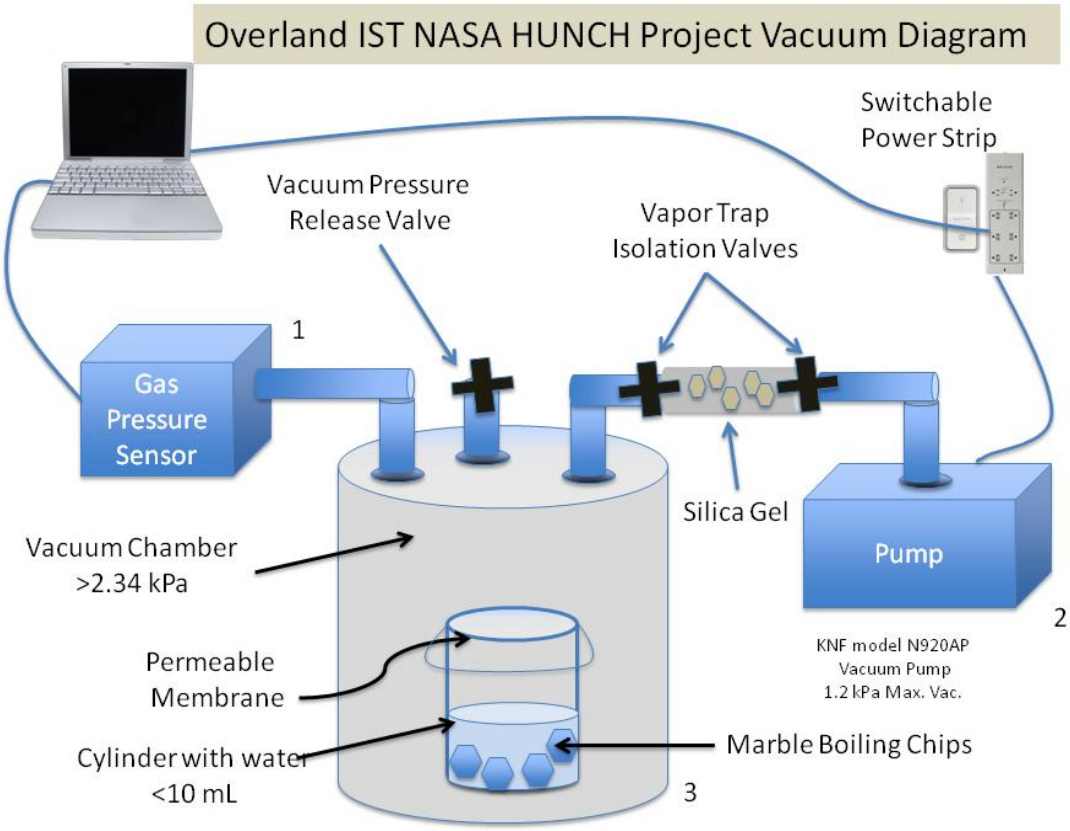


Figure 1. Schematic diagram of the OHS WILD system.

The experiment was conducted in the following manner: the pump was turned on at the beginning of the flight but was isolated from the rest of the system by the valves on the vapor trap. During the microgravity portions of the flight, the valves were opened, allowing the pressure inside the vacuum chamber to drop below the vapor pressure of water and the water to boil. While this approach required the use of a large, heavy, and expensive vacuum pump, it was safer than heating the water, which could have resulted in burns to the experimenter. The low-pressure distillation separated the water from its contaminants according to vapor pressure in the same manner as the ECLSS system. However, while the ECLSS system uses a rotating drum to separate the liquid and vapor phases, in our experiment it was the vapor-permeable fabric that acted as the phase separator. The vapor passed through the phase separator and traveled to the vapor trap where it became “trapped” in the form of a silica gel hydrate. Meanwhile, the contaminated liquid phase remained contained inside the water chamber. During the nonzero portions of the flight, the vapor trap isolation valves were closed and the exhaust valve opened to equalize the pressure before being closed again. The sequence was repeated for each of the parabolas of the flight.

The transpiration rate was calculated using the difference between the initial and final masses of the vapor trap and the known amount of exposure time. A larger difference in the masses for a given exposure time equates to a higher transpiration rate and therefore a potentially more effective phase separator. Timing data was achieved by reviewing the video files taken of the flight to determine the total amount of time the vacuum chamber was subjected to the reduced pressure environment in microgravity.

RESULTS

During our two flights, we measured a transpiration rate of 1.36- x 10^{-3} g/s for 1000-denier-coated Cordura® nylon and 7.48 × 10^{-4} g/s for 2-layer Gore-Tex®.

Table 1. Mass Differences of the Vapor Traps used to Measure the Transpiration Rate of the Two Commercially Available Breathable Fabrics in Microgravity

	1000 Denier-coated Tube 1 Weight-Pre (g)	**1000 Denier-coated** Tube 1 Weight-Post (g)	**Gore-Tex® 2-layer** Tube 4 Weight-Pre (g)	**Gore-Tex® 2-layer** Tube 4 Weight-Post (g)
Trial 1	58.335	58.824	56.4291	56.7056
Trial 2	58.3343	58.8242	56.4279	56.7063
Trial 3	58.3337	58.8255	56.4285	56.7058
Mean	58.3343	58.8246	56.4285	56.7059
Mean Diff.		**0.4902**		**0.2774**

Table 2: Timing Data Recovered from the Experimental Flight Video Files

NASA HUNCH Ozone Wild Water Distillation Results by Flight

	Parabola #	Start Time	End Time	Valve open		Elapsed time	MicroG Time		Parabola #	Start Time	End Time	Valve open		Elapsed time	MicroG Time
Flight 1	1	8:09:01	8:09:25	No		0:00:24	0:00:00	Flight 2	1	11:50:43	11:51:06	No		0:00:23	0:00:00
Flight 1	2	8:10:22	8:10:42	No		0:00:20	0:00:00	Flight 2	2	11:52:18	11:52:44	No		0:00:26	0:00:00
Flight 1	3	8:11:34	8:11:53	No		0:00:19	0:00:00	Flight 2	3	11:53:36	11:53:59	No		0:00:23	0:00:00
Flight 1	4	8:12:52	8:13:03	yes		0:00:11	0:00:11	Flight 2	4	11:55:00	11:55:15	Yes		0:00:15	0:00:15
Flight 1	5	8:13:57	8:14:17	yes		0:00:20	0:00:20	Flight 2	5	11:56:09	11:56:23	yes		0:00:14	0:00:14
Flight 1	6	8:15:06	8:15:25	yes		0:00:19	0:00:19	Flight 2	6	11:57:18	11:57:38	yes		0:00:20	0:00:20
Flight 1	7	8:16:25	8:16:38	yes		0:00:13	0:00:13	Flight 2	7	11:58:27	11:58:42	yes		0:00:15	0:00:15
Flight 1	8	8:17:37	8:17:56	yes		0:00:19	0:00:19	Flight 2	8	11:59:38	11:59:58	yes		0:00:20	0:00:20
Flight 1	9	8:18:50	8:19:10	yes		0:00:20	0:00:20	Flight 2	9	12:06:13	12:06:32	yes		0:00:19	0:00:19
Flight 1	10	8:20:12	8:20:20	yes		0:00:08	0:00:08	Flight 2	10	12:07:26	12:07:45	yes		0:00:19	0:00:19
Flight 1	11	8:21:16	8:21:35	yes		0:00:19	0:00:19	Flight 2	11	12:08:40	12:08:59	yes		0:00:19	0:00:19
Flight 1	12	8:22:33	8:22:50	no		0:00:17	0:00:00	Flight 2	12	12:09:55	12:10:14	yes		0:00:19	0:00:19
Flight 1	13	8:23:49	8:24:08	no		0:00:19	0:00:00	Flight 2	13	12:11:13	12:11:30	yes		0:00:17	0:00:17
Flight 1	14	8:25:06	8:25:23	yes		0:00:17	0:00:17	Flight 2	14	12:12:35	12:12:54	yes		0:00:19	0:00:19
Flight 1	15	8:26:29	8:26:40	yes		0:00:11	0:00:11	Flight 2	15	12:13:55	12:14:16	yes		0:00:21	0:00:21
Flight 1	16	8:27:41	8:27:53	yes		0:00:12	0:00:12	Flight 2	16	12:15:24	12:15:33	yes		0:00:09	0:00:09
Flight 1	17	8:28:54	8:29:07	yes		0:00:13	0:00:13	Flight 2	17	12:16:33	12:16:47	yes		0:00:14	0:00:14
Flight 1	18	8:33:48	8:33:59	yes		0:00:11	0:00:11	Flight 2	18	12:17:47	12:18:00	yes		0:00:13	0:00:13
Flight 1	19	8:34:59	8:35:12	yes		0:00:13	0:00:13	Flight 2	19	12:19:08	12:19:18	yes		0:00:10	0:00:10
Flight 1	20	8:36:07	8:36:27	yes		0:00:20	0:00:20	Flight 2	20	12:23:54	12:24:15	yes		0:00:21	0:00:21
Flight 1	21	8:37:27	8:37:45	yes		0:00:18	0:00:18	Flight 2	21	12:25:10	12:25:25	yes		0:00:15	0:00:15
Flight 1	22	8:39:45	8:40:06	yes		0:00:21	0:00:21	Flight 2	22	12:26:19	12:26:38	yes		0:00:19	0:00:19
Flight 1	23	8:41:07	8:41:16	yes		0:00:09	0:00:09	Flight 2	23	12:27:38	12:27:51	yes		0:00:13	0:00:13
Flight 1	24	8:42:17	8:42:30	yes		0:00:13	0:00:13	Flight 2	24	12:28:46	12:29:05	yes		0:00:19	0:00:19
Flight 1	25	8:43:32	8:43:43	yes		0:00:11	0:00:11	Flight 2	25	12:30:01	12:30:22	yes		0:00:21	0:00:21
Flight 1	26	8:44:50	8:45:02	yes		0:00:12	0:00:12	Flight 2	26	12:31:13	12:31:32	no		0:00:19	0:00:00
Flight 1	27	8:46:01	8:46:13	yes		0:00:12	0:00:12	Flight 2	27	12:32:26	12:32:47	no		0:00:21	0:00:00
Flight 1	28	8:47:12	8:47:27	yes		0:00:15	0:00:15	Flight 2	28	12:33:47	12:34:08	no		0:00:21	0:00:00
Flight 1	29	8:48:28	8:48:38	yes		0:00:10	0:00:10	Flight 2	29	12:35:04	12:35:23	no		0:00:19	0:00:00
Flight 1	30	8:49:33	8:49:53	no		0:00:20	0:00:00	Flight 2	30	12:36:17	12:36:37	no		0:00:20	0:00:00
Flight 1	31	8:50:53	8:51:06	yes		0:00:13	0:00:13	Flight 2	31	12:37:41	12:38:05	no		0:00:24	0:00:00
Flight 1	32	8:52:01	8:52:28	no		0:00:27	0:00:00	Flight 2	32	12:39:04	12:39:36	no		0:00:32	0:00:00
					Flight 1 Totals	0:08:26	**0:06:00**						**Flight 2 Totals**	0:09:59	**0:06:11**
					Flight 2 Average MG Time		0:00:14						Flight 2 Average MG Time		0:00:17

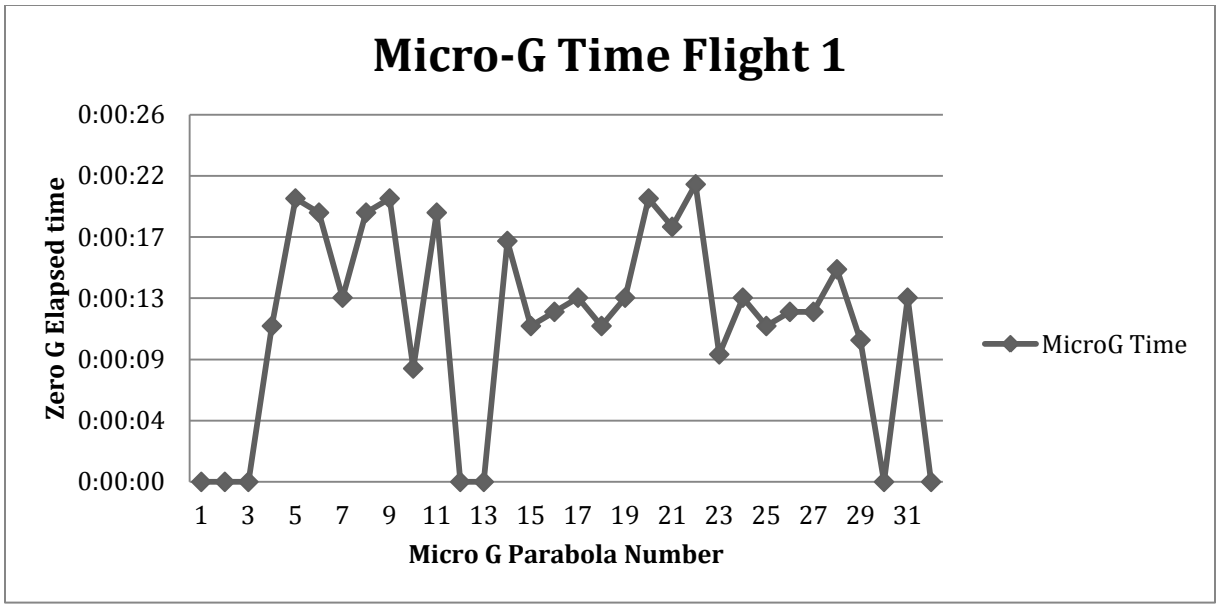


Figure 2. Seconds of low pressure distillation per microgravity parabola in flight 1.

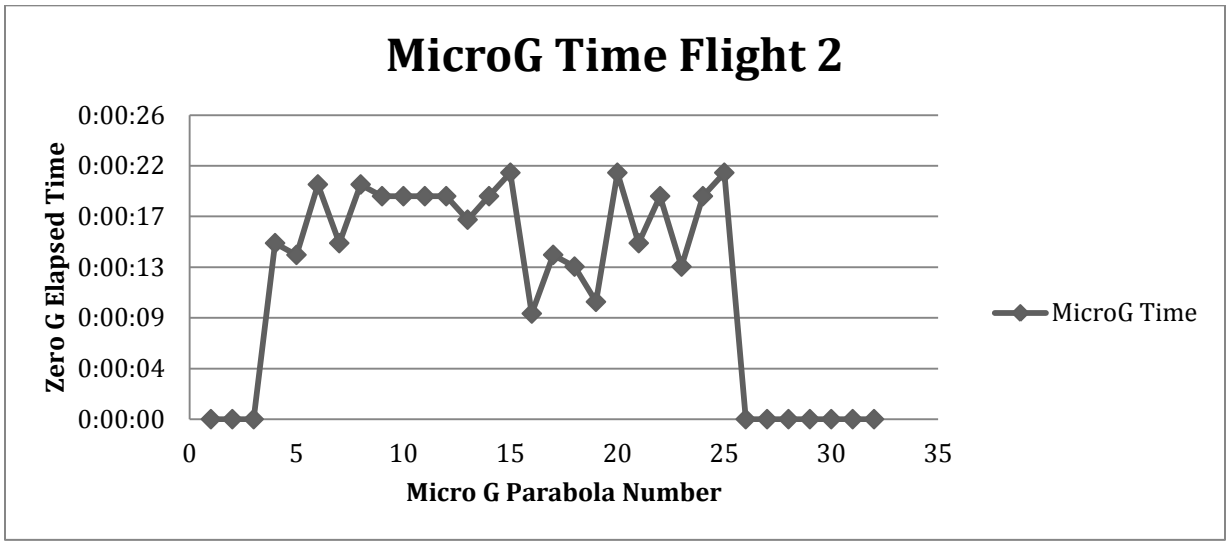


Figure 3. Seconds of low pressure distillation per microgravity parabola in flight 2.

DISCUSSION

The transpiration rate of the 1000-denier-coated Cordura® nylon was found to provide a superior transpiration rate when compared to the 2-layer Gore-Tex®. While the amount of water collected may seem too small to be useful, it must be recalled that the total area of the phase separator available for transpiration was only 0.049 in.^{2}. Although the exact size of the ECLSS phase separation drum is unknown to us, using a photo of the system (Figure 4) we can estimate its size as approximately 10 × 24 in. These dimensions would give an internal surface area of approximately 754 in.^{2}, which, assuming all else equal, would result in the distillation of almost 21 grams of water every second, or 1.81×10^6 g per day (1807.5 L/d). This is much more than the necessary daily consumption of the crew.

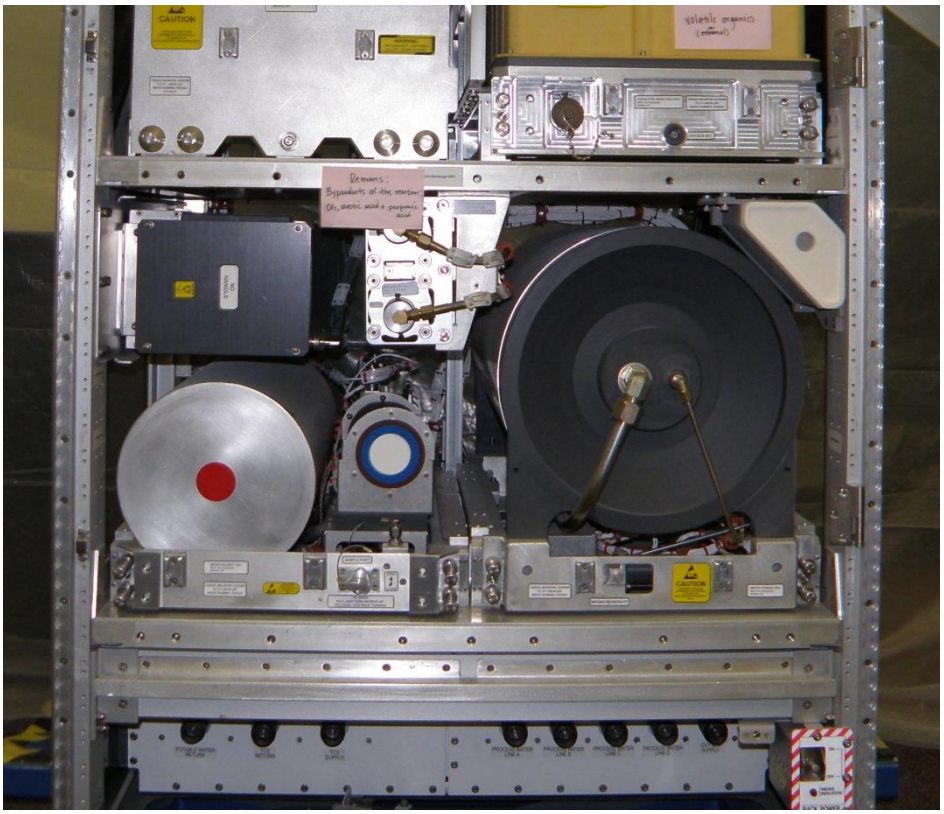


Figure 4. Picture of the ECLSS training rack in Building 9 at the Johnson Space Center.

While this value is initially impressive, it must be recalled that the waste water being distilled in this experiment was clean tap water and therefore the membranes were not subject to fouling by waste contaminants as the actual system may be. Future work on this project will include comparing the results of a preflight 1-G model to the results obtained in microgravity to evaluate the effectiveness of the 1-G model. The tap water will also be replaced with the NASA urine simulation solution and the long-term fouling effects on the transpiration rate of the phase separator evaluated.

CONCLUSION

The students of Overland High School, in collaboration with NASA HUNCH, evaluated the performance of two commercially available breathable waterproof fabrics to act as phase separators. This work was conducted to attempt to find a replacement mechanism for the mechanical phase separation currently used in the ECLSS system which would decrease the power consumption and susceptibility of the system to mechanical failure. 1000-denier-coated Cordura® and 2-layer Gore-Tex® were evaluated in microgravity and produced transpiration rates of 1.36×10^{-3}g/s, and 7.48×10^{-4} g/s, respectively. Both of these commercial fabrics were effective as phase separators and produced extrapolated daily production rates in excess of those required to sustain the 6-member crew of the ISS with no power consumption and no mechanical parts.

ACKNOWLEDGEMENTS

We would like to acknowledge the following NASA offices: HUNCH, Payload, Reduced Gravity, and Education. We would also like to acknowledge our sponsors: The American Chemical Society, picoSpin LLC., and KNF Labs. Thank you.

CONTACT INFORMATION

All correspondence should be directed to John Frost PhD at:

John Frost PhD
12095 East Hoye Drive
Aurora, CO 80012
E-mail: jafrost@mtu.edu
715-437-0308

Title

Effect of Microgravity on Spinal Expansion

Flight Date

April 25, 2012

PRINCIPAL INVESTIGATORS

Avi Aggarwal and Amy Xie

North Carolina School of Science and Mathematics, Durham, NC

CO-INVESTIGATORS

Tyler Hayes, Whitman Groves, Dr. Myra Halpin (Teacher)

NCSSM HUNCH Team: Avi Aggarval, Amy Xie, Whitman Groves, Tyler Hayes (from left to right)

GOAL

For our project, we built a model of the human spinal column and tested movement and tension between vertebrae with force sensors, piezoelectric strips, and a video camera. The goal of our experiment was to observe and understand the effects of microgravity on the behavior of the human spine. The data and conclusions drawn from such research could aid in designing methods to ameliorate back pain caused by spaceflight, possibly include new exercises, special clothing/equipment, and potential treatments to improve astronaut health and performance.

OBJECTIVES

This experiment was flown as a part of the High School Students United with NASA to Create Hardware (HUNCH) program. It was designed, fabricated, and documented by the students at North Carolina School of Science and Mathematics in Durham, NC. The purpose of the experiment was to observe the forces that affect the human spine in microgravity.

During 2010 to 2011, Amy Xie and Avi Aggarwal designed a sleeping pod to provide personal space, air flow, circadian rhythm stimulation, and ergonomic support for astronauts. This project was submitted to the Conrad Spirit of Innovation Competition and earned the National Space Biomedical Research Institute Award for Human Healthcare in Space in May 2011. For this project, we interviewed 3 former NASA astronauts about their sleep experiences in space. The astronauts were Barbara Morgan, Bill McArthur, and Jim Voss. One of the issues the astronauts discussed was chronic back pain while on the International Space Station (ISS). Often, astronauts would sleep hugging their knees so that the pain in their back was somewhat relieved.

The exact cause of astronauts' back pain is unknown, but there are several factors that likely contribute to the discomfort. The microgravity environment is known to cause the human spine to expand vertically, giving astronauts 2 to 3 inches of extra height in space. The increased strain on muscles and ligands could result in chronic back pain. In between the boney spinal vertebrae are fluid-filled discs known as intervertebral discs. Fluid behavior changes from 1 G to 0 G, allowing for gas bubbles that neither move upwards nor downwards. The spinal model we flew in microgravity contained both a force component and a fluid tube column. Our mission was to better understand the differences between the forces on a spine in space and a spine on Earth.

Astronaut health in space is affected by many factors, a major one being microgravity. A notable effect of microgravity is reduced spinal compression in space, which causes the spine to expand in a painful process. Because astronauts frequently report back pain, we sought to identify ways to relieve strain caused by spinal expansion in reduced gravity and test the forces exerted on the spinal column.

We constructed a model of the human spine that incorporated polymer vertebrae, memory foam intervertebral discs, and elastic muscles, and was supported by a central rod and a Lexan plate structure. To test the behavior of the model in 0 G, we attached piezoelectric strips to vertebrae to register movement, as well as force sensors to measure change in forces during the microgravity flight. Additionally, a water column was attached to the structure to observe gases emerging out of solution in microgravity, which is another potential cause of pain. A video camera was attached to the bottom Lexan baseplate to visually record changes in the water column during flight and movement of vertebrae. The entire structure was bolted down to the base plate of a vertical glovebox and flown

during Reduced Gravity Educational Flight Program/High Schools United with NASA to Create Hardware (HUNCH) flight week.

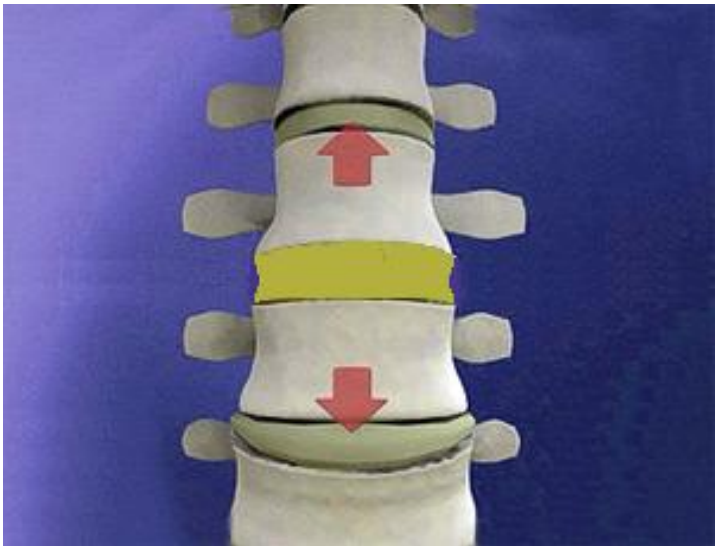


Figure 1. Model of spine.

METHODS AND MATERIALS

How the research began

Our research began with looking at possible factors contributing to spinal elongation and back pain as a result of reduced gravity. There are many potential sources for pain, ranging from muscles, bone, intervertebral discs, the spinal cord, nerves within the spinal column, and many more. We researched the back and consulted several experts to narrow down the most significant source of the spinal expansion to the intervertebral discs. We further researched the anatomy and materials to determine what the best way to model the spine, retaining the key structural components and forces that we wanted to incorporate in our system but allowing the model to be built and effectively measured.

Description of experiment setup

Our experiment required a scale model of the human spine. We began constructing our experimental model using a threaded steel rod bent to emulate the curve of the human spine. Our vertebrae were taken from a medical visual model, and our intervertebral disks were built from memory foam wrapped firmly in tape. Below several of the vertebrae was a small Lexan plate cut to fit the bone model that sensors would be attached to. This spine was secured into a cage with a Lexan base and top plates, which were connected by a series of other threaded steel rods. A third plate was secured in the middle between the top and bottom plates along the same support rods.

To measure the expansion of the human spine once placed in microgravity conditions, we used a combination of force sensors, piezoelectric strips, and accelerometers all connected with a LabQuest interface. Four force sensors were attached to the top and bottom plates, each connecting via spring to a respective intervertebral Lexan plate. Any vertical shift in these plates would register a change in force with the force sensors. Piezoelectric strips extended horizontally from the middle Lexan plate and a threaded steel support rod and were connected to other intervertebral plates. Any vertical shift would cause these strips to bend, creating an electric charge that could be recorded in LabQuest. All data were

recorded alongside accelerometer data, allowing us to superimpose any expansion of the spine with the change in gravitational force and study the correlation.

A PVC pipe containing red colored water was attached to one of the steel rods along with a ruler behind it. This was to observe the change in volume and emergence of gas bubbles from water during reduced gravity, potentially indicating gases coming out of solution inside of intervertebral discs, which is a potential source of the frequently reported back pain.

A video camera was attached to the base plate to visually record changes within this water column and also the lower end of the spine.

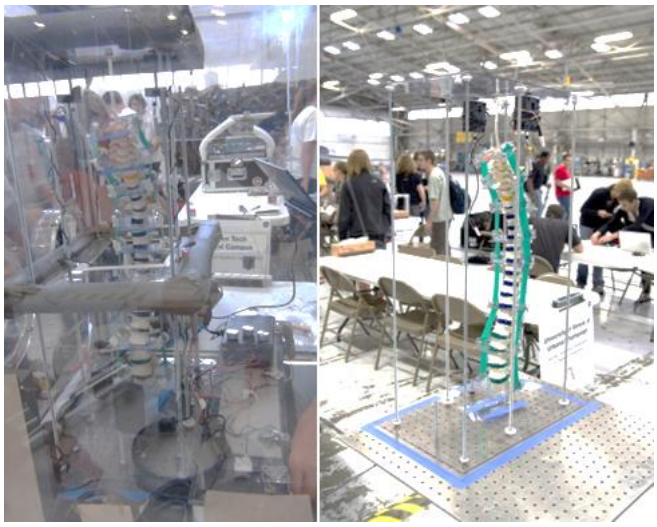


Figure 2. Experimental setup.

The hypothesis

Our team's hypothesis was that the model intervertebral discs would expand during microgravity, causing the spine to expand, resulting in the vertebrae moving apart. This movement would be reflected by visual recording through video, greater magnitude of voltage generated by piezoelectric strips attached to different vertebrae, and changes in value of force between the force sensors and the vertebrae to which they were connected. This data would show whether even short bits of microgravity can cause changes in forces along the spine. We hypothesized that back pain due to spinal elongation is attributed to long durations of muscle and ligand tension. Additionally, we hypothesized that gases coming out of solution inside of the intervertebral discs may cause pain, and we hypothesized that gas bubbles would form within the water column.

Research performed before flight

The research we did before our flight included learning about the anatomical structure of the back and spine so we could design and construct our experiment, and then testing the experiment on the ground so we could get a feel for how the experiment would test while we were flying on the plane.

Before flying our experiment, we ran a series of ground tests to determine exactly how we would operate the experiment in microgravity, and to locate any potential problems with the setup. We tested the local function of each force sensor and piezoelectric strip by monitoring only one at a time and

putting force on the spine in different nearby locations. This allowed us to not only confirm that our setup was working, but to give us an idea of the magnitude of forces we could expect to see. We did the same thing with each accelerometer, accelerating them in various ways. We also ran tests with our LabQuest set up exactly how it would be on the plane, with all the sensors plugged in accordingly. By doing this we were able to determine the optimal amount of time to record data and also establish an effective method of recording, saving, and reinitiating the data.

RESULTS

Through this experiment forces on the spine, gas bubble formation in fluids were to be tested. Due to technical difficulties securing and maintaining the position of the video camera, footage of the level of the fluid column was inconclusive. Data from the force probes were consistent throughout the duration of the flight, although the interpretation and application of the data collected varied.

On Earth (1 G), the total force (sum of top force probe measurement and bottom force probe measurement) is consistently 0.0 N, and does not change with time. This is expected because positive force exerted on one probe directly correlates with negative force (force in opposite direction) on the other force probe. Neither total force nor acceleration changes in this situation.

During the flight, acceleration changed from approximately 0 G to 2 G according to the parabolic motion of the Zero G plane. Because the acceleration changed, the force was expected to change proportionally with acceleration, as well. This comes from the physics equation, F = ma, where force equals mass (which remains constant, as no material is added to or taken away from the experiment) multiplied by acceleration. However, when total force was graphed against acceleration (Figure. 3), no correlation between the two was found.

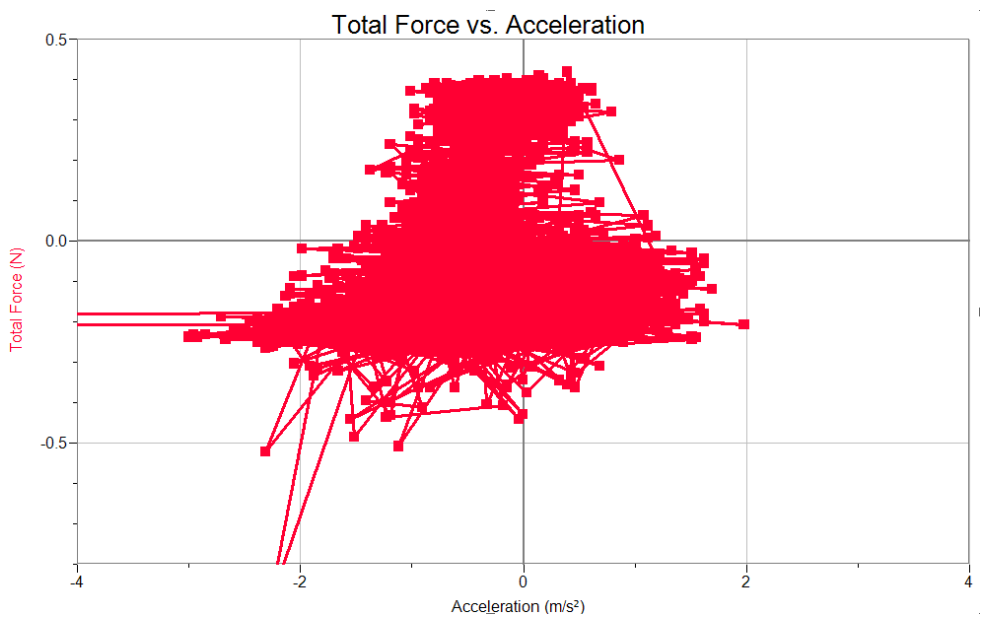


Figure 3. Total force versus acceleration.

We were surprised that there seemed to be no relationship between force and acceleration, so we looked back at the measurements of force and acceleration over time, individually.

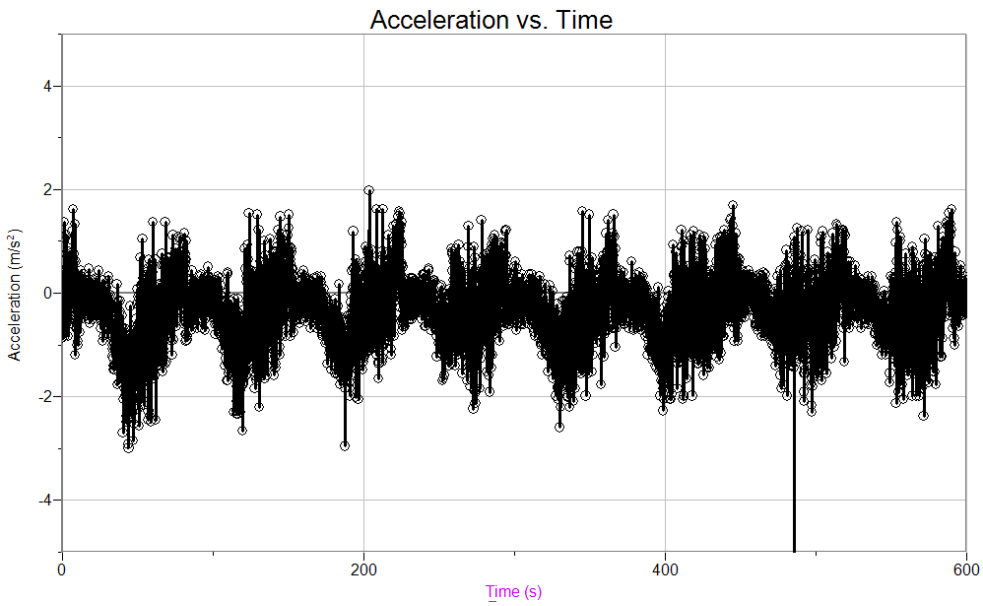


Figure 4. Acceleration versus time.

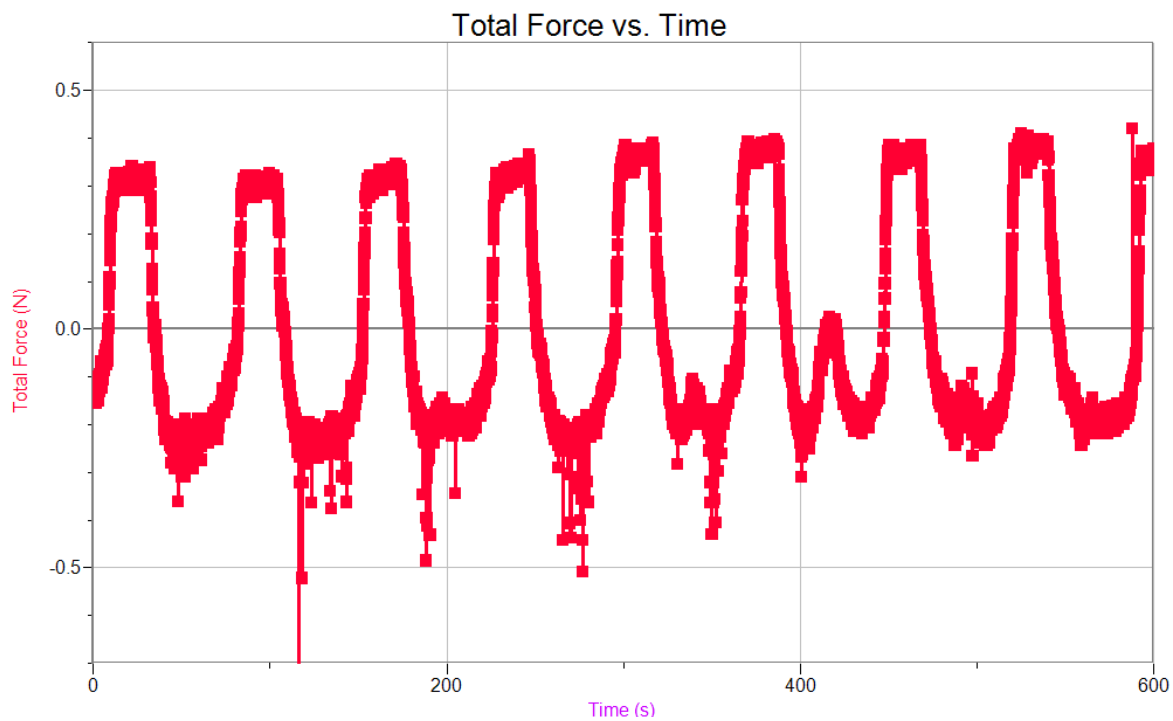


Figure 5. Total force versus time.

From Figures 4 and 5, it is evident that both acceleration and force oscillated over time. Figure 6 shows the two overlayed in real time.

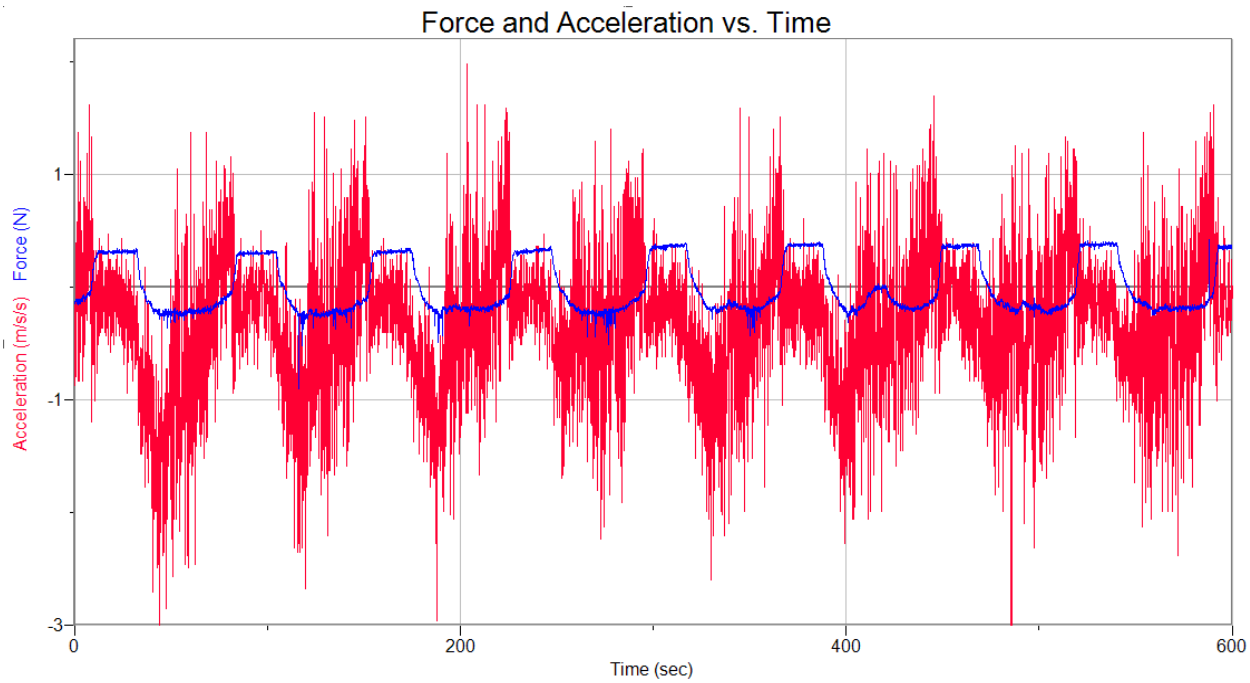


Figure 6. Total force and acceleration versus time.

Figure 6 shows that although both force and acceleration oscillated over time, there was a period shift between the two. This justifies the lack of direct correlation when force and acceleration were graphed against each other. This means that movement of the spine was affected by acceleration, but with a time lag.

DISCUSSION

The NCSSM HUNCH team arrived at Ellington Field ready to assemble the experiment inside the glove box, but found that the ¼ inch holes in the base plate of the glove box were not big enough for the ¼ inch bolts we intended to use to secure our apparatus. Adjustments to the base plate were made by the helpful NASA crew in the hangar.

The video footage of the flight on the Zero G plane was less helpful than we had hoped. Our experiment had a video camera inside the glove box, screwed into a ¼ inch bolt, and an external video camera with the arm provided by NASA. The intent of the inner camera was to observe any gas bubbles in the tube of liquid and the outer camera would capture any visible shift in the spinal column. We quickly learned that simply screwing the inner camera onto its threaded bolt stand was not enough to keep it steady, as it frequently swiveled about. A simple adhesive such as tape would have aided the secure placement of the camera. Also, a more effective way to measure gas bubble formation in water was needed. The outer camera, although more steady, was also bumped from time to time by the flyers in the plane. This occurred most frequently during low Gs, when it was possible for one's feet and body to be floating in the cabin.

During our visit at the Johnson Space Center, we were able to tour research facilities and labs. Dr. Sudhakar Rajulu's lab works on mechanical design of hardware sent into space that accommodates astronauts' increase in height. He noted that one of the differences between our spinal model and what happens realistically is the increased flexibility of the spine curvature. When making our model, we bent

a metal rod into an anatomically correct curvature and put mobile vertebrae and intervertebral discs on this rod. We measured the force of movement of the vertebrae, but did not account for the adjustment in curvature to changes in gravity. In the future, changing the material of the core of the spine to simulate the human spine more accurately should be made a priority; we need a more flexible material that can alter curvature in response to microgravity but still return to its original position afterwards.

From building this experiment, the NCSSM HUNCH team learned how to model complex anatomical systems using artificial materials, and to adapting to limitations and complications. While the experimental design at the beginning was fairly simple, we discovered that building a payload is always a work in progress – there are always adjustments and ways to make our model more biologically accurate or measurements more precise. Teamwork is essential to the progress of the project. While team members can disagree over a design or the best data collection method, we all worked toward the larger goal of a successful and rewarding flight day.

CONCLUSION

The data collected from the force probes turned out to be the most useful; therefore, we have learned that force probes are effective data collecting devices. However, though the data confirm slight expansion within our spinal model during periods of 0 G, other potential confounding factors exist such as vertical movement of the entire spinal column structure. The piezoelectric strips were helpful in showing some evidence of movement, but the nature of this movement cannot be determined from the data; piezoelectric compression sensors may provide more useful data for future experiments. The video recorder was not steady, resulting in a lack of reliable visual data. The water column analysis was inconclusive due to inability to keep camera steady, but it is worth further investigation. This experiment served as an excellent pilot study for future experiments of its nature; we now know to focus on reinforcement and structural sturdiness to prevent wobble and to focus on obtaining more useful measurements.

Data were mostly inconclusive but suggest further work on this topic. Force sensor readings confirmed slight expansion within the model during periods of 0 G. Recommendations for future modifications include a sturdier structure, an expandable central rod, and replacing ineffective measuring devices with more useful data collection. Eventual data and conclusions drawn could aid in designing methods to ameliorate back pain resulting from spaceflight, possibly including new exercises, special clothing/equipment, and potential treatments.

Recommendations for future flight experiments include building a more sturdy structure to obtain reliable measurements and anchoring the camera for steady video recording. This would eliminate the possibility of vertical displacement of the entire apparatus as a confounding factor in measurements. Another recommendation would be to change the central rod through the vertebrae to a more flexible material that can elongate vertically for a more functional model and more accurate representation of the spine. Another recommendation is to use a liquid with viscosity similar to that of intervertebral disc fluid in the water column to improve the validity of data.

Both the moon and Mars have gravity levels less than that of Earth. Earth's gravity is 9.78 m/s^2, whereas Mars' gravity is 3.711 m/s^2 and the moon's gravity is 1.624 m/s^2. In these reduced-gravity

environments, humans are likely to encounter health problems similar to those occurring in 0 G. Studying spinal expansion in a range of gravity settings will contribute to our understanding of space adaptation syndrome and the problems and solutions for spinal expansion on the moon and Mars. This will serve to make spaceflight safer and more productive for astronauts.

CONTACT INFORMATION

Dr. Myra Halpin
E-mail: Halpin@ncssm.edu

Dr. Florence Gold
E-mail: Florence.V.Gold@Nasa.gov

TITLE

Hydrofuge Alpha and Bravo Plant Chambers

FLIGHT DATES

April 24 and 25, 2012

PRINCIPAL INVESTIGATOR
Matthew Brown, Lakewood High School, Lakewood, CO

CO-INVESTIGATORS

Matthew Day, Joshua Nelson, Lauren Martin, Megan Franke, Sarek Iannacone, Craig Kurtzman, Daniel Daneshka, Craig O'Dell, Brent Logan, Rebecca Marshall, Miranda Kurtz, Lena Gibbs, Lea Connors, Daniel Gentile, Michael Concannon, Calder Sett, Daniel Duran, James Hill, Mike Adamczyk, and Patrick Gilbride.

Lakewood High School and Warren Tech HUNCH students

GOAL

For our project, we created a unique, functional plant growth chamber using centrifugal technology and terraponics to produce an ideal environment for vegetation under microgravity conditions.

OBJECTIVES

Alpha

- A common problem in space is that the water retention on the roots and lack of gravity prevent the water from dripping off the roots, causing the plants to drown or develop disease such as Root Rot. The main project objective was to develop a solution to this issue. The chamber used a centrifuge to flick the water off of the roots, while simultaneously simulating gravity through the forces of inertia.
- The Zero-G flight objectives were to observe whether or not the water would pump in and out of the plant chamber and if the centrifuge would be able to spin the plant successfully. We also tested the control panel and whether or not it was successful for both the experiments.

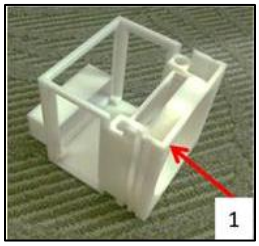
Bravo

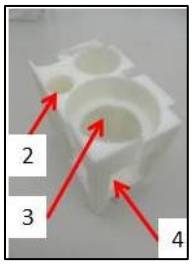
- To develop a much simpler alternative solution to the root rot problem. The solution used terraponics and a percolation system that pumped water into the terraponics.
- The 0-G flight objectives were to test if the pumps were able to pump water effectively into the nutrients to ensure that the control panel worked.
- Ultimately, both Alpha and Bravo plan to provide alternative, fresh food sources for astronauts in space. We hope to actualize this concept through a personal plant growth chamber (PPC) for astronauts.

METHODS AND MATERIALS

Alpha

The Alpha design was based on the concept of ebb and flow, a plant system that suspended a plant in air and then flooded a roots chamber with a nutrient and water solution located in a refillable water chamber. The root chamber was then evacuated back into the same water chamber and the centrifuge was able to spin the plant. A motor spun a band connected to a bearing that held the plant in the root chamber.





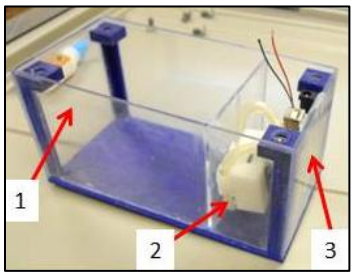
The picture on the left contains the control panel, water chamber (1), and the setup pictured right slides into the gap in the left picture. The setup pictured right contains a motor (2), bearing to hold the plant (3), and root chamber (4).

Bravo

The Bravo design used terraponics and a percolation system to grow the plants. The plants roots were placed into a nutrient substance known as terraponics. On the outside of the system, water was

pumped from a clear IV bag into the terraponics. The plant absorbed the water and the nutrients. After the plant has been watered for the allotted time, a pinch valve was activated to pump the water into a secondary chamber to test for modularity.

The plant was housed in the terraponics (1). The pinch valve (2) allowed the cube to be modular. The whole cube was controlled by the control panel (3). A lid was fitted in top and has Gore-Tex® vents to allow airflow to the plant but not let water escape the cube.

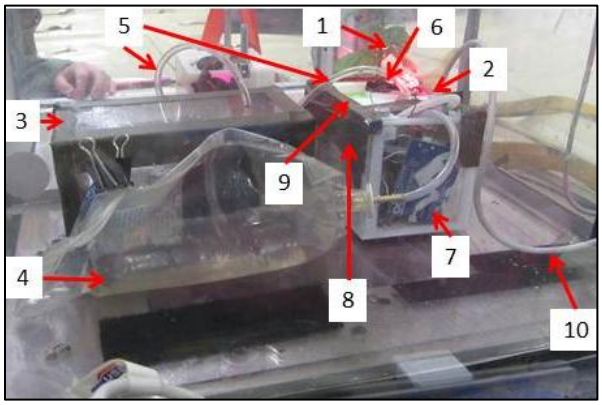


Materials

The Bravo system was contained inside a 2 × 3 × 3 foot Lexan box placed inside a NASA Reduced Gravity Office Glove Box to provide the required double containment. The Bravo and IV bag were velcroed into the Lexan box that was ratcheted to the glove box. The Alpha was located next to the Lexan box because it was double contained by the water chamber and NASA Glove Box. It was velcroed to a sheet of Lexan attached to the ratcheted Lexan box. The primary system parts (water and root chambers of the Alpha, corners and lid of the Bravo) were printed in a Dimension 3D printer out of ABS plastic. All Lexan to ABS plastic joints were sealed with silicone sealant and calking. Lexan windows were used for better viewing of the experiments as were 1.4 by 0.5 inch full spectrum LED lights. All plants were placed inside a neoprene collar and then a steel bearing. Both experiments were controlled by an Ardiuno Uno (200 mA) board located within each cube. Each of the boards ran off of a 9v adapter run from aircraft power. The Alpha required an extra 9v battery to power the pump, which was velcroed to the outside of the Alpha. The board operated lights, a pump, and pinch valve on each experiment, with the addition of a motor on the Alpha. Each board was connected to an accelerometer, which would sense a loss of gravity and begin the cycle for each parabola.

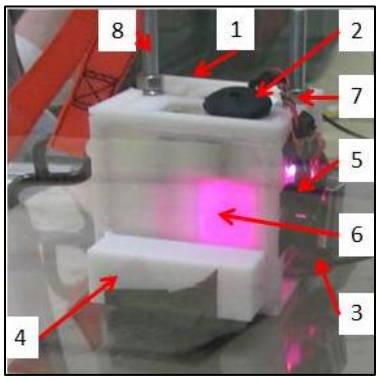
Diagrams

Bravo (contained in Lexan box)



1. Plant in neoprene collar
2. Main Bravo chamber
3. Secondary Bravo chamber
4. IV water bag
5. Water tubes
6. LED lights
7. Location of Ardiuno Uno Board, pump and pinch valve
8. Terrapots
9. Gore-Tex® vents
10. Power supply

Alpha (beside Lexan box)



1. Outer case
2. Neoprene collar
3. External 9v battery
4. Location of Arduino board, pump and pinch valve
5. LED lights
6. Root chamber
7. Motor
8. Blots to hold design together
9. Water chamber (On other side)

RESULTS

Alpha

System/Part	Function of system	Appearance	Efficiency	Errors	Needed Changes
Water Removal	A centrifuge spins the bearing to remove water from the roots.	The band did not spin the bearing.	Not very efficient.	The bearing was too stiff; the band did not grip the bearing well; the motor did not spin with enough torque.	Need a less stiff bearing, a better band system and a motor with more torque.

System/Part	Function of system	Appearance	Efficiency	Errors	Needed Changes
Water/watering system (micropump)	Water is kept in the water chamber where it is pumped through the micropump to the plant roots, and then recycled back into the chamber.	The system remained water sealed in the water chamber for the duration of the experiment.	Not very efficient.	Pumps de-primed in 2 G's and were unable to push water through the tubes.	Need a self-priming reversible pump.
Control system	An Arduino Uno board with accelerometer activated in micro gravity to start systems.	Located at bottom of experiment, was not shorted by water. Turned on lights in micro gravity.	Very efficient, was easy to use.	None.	The system could have recorded data.

Bravo

System/Part	Appearance	Function of system	Efficiency	Errors	Needed Changes
Plants	Plant is grown in a terraponics system. Sealed by a neoprene collar.	The plant appeared healthy and did not go into shock.	Very efficient and safe for the plant.	None.	None.
Water/watering system into main chamber	A clear I.V. bag is connected to a tube with a micropump that pumps the water into the terraponics/root chamber.	On flight 1, the pump de-primed in 2Gs. On flight 2, all air was removed from the system and it pumped to fill the chamber.	Efficient, slightly slower than anticipated but about 150 ml was pumped into the cube.	De-primed pump.	Use a self-priming pump.
Water/watering system into secondary chamber	A clear IV bag is connected to a tube with a micropump that pumps the water into the secondary chamber.	On flight 1, the pump de-primed in 2 G. On flight 2, there was no pressure release for the box so water was not pumped into the cube, however, the pinch valve worked.	Slightly efficient, the pinch valve and pump worked, but there was too much pressure in the secondary chamber.	Too much pressure.	A pressure release in the secondary cube.

System/Part	Appearance	Function of system	Efficiency	Errors	Needed Changes
Control system	An Arduino Uno board with accelerometer activated in micro gravity to start systems.	Located at bottom of experiment, was not shorted by water. Turned on lights in micro gravity.	Very efficient, was easy to use.	None.	The system could have recorded data.

DISCUSSION

Challenges

A number of challenges arose on our first flight. For the first parabola of the Alpha, a small amount of water was pumped from the water chamber to the root chamber. However, during the first 2G portion of the flight, the pump was de-primed and could no longer fill or evacuate the chamber. The centrifuge system on the Alpha also suffered. The motor did not have enough torque to efficiently spin the plant, the band could not grip the bearing pulley, and the bearing was too stiff to spin. On the first flight, the Bravo experiment suffered a similar fate. The pumps worked for one parabola but de-primed during 2G. Once the pump on the Bravo was running for multiple parabolas, it was not able to pump to the secondary cube because of the high pressure in that cube.

Success

Despite challenges in flight, we had an overall successful experiment. In both the Alpha and Bravo, the Arduino control system worked perfectly. The accelerometer sensed a loss of gravity and ran the experiments as planned – as proved by the lights on each system and running water and pinch valve on the Bravo. This fully automated system will allow for accurate watering, lighting, nutrient deposit, modularity, making plant care easy for astronauts in space. Although both experiments' pumps de-primed in 2G, the team was able to fix the Bravo. Before the second flight, all of the air was removed from the IV bag. The pump was able to pump 150 mL into the main chamber during the second flight. Though the pump was not able to physically pump water into the secondary chamber, the pinch valve that allowed the main cube to be modular did work. All that is needed is a simple pressure release system, which a fully functional cube has, to be modular. The team has accomplished making a fully automated, modular plant growth chamber.

CONCLUSION

Our experience on the Zero G plane was enlightening; we learned that the simpler design was more successful. The in-organic soil simulate, terraponics, meant that no centrifuge was needed and the design worked. The plant appeared healthy and unharmed. However, the most complex part of either design, the control system, worked flawlessly and made our job in flight easier and less stressful. We learned that a fully automated system is preferred to last year's labor-intensive system and this should be the direction we pursue in the future regardless of the watering system. We also learned that if we are to use a pump in the future, we will use a self-priming pump. Furthermore, we learned that a stronger motor and looser bearing should be used in the future. Additionally, we learned that a pinch valve is an effective way of making the system modular and that pressure release plays a significant role in the success of the design.

The outreach items we primarily used were a Frisbee and a ball. We discovered that the Frisbee could glide across the plane with almost no effort exerted. Unlike in gravity, the Frisbee could fly through the air perpendicular to the ground. The ball, similarly, took almost no effort to travel greater distances than on Earth.

ACKNOWLEDGEMENTS

The Lakewood High School HUNCH team would like to thank our teacher and sponsor, Mr. Brown, for introducing us to this amazing project, helping us along, and making all of it possible. We would also like to thank our mentor, Mrs. Gold, for her invaluable assistance throughout the process; our team and teachers, Mr. Olsen, Mr. Snare, and Mr. Shaw, over at Warren Tech for bringing HUNCH to Jefferson County and making it all that they can make it; our sponsors, The Big Tomato and Dimension 3D Printing, for their generosity and support; and the astronauts that we have talked with who encourage us in our endeavor. Also, we would like to thank all of our parents for being there and accommodating the large amounts of time we spend beyond school hours to design and produce the experiment.

We would like to express our gratitude to the Reduced Gravity Office and the HUNCH program for this amazing opportunity. We sincerely appreciate the support in producing, conducting, and adapting our experiment, as we work to make a personal plant chamber.

CONTACT INFORMATION

Matthew Brown
Lakewood High School
9700 W. 8th Ave.
Lakewood, CO 80215
303-982-7096
E-mail: lhs.hunch@gmail.com
Cell: 303-884-9975

TITLE

Aquaponics

FLIGHT DATES

Flight Day: April 25, 2012

PRINCIPAL INVESTIGATOR

Nate Olsen, Warren Tech, Lakewood, CO

CO-INVESTIGATORS

Brittany Thang, Tristan Babcock, Zach Fluetsch, CJ Chavez, Manuel Luna, Jenna Osborn, Nancy West, Derik Daniels

Warren Tech and Lakewood High School students and astronaut

GOAL

Our goal was to provide a self-sustaining ecosystem that supports plant growth on the International Space Station (ISS).

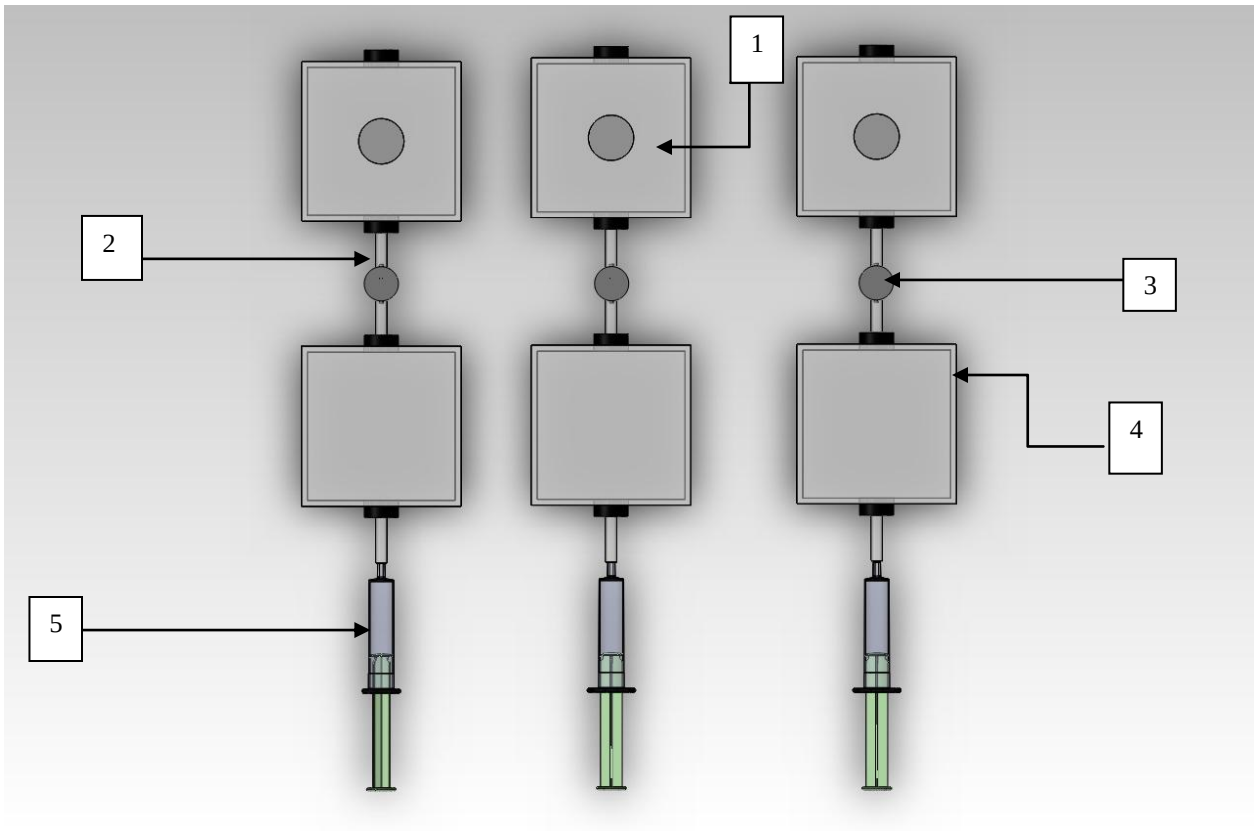
OBJECTIVES

The experiment was flown as part of the High School Students United with NASA to Create Hardware (HUNCH) program. It was designed by the students of the Drafting and Engineering Graphics, Warren Tech High School, Lakewood, CO. The reason for doing the project was to provide fresh food and effervescence on the ISS. By using the growing method of aquaponics, the students tested the water transfer through a syringe to inject the nutrient water to the plant chamber. We tested several methods of water transfer as well as the saturation levels in our growing medium. In the nutrient container, we used two shrimp and java moss to provide the appropriate nutrients for proper plant growth.

The experiment was a plant growth chamber that is capable of growing plants that astronauts have suggested could be grown in micro-gravity. The chamber was designed in such a way that it requires minimal care for the system but enough care for the plant which was a desire of the astronauts we surveyed.

METHODS AND MATERIALS

Aquaponics is a combination of hydroponics and aquaculture. Hydroponics is the process of growing plants without soil and aquaculture is the farming of fish and aquatic species in a controlled environment. Aquaponics is the symbiotic cultivation of plants and aquatic animals in a recirculation environment. By using aquaponics we can control the use of accessing the aquaponics chamber with the use of a moss that creates oxygen and algae that feeds the shrimp. The nutrient solution used to feed the plants is organically produced by the shrimp that are not meant to be harvested. The experiment was contained inside a box constructed from Lexan that was placed inside a NASA Reduced Gravity Glove Box to provide the double containment of water that is required. The experiment tested the displacement of water through a syringe while passing through the nutrient water tank and into the plant chamber. We controlled the amount of water injected into the chamber while observing the measurements markings on the syringe. We also observed a moisture meter, which was placed into the growing chamber to test the levels of moisture in that specific chamber.



1. Lexan plant container
2. Hose
3. Control Valve
4. Lexan water container
5. Syringe

Figure 1. Diagram of the aquaponics experiment.

RESULTS AND DISCUSSIONS

The water displacement through the syringe and cubes gave us great results. We were able to observe the water going into the water chamber, while manually pressing the syringe. As a result of this test, we have concluded that taking this to the next level by automating the process should work, but will require further testing on the Zero-g aircraft.

There were a few challenges during the 0-G flight. One of the biggest problems was the recording of data on a piece of notebook paper while floating. Another challenge was the noise created by the aircraft engines. Hearing the measurements as read by a fellow team mate was difficult and nearly impossible to record. The placement of the experiment in the glove box was not in an ideal location to obtain the most accurate data.

The experiment successfully tested the displacement of water through a syringe while passing through the nutrient water tank and into the plant chamber. We were able to control the amount of water injected into the chamber using the measurements markings on the syringe. We also had successful observations of moisture level changes when water was injected into the plant chambers.

CONCLUSION

The aquaponics system tested will work by using a syringe to push and pull water out of the growing and nutrient chambers while still providing adequate growing resources.

CONTACT INFORMATION

Nate Olsen
Warren Tech
13300 West 2nd Place
Lakewood, CO 80228
303-982-0690
E-mail: nolsen@jeffco.k12.co.us
Cell: 303-949-1667

TITLE

Frying an Egg in Space

FLIGHT DATES
April 25, 2012

PRINCIPAL INVESTIGATOR
Nate Olsen, Warren Tech, Lakewood, CO

CO-INVESTIGATORS:
Brittany Thang, Jacob Treantos, Brett Grow, Dane Smith, Tyler Follett, Dnaiel Lamas, Walt Steinberg

Warren Tech and Lakewood High School students and astronaut

GOAL

Our goal was to provide an innovative cooker that is capable of frying an egg in microgravity.

OBJECTIVES

The experiment was flown as part of the High School Students United with NASA to Create Hardware (HUNCH) program and designed by the students of the Drafting and Engineering Graphics, Warren Tech High School, Lakewood Colorado. The objective was to successfully fry an egg in reduced gravity and provide astronauts with fresh food, as well as protein. The fried eggs will be a hot, home cooked meal that astronauts may enjoy. The experiment tested whether or not it is possible to cook an egg in microgravity.

METHODS AND MATERIALS

Eggs provide protein is a part of a healthy diet and helps prevent muscle loss. The experiment used aluminum foil packets that contained approximately 3 mL of egg (2 mL of white and 1 mL of yolk). The experiment relied on a commercial cooker as our heating element to fry the egg.

RESULTS AND DISCUSSIONS

The aluminum foil packets were successful in cooking eggs during microgravity. This experiment helped us to learn how an egg cooks in reduced gravity. There were some eggs that did not cook due to different variables.

There were a few complications that made this experiment challenging. One of the biggest challenges we encountered was that everything had to be done manually. We had to open the cooker by hand and put the egg packets in using tongs. This process could have caused come of the eggs not to cook completely because the packets may not have been inserted correctly. Another problem we faced was the surface touch temperature. We had to manually check the touch temperature while the eggs were cooking so temperature did not exceed the maximum limit.

During the flight, we successfully cooked the small portion of egg in reduced gravity. Our main question was whether or not the egg would cook in microgravity, and if it did, how. These questions were answered after our flight, when we opened the foils containing the eggs. We noticed that the eggs cooked along the crease of the aluminum foil packets which make the egg look somewhat stringy after cooking in microgravity.

CONCLUSION

The experiment was a success and our goal to fry an egg in reduced gravity was met. The next step is to create an automated cooker for the egg, keeping touch temperature of the cooker and egg containment under 120°F.

CONTACT INFORMATION

Nate Olsen
Warren Tech
13300 West 2nd Place
Lakewood, CO 80228
303-982-0690
E-mail: nolsen@jeffco.k12.co.us
Cell: 303-949-1667

Background Information about NASA's Reduced-Gravity Program

The Reduced-Gravity Program, operated by the NASA/Johnson Space Center (JSC), provides engineers, scientists, and astronauts alike a unique opportunity to perform testing and training in a weightless environment but without ever having to leave the confines of Earth's orbit. Now that the Space Shuttle Program and that the construction of the International Space Station have been completed, the Reduced-Gravity Program provides a truly ideal environment to test and evaluate space hardware and experimental procedures before launch.

The Reduced-Gravity Program was established in 1959 to investigate the reactions of humans and hardware during operations in a weightless environment. A specially modified turbojet, flying parabolic arcs, produces periodic episodes of weightlessness lasting 20 to 25 seconds. The aircraft is sometimes also flown to provide short periods of lunar (1/6) and Martian (1/3) gravity. Over the last 50 years, over 100,000 parabolas have been flown in support of the Mercury, Gemini, Apollo, Skylab, Space Shuttle, and Space Station programs.

Excluding the C-9 Flight Crew and the Reduced Gravity Program Test Directors, NASA's C-9 aircraft accommodates seating for a maximum of 20 other passengers. The C-9's cargo bay provides a test area that is approximately 45 feet long, 104 inches wide, and 80 inches high.

NASA has also transitioned to using Zero G Incorporated's 727 aircraft, which will hold up to 30 investigators. Zero G's 727 is nearly identical in size and volume to the KC-135 aircraft previously used by NASA to support the Reduced Gravity Program. This Boeing 727 has a larger cargo door to accommodate large payloads and provides a test area that is approximately 70 feet long, 140 inches wide, and 86 inches high.

Both aircraft are equipped with electrical power for test equipment and photographic lights. When requested, professional photography and video support can be scheduled to document activities in-flight.

A typical flight lasts 2 to 3 hours and consists of 30 to 40 parabolas. The parabolas are flown in succession or with short breaks between maneuvers to allow time for reconfiguration of test equipment.

For additional information concerning flight weeks sponsored by the Johnson Space Center's Human Adaptation Countermeasures Division or other Reduced-Gravity Program opportunities, please contact:

Todd Schlegel, MD
Technical Monitor
NASA Lyndon B. Johnson Space Center
Mail Code: CC43
Houston, TX 77058
Telephone: 281.483.9643

Dominic Del Rosso, Test Director
Reduced-Gravity Office
NASA Lyndon B. Johnson Space Center
Mail Code: SK
Houston, TX 77058
Telephone: 281.244.9113

Explore the Zero G Experiments and Aircraft Operations Web pages at:
http://zerog.jsc.nasa.gov/
http://jsc-aircraft-ops.jsc.nasa.gov

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	January 2013	NASA Technical Memorandum

4. TITLE AND SUBTITLE
Zero G and Other Microgravity Simulations
Summary Report

5. FUNDING NUMBERS

6. AUTHOR(S)
Human Health and Performance Directorate
Human Systems Engineering and Development

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Lyndon B. Johnson Space Center
Houston, Texas 77058

8. PERFORMING ORGANIZATION REPORT NUMBERS
S-1135

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
TM–2013-217373

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Available from the NASA Center for AeroSpace Information (CASI)
7121 Standard
Hanover, MD 21076-1320 Category: 52

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This document represents a summary of medical and scientific evaluations conducted on board the Zero G and other NASA sponsored aircraft from June 2011 to June 2012. A general overview of investigations manifested and coordinated by the Human Adaptation and Countermeasures Division is included. A collection of brief reports that describe tests conducted on board the NASA sponsored aircraft follows the overview. Principal investigators and test engineers contributed significantly to the content of the report describing their particular experiment or hardware evaluation. Although this document follows general guidelines, each report format may vary to accommodate differences in experiment design and procedures. This document concludes with an appendix that provides background information concerning the Reduced Gravity Program.

14. SUBJECT TERMS	15. NUMBER OF PAGES	16. PRICE CODE
weightlessness; parabolic flight; zero gravity; plant growth; astronaut health	60	

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited