KC-135 and Other Microgravity Simulations
Summary Report - August 1, 2001

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center

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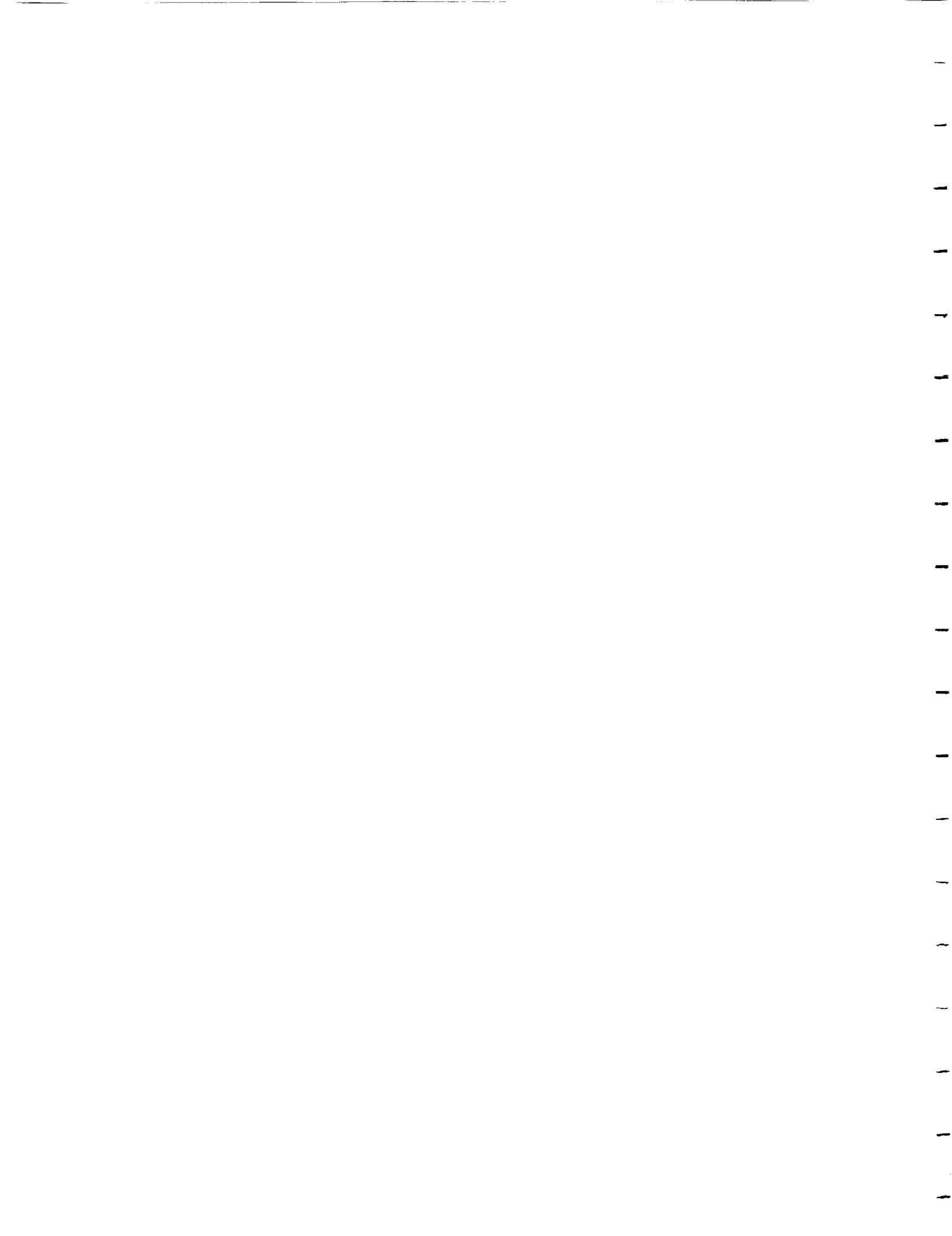Reduced Gravity Program
NASA Johnson Space Center

PREFACE

This document represents a summary of medical and scientific evaluations conducted aboard the KC-135 from January to June 15, 2001. Included is a general overview of KC-135 activities manifested and coordinated by the Human Adaptation and Countermeasures Office. A collection of brief reports that describes tests conducted aboard the KC-135 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 KC-135 and the Reduced-Gravity Program.

NASA Photo: 96_05261

CONTENTS

Overview of KC-135 Flight Activities sponsored by the Human Adaptation and Countermeasures Office

Every four years the KC-135 undergoes an extensive maintenance and inspection phase per U.S. Air Force standards. The KC-135 entered the most recent maintenance and inspection phase in May 2000. As a result, the aircraft was unavailable again for use by investigators until January 2001. From January to June 30, 2001, three weeks were specifically reserved for flights sponsored by the Human Adaptation and Countermeasures Office (HACO). In addition, we were able to obtain seating during seven weeks for HACO customers with other organizations sponsoring the flight weeks. A total of 35 flights with approximately 40 parabolas per flight were completed. The average duration of each flight was 2 hours. The KC-135 coordinator assisted principal investigators and test engineers of 40 different experiments and hardware evaluations in meeting the necessary requirements for flying aboard the KC-135 and in obtaining the required seating and floor space. A total of 313 seats were purchased by HACO customers. The number of seats supported and number of different tests flown by flight week are provided below:

Flight Week	Seats	# Tests Flown	Sponsor
January 9 - 12, 2001	52	4	HACO
Jan. 23 - 26	32	3	Ellington
Jan. 30 - Feb. 2	16	1	Ellington
Feb. 13 – 14	10	2	Undergraduate Program
Feb. 28 - March 1	34	9	Undergraduate Program
March 16 - 17	10	2	Undergraduate Program
March 27 - 30	25	5	Undergraduate Program
April 17 - 20	61	6	HACO
April 27	24	4	Fly High Program
May 8 - 11	49	6	Fly High Program/HACO

Support was provided to the undergraduate/community college program during weeks in February and March and to the "Fly High" high school student program during April and May 2001. Local and major network radio, television, and newspaper journalists accompanied the students on some of these flights. The inflight experiments were supported by a large ground crew from the respective university, college, or high school.

Other HACO sponsored KC-135 flight opportunities are scheduled for weeks during July and September 2001. Additional flights will be added throughout the remainder of the calendar year to accommodate customers as needs arise.

Medical and Scientific Evaluations aboard the KC-135

TITLE:
Evaluation of Endotracheal Intubation Methods in Microgravity

FLIGHT DATE:
January 9, 2001

PRINCIPAL INVESTIGATORS:
George Beck, Wyle Life Sciences
Richard Pettys, Wyle Life Sciences
Laurel Lee Smith, Wyle Life Sciences

NASA Photo: JSC2001E00484

GOALS:

- Evaluate limitations imposed by crew medical restraint system (CMRS) head fixation straps during laryngoscopic intubation
- Evaluate endotracheal tube securing device
- Evaluate use of ILMA in microgravity

- Evaluate Advanced Projects developed digital x-y-z accelerometer and associated video overlay board.

OBJECTIVE:

Compare two methods of endotracheal intubation in microgravity in an operational context.

INTRODUCTION:

Endotracheal intubation using direct visualization is the current method for providing an airway for mechanical ventilation or airway protection during medical contingencies in space flight. The Clinical Care Capabilities Development Project (CCCDP) is evaluating use of direct laryngoscopic visualization for endotracheal tube placement as part of an overall review of on-orbit airway management. Studies have demonstrated high failure rates (Bradley, Li, Sayre) for laryngoscopic intubation when individuals have less than 12 hours of initial training in the procedure. The intubating laryngeal mask airway (ILMA) has recently been shown to facilitate intubation by individuals with minimal training, (Rosenblat, Levitan). The LMA Fastrach (LMA North America, San Diego, CA) is designed to provide an initial airway and subsequently to facilitate placement of an endotracheal tube. It is specifically indicated for the intubation of difficult airway cases or for conditions where there is limited ability to orient the patient for direct visualization of the larynx. Intubation in microgravity poses limitations and using the LMA Fastrach or a similar device may improve the likelihood that a modestly trained crew member will secure an airway in an emergency.

These KC-135 tests were designed to compare the positioning mechanics of the two intubation procedures in microgravity. Traditional laryngoscopic intubation requires very specific positioning of both the patient and care provider. The study analyzed the microgravity process and identified positions and methods to optimize currently deployed on-orbit procedures. The study also evaluated the potential benefits of the ILMA when used in microgravity. The ILMA does not require visualization of the larynx or vocal cords for successful placement. This allows the airway to be stabilized from a number of position rather than the traditional head-of-the-bed position

METHODS AND MATERIALS:

Ground
Personnel from the CCCDP were trained to intubate an Airway Management Trainer (AMT) (Laerdal Medical Corp., Armonk, NY) using both direct laryngoscopy (DL) and the ILMA. Laryngoscopic intubation was taught using the International Space Station (ISS) Medical Checklist (MCL), ISS Expedition 1, (Med-checklist) using a standard 7.5 mm I.D. endotracheal tube (ETT) and #3 McIntosh laryngoscope. A demonstration was given highlighting the necessary techniques and potential problems (i.e. leveraging off the teeth, esophageal intubation). Training with the ILMA used material provided by the

manufacturer (LMA Fastrach Instructional Video, Cat. #5561-02; Anatomy and Physiology Video, Cat. #5451-01). A size 4 ILMA and its silicon 7.5 mm I.D. endotracheal tube were used throughout the training and experiment. Participants were then able to practice both methods as much as required (~3 hours) to gain what they felt was competency, usually 10-20 successful intubations. A non-flight certified CMRS was used to secure an AMT in an orientation identical to what would be experienced during use on the ISS. Ground-based training included identifying "optimal" investigator positions and equipment fixation for procedures in microgravity.

Investigators also trained in the use of the Thomas Endotracheal Tube Holder (STI Medical Products, Costa Mesa, CA). The ETT holder is designed to eliminate the need for taping the ETT in place after insertion. This unit has an integrated bite block that prevents damage or occlusion of the ETT.

Flight
Data were collected during the flight using three video cameras, one fixed, one handheld and one affixed to the head of the investigator performing the intubation (see section 12.5). The head camera was a small cold-cathode display CCD camera that was focused approximately 14" (36 cm) along the investigator's direct line of sight. Use of the camera allowed analysis of what the investigator was able to see during procedures using different techniques. In addition, the audio comments of the intubating investigator were recorded. All of the investigators maintained real-time commentary during procedures.

RESULTS:

- Proper alignment of the airway for laryngoscopic intubation is not possible with the patient's head secured in the CMRS with the chinstrap. Positioning a patient in the CMRS as described in the Med-checklist will hinder or prevent intubation.
- Use of cricoid (Adam's Apple) or laryngeal pressure is not mentioned as an aid to intubation in the medical checklist, based on the current flight data file (FDF).
- The primary intubation position placed the intubator at the head of the CMRS. Both methods, DL and ILMA were effectively used in microgravity, all intubation attempts were successful.
- One of the smaller (5'4") investigators needed to kneel to visualize the airway. Larger investigators were able to secure themselves to the head of the CMRS by wrapping their legs around the CMRS legs while seated on the deck with the CMRS (see section 12.4).
- The ILMA facilitated intubation from positions other than the head of the CMRS.
- The Thomas ETT holder was effective in microgravity. It secured the ETT in less than 30 seconds.
- The digital x-y-z accelerometer/video overlay board worked well allowing investigators to stamp video data with the time and acceleration data.

DISCUSSION/CONCLUSION:

Issue 1:
The digital x-y-z accelerometer/video overlay board worked well. Its use during this flight was to evaluate the unit's operation, data collected during this flight did not require accurate knowledge of acceleration forces. The device was designed for physiologic studies where small changes in acceleration may affect interpretation of the data. The device allows acceleration data to be stamped on video as well as data saved to computer files.
Action 1: Use device for subsequent physiologic studies.

Issue 2:
The currently flown procedures for securing a patient to the CMRS compromised proper placement of an ETT using a laryngoscope. Failure to remove the CMRS chin strap will result in the inability to visualize the vocal cords and in most cases, failed intubation. Inability to visualize adequately may lead to tracheal, esophageal or glossopharyngeal damage.
Action 2: A change request to the Station Operations Data File (SODF) MCL will be generated to include a line in the intubation procedures to remove the chin strap during intubation.

Issue 3:
There is no mention of the application of cricoid cartilage (Adam's Apple) pressure in the ISS Medical Checklist. This procedure also known as "Sellick's maneuver" is an effective adjunct to enhance visualization of the trachea and to occlude the esophagus preventing aspiration.
Action 3: A change request to the SODF MCL will be generated to include a line in the intubation procedures describing the method and use of cricoid pressure.

Issue 4:
Current SODF MCL procedures call for the use of tape to secure the ETT following intubation. In terrestrial hospitals, this procedure usually requires two people and ~5 minutes to secure the tube adequately. In microgravity with inexperienced personnel the procedure could easily result in inadvertent extubation or right main stem intubation. The Thomas Endotracheal Tube Holder or similar device was found to quickly secure the ETT (< 30 seconds in microgravity). In addition, the device prevents occlusion of the ETT by biting and provides access for oropharyngeal suctioning.
Action 4: A review of the market for devices similar to the Thompson unit will be conducted to determine the best product for ETT fixation. CCCDP will also generate a change request to the SODF MCL and the Crew Health Care System (CHeCS) manifest for the Advanced Life Support Pack (ALSP) for the addition of the device.

Issue 5:
An ETT remains the definitive airway for complete control of the airway and prevention of aspiration. The traditional method of securing the airway with an ETT has been direct

visualization using a laryngoscope. The literature supports use of the ILMA by non-physician care providers in emergency situations. This KC-135 flight demonstrated the ease of ETT insertion using the ILMA from multiple positions that could not be accomplished using laryngoscope visualization. Two of the investigators had no prior intubation training. By its design the ILMA provides an initial airway that will support positive pressure ventilation up to ~30 cm H_2O, depending on the patient (Keller). This would allow crew to place an initial airway during the acute phase of the emergency and continue on with the medical procedures required to treat the condition. Once the patient has been stabilized, an ETT can be inserted by a non-physician.

Action 5: A video has been prepared showing laryngoscopic and ILMA intubation. It is available from the PI (gbeck@klsiems.jsc.nasa.gov). CCCDP personnel are developing a white paper addressing airway management that will include recommendations for the ILMA as well as other aspects of airway management. It is hoped that a change request to the SODF MCL and CHeCS manifest will be generated to include the ILMA.

REFERENCES:

Bradley JS, Billows GL, et al. Prehospital oral endotracheal incubation by rural basic emergency medical technicians. *Ann Emerg Med* 1998;84: 26-32

Keller C, Brimacombe J, Pharyngeal Mucosal pressures, airway sealing pressures, and fiberoptic position with the intubating versus the standard laryngeal mask airway. *Anesthesiology* 1999;90(4): 1001-1006

Levitan RM, Ochroch EA, et al, Use of the intubating laryngeal mask airway by medical and nonmedical personnel. *Am J Med 2000;18:12-16*

Li J, Murphy-Lavoie H, et al. Complications of emergency intubation with and without paralysis. Am J Emerg Med 1999;17(2): 141-143.

Sayre MR, Sakles JC, et al. Field trial of endotracheal intubation by basic EMTs *Ann Emerg Med* 1998;31(2): 228-233.

Rosenblatt WH, Murphy M. The intubating laryngeal mask: Use of a new ventilating-intubating device in the emergency department. *Ann Emer Med* 1999;33(2): 234-238.

PHOTOGRAPHS:

JSC2001E00477 to JSC2001E00486

VIDEO:

- Zero-G week of January 9-12, 2001; Reference Master: 712564

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Medical Operations KC-135 Familiarization Flight

FLIGHT DATES:
January 10 – 11, 2001

PRINCIPAL INVESTIGATOR:
Shannon Melton, Wyle Life Sciences

CO-INVESTIGATORS:
Jessica L. Hughlett, Wyle Life Sciences
Kelly J. Kampe, Wyle Life Sciences
John W. Welch, Wyle Life Sciences

NASA Photo: JSC2001E01505

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GOAL:

To experience the difficulty of performing medical procedures in microgravity.

OBJECTIVES:

To perform three medical procedures with the effects of microgravity
1. IV Station
    a. Prepare equipment, insert catheter, and connect IV line
    b. Assemble Tubex injector and perform medication administration
2. Restraint Station
    a. Restrain a manikin using the Crew Medical Restraint System
    b. Perform CPR using the traditional, straddling, and inverted methods
3. Airway Station
    a. Perform tracheal intubation using a laryngoscope and endotracheal tube

METHODS AND MATERIALS:

1. IV Station
    a. Table with IV training arm
    b. IV Administration Pallet
2. Restraint Station
    a. Crew Medical Restraint System (CMRS)
    b. Test fixture
    c. Full-body Manikin
3. Airway Station
    a. Intubation Manikin
    b. Equipment for Endotracheal Intubation method

For the IV Station, an ISS IV Administration Pallet was used to restrain the necessary equipment and supplies. An IV catheter was placed in the training arm and administration of an IV medication was simulated.

A full-body manikin was used with the Crew Medical Restraint System (CMRS) at the Restraint Station. Once the manikin was restrained on the CMRS, three different methods of Cardiopulmonary Resuscitation (CPR) were performed. The first was the traditional CPR with the rescuer beside the patient using back and stomach muscles for force to compress the chest. The second method was to straddle the patient, with the rescuer wrapping his/her legs around the patient and the CMRS, and using the back and stomach muscles for force to compress the chest of the patient. The third method required the rescuer to invert him/herself; so that rescuer's feet were on the ceiling of the plane; using the leg muscles for force to compress the patient's chest.

The method used to perform an endotracheal intubation was the same method used in 1-g. The intubation manikin was already restrained. Using a laryngoscope as a guide, the

rescuer places the endotracheal tube through the patient's vocal cords and into the trachea. Once the tube is in place, the laryngoscope is removed and the endotracheal tube cuff is inflated, using a 10cc syringe. The ambu bag is placed on the tube and air is administered to the patient. If the tube was placed correctly, the lungs inflate evenly and together. If the tube was in too far, only one lung inflates or the lungs do not inflate evenly. If the tube was placed into the esophagus, the stomach inflates.

RESULTS/DISCUSSION:

The co-investigators felt the IV Station was the most difficult, due to the number of small supplies required. The value of restraint, with Velcro and/or tape, was realized. This information will prove useful when designing kits and writing procedures.

The Restraint Station was a valuable experience. The control required to restrain an incapacitated patient was not understood until practiced at this station. It would be impossible to correctly and effectively administer Cardiopulmonary Resuscitation (CPR) any other way but inverted.

The Airway Station was the easiest of all the stations, because the rescuer could strap him/herself down and stay in one position throughout the procedure. The instruments were larger than those used at the IV station, which aided the level of control of the rescuer.

CONCLUSION:

This flight experiment gave all participants a better understanding of how time-consuming and difficult procedures can be in microgravity. It was difficult to perform the tasks, even with extensive ground-based training. Co-investigators could only imagine how difficult it would be while reading through the procedure and with time constraints. The knowledge gained will prove very useful when writing procedures, training crews, or "timelining" onboard activities.

PHOTOGRAPHS:

JSC2001E00745 to JSC2001E00766
JSC2001E01505
JSC2001E01513 to JSC2001E01515
JSC2001E01522 to JSC2001E01524
JSC2001E01528 to JSC2001E01531

VIDEO:

• Zero-G week of January 9-12, 2001; Reference Master: 712564

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Adaptation in Artificial Gravity Environments

FLIGHT DATES:
January 9 – 12, 2001

PRINCIPAL INVESTIGATORS:
James R. Lackner, Brandeis University
Paul DiZio, Brandeis University

NASA Photo: JSC2001E01485

INTRODUCTION:

Transitions between various G-force environments severely tax sensory-motor control of movement, posture, and orientation. Significant disturbances can be anticipated until adaptation to the new force environment is achieved. Two experiments were conducted during 9-12 January 2001 parabolic flights to study these adaptation processes.

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METHODS AND MATERIALS:

Experiment 1

We studied whether head movements during rotation evoked different responses in 1g, as well as hyper- and hypo-gravity phases of parabolic flight. In the 0g phases, due to combined effects of rotation and subject's body tilt, the net linear acceleration was the centripetal force of 0.33g, approximating Martian G (0.38 g). Eight subjects participated after giving informed consent. In each experimental session, the blindfolded subject made four pitch head movements at intervals of 5 min or more while rotating at a constant velocity of 20 rpm with their head 75 cm off the rotation axis (centripetal acceleration at the head ~0.33 g). Monocular horizontal and vertical eye position were measured with an ISCAN video system, head movements with an Optotrak™ infrared motion analysis system, motion sickness severity with the Graybiel scale, and the duration of tumbling sensation with an event marker pressed by the subject. Each subject's first session was on the ground at least a week prior to parabolic flight. In flight, the same subjects rode the chair continuously through a series of parabolas, making head movements in the 1.8g and 0g phases of different parabolas as well as during 1g straight and level flight Each subject made 1-2 head movements per g level, in a balanced order.

Experiment 2

We studied subjects' ability to control posture and body sway. We have demonstrated that contact of the index finger with a stationary surface stabilizes posture under 1g conditions. Such haptic contact or precision touch at mechanically non-supportive force levels provides sensory information about body sway that is more effective than visual or vestibular information in stabilizing the body. We assessed whether this technique for stabilizing balance and orientation can possibly be used to minimize the sensory-motor re-entry disturbances exhibited by astronauts.

We tested the postural stability of eight individuals immediately before and after parabolic flight missions in which subjects participated in experiments that required standing or moving about during the 0g and 1.8 background force levels as well as force transitions. They remained seated after the last parabola until tested post-flight in the aircraft on the ground. Post-flight testing began within 3 minutes after the plane stopped moving. For both pre- and post-flight testing the subjects attempted to stand, eyes closed, heel-to-toe, on the aircraft deck. An Optotrak™ infrared motion analysis system monitored head (H) and center of mass (CM) position for alternating precision touch (<100g of finger force) and no touch trials. Trials were 30 s in duration.

RESULTS:

Experiment 1

The results were that head movements during rotation in 1.8g were more nauseogenic and disorienting than in 1g. In 0.33g, only one subject experienced increased motion sickness severity relative to the background level evoked by the parabolas alone. Four experienced subjects who had previously performed head movements during on-center rotation in 0g

reported that their head movements in 0.33g were comparable, in terms of disorientation and motion sickness provoked. Eye and head movement records are currently being analyzed.

The results suggest that some negative side effects of Coriolis, cross-coupled vestibular stimulation are less severe than would be predicted by linear extrapolation between 1g and 0g.

Experiment 2
Post-flight, most subjects could not stand for more than a few seconds without grasping a safety rail when denied touch of the hand; all could do so pre-flight. Mean sway amplitude (MSA) of H and CM were significantly elevated post-flight relative to pre-flight without touch. With precision touch, the MSAs did not differ significantly pre-flight versus post-flight. In the four post-flight trials without touch, the MSAs of H and CM decayed linearly from elevated levels toward the pre-flight baseline.

DISCUSSION/CONCLUSION:

Experiment 1
The results suggest that some negative side effects of Coriolis, cross-coupled vestibular stimulation are less severe than would be predicted by linear extrapolation between 1g and 0g.

Experiment 2
These results indicate that parabolic flight is an effective model for studying re-entry disturbances, and suggest that precision touch attenuates aftereffects and possibly hastens re-adaptation

PHOTOGRAPHS:

JSC2001E01483
JSC2001E01485
JSC2001E01489 to JSC2001E01492

VIDEO:

- Zero-G week of January 9-12, 2001; Reference Master: 712564

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Engineering Evaluation of the Reduced Gravity Testing (KC 135) of the Human Research
Facility (HRF) Refrigerated Centrifuge

FLIGHT DATES:
January 9 – 12, 2001
March 1, 2001

PRINCIPAL INVESTIGATOR:
Sharon Campana, Lockheed Martin

CO-INVESTIGATORS:
Cynthia Hudy, Lockheed Martin
Brandon Ruiz, Lockheed Martin
Jon Olansen, United Space Alliance
Adolfo Colorado, Lockheed Martin
Javier Jiminez, Lockheed Martin
Grant Threatt, Lockheed Martin
Scott M. Smith, NASA/Johnson Space Center
Patti Gillman, Wyle Life Sciences
Laurie Darling, NASA/Johnson Space Center

NASA Photo: JSC2001E01525

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PURPOSE:

The purpose of testing the Human Research Facility Refrigerated Centrifuge (RC) on the KC 135 was primarily to verify that the refrigeration system would operate in a reduced gravity environment. Use of the KC 135 micro gravity environment will allow specific observation of the RC unit in a near weightless environment, therefore allowing simulation of its performance on the International Space Station. Specific testing will provide practical data concerning the RC's micro gravity disturbance; the fit of the rotor, test tubes, and sample adapters in a reduced gravity environment; the feasibility of proposed on-orbit scenarios; crew evaluation of the RC unit; and engineering evaluation of hardware operation.

OBJECTIVES:

1. Perform engineering evaluation to determine if the hardware operates correctly in a reduced gravity environment.
2. Determine if compressor is effected by reduced gravity environment (i.e. monitor current draw and cooling capability)
3. Test the friction fit between the test tubes and sample adapters, as well as between the sample adapters and the rotor wells.
4. Test the feasibility of proposed on-orbit use scenarios.
5. Perform crew evaluation of the RC with the assistance of a crew representative.
6. Test the RC unit for future Human Factor concerns regarding ease of use and simplicity of operation.

METHODS AND MATERIALS:

Test Setup
Five KC 135 flights were flown, January 9th-12th and March 1. The hardware was installed into a Ground Support Fixture designed specifically for the HRF Refrigerated Centrifuge. The fixture was mounted to the floor of the KC 135 (See Figure 1). The fixture allows for the users to rotate the hardware from a vertical position, to horizontal.

Each flight consisted of 40 parabolas with 25 second intervals of zero g. Fifteen minute breaks occurred at the 20th and 40th parabola. These breaks were in support of other experiments and did not affect Centrifuge data collection.

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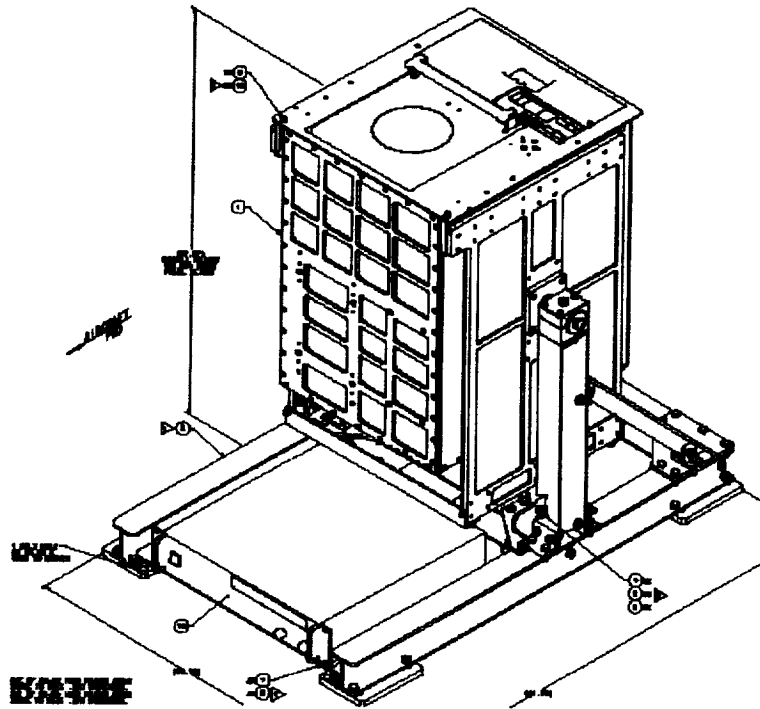
Figure 1: KC 135 Test Set-up

Flight Day 1 Test Protocol

The front panel of the HRF Centrifuge was set to +4 deg C to allow compressor operation and cooling of the temperature chamber. Currents and voltages were observed between parabolas. To ensure the cooling was adequate, the temperature of the chamber was measured with a thermal sensor gun.

Rotor operation involved setting the rotor into 14k, 10k, 6k, and 3k, with ramp speed 9. Current and voltages were observed. Rotor operation occurred only during the zero g of the parabola.

The HRF Centrifuge compressor was operating from the 3rd through the 18th parabola.

Note: Some difficulty was encountered in configuring the front panel on the 1st and 2nd parabola. The difficulty was due to the operators getting used to the zero g environment. The compressor and rotor operation is documented in Table 3.1.1-1.

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TABLE 3.1.1-1. DATA COLLECTION FOR ROTOR OPERATION

Parabola	PS 1 Current (A) @ 27.9 VDC	PS 2 Current (A) @ 27.9 VDC	PS 3 Current (A) @ 28.1 VDC	Total Current (A)	Est. Power Consumption (W)
1	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A
3	10	14	14	38	1064
4	10	13	14	37	1036
5	10	13	14	37	1036
6	10	12	12	34	952
7	10	10.3	11.5	31.8	890.4
8	8.5	10.3	11.5	30.3	848.4
9	8.5	10.3	11.5	30.3	848.4
10	Compressor Shut off (Reached Chamber Temperature)				
11	10	14	14	38	1064
12	10	13	14	37	1036
13	10	13	14	37	1036
14	10	11	11	32	896
15	10	10.3	11.5	31.8	890.4
16	8.5	10.3	11.5	30.3	848.4
17	8.5	10.3	10	30.3	848.4
18	Compressor Shut off (Reached Chamber Temperature)				

The 19th and 20th parabolas occurred as in Table 3.1.1-2.

TABLE 3.1.1-2. ACTIVITY FOR REMOVING ROTOR FROM STOWAGE DRAWER

Parabola	Activity
19	No Data – Removed 14k Rotor from Stowage Drawer
20	No Data – Inserted 14,000 RPM rotor into chamber; set front panel to 15

The 21st through the 30th parabolas were used to determine differences between rotor (14,000 RPM) power consumption at zero g as compared to ground power consumption. The 31st through the 40th parabolas were used to determine differences between rotor (6,000 RPM) power consumption at zero g as compared to ground power consumption. Because rotor power consumption was not a requirement, the activity was highly involved in setting up rotors and spinning, and no noticeable difference between ground and zero g start up power consumption was observed; the data were not documented. Ground testing with the HRF Centrifuge (in vertical position) will yield the same results as zero g.

Fight Day 2-4 Protocol
During flight day 2, 3, and 4, each rotor and adapter were tested to determine if the samples would be contained in a reduced gravity environment. Each rotor test took approximately four to five parabolas to complete. During the first parabola, the rotor was

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loaded. The adapters were loaded during the second parabola, and samples were loaded during the third parabola. During the subsequent parabolas, the rotor was spun by using the IMPULS key. This key allowed the rotor to be spun while the user was depressing the button. Table 3.2-1 provides the various test configuration performed in flight.

Table 3.2-1

Rotor	Adapter	Test tube	Results
6000 RPM	None	50 ml (3 types)	Samples stayed in, but only because the samples held each other in place. If the samples had not had the screw cap lids, they would have all floated out.
6000 RPM	7 ml adapter	7 ml	Tubes and adapters were difficult to install (they kept floating out). During centrifugation they would stay in place, but in reduced gravity, they would float out.
6000 RPM	15 ml adapter	12 ml	In reduced gravity, the tubes and adapters would float out of the rotors.
5000 RPM			Buckets to rotor were difficult to work with. They would float out during rotor installation
5000 RPM		3 and 5 ml	Tubes as well as buckets would float out during reduced gravity.
14000 RPM	.5 ml and 1.5 ml	1.5 and .5 ml	All the samples and adapters floated out after being spun

Flight Day 5 Protocol
The fifth flight was completed on March 1. The purpose of this flight was to evaluate the modifications made to the rotors and adapters based on findings determined during the first four flights.

RESULTS/CONCLUSION:

As a result of the first four flights, the engineering team will recommend that the 5000 RPM rotor be removed from the manifest. Testing of the modifications to the rotors and adapters prior to the March 1 flight revealed that the modifications provided a good

friction fit. All of the tubes remained in the rotors as required. Additional modifications are anticipated to prevent samples from sticking in the rotors.

PHOTOGRAPHS:

JSC2001E00476 to JSC2001E00462
JSC2001E00735 to JSC2001E00744
JSC2001E01478 to JSC2001E01481
JSC2001E01487 to JSC2001E01488
JSC2001E01509 to JSC2001E01512
JSC2001E01525 to JSC2001E01527
JSC2001E05567 to JSC2001E05573

VIDEO:

- Zero-G week of January 9-12, 2001; Reference Master: 712564
- Zero-G Flight March 1, 2001; Reference Master: Provided to customer

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:

Exercise Evaluations on the Interim Resistive Exercise Device aboard KC-135

FLIGHT DATES:
January 23 – 26, 2001

PRINCIPAL INVESTIGATORS:
Suzanne M. Schneider, Ph.D., NASA/Johnson Space Center

CO-INVESTIGATORS:
Michael Rapley, Wyle Life Sciences
Jason Bentley, Wyle Life Sciences,
Sudhaker Rajulu, NASA/Johnson Space Center
Kendall Cobb, University of Houston at Clear Lake
Jeff Jones, M.D., NASA/Johnson Space Center

NASA Photo: JSC2001E02329

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GOAL:

The Interim Resistive Exercise Device (IRED) will be aboard the International Space Station (ISS) to serve as a central exercise countermeasures device. It is designed to provide resistive exercise as a countermeasure to musculoskeletal deconditioning during exposure to microgravity. Therefore, it is important to determine how crewmembers may be able to perform exercise with this device in a safe and effective manner.

OBJECTIVE:

It is necessary at this time to evaluate IRED in a microgravity environment as the development leads future deployments on ISS. In this evaluation, we hope to compare forces generated during exercise in a 1 g environment vs. the same exercises performed in a 0 g environment. We also hope to establish a relationship between subject's position during exercise and the corresponding timed force curve. Performance evaluation of the IRED in 0g will also be performed. The performance evaluation will include, but not be limited to, the measurements of force experienced by the subject, friction points in the hardware, and accuracy of force settings.

INTRODUCTION:

It is anticipated that the IRED will be found to be a safe and effective means to perform resistance exercise during microgravity. Measurement of forces experienced by the subject during exercise in microgravity will aid in the development of exercise prescription and aid in the development of future isolation systems.

The interim Resistive Exercise System is aboard the International Space Station (ISS) serving as a central exercise countermeasures device. It is designed to provide resistive exercise as a countermeasure to musculoskeletal deconditioning during exposure to microgravity. Therefore, it is important to determine how crewmembers may be able to perform exercise with this device in a safe and effective manner.

It was necessary at that time to evaluate iRED in a microgravity environment as the development leads future deployments on ISS. The purpose of the current evaluation was to compare forces generated during exercise in a 1 g environment vs. the forces generated from the same exercises performed in a 0 g environment. We also established a relationship between subject's position during exercise and the corresponding timed force curve. This enabled us to better coordinate exactly where in the range of motion (ROM) during exercise the subject experiences the peak force. Performance evaluation of the RED in 0g was also performed. The performance evaluation will include, but was not limited to, the measurements of force experienced by the subject, friction points in the hardware, and accuracy of force settings.

METHODS AND MATERIALS:

We recruited 6 subjects (3 main and 3 back-up) through the Human Test Subject Facility at the Johnson Space Center. Each qualified by passing an Air Force Class III physical and their physiological training. Subjects also were required to have a moderate level of resistance exercise experience. Men and women were recruited between, 22-55 years of age.

Prior to each flight, the subjects were asked to perform three pre-determined exercise (Squats, Heel raises, Deadlifts) for one to four sets (depending on allotted time) of ten repetitions at appropriate loads (Range of 60-70% of their predicted 1RM). The three exercises were chosen from exercises listed in the *ISS CheCS Specification, SSP 50470, section 3.7.16.1.2. (squats, dead lifts, calf raises, bent over rows, single leg squat, upright rows, shoulder presses, leg curls, hip abduction, hip adduction, hip flexion, hip extension, biceps curls, triceps extensions, and wrist curls.)*. During exercises, subjects stood on a force plate to assess the characteristics of the forces experienced during each exercise. Video footage of the exercises performed were taken and time sequenced with the corresponding force plate data.

During each flight, the subjects were asked to perform the three exercises for three to four sets (depending on number of parabolas and available time) of ten repetitions at appropriate loads (Range of 60-70% of predicted 1RM). Only one subject exercised per day and all subjects performed the same three predetermined exercises (ex: Squats, Heel raises, Deadlifts). During exercises, subjects stood on a force plate to assess the characteristics of the force supplied by the hardware. Video footage of the exercises was taken and time sequenced with the corresponding force plate data. Also, modifications to the hardware were recently conducted by engineering, and observations were made as to how well the device performed during microgravity exposure.

At the conclusion of each flight, subjects participated in a debrief of the flight to capture the comments and concerns expressed with regard to the flight

RESULTS:

Data reduction is in progress. However, significant differences have been observed during the performance of the exercises, including the load observed at the feet, the time to perform the exercises, and the excursion of the subject. Further data analysis is required to complete the description.

DISCUSSION/CONCLUSION:

Caution must be taken in the interpretation of these results as they may be particular to parabolic flight. However, visual observation of ISS crewmembers suggests that the biomechanics of the exercises during parabolic flight may be similar to long duration microgravity exposure. Specific investigation of these factors may be indicated.

Final results from this investigation may impact the design of future resistance exercise devices as well as the performance of exercise by ISS crewmembers.

PHOTOGRAPHS:

JSC2001E02935 to JSC2001E02947
JSC2001E02085 to JSC2001E02090
JSC2001E02249 to JSC2001E02262
JSC2001E02326 to JSC2001E02338

VIDEO:

- Reduced Gravity Flight Jan. 23 – 26, 2001, Reference Master: 619047

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Microgravity Investigation and Crew Reactions in 0-G (MICR0-G)

FLIGHT DATES:
January 23 – 26, 2001

PRINCIPAL INVESTIGATOR:
Professor Dava Newman, Massachusetts Institute of Technology (MIT)

NASA Photo: JSC2001E02065

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GOAL:

The MICR0-G experiment aboard the KC-135 aircraft tested an integrated ground-based technology, assessing crew-induced disturbances and crew motor behavior in microgravity. The ultimate objective is to further develop a space-qualified system for use in the International Space Station.

INTRODUCTION:

The Department of Aeronautics and Astronautics of MIT and the Department of Bioengineering of the Politecnico di Milano University developed systems respectively, to measure crew-induced reaction forces and moments and to conduct a quantitative kinematics analysis of crew intra-vehicular activity (IVA) in space. Both the U.S. EDLS (Enhanced Dynamic Load Sensors) and the Italian ELITE-S (Elaboratore di Immagini Televisive-S2) systems were flown successfully on the Russian orbital complex *Mir*. The MICR0-G project team, funded by NASA, and the Italian Space Agency (ASI) collaborated to develop enhanced ground-based versions of EDLS and ELITE-S, trying to integrate both prototypes into a unique kinematic and kinetic measurement system.

Quantitative analysis of human performance in microgravity is important for both scientific investigations and spacecraft engineering design. By collecting and evaluating the kinematic and kinetic data of astronauts in space, it becomes possible to characterize human motor strategies, postural behavior in weightlessness, improve the design of orbital modules, help maintain a quiescent microgravity environment for acceleration-sensitive science experiments, and optimize the human operative capabilities during long-duration space missions.

METHODS AND MATERIALS:

The MICR0-G experiment combines advanced load sensors and an opto-electronic motion analyzer. Both systems acquired synchronized data aboard the KC-135 in January 2001 during the microgravity periods.

Equipment
The key experiment hardware of the kinetic system is based on two types of sensors - a handhold and a foot restraint. The sensors provide the functionality of crew restraint devices and mobility aids while measuring the applied forces and moments in the x-, y-, and z- axes (6 degrees of free-dom). Each sensor is connected to a Lexan box housing the necessary electronics for data processing and networking. The data acquired locally are sent wirelessly to a laptop computer, which stores the data recorded by all the sensors.

The kinematic measurement component of the MICR0-G system consists of a versatile opto-electronic motion analyzer, called ELITE-S, based on the recognition of passive markers. The system is composed of two TV Cameras (TVC) equipped with infrared (IR) flashes and connected through a bus to an electronics box housing the main electronics

components. The electronics box is connected to a Processing Unit, namely an IBM compatible PC. Reflective markers are affixed to the subject clothes at the body joints. The IR flashes illuminate the markers, allowing infrared video acquisition of the subject motions. The Processing Unit performs data processing in real-time. An LCD monitor is mounted on top of the Processing Unit monitor to provide a real-time feedback on any of the two TVC infrared views.

Flight Operations
At least three out of the four team members are required to conduct the MICRO-G experiment, thus allowing for expected occurrences of motion sickness in microgravity. One team member operates the kinetic system and another team member operates the kinematic video system. The subject has reflective markers fixed at his body joints and is instructed to perform prescribed IVA tasks using the combination of two sensors: either a handhold and a foot restraint or two foot restraints.

The forces and moments applied by the subject on the sensors are acquired during microgravity sessions and the position of the reflective markers on his/her body are analyzed by the TV cameras' system. The subject is required to stay in a defined working volume of 1 m x 2 m x 2 m during the experiment to stay in the field of view of the cameras.

For the ELITE-S kinematic system, availability of a supporting table and the supporting poles allowed for the set-up of the kinematics facility to assure the collection of high-quality kinematics data. The lack of a portable PC as data collection unit for the system instead of a PC Desktop did not cause problems apart from the necessity to strap firmly the PC and its monitor during flight. However, the PC had to be de-mounted for take-off and landing. The poles made available onsite turned out to be suitable for camera fixation and orientation. Also the fixation position of the poles at the side of the plane guaranteed a good angle between TV cameras optical axis, necessary for accurate 3-D reconstruction of markers location. The poor stability of the poles against the strong vibrations experienced during take-off and landing required the performance of a system calibration after take-off and landing to acquire in-flight and post-flight data, respectively. The total working volume, which was requested on the plane was just sufficient to allow successful whole body acquisitions with 8.5 mm focal lengths optics equipping both TV cameras.

RESULTS:

Four days of flight provided the collection of kinematics and kinetics data relative to six different protocols on four subjects. Repeated sessions for two of the four subjects were performed on the second and fourth flight day. Pre-flight and post-flight data collection sessions for motor control related protocols were performed at each flight day immediately before take-off and landing respectively.

In-flight acquisitions were performed from the 3rd to the 37th parabola. The whole period of weightlessness at each parabola was used for data acquisition requiring the test subject

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to repeat continuously the motor task according to the instruction. A total of 240 files (67 Mb) were collected on the four flight days

Data processing is being performed for marker tracking and 3-D reconstruction. First results indicate an accuracy in 3-D marker localization in the range 2-5 millimeters. The entire set of kinetic flight data will be processed and analyzed at MIT during further post-flight analysis to provide force and moment data, respectively, in calibrated units (N, Nm). The kinematic data will be analyzed at the Politecnico di Milano University and then later correlated with the results of the kinetic analysis in order to characterize nominal loads for each prescribed motion performed in microgravity.

CONCLUSION:

The MICRO-G flight experiment aboard the KC-135 aircraft confirmed the capability and performance of the integrated advanced kinetic and kinematic system. The newly designed kinetic sensor wireless architecture provided a greatly enhanced capability over previous force/torque data acquisition systems. The KC-135 operational environment helped identify improvements for improved electronic integration. Also, the flight experiments revealed task and activity timelines appropriate for the desired astronaut motions. Future development includes the integration of the microelectronics underneath the sensor plate, the development of a graphical user interface to simplify the operations and additional tests on the synchronization of the sensors and the kinematic motion analyzer. The final ground-based prototype will be used to propose further development of a space qualified integrated kinetic and kinematic astronaut motion system for the ISS.

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PHOTOGRAPHS:

JSC2001E02081 to JSC2001E02056
JSC2001E02225 to JSC2001E02243
JSC2001E02305 to JSC2001E02325
JSC2001E02913 to JSC2001E02934

VIDEOS:
- Reduced Gravity Flight Jan. 23 – 26, 2001, Reference Master: 619047

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Evaluation of a Microgravity Compatible Blood Collection/Preservation/Storage Apparatus

FLIGHT DATE:
January 26, 2001

PRINCIPAL INVESTIGATORS:
Clarence Sams, Ph.D., NASA/Johnson Space Center
Brian Crucian, Ph.D., Wyle Life Sciences

CO-INVESTIGATOR:
Matthew Alexander, Ph.D., National Research Council

NASA Photo: JSC2001E02900

GOAL:

To evaluate novel microgravity-compatible hardware designed to draw whole blood specimens and deliver them to preservative reagents.

INTRODUCTION:

We have developed the whole blood collection/preservation/storage apparatus (BCPSA) as a system for the preservation of whole blood collected during space flight for ground-based analysis. A variety of assays may be performed, using preserved blood, that assess various aspects of human physiology. This device contains all liquids to address safety issues concerned with space flight as the whole blood sample is first collected and then transferred (via an interlink adapter) into a storage vessel containing preservative. The preservative maintains the structural integrity of the blood cells without the need for cold storage or power requirements. In this configuration the preserved blood cells are stable at room temperature for over 14 days.

METHODS AND MATERIALS:

The investigators carried pre-loaded monovettes containing anticoagulated whole blood or dyed water samples (collection Monovette-CM). Initial manual manipulations and fluid mixing analysis were performed using the water samples; later in the flight evaluations were performed using the blood samples for subsequent ground based analysis. For transfer, the CM was fitted with a double sided interlink adaptor (IA). The free end of the IA was then fixed to a storage Monovette (SM) which was preloaded with preservative. The three units joined create a closed system and prevent escape of liquids. Transfer of the blood sample to the storage vessel was performed by manual manipulation and the samples were thoroughly mixed. A lock was then activated on the SM and the apparatus was then disassembled and stored.

RESULTS:

Overall, the BPCSA performed extremely well in the microgravity environment. The fluids could be completely contained and moved from chamber to chamber without leakage. The entire device was user-friendly and very easy to manipulate in microgravity. It was noted during the flight that it was difficult to completely deliver a sample due to liquid floating in the dead volume space of a Monovette. By lightly pushing the fluids via artificial gravity (created by swinging the device) it was found that an entire sample could be successfully delivered to the fixative.

CONCLUSION:

A simple system compatible with microgravity has been developed which allows blood samples to be further manipulated during space flight. Samples may be treated with various reagents and preservatives and fluids may be transferred among various vessels without leakage. Protocols for use were developed on this flight.

PHOTOGRAPHS:

JSC2001E02893 to JSC2001E02906

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VIDEO:

- Reduced Gravity Flight Jan. 23 – 26, 2001, Reference Master: : 619047

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Cell Culture Module Hardware and Biology Integration and Verification Testing under Launch Load and Microgravity Conditions

FLIGHT DATES:
January 30 – February 2, 2001

PRINCIPAL INVESTIGATOR:
Thomas Cannon, Walter Reed Army Institute of Research (WRAIR)

CO-INVESTIGATORS:
Cristine Waterhouse, WRAIR
Alison Garcia, WRAIR
Peter Quinn, WRAIR
Michael Schwarz, WRAIR
Herman Vandenburgh, Brown University
Bernie Creswick, Brown University
Peter Lee, Brown University
Captain Don Hill, U.S. Army/NASA/Johnson Space Center

NASA Photo: JSC2001E02989

GOAL:

The goal of the KC-135 reduced gravity flight series was to verify Cell Culture Module (CCM) hardware performance in the microgravity and launch load environments, with focus on performance of biology support modifications. The flight configuration included avian skeletal myofibers in organ-like bio-artificial muscles (BAMs) in order to assess the function of the fluidic support stream.

OBJECTIVES:

1) The determination of an ideal BAM biochamber orientation within the CCM architecture to minimize displacement effects of launch loads.
2) The assessment of the diffusion pattern of the BAM biochamber to verify even distribution of the perfusing nutrient media and injectables.
3) The evaluation of pump speed variations to improve fluid mixing.
4) The observation of air bubbles within the fluidic stream to determine their behavior and its effect on fluid distribution during microgravity.
5) The evaluation of the STS-R2 CCM software program execution.
6) The evaluation of solenoid seal integrity under shuttle gravity conditions.
7) The observation of pressure waveform changes of a pulsatile flow pump during microgravity and launch loads.

INTRODUCTION:

Life science research in space gives scientists and medical practitioners a better understanding of the effects of space flight on living systems. It also presents the opportunity to develop and assess countermeasures against the negative effects of microgravity. This information is essential for long term space flight of humans and has clinical applications on Earth.

The Department of Space Biosciences at WRAIR has been engaged in a collaborative series of experiments with the DOD Space Test Program and NASA Life Sciences to study the effects of microgravity on living systems. The WRAIR CCM is a flight qualified experiment module designed to maintain cell culture preparations and to allow highly automated experiment executions via the nutrient perfusion flow path. Space Biosciences is currently configuring the CCM to support cell cultures comprised of avian skeletal myofibers in organ-like structures called BAMs. These BAM cell cultures, developed at the Brown University School of Medicine, are a good cellular model to study countermeasures for space travel-induced muscle atrophy. The BAMs have been flown in the CCM on three Space Shuttle flights (1) and are manifested on STS-R2 (2).

The WRAIR hardware team has developed a next generation fluid routing architecture and biochamber to house the BAMs in order to maximize the experiment science yield and to improve routing and packaging of the flowpath. KC-135 test evaluations for the new configuration include optimizing biology orientation within the architecture to minimize

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the effects of launch load, modulating flow conditions during injections to maximize mixing, minimizing biology exposure to air bubbles within the fluidic flow path, and maintaining consistent and reproducible nutrient and additive delivery. Other hardware performance factors of interest are the STS-R2 software execution, solenoid seal integrity, and the pulsatile-flow perfusion pump characteristics.

METHODS AND MATERIALS:

Instruments

The experimental apparatus consisted of a 3/4" plywood pallet, bolted to the forward floor of the KC-135 aircraft. A power strip, 30V DC power supply, TEDBox (pump and valve control unit), CCM secondary containment, and a removable Macintosh G3 laptop were secured to the pallet via brackets, straps, and/or mushroom tape.

Within the CCM secondary containment were the motherboard, temperature sensors, a *rail*, a CARD with biochamber, and TAGBox apparatus. The motherboard electronics execute the STS-R2 software program while recording data, including temperature and accelerometer information. The heating and gassing systems were not incorporated as per the normal setup of the CCM.

The *rail* is an aluminum baseplate with mounted pulsatile pumps, heatsink, and circuit board controlled by the motherboard. Two flowpaths were secured to the rail. One flowpath, consisting of tubing, a hollow-fiber bioreactor, two MicroMed® pressure transducers, and recirculating water from a fluid bag, was used for the pressure waveform acquisition experiment (flow rate set to 8.5ml/min). One pressure sensor was located in-line before the bioreactor; the other was on the bioreactor sideport. The second flowpath, consisting of tubing, recirculating dyed water from a fluid bag, solenoid valves, and an empty Teflon fluidic bag, was used for the solenoid seal integrity test.

The CARD is a polycarbonate shell version of the rail. The CARD flowpath contained tubing, valves, and several fluidic bags, as well as a biochamber filled with BAMs. The biochamber consists of a flow-through polycarbonate shell with a pyramid-shaped pattern at the inlet/outlet, a polycarbonate cover plate, and brackets to seal and contain the fluidics. BAMs, attached to velcro glued to silicone boats, are arranged in the chamber shell in rows, starting from the bottom/inlet side. Flow rates were set to 10ml/min nominal and 15ml/min high-speed. A TEDBox software program was used to run the pumps and aid in control of the fraction collections. TEDBox switches could be manually toggled to selectively automate dye injections, sumping, pump speed changes, and fraction collections. A video camera was mounted next to the biochamber to record the fluid distribution of dye injections in the biochamber and the effects of gravitational fields on the BAMs' orientation within the CCM.

The TAGBox apparatus contains an Analog Devices accelerometer (Model ADXL05EM-3), an amplifier to which the rail's pressure transducers were connected, a National Instruments C50 terminal block, and a 9V battery. A DAQ cable connected the TAGBox

instrumentation to a National Instruments PCMCIA DAQ Card 1200. LabVIEW application software (Mink Hollow Systems) was used for data visualization and acquisition on the laptop. Six analog signals were sampled at 1000Hz from the X, Y, and Z-axes of the accelerometer, the battery, and the two rail pressure transducers. A Spectramed Model Xcaliber transducer system was used for calibration.

Procedure

Pre-flight (day before flight day 1).
The pallet was loaded onto the KC-135 aircraft with power strip, TEDBox, power supply, and power pack attached. The CCM secondary containment was taken to Johnson Space Center (JSC), Bldg. 37, Microbiology lab for biologics loading.

At the JSC lab, five sterilized CARDS were primed with phenol red-free nutrient media contained in fluid bags. BAMs were cultured at the Miriam Hospital (Providence, RI), loaded into the biochambers, and transported in a portable incubator to JSC. The biochambers, loaded with five or six BAMs, were then integrated into each CARD. The CARDS were maintained in two humidified incubators, with perfusion pumps powered by a TEDBox.

Pre-flight (daily).
Each morning before flight, one CARD was removed from the incubator, necessary bags were aseptically connected, and the flowpath was de-gassed. On all flight days but the first, injection lines were pre-primed and sump bag stability was verified by a bag-squeeze test. On Day 1 and 2, fluid bags were attached to the card via mushroom tape; on Day 3 and 4, the bags were contained in a Ziplock bag taped to the CARD. The CARD and biochamber were then secured in the CCM.

The motherboard was initialized, and the temperature HOBO® was initialized and secured within the CCM near the CARD. The TAGBox received a new 9V battery each morning before power-up and the gain was set (Gain 11 on Day 1, Gain 9 on Days 2-4). To calibrate each transducer, a known pressure validated by the Xcaliber was generated using a water-filled syringe. Calibration data were stored for each sensor at three pressures per sensor. The TAGBox remained powered until experiment take-down after each flight.

The secondary containment was closed and transported to Ellington Airfield unpowered. The CCM was strapped to the pallet in the aircraft in a horizontal orientation for take-off/landing. Depending on CCM in-flight orientation for each day (horizontal or vertical) the video camera was mounted specifically for optimal BAM viewing. A video check was performed prior to take-off to ensure proper camera position and focusing capability. All equipment was powered and checked for function before takeoff. The on-orbit button press was performed at this time (except days 1,2: auto-initiated performed button press). The experiment was powered-down after all checks were performed. The laptop was placed in a briefcase kept in the aft of the aircraft for takeoff and landing.

In-flight.
Once in transit, the experiment was powered and the laptop was secured to the pallet. The CCM orientation was switched from horizontal to a vertical position on Days 1 and 2 and secured via straps. Baseline data were acquired from the pressure sensor experiment prior to the first parabola. Checklists were utilized for the fluidics and pressure experiments. For the fluidics testing, a member of the science team from Brown University observed the biochamber while a member of the WRAIR team performed a series of injections and fraction collections using the TEDBox. Both normal and high-speed injections were executed. Throughout this experiment the video camera recorded biochamber activity. For the pressure wave experiment, data files 5-90 seconds in length were collected on the laptop during microgravity, 1.8gs, and transitions. After the last parabola, the experiment was powered down and the laptop was removed from the pallet and stored for landing.

Post-flight.
The CCM module was removed from the plane daily and taken to JSC for post-flight analysis. The fluidics experiment was removed from the module and placed under a biological hood for processing. The biochamber and fraction collection bags were aseptically removed from the CARD and stored in the refrigerator and freezer respectively for later analysis at Brown University. The remaining flowpath was properly disposed in the biohazard trash. Post-flight calibration data were collected from the pressure wave experiment. The solenoid seal integrity test was verified by checking for colored fluid in the Teflon bag. The solenoid and Teflon bag were replaced daily. Data were downloaded from the motherboard daily post-flight. The motherboard was re-initialized immediately after data download on Days 1-3 and then powered down.

RESULTS:

The four days of flight-testing yielded results dependent on hardware conditions and events relative to each flight. Specific results relative to experiment objectives follow.

Each flight, the BAMs were arranged in slightly varying patterns within the biochamber. The BAMS were generally in pairs, aligned in a 2x3 matrix, except on Day 4 when only 5 BAMS were flown (2x2 matrix plus one slanted). BAM displacement of an estimated 1-2mm occurred within the biochamber Day 1 and 2, while the CCM was in the vertical position. No evident BAM displacement occurred on Day 3 and 4 while the CCM was horizontal.

Fluid distribution testing took place on flight Days 1, 2, and 4. No fluid data were collected on Day 3 due to a kink in the flowpath. Six injections were captured on videotape Day 1, two of which were high-speed. The dye consistently entered the biochamber, passed over the set of BAMs closest to entry, and then traveled along the biochamber top where no BAMs were seated. The second set of BAMs received little dye during regular speed injections. More dye seemed to pass over the second BAM set during

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high-speed injection. Dye eventually reached the third set of BAMs regardless of pump speed. A sump bag leak limited further data collection.

Eight regular-speed injections were performed on Day 2, of which five were discernable on videotape. Consistently, dye entered the biochamber, passed over the set of BAMs closest to entry, and continued to pass over part of the next BAM pair. The dye then traveled along the biochamber top where no BAMs were seated. Thorough fluid distribution across all BAMs eventually occurred during flushing. The dye distribution on Day 2 showed improvement over Day 1.

Nine injections were performed on Day 4, of which five were discernable on videotape. The dye consistently entered the biochamber, passed across the first two sets of BAMs, and then continued over the last BAM. Dye still traveled across the top where no BAMs were located. Pump speed was increased for three injections but the effects were not observable. Image quality was poor on Day 4 due to a white surface placed behind the biochamber to improve visualization, but instead reduced viewing capabilities.

With the initiation of microgravity on the first parabola of Days 1, 2, and 4, air bubbles entered the biochamber (no air bubbles were seen inside the biochamber on Day 3 when the flowpath was kinked). Once inside the biochamber, the air bubbles pulsed but were not released. Near the biochamber inlet, small air bubbles attached to the cover. No air bubbles sat over the BAMs.

The fraction collection system performed as expected. Three BAM media collects were executed on Day 1. On Day 2, the fraction collection system was utilized to replace a leaking sump bag; multiple collections occurred in bags 2, 3, and 4. No collections occurred on Day 3 due to a flowpath kink; however, a TEDBox program was executed to show that the fraction collection solenoid valves fired successfully (verified by current draw). Three collects were performed on Day 4. Glucose and lactate values for each day may be found in Table 1.

Table 1. Glucose and lactate data.

Flight Day	Glucose (mg/L)	Lactate (mg/L)
Day 1	403.7 +/- 5.1	0.63 +/- 0.2
Day 2	392.7 +/- 5.6	1.7 +/- 0.1
Day 4	353.7 +/- 3.5	4.23 +/- 0.1

The STS-R2 CCM software program also performed as expected each day. On Day 1 and 2, the program was auto-initiated. On Day 3 and 4, the on-orbit button press was performed manually. For all days, the expected number of on-orbit events was executed based on the start time of the program, and the landing button press event was recognized and performed. Temperature and acceleration data were successfully recorded. The average temperature of the module throughout the experiment was 20°C.

Solenoid seal integrity was maintained throughout the entire four days of experimentation. The Teflon bags remained consistently free of fluid.

Pressure waveform data were acquired on all four days of flight-testing. However, the low portion of the signal, which shows characteristics of the pump check valve system, was clipped throughout most of the data collected (no signal below 0.25V). Despite clipping, maximum voltages for the sensors could be measured. On Day 1, 21 data sets were acquired (1 in 1g, 5 in 1.8g, 8 in µg, and 7 in transition). During 1.8g periods, the signals were not clipped. On Day 2, 17 files were collected (1 in 1g, 4 in 1.8g, 4in µg, and 8 in transition). Almost all signals were clipped regardless of gravity vector. On both Day 1 and 2, an increase in the gravity vector paralleled an increase in baseline pressure for both in-line and sideport signals. Based on the calibration data files, the average peak for in-line pressure was 34mmHg during microgravity and 40mmHg during 1.8gs. For the sideport, the peak was 20mmHg during microgravity and 25mmHg during 1.8gs.

On Day 3, 20 files were collected (1 in 1g, 3 in 1.8g, 2 in µg, and 14 in transition). The maximum sideport signal was clipped, so only data from the in-line sensor were meaningful. On Day 4, 19 files were stored (1 in 1g, 5 in 1.8g, 4 in µg, and 9 in transition). Both signals were clipped but maximum values were measurable. On Day 3 and 4, a decrease in the gravity vector corresponded to an increase in baseline pressure. Based on the calibration data files, the average peak for in-line pressure was 32mmHg during microgravity and 30mmHg during 1.8gs. For the sideport, the peak was 15mmHg during microgravity and 13mmHg during 1.8gs.

DISCUSSION:

The objective of the experiment was to verify CCM hardware performance in the microgravity and launch load environments. The hardware, overall, performed successfully throughout the four days of flight-testing. Results including the biochamber orientation, fluidic stream performance, software execution, solenoid integrity, and pressure waveform observation are addressed relative to the objectives.

No ideal biochamber orientation within the CCM for the BAMs during launch could be determined from this test. Minor BAM movement occurred during Day 1 and 2, but it is difficult to ascertain whether the movement was due to the size and placement of the silicone boats, flow, the vertical orientation of the CCM, the acceleration vector, or a combination of the aforementioned items. Technical difficulties on Day 3 and 4 prevented sufficient data collection in the horizontal position. However, lack of BAM movement without flow on Day 3 suggests that flow does play some role. Also, no observable movement on Day 4 and limited movement on Days 1 and 2 suggest that the tight fit of the silicone boats aligned in the biochambers is sufficient to limit displacement. Based on this information, the current biochamber configuration supports BAMs in any orientation although further testing could be performed to validate an ideal orientation.

The diffusion pattern of the biochamber and the actual placement of the BAM silicone boats within the biochamber both played a significant role in fluid distribution. One notable behavior was that injections tended to favor one side over the other. In the favored side, the entry pattern is slightly deeper (<0.25mm), offering less resistance to flow. The injections also favored areas within the biochamber where no BAMs were seated. The dye distribution was consistent for each injection. Therefore, regardless of orientation or gravitational acceleration, the dye injection tests showed that flow follows the path of least resistance in the biochamber. Eventually, the dye mixed throughout the biochamber, exposing all BAMs to the injectable. This suggests that the current diffusion pattern is sufficient. However, because resistance rather than gravity demonstrated the greatest influence over fluid distribution, ground studies should be performed to optimize both the diffusion pattern design and placement of the BAMs within the biochamber.

No conclusion was reached regarding the effect of increased pump speed during injections and improved mixing within the biochamber. From Day 1 video, it appears as if there is better mixing during the high-speed injections. On Day 4, it was difficult to discern if the high-speed injections improved mixing within the biochamber due to the poor backlighting. Because of the limited data, more testing is necessary to determine the value of increased pump speed for mixing.

Air bubbles in the fluid stream were notable in the biochamber. Once in microgravity, air bubbles rushed into the biochamber and remained there, attached to the cover via surface tension. Although air was present in the biochamber each day, the amount of air present was significantly diminished by injection line pre-priming and fluid bags de-gassing. Also, only an initial air influx into the biochamber was observed with microgravity introduction; once inside, additional air did not appear. Because this influx phenomenon has not been seen in ground studies, further microgravity testing would be useful to validate potential bubble trap solutions.

Cellular response was not a primary objective. However, validation of the fraction collection system was performed. To demonstrate the efficacy of sampling, glucose and lactate levels were measured. These levels were within the normal range for the BAMs. Also, the increase in lactate and decrease in glucose over the four days demonstrates BAM viability at time of flight.

The prototype software program to be used on STS-R2 was accelerated in order to maximize the opportunities for events to occur. All events occurred as expected, validating the current version of the CCM STS-R2 code.

The solenoid seals maintained integrity throughout the entire experiment. This validates that the spring-loaded action of a functional solenoid valve was not triggered without voltage stimulation in micro- or increased gravity. Therefore, vibration and changing gravity vectors do not affect solenoid valve function.

The pressure waveform data from the pulsatile flow pump were clipped on all days due to a limitation of the operational amplifiers and power supply set-up used in the TAGBox. However, the signal peaks were not clipped, and changes could be noted. The pressure waveform data shows that baseline pressure changes occur with changing acceleration. The following equation can be used to explain the observations:

$$P_b = P_p + \rho g h,$$

where P_b is the pressure at the bioreactor, P_p is the pressure at the pump, ρ is the density of the fluid, g is the gravity vector, and h is the height between the pump and the bioreactor. Since the density of water and media are approximately 1, this term can be dropped. Therefore, the pressure at the bioreactor will be dependent on acceleration and the height of the media column above the bioreactor. On Day 1 and 2 with the CCM in a vertical position, the pump pressure head was approximately 1 1/2" higher than the bioreactor. Therefore, as g increased, P_b increased. This shift in baseline pressure can be seen in the 1.8g conditions as the peak maximums increased for both the in-line and sideport sensors, and as the entire waveforms can be seen (no clipping). On Day 3 and 4 with the CCM in the horizontal position, the pump pressure head was less than 1/2" below the bioreactor (negative h). It can be seen that as g increased, P_b decreased. It can be concluded that cells in the bioreactor will experience a change in average pressure experienced in microgravity versus 1G based on the height difference between the pump pressure head and the bioreactor. However, it should be noted that as long as the height difference is small, the change in pressure is minor (approximately 3-5 mmHg for a pressure head difference of 1 1/2").

Because the majority of pressure signals were clipped, it could not be determined if waveform shape change occurred during changing acceleration. However, the waveform acquired using a Digi-Med Blood Pressure Analyzer in ground testing is similar to that observed using the TAGBox during 1.8G accelerations on Day 1, which suggests that the pulsatile flow pump mechanism is not affected by gravity conditions.

CONCLUSION:

The purpose of the KC-135 reduced gravity flight series was to validate CCM hardware performance, with particular regard to biological support modifications. Overall, the hardware performed successfully, and useful data were acquired. Non-hardware specific problems, such as the fluid bag leak and the kink, are preventable with use of newer bags and more thorough processing procedures. The software and solenoid valve control and integrity were extremely successful. The fluidics and pressure waveform experiments yielded valuable insight on the current system and potential for further investigation and improvement.

A number of conclusions may be drawn from the fluidics experiment. The displacement effects of launch load on the BAMs were minor. No ideal orientation could be determined, but neither potential launch orientation showed negative effects. The BAM-filled biochamber did not exhibit even fluid distribution as flown; however, since resistance played a larger role than gravity, on-ground testing may be used for pattern design and

BAM placement improvement. This testing should include the biochamber completely filled with BAMs (9 total), which is the potential flight configuration. Pump speed variations showed limited mixing efficacy, but further testing in this area is necessary to make a valid assessment. Air bubbles within the fluid stream do flow into and remain in the biochamber during microgravity. Although processing techniques such as de-gassing and pre-priming reduce this phenomenon, other solutions should be investigated such as selective membranes and bubble traps. Further flight testing on the KC-135 would be required to validate any air removal solution. For all future testing, biochamber backlighting and digital video will be essential to maximize science yield.

The pressure waveform experiment demonstrated enough information to show that the pump pressure in the current configuration is not significantly affected by changes in gravity. Further studies with an improved amplification system and a more thorough calibration procedure would yield insightful information on the shape of the waveform as well as pressure ranges experienced by the cells.

In conclusion, the KC-135 validation testing of the CCM was a successful experiment that yielded valuable information as well as direction for continued testing for hardware improvement.

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(2) NASA Ames: "The Effects of Space Travel on Skeletal Myofibers," 96-HEDS-04/05-496

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JSC2001E02986 to JSC2001E03000
JSC2001E03322 to JSC2001E03339
JSC2001E03367 to JSC2001E03376
JSC2001E03405 to JSC2001E03410

VIDEO:

• Zero G KC-135 Flights Jan 30. Feb. 2, Master Reference: 712563

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights - Wave Reflection of the Cardiovascular System in a
Reduced Gravity Environment

FLIGHT DATES:
February 12 – 16, 2001

PRINCIPAL INVESTIGATORS:
Jeff Wandler, North Dakota State University (NDSU)
Sean Keller, NDSU
James Kahl, NDSU
Andrew Wojtalewicz, NDSU

NASA Photo: JSC2001E04292

GOAL:

To understand the effects of weightlessness on the cardiovascular system.

OBJECTIVE:

Develop an appropriate model of the cardiovascular system to study in a reduced gravity environment.

INTRODUCTION:

The experiment was designed to determine whether there was a change in the velocity of the generated and reflected waves due to changes in the gravity field. The system was designed to produce a reproducible pulse on a constant system, with the only changing variable being the gravity. The gravity field was caused to change during flight operations aboard NASA's KC-135 aircraft varying between 0 G, 1 G, and 2 Gs.

METHODS AND MATERIALS:

The equipment used consisted of a plastic rectangular box which housed the tubing and components. The wave traveled down a length of tubing 28.6 cm long, and was recorded by 2 pressure transducers at different points. The first transducer was 6.3 cm from the front end of the tube, and the second was 6.2 cm from the back end, with the solid stopper used to produce the reflection. The distance between the two transducers was measured at 16.1 cm.

The pulse was delivered by a dc solenoid controlled by a computer and a programmable IC chip for relay control. The computer generated the trigger which was sent to the IC chip. The chip then inserted a 1 second delay to provide time for the computer to get ready to read the incoming data. Two relays were used to keep the solenoid isolated from the system to prevent spurious pulses, and also to prevent noise from the solenoid supply voltage from being picked up by the pressure transducers.

Procedure
A 50 ms pulse was applied to the solenoid, which energized the solenoid, striking and pushing the diaphragm of the tubing, creating the pressure wave in the tubing. The solenoid was then spring returned to the resting position after the pulse turned off. The pressure wave then traveled down the length of the tubing, past the two pressure transducers and to the stopper 28.6 cm from the solenoid, and then reflected and returned toward the solenoid – again passing by the two transducers.

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Signal Pulse to Solenoid
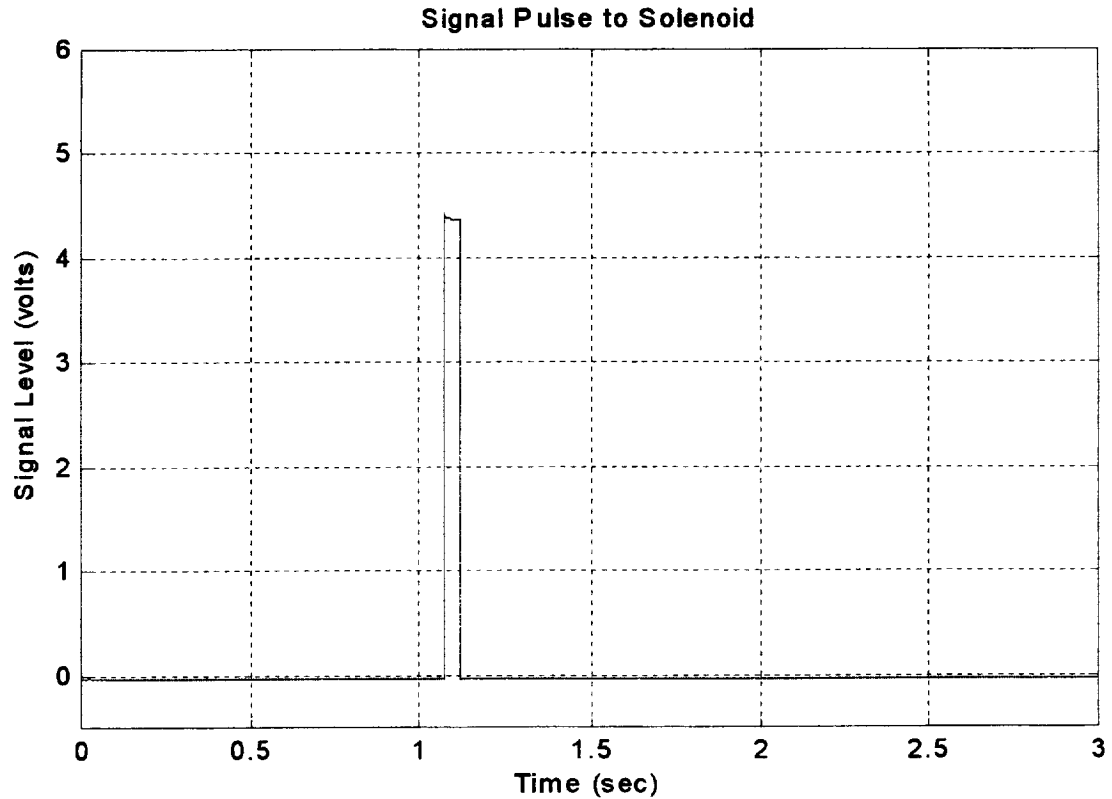
The computer initiated the sequence by writing the pulse to the A/D card. The pulse then went to the programmable IC chip, which inserted the 1 second delay, and then triggered the relays to power the solenoid. After the computer sent the pulse, the A/D card switched from writing mode to read mode, and then collected 4 channels of data at 25,000 samples per second each. These 4 signals were from pressure transducer 1, pressure transducer 2, the output of the IC chip to catch the trigger pulse to the solenoid, and the accelerometer to measure the gravity of the system during the pressure wave travel. The computer was also set to run automatically, creating another pulse every 10 seconds, and reading the data from the pulse for 3 seconds. All of the data were stored on the hard drive for later analysis.

RESULTS:
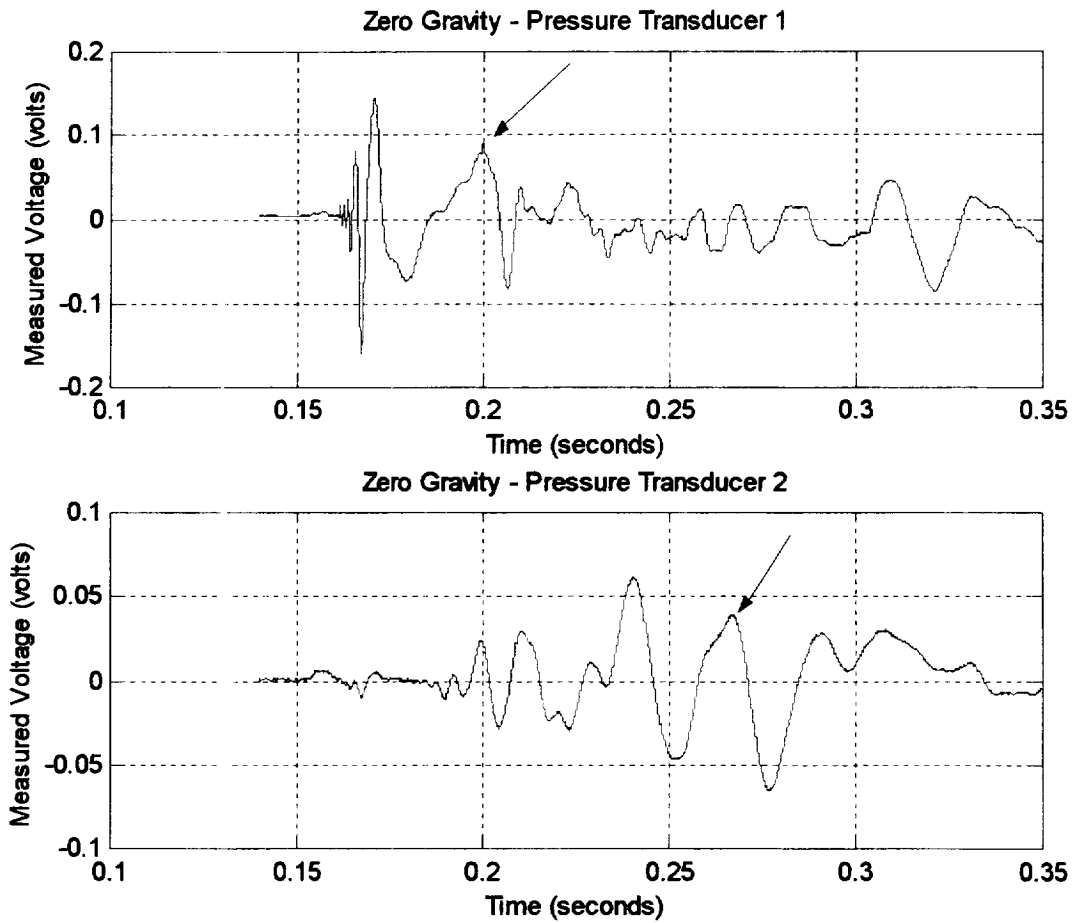
The distances between the two points was 16.1 cm, and the measured time difference was 67 mSec, which produced a velocity of 2.4 meters per second at zero gravity.
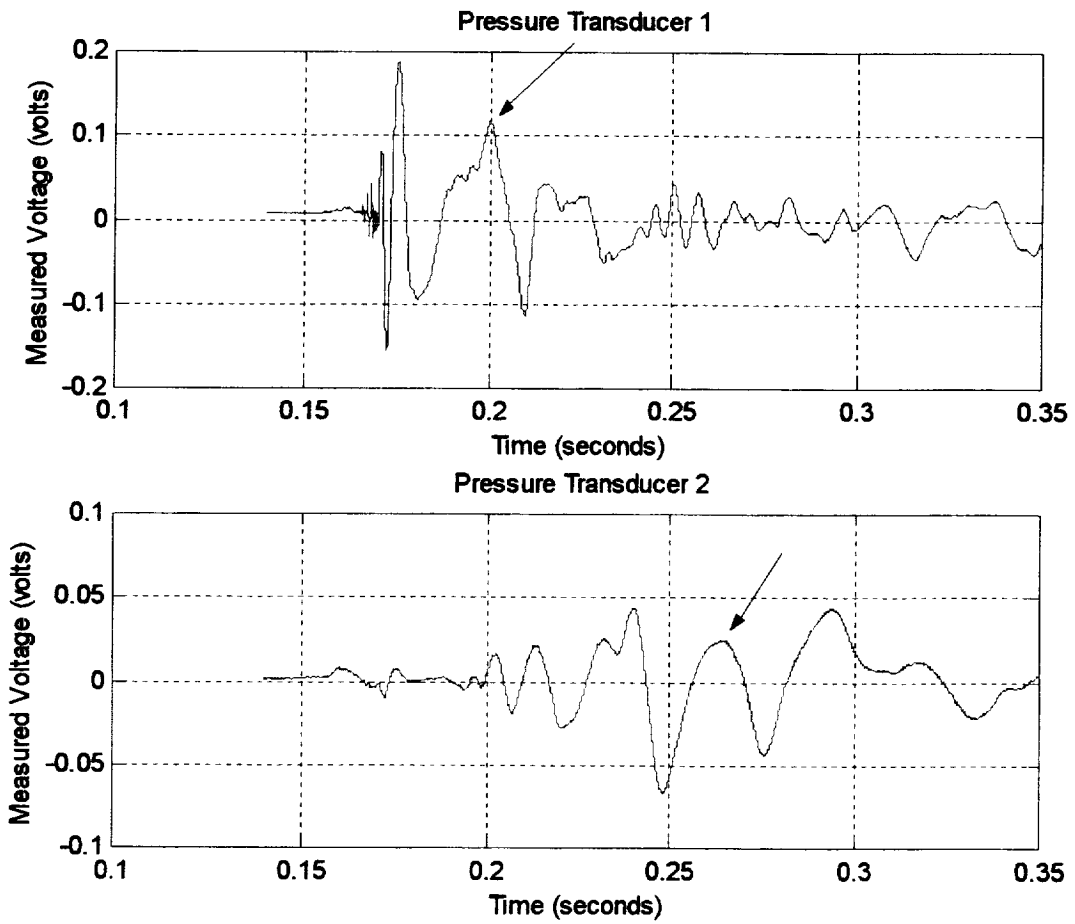
The velocity for the one gravity pressure was calculated at 2.52 meters per second.

Pressure Transducer 1

Pressure Transducer 2
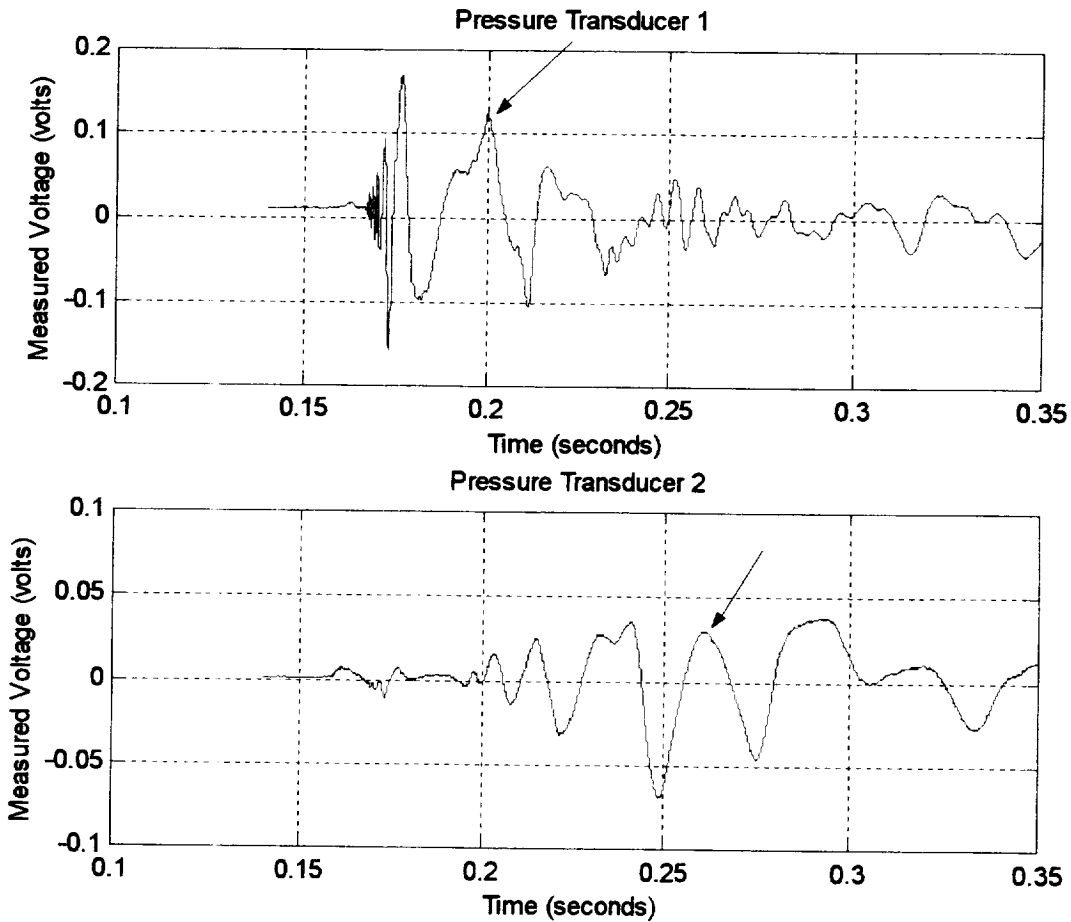
The velocity for the two gravity phase was 2.66 meters per second.

The values for the two days of data are summarized below:

DAY	Gravity	P1 Peak	P2 Peak	Calculated Velocity
1	0	5000	6675	2.40 m/s
1	1	5000	6600	2.51 m/s
1	2	5000	6512	2.66 m/s
2	0	5000	6688	2.38 m/s
2	1	5000	6625	2.48 m/s
2	2	5000	6550	2.60 m/s

This shows that for each day's data, the velocity increases as the gravity goes up, and over time the velocity decreases. This can be shown to be due to the compliance of the tubing increasing the longer it is exposed to the fluid system. The velocity itself is due to the forces acting on the tubing at the various levels of gravity.

CONCLUSION:

The data collected show several things. First, a common point was chosen to be the central point for all analysis. This point was chosen because it was significant, and occurred in relatively the same location in each pressure wave. This point was then used as the center point and all of the average graphs were redistributed such that each common point overlaid each other. Then the tendencies of the graphs were examined for any discrepancies or commonality.

Using the pressure transducer graphs, the most apparent points for the pressure wave to reach the transducer was determined, and from that the velocity of each wave was calculated. The easiest way to calculate the velocity was to determine when the pressure wave passed each transducer, and then use the distance between the transducers – measured at 16.1 cm – to determine the velocity. Below are the graphs of the pressure transducers with the point of most probable occurrence indicated.

PHOTOGRAPHS:

JSC2001E04247
JSC2001E04292
JSC2001E04315
JSC2001E04324

VIDEO:

- Student Campaign 2001 – Group A, Flight 1 &2, Reference Master #: 619706

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights – A Novel Enhancement of Current Exercise
Countermeasures to provide adequate Bone Impact Loading in Microgravity

FLIGHT DATES:
February 13 – 14, 2001

PRINCIPAL INVESTIGATORS:
Diana Chai, University of California – Berkeley
Bev Guo, University of California – Berkeley
Christopher Hamerski, University of California – Berkeley
Larry Rudner, University of California – Berkeley

NASA Photo: JSC2001E04244

GOAL:

The purpose of this experiment is to determine whether a combination of Applied
Horizontal Forces (AHF) and simulated partial gravity during treadmill running in

microgravity induces peak tibial shock values comparable to the forces experienced while running at normal gravity (1G).

INTRODUCTION:

Long-duration space flight in microgravity poses numerous physiological challenges to the human body. The loss of bone mineral adversely affects the biomechanical integrity of the musculoskeletal system. Previous research has shown that regional lower limb bone density was reduced in most astronauts upon their return from minimal duration space flight (Whalen, 1993). These problems will become intolerable with flights that extend to months or years. In addition, bone mineral loss poses a severe threat to astronauts when they encounter partial-G (e.g. Martian) environments. In order for long-term space exploration to be safe, effective countermeasures must be devised to minimize these effects (Baldwin, et. al., 1996). Exercise-based countermeasures are appealing because they provide benefits to the cardiovascular and muscular systems, as well as the skeletal system.

Many researchers believe that bone mineral loss is the result of a lack of impact loading (McCrory, et al., 1996; Cavanagh, et al., 1992). Mechanical loading of bone from impacts experienced in normal daily activity is correlated with the retention of bone mineral density. However, current space flight exercise regimes do not provide adequate impact loads (Cavanagh, et al., 1992). The large impact forces achieved on Earth might be simulated in space by treadmill running with a harness attached to rubber bands that pulls down on the runner's shoulders and hips. Unfortunately, in order to simulate Earth's gravity, the large downward forces generated by such harnesses cause pain and discomfort (McCrory, et al., 1996) and do not provide adequate peak impact forces (Boda, et al., 1998). However, lower partial gravity levels (such as 0.5 G) are tolerable.

It has been previously shown that externally applied horizontal forward pulling forces cause a substantial increase in impact peaks generated at Earth's gravity (Chang & Kram, 1999). This led to the hypothesis that applied horizontal forces (AHF) could increase peak impact forces in reduced gravity as well.

A recent study showed that applied horizontal forces increase peak impact forces in *simulated* reduced-gravity (Chang, et al., 2001). Reduced gravity was simulated by a harness attached to a series of rubber bands that pulled *up* on the subject's torso. The applied horizontal force (AHF) technique shows promise as an effective countermeasure to bone mineral loss during long-term space flight. However, the apparatus used in the Earth based simulation differs from an apparatus that might be used during space flight, which would require a harness to pull *down* on the runner's torso to provide artificial gravity. To test the AHF method in microgravity, we designed an experiment using an artificial gravity apparatus similar to that used in space flight. Using a combination of applied horizontal forces and induced *partial* gravity (IPG) during treadmill running in microgravity, simulated by NASA's KC-135 Reduced Gravity Simulator, we found that

the AHF increased impact forces to magnitudes experienced during normal running at Earth's gravity.

METHODS AND MATERIALS:

Subjects ran on a motorized treadmill borrowed from Dr. Michael Greenisen of NASA Johnson Space Center. The treadmill was bolted to the floor of the plane during in-flight data collection. A galvanized steel frame of Unistrut® Telespar® was built around the treadmill and bolted to the base plate supporting the apparatus using 3/8" steel bolts. The steel frame included handrails for the treadmill.

The in-flight exercise apparatus applied an induced partial gravity (IPG) using surgical rubber tubing and rope fitted through pulleys attached to a harness. The rope was attached to a winch at one end, which controlled the tension in the system. Harken® Wire Bullet Swivel Blocks and steel eyebolts were used to direct the rope along the frame. A Schaefer® 62-065B Delrin pulley wheel connected to two L-fittings was used to direct the rubber tubing. The rubber tubing was attached to a steel eyebolt at the other end. The horizontal force was applied by stretched rubber tubing attached to the front of the harness. A plastic and an aluminum pulley wheel directed the tubing along the frame to a winch, which controlled the tension of the tubing. A force transducer was added in series with the rubber tubing and a display mounted on the frame so that the subject and data collector could monitor the amount of AHF. Both winches were positioned in one corner of the frame, within reach of the experiment controller, but far enough so that the winches could be turned without interference.

A Piezotronics Inc. U353B18 ICP® accelerometer was used to measure tibial acceleration (tibial shock peaks). Impact force peaks and tibial shock peaks are both indirect measures of loading rate. Accelerometer data are comparable to the impact force data collected in previous studies. (Lafortune, et. al., 1995) Due to the difficulty and inaccuracy of using a force platform aboard the KC-135, accelerometer data were used in this experiment.

Four subjects ran in this experiment, 2 males and 2 females. All subjects were considered to be in good physical condition as determined by the pre-flight physical and were between the ages of 20 and 22. The four subjects wore well-cushioned running shoes during the experiment. Two subjects flew during each flight. An accelerometer, embedded in balsa wood, was attached snugly to the tibia of the subject using athletic wrap. The accelerometer was attached to the medial aspect of the left tibia, one third of the distance from the medial tibial condyle to the medial maleolus. Data were acquired using a laptop computer. One experimenter acquired data while the other ran in the apparatus. The two switched roles approximately halfway through the flight. Subjects ran at a speed of 3 m/s (6.7 mph). Two different levels of induced partial gravity were used (0.5G and 0.25G). At each gravity level, we pulled forward with an applied horizontal force (AHF) of 0% and 20% of the subject's gravity-specific body weight. For example, a 20% AHF at 0.5 G is equal to 10% of the normal body weight. Each experimental condition was collected twice. Each flight parabola gave 25-30 seconds of zero-gravity and allowed for one

condition to be collected. Control data were taken during free running at 3 m/s in normal Earth gravity to set a standard level of peak tibial acceleration for each subject.

The elastic band tensions were calibrated the morning of the flight for each subject using a scale to determine the downward force applied to the subject. For each flyer and condition, a winch was used to adjust the elastic bands to pre-marked lengths, corresponding to the desired level of induced partial gravity.

Data were collected on a laptop computer loaned by Dr. Sudhakar Rajulu of NASA JSC, using LabView4® at a rate of 1000 samples per second. The data were then plotted using Microsoft® Excel®. Each trial consisted of approximately 20 stance phases. For each condition, acceleration peaks were measured from 5 consecutive stance phases. The stance phases were chosen after 10 seconds of running to ensure that the subject had sufficient time to adapt to the condition. Each condition was collected twice, so we measured 10 data points for each trial condition. This data were graphed and compared to control 1G data.

RESULTS:

The data for three subjects were analyzed by plotting on Excel, comparing tibial acceleration graphs, and comparing average peak tibial shock values. The data are summarized:

Mean Peak Tibial Shock
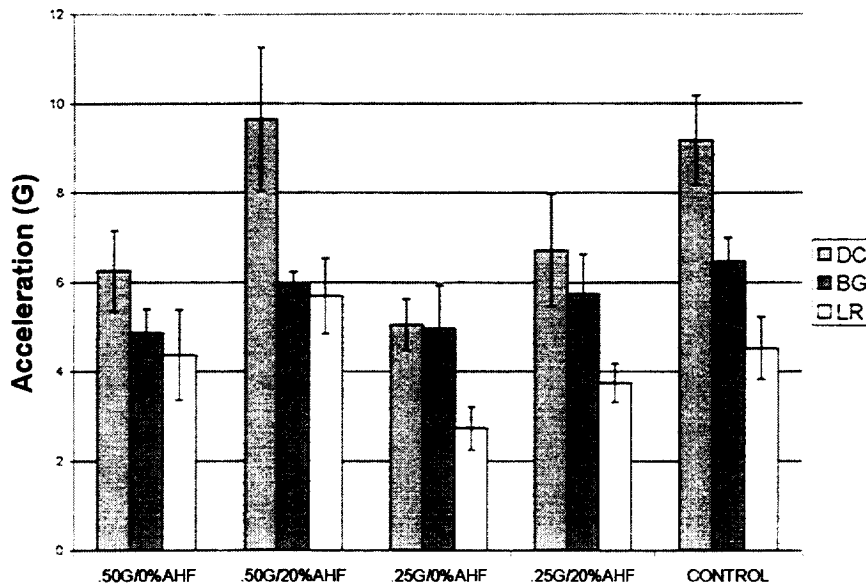
The above bar graph shows the average peak tibial shock values for each of the test conditions and the subjects. The error bars reflect the standard deviation in the data.

Due to a broken accelerometer, the data for CH had to be excluded. The average peak tibial shock value for the 0.5G IPG / 20% AHF test condition was approximately equal, within one standard deviation, to that of the 1G control value for all three subjects. The average peak tibial shock values were 9.64G±1.61G for the 0.5G IPG/20% AHF test condition compared to 9.17G±1.00G at 1G for DC, 5.69G±0.84G compared to 4.52G±0.70G for LR, and 5.94G±0.28G versus 6.47G±0.51G for BG. The AHF was maintained within 10% of the test condition. For LR, the 0.25G IPG / 20% AHF resulted in a peak tibial shock value (3.74G±0.43G) within one standard deviation of control values. Sample data are shown:
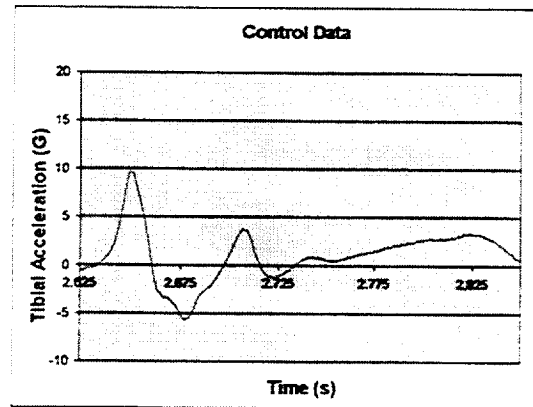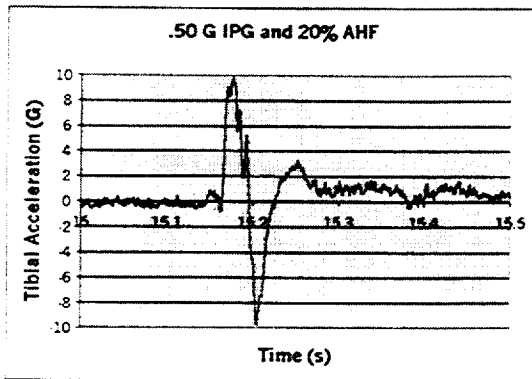
Sample tibial acceleration data are shown above for the .5G IPG/20% AHF test condition and the control data. One stance phase is depicted. The approximate duration of each stance phase is 200ms.

DISCUSSION:

Bone mineral loss in microgravity is correlated with a lack of impact loading (McCrory, *et al.*, 1996; Cavanagh, *et al.*, 1992). Specifically, the passive collision between the leg and foot with the ground is required for bone retention. We hypothesized that adding an applied horizontal force to a subject running in induced *partial* gravity would increase tibial impact loading to a level equal to or greater than seen at running at normal gravity. As predicted, the 0.5G IPG and 20% AHF resulted in average peak tibial shock values on the same order as those experienced at 1G for all subjects. For one subject, LR, 0.25G IPG and 20% AHF achieved normal Earth tibial acceleration values.

Although there are some inconsistencies in the data, the general trend is promising. The inconsistencies might be attributed to imperfect experimental setup. Attaching the accelerometer to the bone instead of skin, decreasing internal friction in the pulley system, increasing the number of subjects, and increasing data collection times would probably result in more conclusive data.

Each subject showed an increase in peak tibial shock with the addition of AHF at each IPG level. The average peak tibial shock value differences between the 20% AHF and 0% AHF conditions show that the AHF is the mechanism responsible for the increased peak tibial acceleration. The 1G control data are consistent with that of previous experiments (Cavanagh, 1990). These results are also consistent with the trends found in the previous UC Berkeley study (Chang, *et. al.*, 1999). Based on the qualitative experience of the subjects, the addition of an AHF does not result in discomfort and adds to the efficacy of the exercise. Although this modification may reduce the cardiovascular benefits of the exercise due to the decreased downward force applied to the subject, the added loading is significant.

CONCLUSION:

One of the major constraints of the current treadmill countermeasure is that it causes significant pain and discomfort, and it does not provide adequate impact loading (McCrory, 1996). Based on the qualitative experience of the subjects, running at 0.5 G with the addition of a 20% applied horizontal force was very tolerable and caused little or no discomfort. In addition, this condition increased impact loading to levels seen at normal running at Earth's gravity. From this data, it appears that the addition of an applied horizontal force to a treadmill runner in an induced partial gravity of 0.5 G may be a promising technique for preventing bone loss during long-term space flight.

ACKNOWLEDGEMENTS:

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JSC2001E04244
JSC2001E04256 to JSC2001E057
JSC2001E04289
JSC2001E04294 to JSC2001E04295
JSC2001E04323

VIDEO:

- Student Campaign 2001 – Group A, Flight 1 &2, Reference Master #: 619706

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights – Spring-Loaded Exercise Device in a Zero-Gravity
Environment – SLEDGE

FLIGHT DATES:
February 27 – 28, 2001

PRINCIPAL INVESTIGATOR:
Beth Todd, University of Alabama (UA)

CO-INVESTIGATORS:
Jenny Taylor, UA
Audrey House, UA
Matthew Chatham, UA
Kristin Wilson, UA
Daina Lee, UA
Bethany Lancaster, UA
Thomas Lee, UA
Deborah Honeycutt, UA
Marshall Jones, UA
Stormy Speer, UA
Richard Wear, UA
Brent Brezenski, UA
Randall Dunavant, UA
Joey Parker, UA

NASA Photo: JSC2001E0502

GOAL:

To develop an exercise device using linear springs that will function in a weightless environment.

OBJECTIVE:

The spring-loaded exercise device designed for use in micro-gravity should provide a constant force during a single repetition regardless of spring extension. It should be able to load the legs, lower back, and particularly the femoral neck. The load on the device should be set within a range of 25 – 700 lb in approximately 5 lb increments. Instrumentation on the device is used to record excursion and load data to be analyzed to determine the capability of the device in micro-gravity. Through this data, the effectiveness of this device can be compared to other proposed exercise devices, such as the Interim Resistive Exercise Device (IRED) that was tested in a previous project [7,8].

INTRODUCTION:

In a zero-gravity environment, astronauts exhibit mineral loss in their spine and lower extremities with no net changes in the upper extremities [1]. Astronauts tend to push off of the spacecraft with their arms for in-flight locomotion. This movement supplies loading to the upper extremities similar to that seen in a gravitational environment. The lower extremities, on the other hand, are not subjected to gravitational loading situations because the astronauts' masses are not being supported by their legs. Since the gravitational forces that are usually applied to the back and lower extremities are absent, there is significant Bone Mineral Density (BMD) loss in these areas. As mission length increases, there is risk that hypercalcuria might lead to the formation of renal calculi during flight and that axial skeletal fractures may occur upon re-entry to earth's or another planet's gravity [1].

NASA has been very interested in developing exercise countermeasures to these deleterious effects of weightlessness. To that end, NASA is exploring several exercise device concepts. One of these concepts, developed at The University of Alabama, is a spring-loaded mechanism to create resistance during exercise. This mechanism was developed for use in a ground-based study that NASA will conduct with the Horizontal Exercise Machine (HEM). NASA/JSC has conducted a number of bed rest studies to simulate the absence of gravity on the musculoskeletal system. BMD loss during bed rest and space flight has been found to be similar in magnitude and extent [2-4]. The HEM was developed to provide exercises for bed rest study participants while maintaining their horizontal position. The HEM was subsequently instrumented with a load cell and a rotary encoder to provide data related to the amount of force generated during a particular exercise as well as the associated excursion or travel [5,6]. Currently the HEM uses weight stacks to produce resistance. The spring-loaded mechanism was developed to replace the weight stacks on the HEM. The purpose of the SLEDGE project was to demonstrate the functionality of the mechanism in micro-gravity.

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The Spring-Loaded Exercise Device (SLED), consisting of a frame and exercise interface for the spring-loaded mechanism, was developed to provide the human interface for the device. The SLED was instrumented to measure the resistance force and the amount of travel of the mechanism. Following ground testing, the SLED was flown aboard the KC-135. The Spring-Loaded Exercise Device and attachment are described below.

Subjects
This device was tested as part of the Reduced Gravity Student Flight Opportunities Program. Thus, the subjects were four of the student investigators on the project – two male and two female subjects in their early 20's. In preparation for flight, the subjects each passed a Class III flight physical. The project received IRB approval at both The University of Alabama and NASA Johnson Space Center. As designers of the device, they were fully aware of its function and capability. Before participation in the project, they developed and signed informed consent forms. Low loads were used so that muscles would not be strained during exercise.

Hardware and Instrumentation
A brief description and photograph (Figure 1) of the equipment is presented here to facilitate understanding of the experiment. Our device is held within a steel frame. The loading portion of the exercise device consists of a system of parallel springs that is loaded through a four-bar slider crank mechanism. The four-bar mechanism is used to control the amount of force that is needed to pull the springs. There are two user interfaces that connect to the four-bar mechanism by a cable. One user interface is a padded back plate with a set of shoulder bars for doing squats and heel raises. The other user interface is an ankle strap for abduction/adduction exercises.
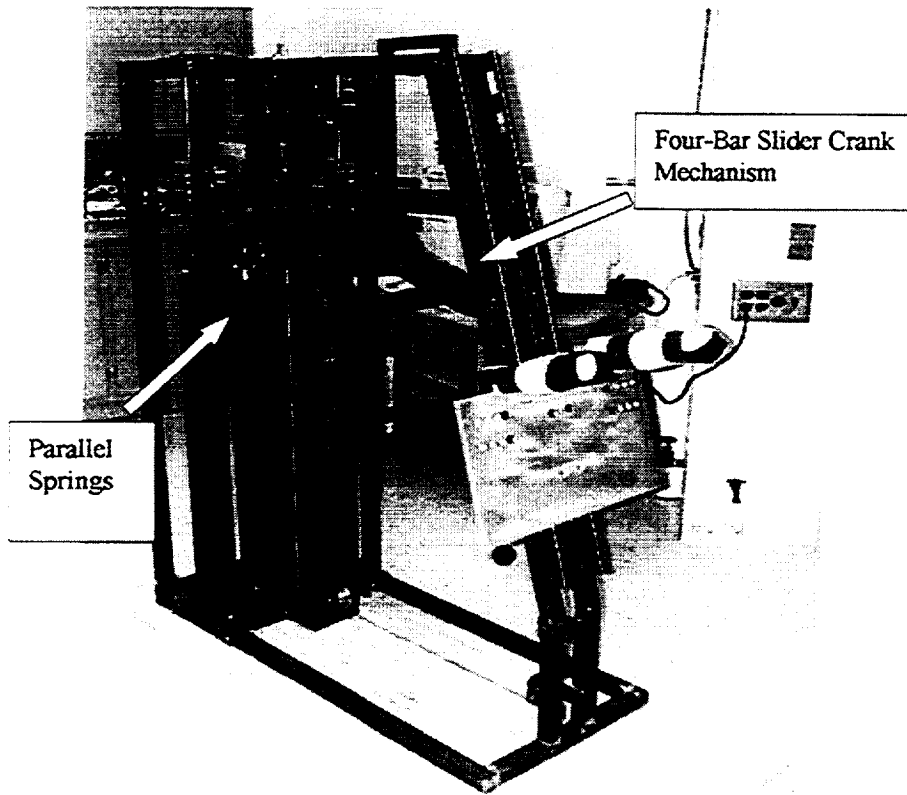
Figure 1. Internal Components of Spring-loaded Exercise Device without Padding

The purpose of the experiment is to verify that the device will function in micro-gravity as designed. When an individual lifts weights on earth, the amount of weight does not vary in the same way that spring force varies during spring-extension. The four-bar mechanism has been designed and sized to keep the amount of force exerted by the human subject constant throughout the 26-inch travel distance of the springs. This device was ground-tested before flight to determine the variation in force that is generated in a 1-g environment. Another question to be answered is whether or not the weight of the mechanism affects its function and how the exercise resistance would need to be adjusted for a micro-gravity environment. Our hypothesis is that exercise on this device will be easier in micro-gravity because the human subject will not have to move the weight of the human interface. Heel raises, one-legged squats, and two-legged squats were performed on both flight days using the padded back plate. It was decided to spend flight time testing different loads using the back plate and forego any testing using the ankle strap.

As shown in Figure 1, the SLED and exercise mechanism consists of a steel frame made from 1 ½ in. tubing and a ¾ in. thick plywood base plate. The steel frame has a length of 51 in. and a width of 21 in. and is less than 65 in. high. The SLED and exercise apparatus, from which all of the exercises are performed, are mounted to the top of the base plate. The internal components of the SLED are described below. Except for the human subject

interface, data acquisition system, and laptop, the SLED was encased in plexiglass for flight to prevent anything or anyone from floating into the mechanism.

The SLED consists of 16 parallel linear coil springs connected to a loading plate and then a four-bar slider crank mechanism that varies the force applied to the springs. This portion of the device is shown in Figure 2. There are five "5 pound" springs (k = 1.10 lb/in), three "25 pound" springs (k = 5.47 lb/in), and eight "75 pound" springs (k = 16.42 lb/in). These springs allow the load to be set in 5-pound increments with a minimum possible load of 20 lb and a maximum possible load of 700 lb. A subset of these springs was used on the KC-135 since the exercise load was much less than 700 lb. Before each flight, the resistance load was set for the subjects.
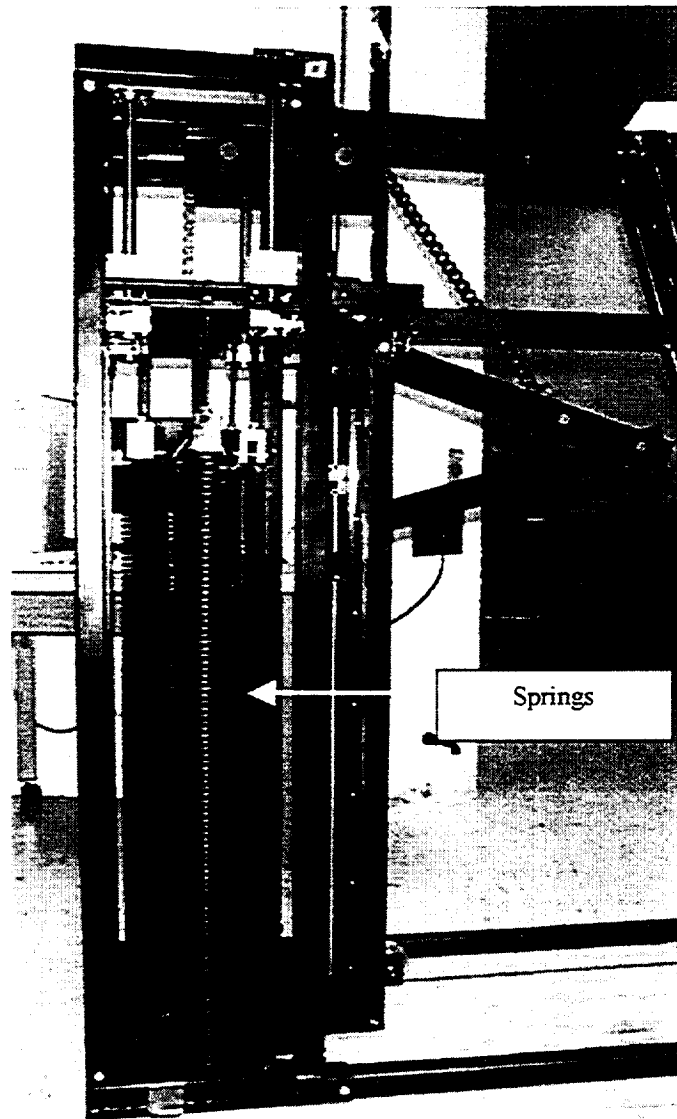
Figure 2. Spring-Loaded Exercise Device (SLED)

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The four-bar slider is attached to the human subject interface by a steel cable with a polymer covering. The cable runs through two or three pulleys on its way to the human subject interface, as shown in Figure 3.
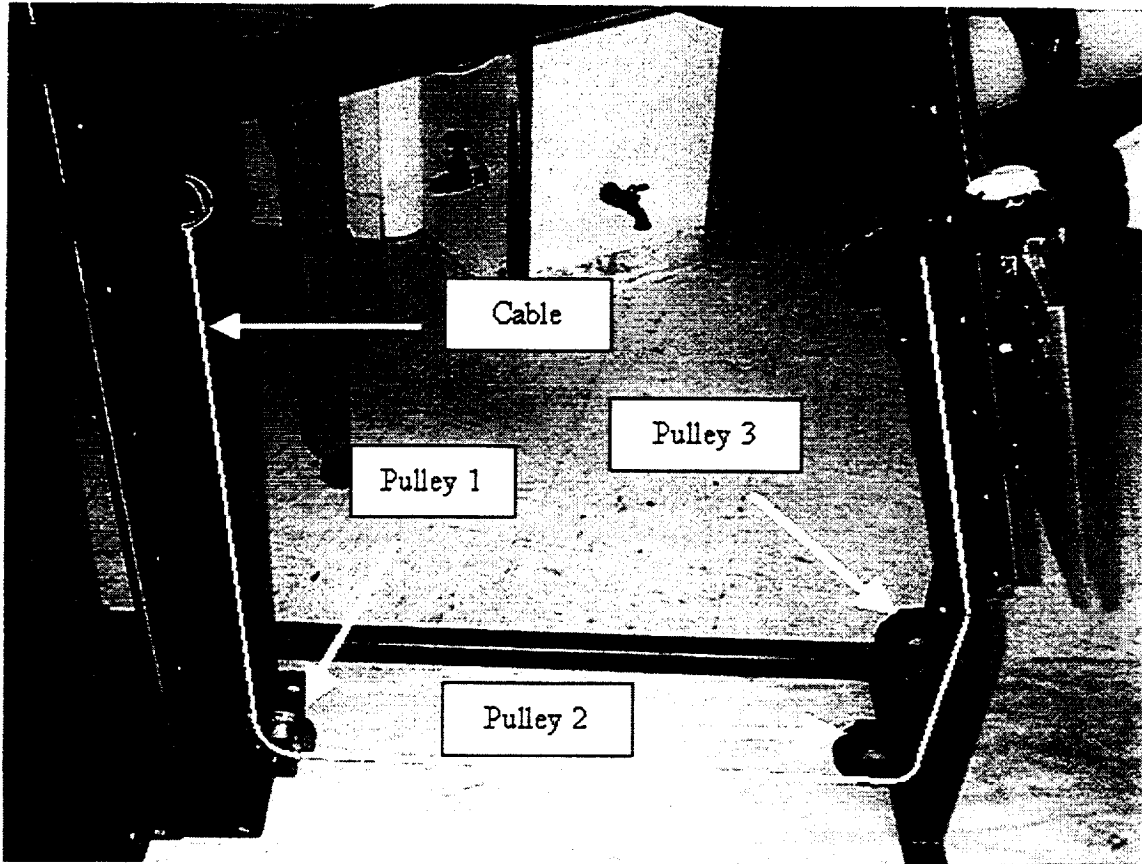
Figure 3. Cable Path using Back Plate

A rotary encoder is attached to Pulley 1 to measure the number of rotations of the pulley shaft and determine the amount of travel of the cable in each direction. A detailed illustration of this component of the device is shown in Figure 4.
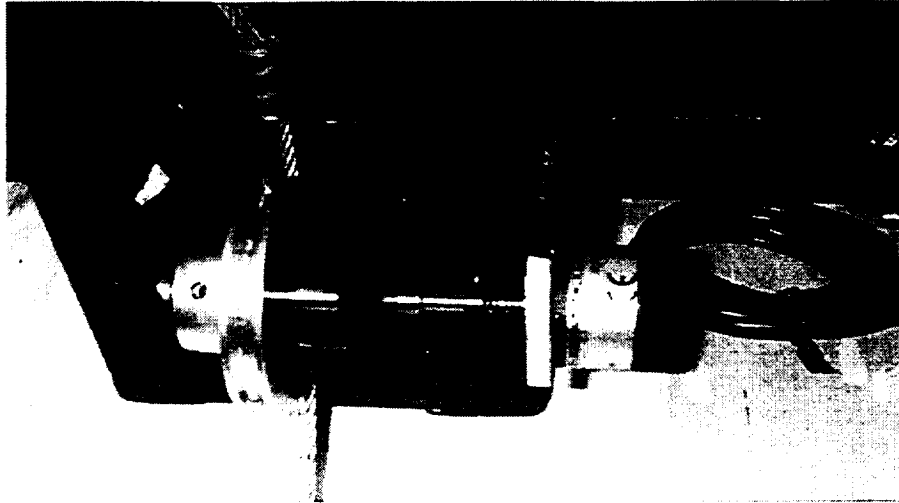
Figure 4. Rotary Encoder

After the cable passes through the final pulley, it is connected to a load cell to measure the amount of force generated by the human subject during exercise as shown in Figure 5. The rotary encoder and load cell are connected by electrical cabling to a data acquisition system (circuit board, data acquisition board, and laptop).
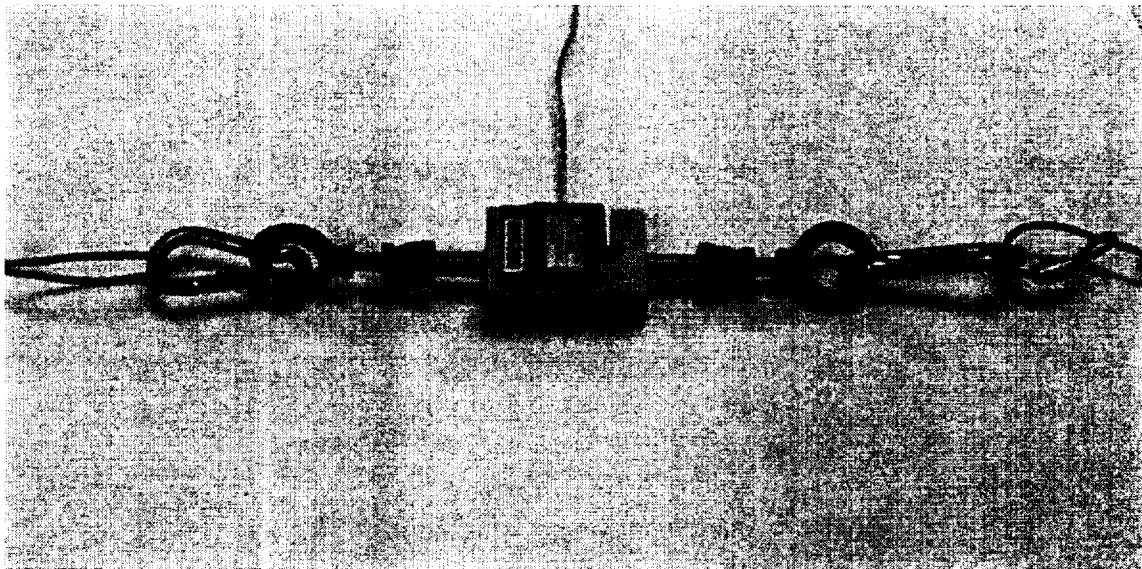
Figure 5. Load Cell

The user interface to be used for squats and heel raises is a padded back plate on a slider with two padded shoulder bars, which project out from it as shown in Figure 6. The back plate is wide enough to provide the human subject with some vertical stability during exercise.
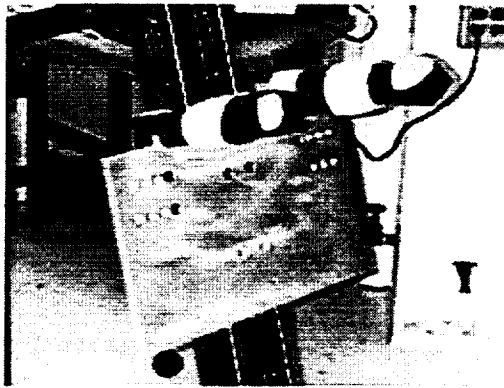
Figure 6. Back Plate (unpadded)

The layout of the equipment in the aircraft is shown in Figure 7. The SLED was oriented with the long direction of the device aligned with the fuselage of the aircraft with the human subject facing the rear of the plane for squats. The subject turned and faced the cockpit for heel raises.
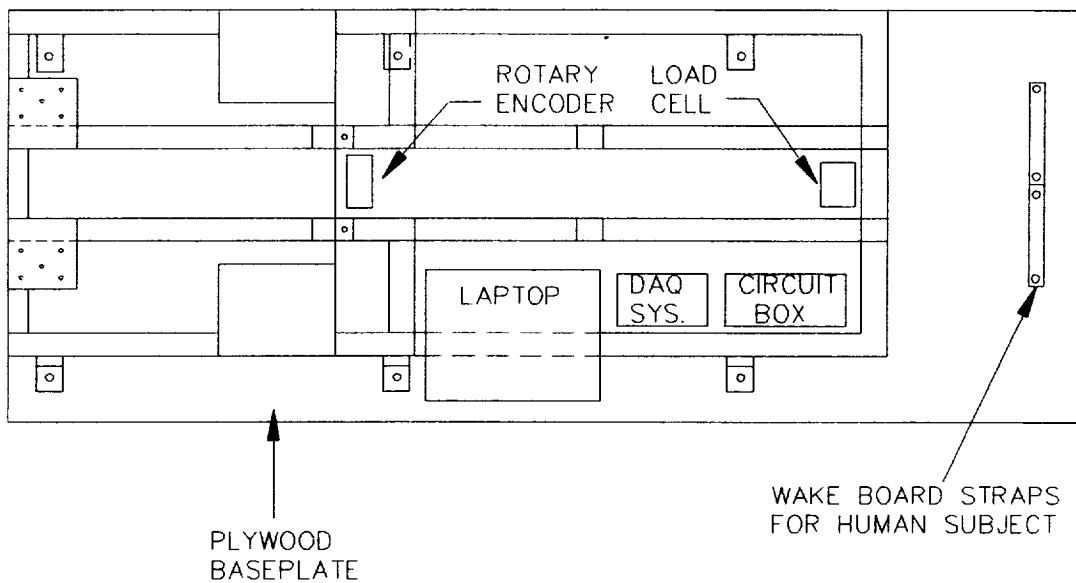
Figure 7. Equipment Layout Aboard Aircraft

Procedure

Each subject performed the exercises described below during zero gravity. The data were recorded through the data acquisition system on our laptop computer. While one subject performed the exercises, the other subject ran the computer and recorded which exercises were performed. Once a period of micro-gravity began, one flyer placed his/her feet in the foot straps and prepared for exercise while the test conductor positioned him/herself next to the laptop with legs under bungee cords. The exercisers found it convenient to stand or sit at the machine during 2g. The exercise procedures for the SLED follow:

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Exercise Procedures for SLED
- Squat
1. With knees in bent position place feet firmly on base plate under the foot straps; they should be placed flat and shoulder width apart
2. Place shoulders under shoulder bars
3. Push up until legs have fully extended while feet are maintained flat against the base plate
4. Return to initial position
5. Repeat for three to five reps
6. One legged squats are performed using the same procedure, but by removing one foot from the foot straps

- Heel Raises
1. Place feet in straps on base plate
2. Push back until legs have fully extended while feet are maintained flat against the base plate
3. Keep knees straight, lift heels up so that you are supported by the balls of your feet
4. Bring heels back to the base plate
5. Repeat for three to five reps

RESULTS/DISCUSSION:

We tested the device both on the ground and in flight aboard the KC-135. Results and discussion from both locations are described below.

Ground Testing
During initial testing of the mechanism, we discovered that the weight of the moment arm and backplate appeared to affect its performance on the ground. Some additional tests were planned for the KC-135 to evaluate how these components would perform in micro-gravity.

On the ground, the subject doing squats also had to lift the weight of the backplate, which was an additional 25 lbs. Thus, the subjects were not comfortable squatting more than 40 lbs on the ground. This relatively low load of 40 lbs was chosen as the exercise weight for the first day of flight. Although we thought that the exercises would be easier to do in micro-gravity, the possibility of some unforeseen resistance in the machine led to this decision. We felt that it was better to start out with a low load instead of discovering that the load was set too high and not being able to get any data on the first day.

After a squat, heel raise, or other exercise, the force from the springs must pull the moment arm back into its initial position. The moment arm is the component of the slider-crank that is attached between the slider and the chain and causes the force to remain constant, as shown in Figure 1. A minimum load of 30 lbs is

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required to reset the moment arm. Thus if the spring-loaded mechanism is set at its lowest load, the device will not reset itself. This was a problem during ankle exercises. The subjects were not comfortable lifting more than 25 lbs with the ankle straps when doing abduction and adduction exercises. Thus, it was decided to change the weight on the machine on the first flight day during level flight when the aircraft turned after the 20th parabola. Each spring is pre-tensioned by a rod that goes through its center as shown in Figure 8. The weight is changed by hand tightening a wing nut on the end of the appropriate spring above the top plate. A procedure was developed to disconnect a 25-lb spring and connect in a 5-lb spring to reduce the weight from 40 lbs to 20 lbs. This way it could be determined if the moment arm would reset itself at a low resistance load in micro-gravity. This would help to determine the capability of the machine for performing abduction and adduction exercises.
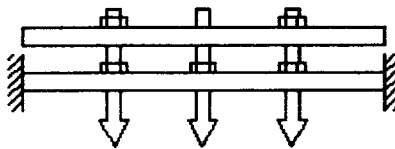
Figure 8. Pre-tensioning of Springs and Force Selection

First Flight Day
As described above, loads of 40 lbs and 20 lbs were chosen for the first flight day. The test subjects on the first flight day experienced little resistance from the device during the 40 lb and 20 lb procedures. The subjects commented that it felt like they were not doing any work; neither subject experienced fatigue. The load change procedure worked fine during flight, and the moment arm reset without any difficulty with the low 20 lb load in micro-gravity. Therefore, we determined that abduction and adduction exercises could be performed with relative ease in micro-gravity as opposed to the difficulty that occurs in 1g. The decision was made to alter the second day's flight plans from abduction and adduction exercises to the same exercises performed on the first day with an increased resistance of 100 lbs. This decision was made due to the fact that the team was testing the device as opposed to human performance on the device. Data were obtained from both resistance levels from the first day for both subjects during two-legged squats, one-legged squats, and heel raises. Currently the data are being analyzed to determine the amount of travel and force that was actually experienced by the subjects.

Second Flight Day
During the equipment setup following take-off on the second day, difficulties were experienced with the computer and with the instrumentation. After the first turn, approximately 10 parabolas into the flight, the computer began to work properly, but the instrumentation was still not able to collect data. Discussion of the second

day of flight is based on the comments made by the subjects and on the video that was made of the exercises.

One test subject noted a significant amount of resistance from the device with the 100 lb load. This test subject determined that an excellent workout could be performed with the device at the higher resistance level. A second test subject experienced fatigue in the legs after several repetitions on the device. She stated that it felt like she was squatting between 70 and 80 lbs. Other than this difficulty with the instrumentation, the SLED functioned adequately on the second flight day.

CONCLUSION:

The team has determined that the SLED and its user interface will function in micro-gravity. The user interface places an additional load on the subject in ground-based studies that does not have to be overcome in micro-gravity. The subjects were easily able to change the load resistance during flight without the use of any hand tools. The data collected on the first day of flight is currently being analyzed. Therefore, it has yet to be determined if the resistance levels are constant and equal to their nominal values.

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JSC2001E05150 to JSC2001E05152

VIDEO:

- 2001 Student Campaign: Week of 2/26/01, Group A Flight 1&2 on Feb. 27-28, 2001, Reference Master: 619709

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights – The Effects of Gravity on Human Information Processing

FLIGHT DATES:
February 27 – 28, 2001

PRINCIPAL INVESTIGATORS:

Ericka Rovira, The Catholic University of America
Chris Rogers, Tufts University
Christina Connor Cerezo, Tufts University
Jesse Cornely, Tufts University
Alicia Scarfo, Tufts University

NASA Photo: JSC2001E05028

PURPOSE:

The purpose of this research was to investigate if differences existed in human information processing in zero gravity versus in earth's gravity. Further, the researchers were interested in examining which type of display features aided information processing.

METHODS AND MATERIALS:

Participants included three females and one male; their ages ranged between 22 and 23 with a mean age of 22.5. A within-subject factorial design was used. The three independent variables included a gravity condition with two levels: zero gravity and earth's gravity; a memory set with two levels: high (four items) and low (two items); and display type with four levels: color, analog & digital, heavy font, and LEDS. The theoretical underpinnings of the task were modeled after the Sternberg memory task (Sternberg, 1966), which is well validated. The processes assumed to take place in performing this task include perceptual encoding, central processing, and responding.

RESULTS:

Total reaction time increases linearly with the number of items in the memory set. Therefore, the slope of this function relating reaction time to memory set is therefore assumed to inversely reflect the efficiency of memory search (Wickens, 1986). Using laptops, the participants were shown a set of displays with different values and were asked to memorize them. They were next shown a probe and needed to respond by determining if the probe was part of the memorized set or not. Reaction times were recorded by computers and then repeated into tape recorders. The data were analyzed using a 2(gravity) X 2(memory set) X 4(display type) repeated measures ANOVA. We observed significant effects of gravity and memory set. Reaction time increased as memory set size increased, $F(1,3) = 21.016$, p=.019. Reaction time increased in zero gravity, $F(1, 3) = 19.799$, p=.021. There was a significant interaction of memory set and gravity, $F(1, 3) = 8.976$, p=.058. Such that information processing time as a function of memory set size is significantly different in zero gravity than in earth's gravity. Figure 1 depicts these results.

Figure 1

RT As A Function of MSet : Zg vs Eg

Memory Set (MSet)
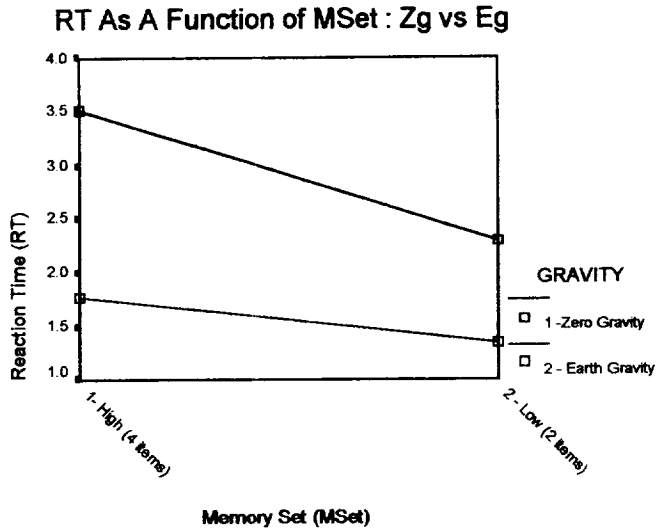
Display type means were inspected and they indicate that in all conditions heavy font produced the shortest reaction time. Figure 2 depicts this result.

Figure 2

Display Means

Display Types
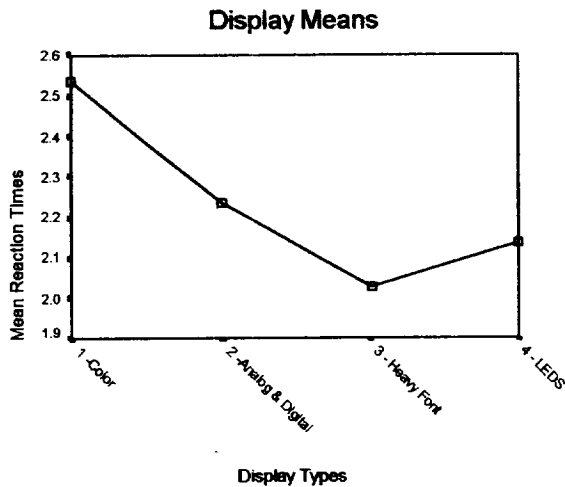
DISCUSSION/CONCLUSION:

Observations based on our preliminary analyses suggest that gravity affects the efficiency of human information processing in novice zero gravity participants. This suggests that the impact of the external factor, zero gravity, imposes an increased load on human capacities which is probably due to adaptation. In addition, heavy font displays aid in processing values more efficiently.

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JSC2001E05134 to JSC2001E05135
JSC2001E05149

VIDEO:

- 2001 Student Campaign: Week of 2/26/01, Group A Flight 1&2 on Feb. 27-28, 2001, Reference Master: 619709

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights – Single Rescuer CPR Augmented with the Kendall
Cardiovent Device is as Effective as Standard Two Rescuer CPR in Microgravity

FLIGHT DATES:
February 27 – 28, 2001

PRINCIPAL INVESTIGATORS:
Heather Goldsmith, Brown University
James Battat, Brown University
Joseph Maurer, Brown University
Hannah Cohen, Brown University
Gregory D. Jay, M.D., Ph.D., advisor, Brown University

NASA Photo: JSC2001E05034

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GOAL:

To determine the effectiveness of Kendall-assisted cardiopulmonary resuscitation (CPR) in a microgravity environment.

OBJECTIVE:

Standard two-rescuer CPR and one person Kendall-assisted CPR are performed in microgravity on a recording CPR Kelly Torso ventilation mannequin (Medical Plastics Laboratory). Depth of chest compression and tracheal airway flow are measured to quantify the effectiveness of each CPR technique.

INTRODUCTION:

Cardiopulmonary resuscitation in zero gravity remains a challenge that has not been adequately addressed. This looms as a larger issue with the construction of the international space station (ISS). The large size of this facility requires that crew members initiate some form of immediate but temporary resuscitative measures, buying time before an external automatic defibrillator can be located and applied. Under terrestrial conditions we know that CPR is most effective when two rescuers are sharing ventilations and chest compressions. Two rescuers are less likely to fatigue but must coordinate their efforts. The most effective position in which to perform CPR in microgravity is a subject of debate. Limited CPR studies performed by NASA in the KC-135 flying a parabolic trajectory have resulted in three recommendations: side straddle (i.e., the standard terrestrial position), patient straddle where the rescuer is facing the patient and a handstand position where the force of compression is generated by the rescuers quadriceps muscle groups.

The NASA studies to date have largely focused on the ergonomics of doing CPR which enabled the design of the Crew Medical Restraint System (CMRS). One intended purpose of the CMRS is a CPR platform which will also restrain the patient. There have been no studies which compared the effectiveness of the different approaches for rescuer positioning in microgravity. Similarly, there has been no investigations of CPR adjunct devices such as the CPR thumper and CPR vest which have been used both routinely and experimentally for sometime.

This study was undertaken to compare the depth of compression for the three recommended CPR positions in microgravity. For each position, comparison was also made for standard two-rescuer CPR and a single rescuer augmented with the Kendall Cardiovent device. This device is a CPR bellows system. The rescuer performs chest compressions with the bellows collapsed. After every 5 compressions, the rescuer allows the bellows to inflate from an oxygen source followed by gentle compression which completes a ventilation through a valved side port connected to either an endotracheal tube or face mask. In this manner, a single rescuer can provide two-rescuer CPR without

the inherent coordination demands. In the microgravity environment we hypothesize that a single rescuer with the Cardiovent device will be more effective than two rescuers.

METHODS AND MATERIALS:

Simulated Microgravity Environment
The KC-135 flying repeated parabolic trajectories was utilized to produce an artificial microgravity environment. Each parabola generated weightlessness for 22 seconds. There were two flights and 30 parabolas in each flight. The KC-135 mission at the time was in support of undergraduate student research activities termed "Student Campaign 2001". On both flight days parabolas were performed within an altitude range of 24,000 to 36,000 feet.

Human Subjects
Four undergraduate college students served as rescuers performing CPR in both the standard side straddle position and a handstand. All participants were certified by the American Heart Association (AA). As the students were not research subjects there were no IRB concerns.

CPR Mannequin
A CPR training mannequin (Medical Plastics Laboratory) was instrumented with a sliding variable resistor which varied from 5K to 0 as chest compression varied from 0 to 1.8 inches. This variable resistor composed one resistor element of a standard Wheatstone bridge configuration. The bridge was powered with a 6VDC lantern battery. The mannequin was also equipped with a 7.5 mm I.D. endotracheal tube. Airway pressure was recorded using a stand alone transducer capable of sensing airway gage pressure changes of up to 5 psi (Sensym Inc.). This device had an internal Wheastone bridge, powered by 12 VDC and was equipped with a reference ambient pressure port which compensated for changes in cabin pressure.

Two types of CPR were performed. Two rescuers using a standard bag-valve-mask and one rescuer using the Kendall Cardiovent device. The Kendall device was covered with velcro over the area that contacted the mannequin's chest between the nipples, two finger-breadths above the xiphoid. This was done to facilitate the positioning of the device as its presence obfuscated these anatomical landmarks. During the Kendall trials, one of the two rescuers used this opportunity to rest and alternated as the flight progressed.

Crew Medical Restraint System (CMRS)
The CPR mannequin was rested on the CMRS which served to strap the mannequin into a supine position 10 inches from the flight deck. The CMRS is the principal patient restraint system for the International Space Station. The CMRS anchoring tracks were bolted to a 3 x 4 ft plywood sheet which was in turn bolted to the K135 flight deck. Straps intended for the crew medical officer were used by the rescuers performing CPR.

Data Collection

Analog outputs from both the compression and airway pressure sensors were digitized using a MP100 analog to digital converter (Biopaq Inc.) connected to a Macintosh 1400 laptop computer running Acknowledge software (Biopaq Inc.). The MP100 also provided the 12VDC bias voltage for the airway pressure transducer. The computer, analog to digital converter and battery were fixed with velcro and strapped into a plexiglass case which was in turn bolted to the flight deck following standard procedures. Foam of two types, differing in compliance, was strategically placed in this assembly to dampen vibration.

Data files were collected for each type of CPR performed: 2 rescuers using a bag-valve-mask and 1 rescuer using the Kendall cardiovent device. This was done for two types of positioning: standard AHA side straddle and a handstand. Thus four different file types were created and saved in flight. Rescuers performed each CPR type-position over at least 4 parabolas, leaving the opportunity to repeat those which were confounded by technical difficulties or motion sickness. An identical effort was repeated on the ground providing a comparison terrestrial data set.

CPR Device Pre-calibration

The bag-valve-mask selected was capable of generating a maximum tidal volume of 850ml (Manufacturer). The Kendall device was adjusted to match this tidal volume. A pre-flight side-by-side comparison was performed to confirm that both devices generated equal pressure-time profiles. The mathematical integration feature of Acknowledge was used for this purpose and for the actual data analysis of pressure change over time.

Data Analysis

Dependent measures included compression depth, frequency of compression-ventilation cycles per unit time and endotracheal tube pressure change per unit time. These data were collected *post hoc* using Acknowledge to analyze each collected file. Confidence intervals around each measure were created for each CPR type-position. Statistical comparisons were performed using the two-tail Student's T test, box plot and analysis of variance (ANOVA). The level of significance was set *a priori* as $p < .05$.

RESULTS:

Depth of compression and tracheal air flow were recorded for CPR cycles in the handstand and side positions with the Kendall device, and in the handstand position using the ambu bag ventilation device during periods of microgravity. From these data, depth of compression and work of breathing statistics are calculated. Two experimenters flew on each day of the two-day trial period, with hopes that each experimenter would perform all permutations of CPR. A combination of technical difficulties and motion sickness, however, forced a reduction in the number of trials. Table 1 lists the CPR scenarios for which data was acquired.

	Compression Depth	Breath Data
Kendall Side	.55 inches	To be available
Kendall Handstand	1.48 inches	To be available
Two-Person Side	NONE	NONE
Two-Person Handstand	.88 inches	To be available

Table 1

Depth of Compression

The mean depth of compression for 2-person CPR in the handstand position is 0.88 inches. Kendall-assisted CPR in the handstand position had an average depth of compression of 1.48 inches, while Kendall-assisted CPR from the side had a smaller depth of compression at 0.55 inches (See Figure 1). The recommended depth of compression for CPR is 1.5 inches. These data demonstrate that the use of the Kendall device in microgravity does not lessen the quality of chest compressions.
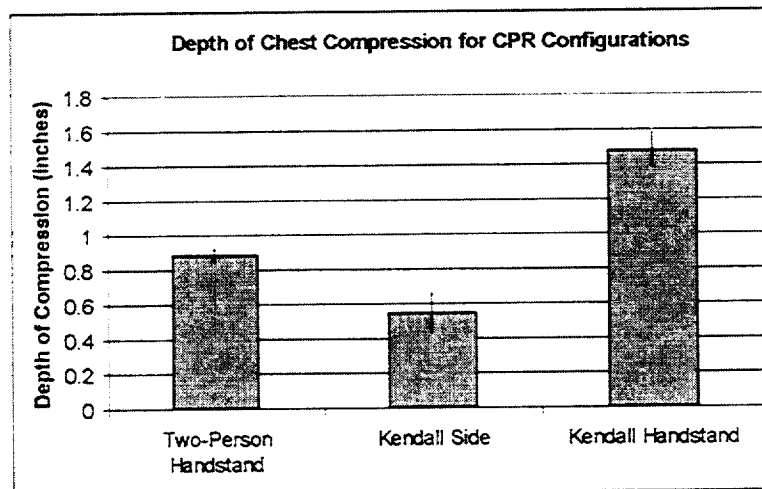
Figure 1
The average (with standard deviation) depth of chest compression for the three CPR positions tested in microgravity. The American Heart Association recommends a 1.5 inch depth of compression.

Work of Breathing

Technical difficulties during the Day 1 flight caused a failure in the airway data collection mechanism. The work of breathing for Day 2 data will be calculated. Currently, however, software problems prevent adequate analysis. Qualitative analysis of the breath data shows fidelity between ambu bag breaths and Kendall device breaths, but quantitative

analysis will follow when possible. Please consult the Brown University Spring 2001 ZeroG Student Campaign website:

http://www.brown.edu/Students/Brown_Space_Club/february01/

for updated information as it becomes available.

Position Comfort

The standard CPR position and a handstand position were tested. Even with the CMRS's adaptations, such as rescuer straps and hand holds, the side position proved frustrating and ineffective. Rescuers found themselves unable to provide compressions and remain securely positioned close to the dummy's chest. The significantly greater depth of compression in the handstand position signals the ineffectiveness of the standard side position in microgravity.

Rescuers found the handstand position comfortable and effective. Transitioning from a seated position to the handstand position proved difficult for Day 1 experimenters, however the Day 2 experimenters were able to make the transition comfortably. The need to repeatedly transition between a seated position and a handstand position are an artifact of the testing environment provided by the KC-135. In outer space, the rescuer can remain in the handstand position as long as needed.

DISCUSSION:

CPR with the Kendall device is as effective as standard two-person CPR in depth of compression. Furthermore the handstand position provides the rescuer with maneuverability and control both over him or herself and the CPR motions.

One limitation of this study was the technical difficulty during Flight Day 1. Due to the plane's vibrations, the electronics system failed and the data on depth of compression and tracheal air flow were not recorded. In addition, three experimenters experienced motion sickness and were therefore unable to carry out the experiments protocol in its entirety.

Another limitation of this study was the pre-intubation of the mannequin. In this experiment, the mannequin received ventilation through a pre-inserted tracheal pipe, however the process of intubating a patient in microgravity was not studied. An upcoming Brown University experiment will evaluate methods of patient intubation in a reduced gravity environment, thereby adding to the robustness of our emergency medicine study. It would also be worthwhile to study the effectiveness of the Kendall device when used with a face mask or other airway adjunct. It may not be valid to extrapolate the results of this experiment to conclude that the Kendall is an effective CPR device when the patient is not intubated.

CONCLUSION:

The Kendall Cardiovent bellows is an effective and beneficial CPR adjunct. One rescuer can provide the intubated patient with adequate chest compressions and breaths without

changing positions. Furthermore, a handstand rescuing position is a comfortable position in which the rescuer retains control over the CPR procedure. In a reduced gravity environment, where precision maneuvers are difficult to carry out, it is important to have a simple protocol in emergency situations. In addition, there are limited numbers of astronauts present on shuttle or on the International Space Station at any given time. Should an astronaut require cardiopulmonary resuscitation, then, with the use of the Kendall device, one rescuer could, in a controlled manner, provide CPR chest compressions and breaths without changing position. For this reason, the Kendall device, if proven effective with other airway adjuncts and a face mask system, should be stored on ISS as a component of the emergency medical kits.

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JSC2001E05132
JSC2001E05138
JSC2001E05145 to JSC2001E05146
JSC2001E05155

VIDEO:

- 2001 Student Campaign: Week of 2/26/01, Group A Flight 1&2 on Feb. 27-28, 2001, Reference Master: 619709

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights – Advanced Pollination in Microgravity

FLIGHT DAYS:
February 27 – 28, 2001

PRINCIPAL INVESTIGATORS:
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Tiffany Allison, LU
Shae Saur, LU
Autumn Gremillion, LU
Daniel Bingham, LU
Brian Sattler, LU
Dr. Jim L. Jordan, faculty advisor, LU

NASA Photo: JSC2001E05024

GOAL:

To advance our understanding of pollinating plants in microgravity.

INTRODUCTION:

The proposed experiment will advance our understanding of the procedures involved with plant reproduction in a microgravity environment. Such knowledge will be valuable for the development of life support systems that will be needed as we pursue long-term human presence in space. The results from the proposed experiment will be presented in several forms, including K-12 presentations, conferences, radio, national print media, seminars, workshops, and television media presentations. In addition, a summary and photographic record of the experiment will be made available on the Internet.

METHODS AND MATERIALS:

Ground Operations
Ground facilities/equipment was not needed to operate our experiment.

Pre-Flight
A 115V outlet was needed to operate video cameras.

In-Flight
Level Flight Pollination: **Group 1-g (Plants A-O)**
Turned on the digital cameras and initiated the recording cycle. Pollinated the first group of plants allowing for the same amount of time as in five parabolas.
- Opened lid
- Used pollination probe for transport of pollen from anthers to stigmas (dowel rod with bee abdomen; pollination brush).
- Retrieved pollen from Plant A's anther.
- Transported pollen to Plant B's stigma.
- Retrieved pollen from Plant B's anther.
- Transported pollen to Plant C's stigma.
- Retrieved pollen from Plant C's anther.
- Transported pollen to Plant A's stigma.
- Closed lid
- Repeated procedure for next 4 sets of plants, D-F, G-I, J-L, M-O, using the same length of time as a parabola for each set.

Control Group: **Group Control (Plants A-O)**
Control group remained closed throughout the flight.

Microgravity Manual Pollination-Parabolas 1-5: Group 0-g (Plants A-O)
- Opened lid.
- Used new pollination probe.

- Retrieved pollen from Plant A's anther.
- Transported pollen to Plant B's stigma.
- Retrieved pollen from Plant B's anther.
- Transported pollen to Plant C's stigma.
- Retrieved pollen from Plant C's anther.
- Transported pollen to Plant A's stigma.
- Closed lid
- Repeated procedure for next 4 sets of plants, D-F, G-I, J-L, M-O.

Post-Flight:
Removed pollinated plants for transfer back to growing facility, and readied apparatus for the second flight with fresh plants.

RESULTS:

First Flight:
No data available.

Second Flight:
Using synthetic pollination wand as means for transporting pollen.

Group Control:
    6 seeds
Group 0-G:
    4 seeds
Group 1-G:
    11 seeds

Due to a one to two day discrepancy in our estimation of plant flowering time, there were few flowering plants on the first flight day. It was our decision to reserve those few flowering plants for the second flight day in the hope that more plants would reach maturity at that time. For this reason, we were unable to collect data on the first flight date. Sure enough, by the next day, many more plants had bloomed. For the second flight, there were a sufficient number of flowering plants available for group 0-G, and group 1-G—only 1/3 of group control had flowering plants, therefore yielding incomplete data for group control.

DISCUSSION:

Prior to growing the plants used during flight, tests were preformed to determine the germination period. These tests were preformed using standard florescent bulbs as the light source, and bee abdomens as the pollinating agent. These plants produced approximately double the amount of seeds the flight plants produced.

We were faced with a problem; there was no way to be certain of our exact flight dates. This was crucial to our experiment as the results from our previous tests indicated a three-day pollinating window. Allotting the amount of time previously needed for the Astro-plants to flower, we planted on two consecutive days. Our mistake was here—we should have planted larger groups of plants over a period of several days. Had we done this, the likelihood of having a sufficient number of flowering plants for both our flight dates would have increased dramatically. Funding was one of our problems in this area. There was only one set of lights for the plants; we filled the area in the light field. Ideally, we should have had two to three more light setups for the growing process. This would have ensured a sufficient number of flowering plants for an accurate experiment. In an effort to accelerate the growing process for our flight plants, we exchanged the standard bulbs for special grow lights. This produced an adverse effect on our experiment slowing the growth time of the plants.

CONCLUSION:

Alvin Community College flew a similar experiment aboard the KC-135 previous to our flight. Due to their pollinating technique approximately one-third of the plants were left unpollinated. Although they did not produce a final report an email to their mentor states that out of 54 plants, 22 plants had seed pods. We corrected the pollinating technique therefore allowing optimum pollination. From our observation of the pollination of plants before the flight, we feel that the bee abdomen is a more effective pollinating agent than the synthetic wands.

PHOTOGRAPHS:

JSC2001E05024
JSC2001E05035
JSC2001E05041
JSC2001E05043
JSC2001E05047
JSC2001E05061
JSC2001E05131
JSC2001E05137 .

VIDEO:

* 2001 Student Campaign: Week of 2/26/01, Group A Flight 1&2 on Feb. 27-28, 2001, Reference Master: 619709

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights –
Test #1: Human perception and Spatial Orientation: Effects on Motor Coordination

FLIGHT DATE:
March 1, 2001

PRINCIPAL INVESTIGATORS:
Elizabeth Jackson, San Francisco Art Institute (SFAI)
Lorelei Lisowsky, SFAI
Thomas Proctor, SFAI
Pamela Servatius, SFAI
Ethan Vosburgh, SFAI

CO-INVESTIGATOR:
Coral Clark, faculty advisor, SFAI

NASA Photo: JSC2001E05207

GOAL:

To determine whether providing human test subjects in a weightless environment with a visual orientation cue (VOC) will increase their motor coordination and slightly decrease their time to perform a specified test task.

INTRODUCTION:

Students enrolled in the San Francisco Art Institute's class "Motion in Comparative Environments" developed the experiment as a team-based class project. Students chose the topics, motion and perception, because they bridge science, art, and human experience in changing environmental conditions, such as micro-gravity.

A continuing difficulty with space travel is disorientation of astronauts in the micro-gravity environment resulting in space sickness, impaired motor coordination, and/or hallucination. Humans and other animals exhibit changes in behavior and coordination, ranging from permanent lack of ability to function normally to rapid adaptation to changing gravitational conditions. The range of reactions to micro-gravity is illustrated on every flight of the KC-135.

Recently, astronauts have reported difficulty in maintaining the increasingly complex computer systems aboard the space station and space shuttle. The visual and vestibular systems provide frames of reference for the central nervous system to build its understanding of the environment. In the case of weightlessness, the user's ability to interact with objects in the environment is greatly affected by the lack of vestibular cues. Like any tool, computer interfaces need to be designed with the user and environment in mind, and the increased dependence on visual orientation cues must be considered when designing systems for use in zero gravity.

Our experiment asks the subject to perform a simple point-and-click test while wearing a head mounted display (HMD) and hand-mounted pointing device, in zero gravity. The HMD is intended to remove all external visual orientation cues and provide the subject with a circular test field, a circular cursor, and a circular target. Upon entering zero gravity, the subject double-clicks with the pointing device, and moves the cursor to the target. Each time he clicks on the target, it repositions itself on the screen. The subject attempts to hit the target as many times as possible during the parabola. Half of the parabolas have a blank black background and half have a visual orientation cue that indicates "up" and "down to the subject. The software records the mouse's X and Y coordinates every sixtieth of a second, misses, and successful hits. After 24 seconds (the length of the parabola) the test times out, to be reactivated on the next parabola.

Scientists seeking to understand human spatial orientation, and its reliance on gravity, will be able to use information gathered from such an experiment to aid the development of better human-computer interfaces for use in zero gravity and on earth.

We hypothesized that the user would perform significantly better in the presence of the VOC.

METHODS AND MATERIALS:

Subjects
The proposed experiment was to carry out the test on the four flying team members. Due to the cancellation of the second flight and motion sickness of one of the flying members, we were only able to perform the test on one subject. Prior to the flight, the subject was asked to fill out a questionnaire on his past experience with motion sickness, computers in general, and the specific equipment to be used in the test. The subject reported no past experience with motion sickness, severe or otherwise, and reported little or no time spent on roller coasters, sky-diving or in similar acts. The subject reported familiarity with computers, had spent approximately 20 hours using the equipment used in the test, and over 100 on the software, in development and testing.

Instruments
We did quite a bit of research on makes, models and prices of HMDs available, and eventually decided on the i-Glasses LC manufactured by i-o Display Systems. We used a hand-mounted trackball as a pointing device and ran our custom test software from an IBM ThinkPad laptop that was strapped to our test equipment data package. The subject was secured to the cabin floor by a surf leash so they could perform the tests without floating away. The software used for the test was written in Macromedia Director using the Lingo programming language called gravOrienTest. It ran the test and recorded data to a file on the hard drive for later analysis.

Procedure
The subject secured himself to the plane and readied the computer and devices during the first ten parabolas. On the eleventh parabola, at the onset of zero-gravity, the subject double-clicked the cursor to initiate the test. The test software makes one of every two parabolas an experiment and the other a control. During the control parabolas, the cursor and target appear over a black background (fig.1), and during the experimental parabolas it features them over a background image (fig.2). The background image is of a country road stretching away to the horizon. The subject attempts to click on the target as many times as possible.
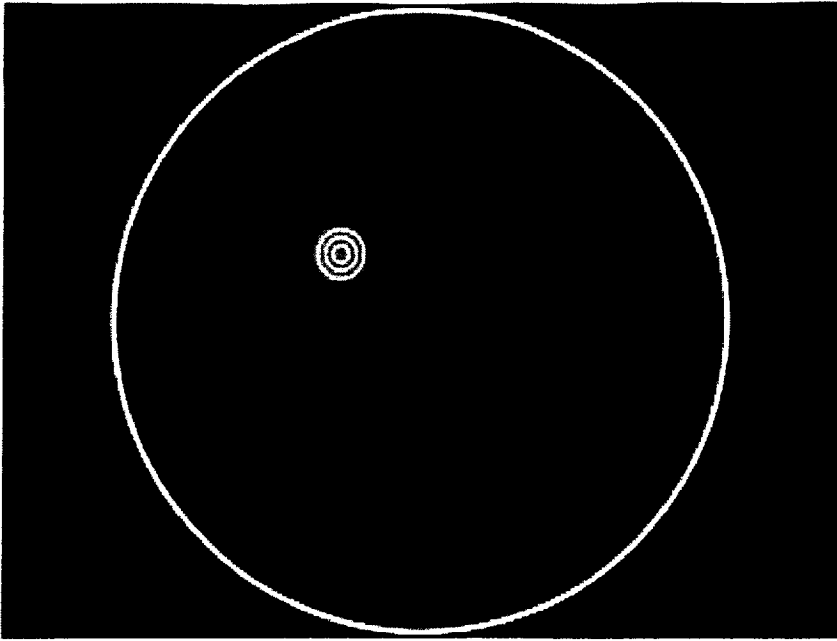
Figure 1: gravOrienTest screen w/o VOC
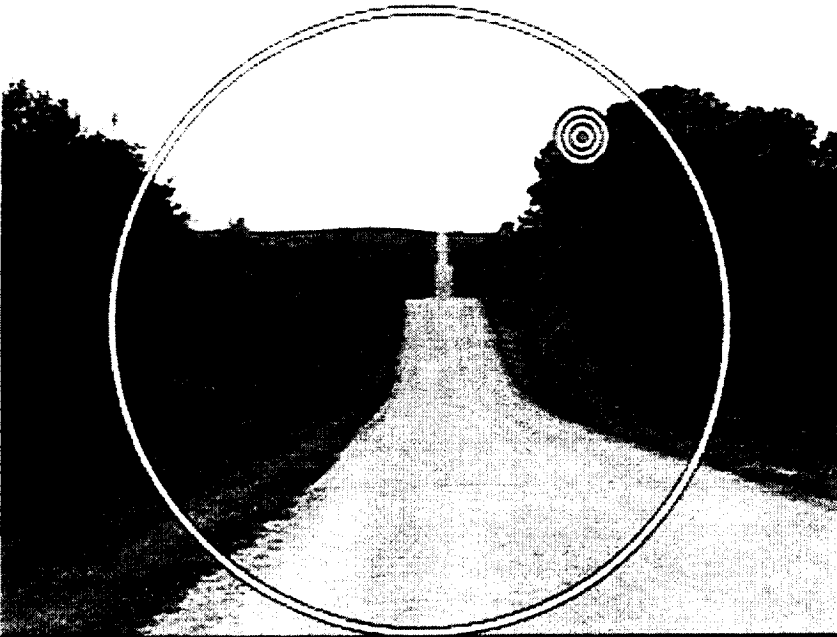
Figure 2: gravOrienTest screen w/ VOC

RESULTS:

Our results show significantly better performance in the parabolas without the visual orientation cue. There was an average of 9.3 successful hits during VOC-absent parabolas and 6.3 during VOC-present parabolas. In addition, there was an average of 1.13 misses during VOC-present parabolas and 0.29 during VOC-absent parabolas.

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DISCUSSION:

There were several factors that interfered with the accuracy of the intended experiment. First and foremost was the visibility of external visual orientation cues around the edges of the head-mounted-display. The subject reported that he was able to infer his orientation from these rather directly throughout the flight. The VOC on the screen was such that it reduced contrast between the target and the background, so that the subject may not have spotted the target as readily as over the blank background. In addition, the restraint system used to tether the subject was designed with the other team flyer acting as a "spotter." Severe motion sickness on the part of the second flyer required the subject to look after himself, which presented quite a challenge in addition to the test itself. Finally, the lack of additional subjects or a second flight left us with only one data point.

CONCLUSION:

Although our data points toward greater accuracy without the VOC, we feel strongly that the inaccuracies of the experiment and single data point make it unreliable. We have submitted a revised proposal for another flight in August which addresses the above concerns. We will be looking into purchasing more immersive HMDs, or at the very least modifying the i-Glasses to block the visibility of external orientation cues with an opaque hood. The subject restraint system will be more secure and will eliminate the need for a "spotter." Also, importantly, the VOC will be changed to a less obtrusive horizon plane to keep the background/target contrast at the same level as in the control parabolas (fig.3). We feel these modifications, and four more data points will provide significantly improved data and allow us to draw a more solid conclusion.
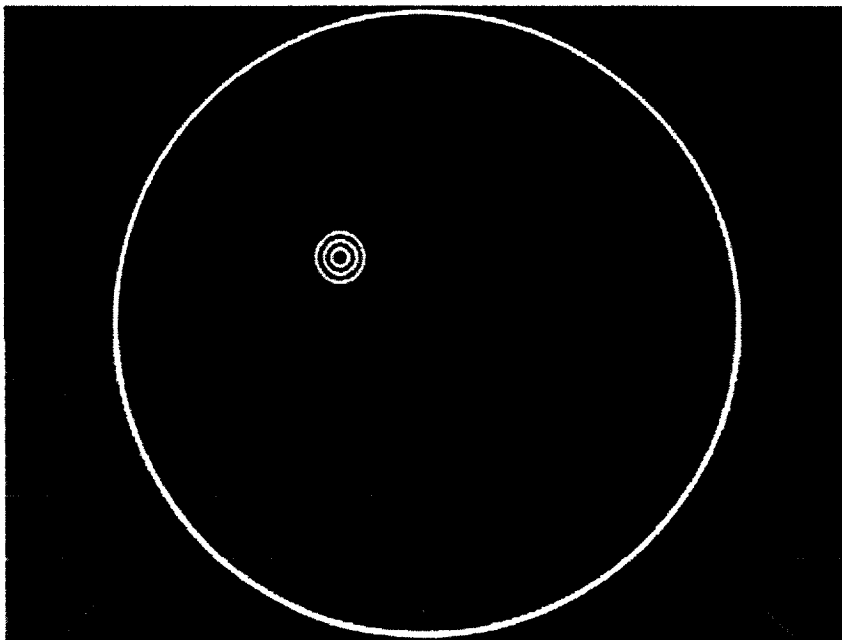
Figure 3: gravOrienTest screen w/ improved VOC

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PHOTOGRAPHS:

JSC2001E05162 to JSC2001E05163
JSC2001E05168 to JSC2001E05170
JSC2001E05181
JSC2001E05206 to JSC2001E05207

VIDEO:

- 2001 Student Campaign: Week of 2/26/01, Group B Flight on March 1, 2001, Reference Master: 619710

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights –
Test #2: *Danaus plexippus* (Monarch butterfly) Coordination and Acclamation to a Micro
Gravity Environment

FLIGHT DATE:
March 1, 2001.

PRINCIPAL INVESTIGATORS:
Elizabeth Jackson, San Francisco Art Institute (SFAI)
Lorelei Lisowsky, SFAI
Thomas Proctor, SFAI
Pamela Servatius, SFAI
Ethan Vosburgh, SFAI

CO-INVESTIGATOR:
Coral Clark, faculty advisor, SFAI

NASA Photo: JSC2001E05181

GOAL:

To determine whether or not the *Danus plexippus* (Monarch butterfly) will adapt rapidly to a weightless environment.

INTRODUCTION:

Butterflies instinctively exhibit chaotic flight paths, most likely an instinctual defense behavior. However due to the chaotic nature of danaus plexippus flight, their existing navigational methods, navigating with rapidly changing visual input, may allow them to adapt quickly to changing gravitational environments. Based on their adaptable flight behavior in normal earth environment, we anticipated that they would rapidly adapt to changes in gravitation acceleration.

METHODS AND MATERIALS:

Test specimens
All six *Danaus plexippus* test specimens were videotaped on the ground (normal Earth gravity) so that their motion could be analyzed and compared to their flight aboard the KC-135 Turbojet. The test specimens were then videotaped for all 30 Parabolas on the K-C 135. We were looking at each test specimen in terms of number of flights in a ten minute period, time aloft for each flight and number of wing beats per flight We had predicted that by the 20th Parabola that the majority of test specimens would demonstrate at least one controlled flight during a period of micro gravity.

Instruments
All six-test specimens were enclosed in a clear Plexiglas cylinder 12 inches in diameter x15 inches in height. The cylinder was covered with a screen to allow for loading and unloading of the test subjects. The test specimens were then videotaped in flight.

RESULTS:

The test specimens did not demonstrate any controlled flights. They floated to the top of the enclosure and attached themselves to the screen on the top of the cage, slowly opening and closing their wings. While they did not display a controlled flight at any time during periods of micro-gravity, they did display typical at rest behavior for the Monarch.

DISCUSSION:

After observing the test specimen's behavior on their first flight we decided to cover the screen on the top of the enclosure with wax paper so they would not have a place to land. We believe that this would have forced the test specimens to fly during periods of micro gravity. We were unable to make this crucial modification to our experiment due to the cancellation of our second flight.

CONCLUSION:

Although we were unable to collect the data that would have allowed us to prove or disprove our hypothesis, we believe that we did collect significant data with regard to the Monarch butterfly's ability to rapidly adapt to a micro-gravity environment. Rather than displaying a controlled flight in micro-gravity the Monarch adapted by holding on to the screen at the top of the cage displaying typical at rest behavior. We believe that this is significant. We also believe that it was significant that the test specimens lived and by all indications were not adversely effected by their exposure to micro-gravity an/or 2-g forces.

We would like the opportunity to continue our research to prove or disprove our hypothesis, and believe that with a few minor modifications to our experiment that this would be possible. We propose a second flight with a bigger enclosure for the test specimens. This will allow a larger area for the butterfly's and allow a longer time for the upward flight in periods of zero g. We also propose a modification to the top of the enclosure i.e. Wax paper. This will prevent the test specimens from having a place to cling to during periods of zero g.

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The Butterflywbsite.com

E.Jaediker Noseaard How to raise Butterflies

PHOTOGRAPHS:

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JSC2001E05168 to JSC2001E05170
JSC2001E05181
JSC2001E05206 to JSC2001E05207

VIDEO:

* 2001 Student Campaign: Week of 2/26/01, Group B Flight on March 1, 2001, Reference Master: 619710

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights –
Test #3: *Artemia* Instinctual Photo Response in a Micro-Gravity Environment

FLIGHT DATE:
March 1, 2001.

PRINCIPAL INVESTIGATORS:
Elizabeth Jackson, San Francisco Art Institute (SFAI)
Lorelei Lisowsky, SFAI
Thomas Proctor, SFAI
Pamela Servatius, SFAI
Ethan Vosburgh, SFAI

CO-INVESTIGATOR:
Coral Clark, faculty advisor, SFAI

NASA Photo: JSC2001E05163

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GOAL:

Artemia Instinctual photo Response in a Micro-Gravity Environment," inquired whether or not the photo response behavior displayed by *artemia* is dependent or independent of gravitational input. Artemia swim in all directions, sometimes even in loops and circles; they do not consistently orient themselves to "gravitational up" as fish and other swimming creatures do. These observations led to our hypothesis that *artemia* photo response behavior is entirely independent of gravitational orientation because *artemia* may have an extremely weak gravity sense.

INTRODUCTION:

Artemia (brine shrimp) instinctually respond to changes in light levels. Experiments performed by the Exploratorium biology department have shown that 80%-90% of all tested artemia are attracted to red light and repelled by blue light. Furthermore, *artemia* also displayed similar behavior when exposed to regular white light (incandescent). Because the spectral output of incandescent bulbs is clustered in the low frequency visible spectrum and infrared, *artemia* respond to white light by moving towards the light source.

METHODS AND MATERIALS:

Test Specimens
Two cups of Artemia in salt water.

Instruments
Housing water tight acrylic tube two incandescent lights on a circuit.

Procedure
Pre flight on the KC-135, the *artemia* were videotaped 10 times to gather control data for the specific group of test specimens. The *artemia* responded all ten times by swimming towards the light source.

During the flight Artemia were housed in a watertight acrylic tube, which was secured to the floor of the equipment frame with one battery-powered incandescent light attached to the bottom and the top of the tube. The test specimens were video taped in flight for 10 parabolas for later data analysis. The lights were to be hand operated by the second flyer; one light on at a time and when the switch was pushed the light, which was on, would shut off and vice a versa. In addition to operating the light source the second flyer was supposed to monitor video equipment during the turnaround, to insure correct data collection. Due to the severe motion sickness of one of our flyers we were unable to monitor this experiment, and video data collection during the flight was nonexistent. Post flight we videotaped the control group to see if there were any significant changes in swimming ability and or their photo response mechanisms. We did not observe any significant changes in their swimming ability, and the test subject's photo response mechanisms remained the same.

RESULTS:

The test specimens (Artemia) were not adversely effected by their exposure to micro-gravity and or periods of 2-g. They retained their typical behavior and remained alive.

DISCUSSION:

Due to the severe motion sickness experienced by one of our team members we feel that the data are inconclusive. We feel with some minor modifications that we would be able to collect more reliable data. We propose an automatic switch on the brine shrimp tank, as well as some modifications to the tank itself. The circular tank made it difficult to videotape with the existing light source on the KC-135. We believe that with a square or rectangular tank we would have fewer problems adjusting the light levels necessary to videotape the test specimens.

CONCLUSION:

Although our data are inconclusive we feel that it is significant that the test specimens remained alive after the first flight. We also feel that it is significant that there was no visible change in their photo response mechanism and/or swimming patterns.

REFERENCES:

Dr. Charles Carlson, Director, Biology Department Exploratorium

Dr. Thomas Humphreys, Senior Staff Scientist, Exploratorium

Schone Herman, The Spatial Control of Behavior in Animals and Man

PHOTOGRAPHS:

JSC2001E05162 to JSC2001E05163
JSC2001E05168 to JSC2001E05170
JSC2001E05181
JSC2001E05206 to JSC2001E05207

VIDEO:

- 2001 Student Campaign: Week of 2/26/01, Group B Flight on March 1, 2001, Reference Master: 619710

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights – A Continuing Study of the Effects of Hydrostatic
Pressure of the Left Ventricle under Varied Acceleration

FLIGHT DATE:
March 1, 2001

PRINCIPAL INVESTIGATORS:
Jasmin Jensen, University of Utah (UU)
Daniel Pungor, UU
Michael Fowler, UU
Lane Christensen, UU
Paul Murdock, UU
John Zeigler, UU

NASA Photo: JSC2001E05187

GOAL/OBJECTIVE:

To explore cardiac output and function in a varying acceleration environment with emphasis on comparing function in normal gravity to function in a weightless environment. In addition, we wish to verify the function of student initiated and implemented revisions made on the mock circulation hardware since its last orbital flight on board STS-95 as a Get Away Special payload. Data from this flight opportunity will be compared both to the limited previous orbital flight data and on data we will obtain from a third orbital flight in the near future.

INTRODUCTION:

As a result of the size and orientation of the heart, there is a gravitationally dependent hydrostatic pressure gradient inside the heart (5 mmHg) that contributes to normal diastolic filling. We hypothesize that in weightlessness, this contribution to diastolic filling is absent, resulting in a reduced stroke volume. Using an instrumented artificial left ventricle and a hydraulic circulation simulator, cardiac function and hardware performance will be continuously monitored during the KC-135 flight. The experiment will inject fluid into the system, stabilize the system by adjusting the resistor plate, and record pressure and flow measurements. The resulting test data can then be plotted allowing a comparison of diastolic filling in varying acceleration environments in the format of a ventricular function curve. The experiment will be oriented with the cardiovascular simulator in the "upright" posture for one flight and in the "supine" posture for the second flight. The experimental data should verify the correct operation of the system by yielding similar results to previous experiments. The desired result of this flight opportunity is to verify that the new design of the system functions correctly in a zero gravity environment, and to gather additional scientific data.

METHODS AND MATERIALS:

Equipment Description

The function of the experiment is to measure circulatory flow through the mock circulation unit. This unit generates physiologic pressure and flow conditions that do not exceed 150 mmHg (3 psi).The experiment will be placed in two different postures, upright and supine. For the first flight the experiment will be evaluated to make sure all components are fully operational. Once in flight the experiment will begin by increasing fluid volume and then adjusting pressure and finally measuring flow. This process will be repeated for the second flight with the experiment in the supine posture.

The main part of the experiment is contained within an aluminum frame, with an experiment mounting plate in the middle. The aluminum frame contains an artificial left ventricle, mock circulation (figure 1). The experiment is designed to occupy a 20" x 20" footprint (figure 2). The data acquisition hardware, that includes a TEAC magnetic FM data recorder, seven pressure sensors, a flow meter, a small patient monitor, and

electronic circuitry for power distribution, are mounted on the panel within the aluminum frame. As a safety precaution the frame is covered with foam and all connections are covered. The power output of the experiment comes from a single power strip from which all the components of the experiment are powered. The only components not connected to the power strip are the pressure catheter control boxes and accelerometer, because these devices are completely battery operated. The total weight for the experiment is 143 lbs.

Procedures

Ground Operations:
Upon initial arrival the experiment is removed from the shipping container and is evaluated to ensure no damage was sustained. Any additional assembly required is taken care of. For safety, the entire experiment frame is covered with foam padding, so all sharp edges are removed. For initial flight the experiment is mounted on the holding plate in the "upright" posture. The experiment is taken through a mock flight procedure where all operations that will occur during flight are reviewed. The experiment now is ready for flight.

Pre-Flight Operations:
The experiment is taken on the airplane and properly secured with bolts to the floor of the plane in the designated area. The power strip containing all the connections to the experiment is turned off and plugged into the provided power of the plane. Positions of personal are reviewed and set up to ensure all operational aspects are covered. At this point the experiment and operators are ready for flight.

In-Flight Operations:
The experiment is setup for the initial volume setting prior to flight. Measurements are taken during the first ten parabolas. During the rest phase between the ten parabolas, the volume is decreased and the system is stabilized. The same measurement procedures are taken during the next ten parabolas. This procedure continues until all parabolic flight has been completed. During the parabolas, data are continuously recorded in the zero and 2'g phases. At the end of the flight, all data collected on paper are securely stored by the operator and the experiment is shut off. The operators then prepare for landing.

Post-Flight Operations:
The flight data that were obtained from the first flight is stored in files, and the experiment is prepared for second flight. If any complications occur during first flight they are addressed and take care of. At the same time the experiment is place in the supine position for data to be recorded during the second flight. If needed the patient monitor is repositioned for better viewing purposes.

RESULTS:

Aortic Pressure Vs Acceleration
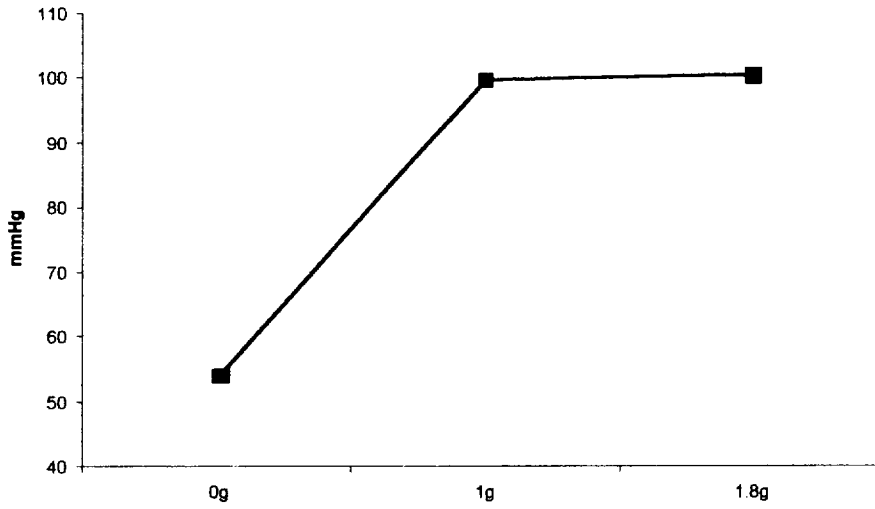
Aortic Flow Vs Acceleration
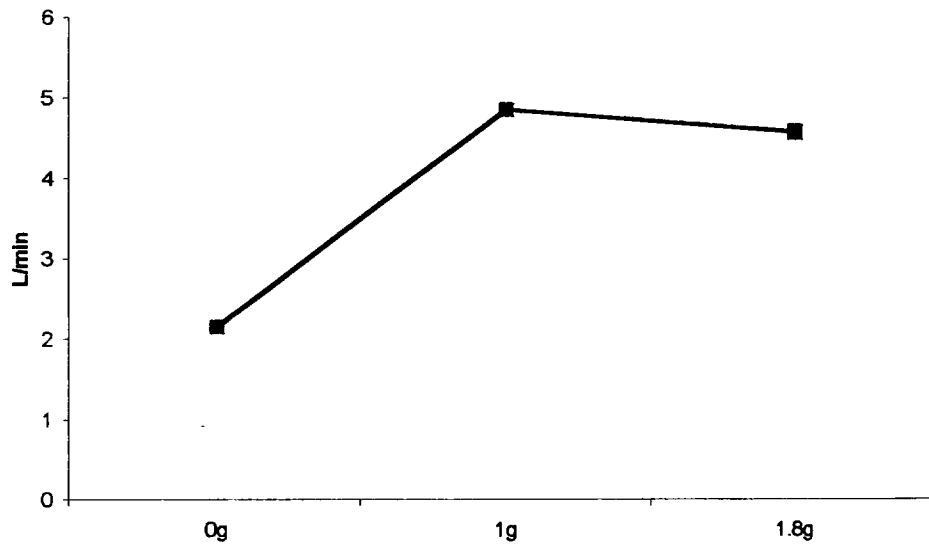
DISCUSSION:

The above results confirm that in weightlessness the gravitationally dependent hydrostatic pressure gradient inside the heart (5 mmHg) that contributes to normal diastolic filling is absent, leading to a reduction in stroke volume. The results from our flight experiment correspond with past research done at the University of Utah which indicates that the student implemented design changes function correctly weightless and hyper-gravity environments. Our data were collected during a single flight while the experimental hardware was oriented in the upright posture, which represents the position when the hydrostatic pressure difference in the heart is greatest. We hope to compare the results from this flight experience with data from future flights when the experiment will be flown in the supine position.

CONCLUSION:

Our team's experimental equipment functioned well in the weightless environment onboard the KC-135 and we were able to collect a limited amount of useful data, which supported our hypothesis. The data we collected will be compared with previous work done on this project and the observations we made of the equipment function and design will be used to improve the experiment for future research.

FUTURE STUDENT TEAM WORK:

The undergraduate team at the University of Utah hopes to complete their research in a future student flight opportunity. Our goals for the next flight campaign are to:

> Collected data in the supine position during last student campaign
> Retest resistor with variable resistance instead of a fixed resistance
> Improve the motors used with the resistor cartridge and fluid pump
> Replace a patient (pressure) monitor was damaged during transport to Houston

The results of this flight opportunity and the improvements we intend to make to the experimental equipment will be used to prepare the Hearts in Space project for a future flight on the Space Shuttle

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Woodruff, S.J., Sharp, M.K. Pantalos, G.M., (1997): Compact Compliance Chamber for the Study of Cardiac Performance in Microgravity." ASAIO Journal; 43:316-320.

PHOTOGRAPHS:

JSC2001E05187 to JSC2001E05189
JSC2001E05193 to JSC2001E05194

VIDEO:

• 2001 Student Campaign: Week of 2/26/01, Group B Flight on March 1, 2001, Reference Master: 619710

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights – Evaluating the Use of Diagnostic Ultrasound in a Microgravity Environment

FLIGHT DATES:
March 15 – 16, 2001

PRINCIPAL INVESTIGATORS:
Peter Derrick, University of Washington
Ryan Ollos, University of Washington
Laurence Tomsic, University of Washington
Nicole White, Seattle University
Michael Bailey, University of Washington

CO-INVESTIGATORS:
Stephen Carter, University of Washington
Kirk Beach, University of Washington
Shannon Melton, Wyle Life Sciences
Marla Paun, University of Washington
Douglas Hamilton, Wyle Life Sciences

NASA Photo: JSC2001E08023

GOAL:

We are investigating the potential for ultrasound to be used in microgravity and determining potential problems that may arise with its application in this environment.

OBJECTIVES:

The experiment consists of two portions: determining the anatomical variations that may be seen when viewing the liver, kidney and other abdominal organs in differing gravitational environments from zero to 2-g, and evaluating the feasibility of performing a free-hand diagnostic scan of different portions of the body. We also observe the firing of the ureteral jets with the aim of determining the potential for diagnosing a kidney blockage due to a renal stone.

INTRODUCTION:

Ultrasound may potentially be valuable as both a diagnostic and therapeutic device in manned space travel because of its size, versatility, cost advantage and minimal operational needs. Potential exists to diagnose and treat a number of ailments from kidney stones to internal bleeding. The Center for Industrial and Medical Ultrasound (CIMU) at the Applied Physics Laboratory (APL) of the University of Washington has undertaken an extensive effort to develop technology for space and terrestrial use that would permit minimally trained personnel to utilize diagnostic and therapeutic ultrasound to stop bleeding from injured vessels. The SonoSite 180 is a commercially available diagnostic device developed in collaboration with APL that could be used in space travel. NASA has used ultrasound imaging previously on the KC-135 Reduced Gravity Flight and in space. We tested the use of the SonoSite in a microgravity environment during parabolic flights aboard NASA's KC-135. Shifting of the organs as well as changes in pathology and dynamics of the body may present challenges to the use of diagnostic and therapeutic ultrasound in a microgravity environment. We have undertaken the goal of determining how imaging can be performed in a microgravity environment and how it may differ form its frequent use as a diagnostic device on earth.

METHODS AND MATERIALS:

Subjects
One of the fliers operated as the test subject and the second performed the scanning. The subject was scanned in the supine position or standing with his feet restrained and holds for his hands. Approval was obtained from both JSC IRB and the University of Washington Human Subjects Committee as to the use of human subjects in the experiment.

Instruments
The SonoSite 180 Ultrasound System was used with the C-60/5-2 Abdominal probe for image acquisition. The images were displayed to the monitor via the composite video

output to provide better real-time viewing in-flight. The images and audio from the flight were also recorded to VCR. The Horita SCT-50 Serial Control Titler allows us to post text in a small corner of the monitor. The accelerometer is constructed using three Analog Devices ADLX105 chips to provide data in the X-Y-Z directions. The analog signal is subsequently fed to an analog-to-digital converter and routed to the serial port of the laptop computer. A LabView program formats the data to text to be displayed on the video monitor. Text is transferred via the RS-232 serial port to the SCT-50 to display accelerometer data on the monitor. Data from the accelerometer were generated and posted to the screen to allow synchronization of the accelerometer data with the images.

Procedure
The subject would secure himself to the positioning table prior to the first parabola. The operator would use nylon straps secured to the floor of the plane to secure his/her feet or lower legs during the microgravity portion of the flight. This allowed them to release and lie down during the hypergravity pullout to reduce the associated motion sickness. During the microgravity portion the operator would perform a scan of some portion of the subject. Standard abdominal scans as well as the imaging of the ureteral jets were performed. For a portion of the flight the subject was secured to the padded table using nylon straps around the lower legs and midsection. Straps at the level of the shoulders allowed the subject to hold himself in place during microgravity. We also performed scanning with the subject standing, securing himself using nylon straps attached to the floor of the plane for the feet and handholds secured to the wall of the plane. The operator would similarly secure their feet and steady him/herself by holding the subject while performing the scan.

RESULTS:

We determined that ultrasound scanning could feasibly be performed in microgravity in a similar fashion to a terrestrial diagnostic scan. We qualitatively observed small movements of the organs and an increase in the size of the inferior vena cava during microgravity. The ureteral jets were imaged and the potential was shown to diagnose a blocked ureter.

DISCUSSION:

A diagnostic scan can be performed with the subject either supine or standing. The devices used to position the subject either prone or supine should be optimized to improve comfort and limit movement. Motion sickness was a problem and at times inhibited our ability to perform a scan. Equipment should be located to minimize patient and operator movement during the procedure when future studies are performed during parabolic flight. The ultrasound device should also be located within reach of the operator to allow for adjustments to be made for gain and depth. The SonoSite 180 is a potentially valuable diagnostic tool to be used in space flight due to its size and weight. Improvements are needed in both image quality and versatility in order to compete with larger and heavier units in usability and value in diagnosis. Two significant problems

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that should be noted for future use are the random movement of the trackball in microgravity that caused the Doppler sector box to move randomly and the sleep mode that is activated after 10 minutes of inactivity.

Further work in this area should be targeted at specific areas that may be of clinical interest to diagnosis in space. In addition to its value in diagnosis, therapeutic applications of ultrasound may prove to be valuable in space and should be explored. NASA recently launched a reengineered version of the ATL HDI5000 aboard the international space station for research purposes. Further research is needed into the effects of microgravity on the body in order that medical conditions can be adequately diagnosed in space. Procedures and protocols should also be developed so that a minimally trained medical officer or crewmember could perform a scan and diagnosis with or without assistance from a ground crew. Future work aboard the KC-135 that would be valuable to space flight may concentrate on the ability to guide an ultrasound operator from a remote location to perform a diagnosis.

CONCLUSION:

Ultrasound should prove to be a valuable tool to be used in diagnosing medical conditions in space. Any movement of the organs did not significantly impair our ability to perform a normal ultrasound scan in microgravity. Movement of the organs is less likely to be a problem in diagnostic applications than in therapeutic applications, where even a small degree of freedom may cause potential problems when treating a patient.

PHOTOGRAPHS:

JSC2001E08020 to JSC2001E08023
JSC2001E08504
JSC2001E08514 to JSC2001E08519

VIDEO:

• 2001 Student Campaign, March 15-16, 2001; Reference Master: 619716

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights – The Perceptual Effects of Altered Gravity on Tactile Displays

FLIGHT DATES:
March 15 – 16, 2001

PRINCIPAL INVESTIGATORS:
Ryan Traylor, Purdue University
Dan Hromis, Purdue University
Lauren Naessens, Purdue University
Joachim Deguara, Purdue University

CO-INVESTIGATOR:
Dr. Hong Tan, Purdue University
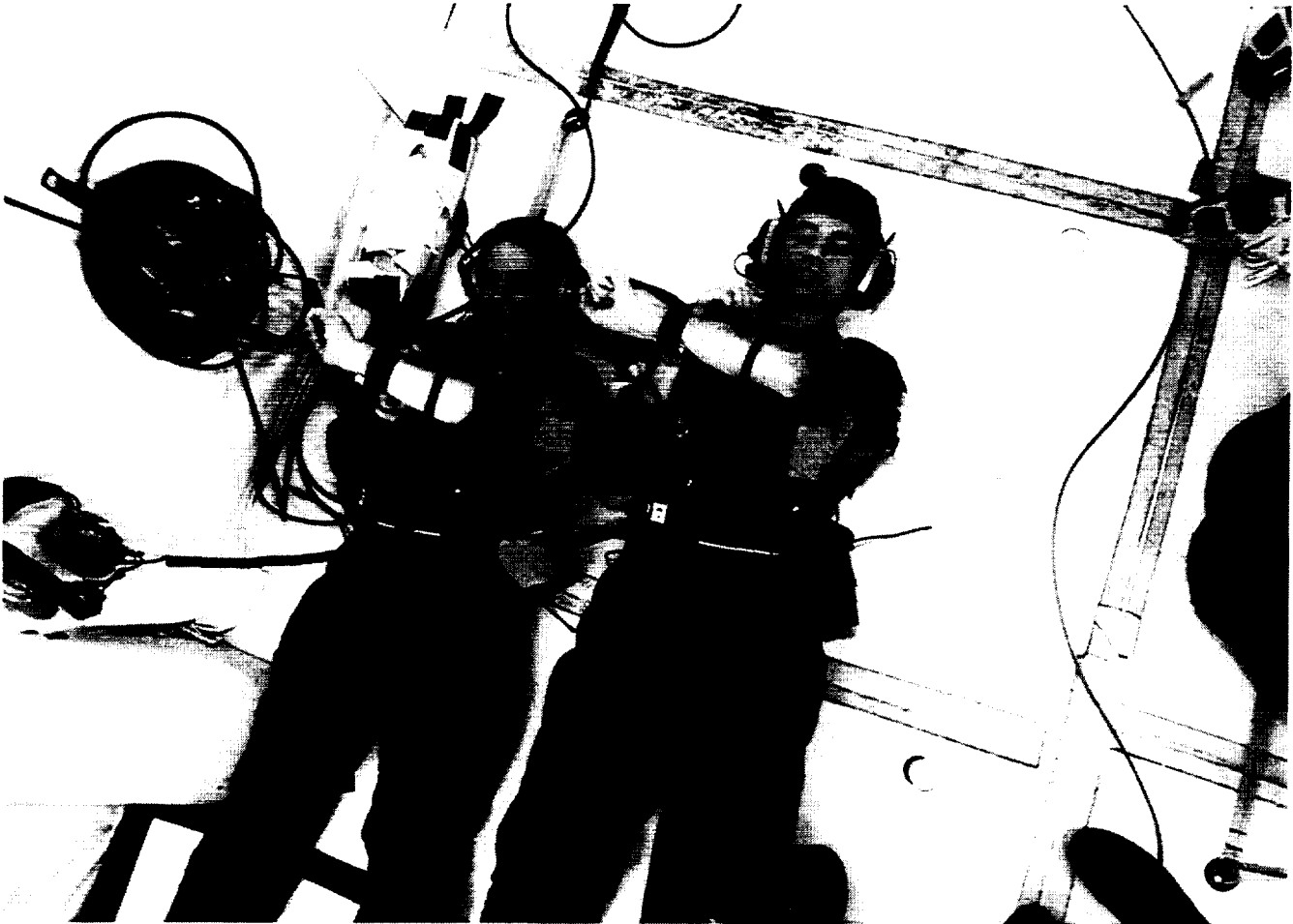
NASA Photo: JSC2001E08014

GOAL:

The goals of our proposed experiment are (1) to determine if tactual perceptual threshold changes in altered gravity environments, and (2) to determine if the amplitude of vibration of a tactor is reduced in microgravity.

OBJECTIVE:

This is a follow-up experiment of a project that flew aboard the KC-135 in August, 1999. Our objective is to determine why subjects on the previous flight reported that the vibrating tactors felt weaker in microgravity than in one-g.

INTRODUCTION:

In August 1999, the Purdue Electrical Engineering flight team flew an experiment aboard NASA's KC-135 geared toward reducing the occurrence of special disorientation. The experiment consisted of a vest equipped with a tactile feedback system that "draws" directional lines on a user's back. The directional signals are used to provide the user with a sense of direction and to alleviate some of the problems associated with spatial disorientation. The directional lines are drawn using a phenomenon known as sensory saltation.

Sensory Saltation

The "sensory saltation" phenomenon was discovered in the 1970's in the Cutaneous Research Laboratory at Princeton University (the word "saltation" is Latin for "jumping") [1]. In an initial setup that led to the discovery of this phenomenon, three mechanical stimulators were placed with equal distance on the forearm (see Figure 1). Three brief pulses were delivered to the first stimulator closest to the wrist, followed by three more at the middle stimulator, followed by another three at the stimulator farthest from the wrist. Instead of feeling the successive taps localized at the three stimulator sites, the observer is under the impression that the pulses seem to be distributed with more or less uniform spacing from the site of the first stimulator to that of the third (see Figure 2). The sensation is characteristically described as if a tiny rabbit was hopping up the arm from wrist to elbow; hence the nickname "cutaneous rabbit".
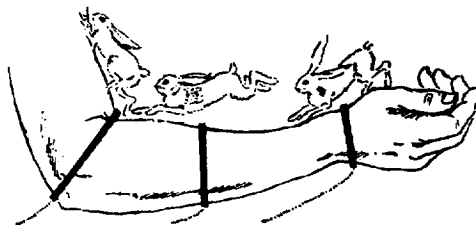
Figure 1. A Norwegian artist's interpretation of the "sensory saltation" phenomenon [1]
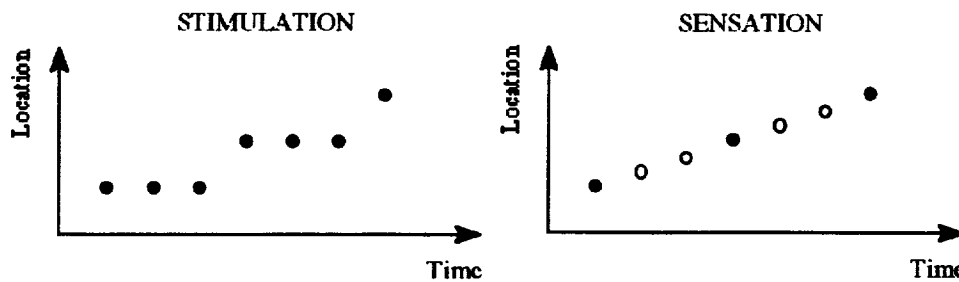
Figure 2. Stimulation vs. Sensation. Open circles indicate the perceived "phantom" locations [5]

The tactile display worn by our previous flight team consisted of a 3-by-3 tactor array that allows the simulation of "rabbit" paths in many directions. A tactile display is desirable because it is very intuitive to use. The user does not have to actively look for a signal or listen for a command rather s/he simply *feels* it. On-ground tests prior to the flight revealed that users who had no prior training with the vest or experience with sensory saltation correctly perceived the directional signals 79% to 91% of the time [4]. This fact reveals the intuitive nature so important to the design of our vest. In-flight evaluation of the vest by our flight team, however, produced interesting results. On average, the flight team members were only able to correctly identify the direction of the signals 44% of the time. The team members reported that the signals felt considerably weaker in micro-g than in a one-g environment.

Our new experiment tests the physical peak-to-peak amplitude of vibration of a tactor to determine whether there is a change during microgravity conditions. The project also tests whether a person's perceptual threshold changes while in microgravity. From this test, it is possible to compare the intensity perception of vibrotactile signals in zero-g, one-g, and two-g. During the experiment, the subject is presented with vibrations of various intensities from a tactor located on the subject's arm. For the zero-g portion of each parabola, the tactor vibrates 250ms once every second with a predefined vibration of constant amplitude called the "reference signal". During two-g periods, the tactor vibrates with an intensity randomly chosen from a pool of seven discrete sinusoidal driving amplitudes. The subject then records whether this signal felt weaker or stronger than the reference signal. The data are later analyzed and compared to data recorded in one-g to determine whether the subject's perception of the tactor's intensity changes under the influence of altered gravity.

METHODS AND MATERIALS:

Subjects

This experiment consists of a total of four subjects, which are the four members of our flight team. There are three males and one female all between the ages of 21 to 22 years old. Subject 3 and Subject 2 flew the first day while Subject 1 and Subject 4 flew the following day. The data recording circuitry that makes up our experiment is self-contained and can be easily operated by one person. Two data recording devices were constructed thereby allowing the two flyers on each flight to participate in data collection.

Instruments

The hardware used to drive the tactor and to measure signal intensity can be described using five main functional blocks. These blocks include the accelerometer, keypad, microcontroller, tactor driver circuit, and tactor as shown in Figure 3. The keypad and associated electronic display (LED's) allow the user to interact with the system. A microcontroller is used to control the intensity of the signal supplied to the tactor and record any data input by the user. An accelerometer is used to measure the displacement of the vibrating tactor and condition the signal for sampling by the microcontroller. The tactor driver circuit generates a 300 Hz sinusoidal signal and acts as a power amplifier to produce oscillations at the natural frequency of the tactors. Finally, the tactile display is implemented with a single tactor located on the user's forearm. All of this hardware is enclosed in a box with a length of 6 inches, width of 3 inches, and depth of 2 inches.
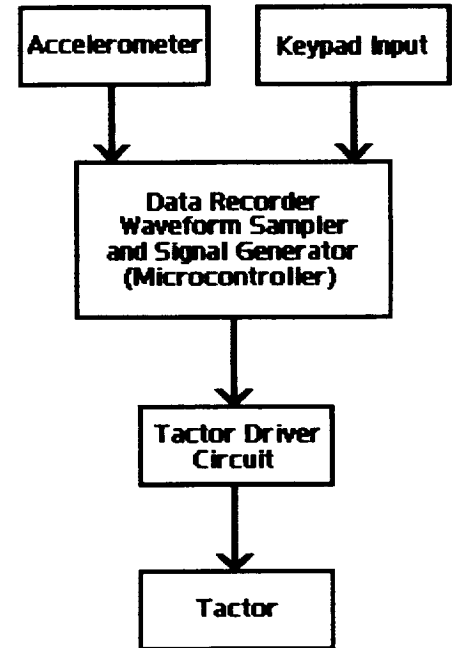
Figure 3. Functional Flowchart

Keypad Input

The keypad circuitry consists of an encoder, LED's for a digital readout and the keypad itself. Using the keypad, the user is able to prompt the system for a new random intensity vibration on the tactor and then input the perceived intensity. The keypad is interfaced to the microcontroller with encoding hardware provided by a 74C922J integrated circuit. The binary output from this chip is of a form that can be read and interpreted by the microcontroller.

Microcontroller

The next functional block contains a microcontroller which directs information to and from the user, controls the intensity of the signal sent to the tactor, and records the displacement of the tactor. The microcontroller chosen for this task is the Motorola 68HC912BC32 16-bit microcontroller equipped with flash memory (Motorola Inc., IL). The 68HC912BC32 (HC12) is an ideal choice because it is compatible with a vast array of peripheral devices and is very well documented [2]. The HC12 is programmed to

selectively present one of seven discrete sinusoidal signals of various intensities to the user as a 250ms pulse. A 250ms duration reference signal is applied to the tactor once every second in zero-g and one signal is randomly chosen then fed to the tactor upon entering the two-g interval of the parabola. The microcontroller records the users reaction to the random signal by storing a response of either stronger or weaker in EEPROM. EEPROM is used because the data are retained even if electrical power is somehow disconnected from the data recording circuitry during flight. Data are sampled from the accelerometer by the HC12's on-chip A/D converter and stored in SRAM. Consequently, in the event of a power failure, accelerometer data are lost.

Accelerometer

The HC12 is also able to record the displacement of the tactor with the aid of an accelerometer fixed to the tactor's surface. As the tactor oscillates, the accelerometer is displaced in the same manner. The signal output by the accelerometer reflects the acceleration of the tactor at certain instants in time. However, the actual position of the tactor is of interest in this experiment. Since the movement of the tactor is sinusoidal due to the sinusoidal driving voltage, the signal viewed from the accelerometer will also be sinusoidal in nature. Noting that position is two integrations of acceleration with respect to time and $\int(\int\sin(t)\,dt)\,dt$ = $-\sin(t)$, the tactor's position function is just a constant multiple of its acceleration function. The microcontroller is not able to record the continuous waveform output by the accelerometer, so samples must be taken and later pieced together in the form of a discrete function. If the microcontroller does not sample at a high enough rate, higher frequency components of the signal are aliased and the reconstructed waveform is distorted. Preliminary tests were carried out on the tactors used in this experiment and through Fourier transform techniques, a sampling rate of 7.759 KHz was found that eliminates any problems associated with aliasing. The discrete data points collected by the HC12 will be stored in RAM and used post-flight to reconstruct the continuous waveform for further analysis.

Tactor Driver Circuit

The HC12 is not capable of supplying the current and voltages required to directly drive a tactor. Thus, an intermediate device was designed to translate the control signals from the HC12 and then to output the appropriate driving signal necessary to actuate the tactor. The driver's main function is to supply an amplified oscillating signal to a tactor when prompted by the HC12 to do so. The circuit consists mainly of a power supply, a 300 Hz oscillator, and a 16-Watt bridge amplifier. When the driver circuit receives an enable signal from the microcontroller, it responds by supplying an amplified 300 Hz oscillating signal to the tactor. The amplitude of this oscillating signal is governed by the voltage level on a control line generated by the HC12. A schematic of the bridge amplifier is shown in Figure 4.

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16W Bridge Amplifier
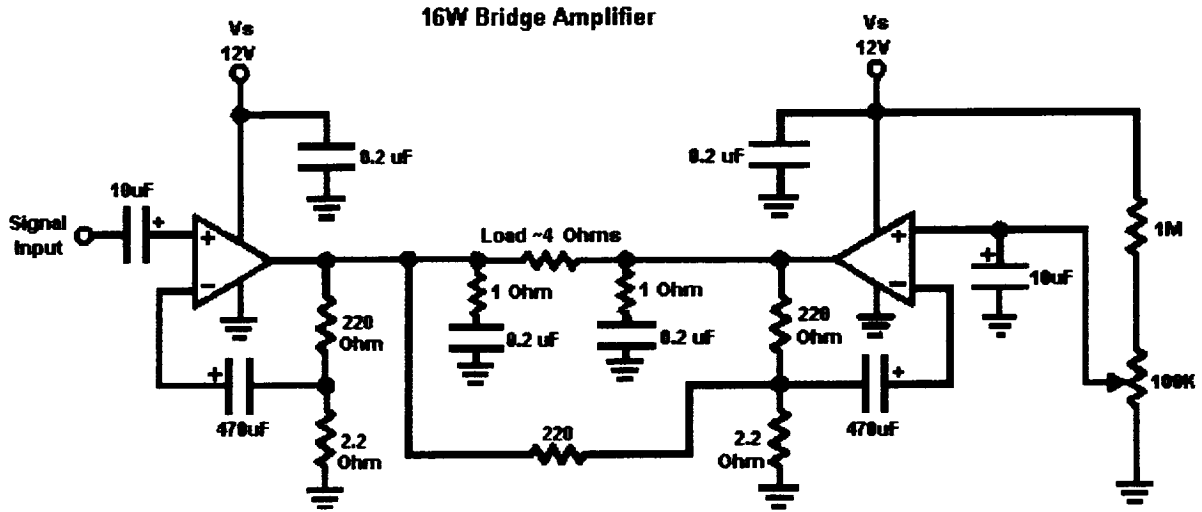
Figure 4. A schematic for the 16W Bridge Amplifier [3]

Tactile Display

The tactile display consists of a single tactor placed on the user's forearm. The tactor is made of a flat speaker, four centimeters in diameter, designed to resonate around 300 Hz (Audiological Engineering Corp., MA). The sensation delivered by the tactor is similar in nature to the vibrations felt from a commercially available massage chair.

Procedure

Just before the KC-135 begins the first parabola, the test subject puts on the control box containing the supporting electronics on the upper arm. The tactor is pressed against the skin by slipping it under an elastic band worn on the forearm. The battery is strapped around the subjects waist. When the plane enters into the zero-g portion of a parabola, the subject presses the "zero-g" key on the keypad. The reference signal is now presented to the subject. When the zero-g period is over, the subject presses the "exit" key. As the plane enters into the two-g portion of the parabola, the user presses the "two-g" key on the keypad. Shortly thereafter, the tactor vibrates once for 250ms with an intensity randomly chosen from the seven possible intensities. The subject then records whether the vibration felt stronger or weaker than the reference signal by pressing either the "stronger" or the "weaker" keys respectively. After the subject's response is logged, another randomly chosen intensity signal is supplied to the tactor. The subject records his/her responses until the end of the two-g period when the "exit" key is pressed to pause data collection. The cycle repeats for every parabola. During one of the zero-g periods, the subject presses the key sequence "2*", which initiates data sampling from the accelerometer. Upon completion of the test, the subject removes the electronic testing equipment and prepares for landing.

RESULTS:

The data downloaded from each box contains a record of which signal was presented to the flyer and if that signal felt stronger or weaker than the reference signal. The number of times the flyer indicated that a certain random intensity signal was stronger than the reference is compared to the total number of times that signal was presented. Ideally, for the weakest signal, the subject would say it is stronger than the reference signal 0% of the time. Likewise, the subject would say the strongest signal felt stronger than the reference signal 100% of the time and the actual reference signal would feel stronger 50% and weaker the other 50% of the time. When the data points are plotted, the graph can be modeled by a gaussian cumulative distribution function. Knowing the gaussian CDF allows us to extract the mean and standard deviation from the data. In the ideal case, the mean lies right at the reference signal as one would expect.

During preflight testing, 602 trials were collected from Subject 1, 598 from Subject 2, 596 from Subject 3, and 263 from Subject 4. During thirty microgravity parabolas of the flight, 304 trials were collected from Subject 1, 253 from Subject 2, 365 from Subject 3, and 312 from Subject 4. The mean and standard deviation extracted from the gaussian model fit to each of these data sets are listed in Table 1. The peak-peak amplitudes of the tactor vibration on the equipment used by Subject 3 and Subject 1 range from 2.19μm to 15.40μm with the reference set at 8.90μm. The peak-peak amplitudes for the equipment used by Subject 4 and Subject 2 range from 2.35μm to 8.76μm with the reference set at 6.24μm. The difference in amplitude ranges is due to the tolerances in the electrical components used to generate the driving waveforms.

If the subject actually felt the signal to be weaker in microgravity, one should see the mean from the flight data as being less than the mean from the on-ground data. However, one can see from the data that in all cases, the reference signal lies within one standard deviation of the mean. Therefore, it is not possible to conclude that tactual perception changes in a microgravity environment. After analyzing the data recorded from the accelerometer, it was found that the peak-peak amplitude of vibration collected in microgravity is equal to the amplitude of vibration in one-g for the same driving waveform. Both amplitudes were found to be 1.6μm peak-peak.

Subject	Reference Signal Intensity (μm)	Preflight Testing (1-g) Mean, Standard Deviation (μm)	In-flight Testing (0-g, 2-g) Mean, Standard Deviation (μm)
4	6.24	6.19, 1.15	5.72, 1.85
2	6.24	5.14, 0.99	6.24, 1.23
3	8.90	9.78, 2.64	5.10, 4.40
1	8.90	9.00, 2.30	7.38, 3.24

Table 1. Mean and Standard Deviation data extracted from a gaussian model fit to data taken preflight and during flight.

DISCUSSION:

Measuring the intensity of the tactors turned out to be difficult due to the frequency characteristics of the tactor hardware itself. While taking accelerometer readings to determine tactor intensities, it was found that the amplitude of vibration changed considerably under various loaded conditions. Fourier analysis of the accelerometer waveform showed that on the tactor worn by Subject 4 and Subject 2, the third harmonic was excited under loaded conditions, which reduced the overall peak-peak amplitude of the vibration. The amplitude could be made to change significantly by simply flexing the arm muscles. The tactor attached to the data recording equipment used by Subject 1 and Subject 3 was less affected by changes in the loading conditions. The second harmonic amplitude changed slightly under different loads, but the overall amplitude remained relatively constant.

After experiencing the unique environment of microgravity, it became apparent that cognitive load may play a large part in hampering the ability of a subject to correctly discern the direction of a saltatory line drawn on one's back. In microgravity, the brain seems to have much more information to process than in one-g environments. In one-g, a person can usually take for granted that his/her feet are on the ground and the ceiling is up above. However, in microgravity one must always keep track of the body's orientation and rely on cues other than vision alone. As one becomes more experienced with navigating in microgravity, increased cognitive load should become less of a problem. It may be interesting in the future to run the same experiment on an experienced NASA official to see if the results can be improved.

CONCLUSION:

According to the data collected aboard the KC-135, it was not possible to conclude that one's tactual perception changes in a microgravity environment. With regard to the mechanical behavior of the tactors, it was found that the peak-peak amplitude of vibration collected in microgravity is equal to the amplitude of vibration in one-g for the same driving waveform.

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[2] Motorola Inc."HC12." MC68HC912B32 MC68HC12BE32 Advance Information. 1999.

[3] National Semiconductor ®."LM 383 / LM 383A 7W Audio Power Amplifier." *Datasheets*. Jan. 7, 1996. 1-6. March 30, 1999. Online. Internet. *Available <http://www.national.com/ds/LM/LM282.pdf>*

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[5] Tan, H. Z., & Pentland, A. "Tactual displays for wearable computing". *Digest of the First International Symposium on Wearable Computers*, 84-89. 1997.

PHOTOGRAPHS:

JSC2001E08005 to JSC2001E08006
JSC2001E08014
JSC2001E08031 to JSC2001E08032
JSC2001E08507
JSC2001E08524 to JSC2001E08528

VIDEO:

- 2001 Student Campaign, March 15-16, 2001; Reference Master: 619716

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights – IPAGE II: Improved Productivity in Altered Gravity
Environments

FLIGHT DATES:
March 27 – 28, 2001

PRINCIPAL INVESTIGATORS:
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Richard Tormey, CMU
Lydia Choy, CMU
Daniel Maynes-Aminzade, CMU
Adrian Perez, CMU
Kathleen Williams, CMU

NASA Photo: JSC2001E08470

GOAL:

The goal of our proposed experiment was to determine whether fundamental virtual reality
training has an affect on motion sickness profiles for flyers on the KC-135 aircraft. This
goal involved implementing and carefully investigating the effectiveness of Carnegie

Mellon's upgraded IPAGE-2 Virtual Reality preflight training system, as a follow-up from positive impressions of our IPAGE-1 training system (tested during the March 2000 Reduced Gravity Campaign). With our results, we aspired to gain critical insight into the issues of simulator training, space motion sickness, and Virtual Reality's ability to prepare human test subjects for altered-gravity conditions.

By training the RGSFOP flyers within the IPAGE-2 "Virtual KC-135" environment and administering simple but effective post-flight questionnaires, our goal was to explore several of the many issues surrounding Virtual Reality simulation through careful and objective evaluation. Moreover, through our own in-flight observations, we aimed to thoroughly analyze the effectiveness of new techniques we have added to the IPAGE-2 system.

OBJECTIVES:

The Carnegie Mellon team sought to achieve the following objectives:

(1) To compare motion sickness profiles of flyers who underwent preflight IPAGE 2 Virtual Reality training with a control group (flyers with no virtual reality training)

(2) As developers and testers of the system, to use in-flight impressions to thoroughly examine how to better develop rapid simulations of altered-gravity environment using sophisticated Virtual Reality systems.

INTRODUCTION:

With lack of appropriate preparation, first-time exposure to new situations and environments poses dangerous risks to a flyer's safety and effectiveness. This holds true for KC-135 novices as well as for astronauts. Current training measures at Johnson Space Center aim to simulate environments and tasks well enough that the trainee can achieve veteran status on ground, which allows for more efficient and reliable flights[1].

While current training methods are innovative and useful, there is still much room for improvement. While such simulators as the Neutral Buoyancy Lab allow astronauts to practice their tasks within an environment similar to space, the physics of microgravity cannot be fully mimicked within an underwater environment[2].

In addition, current training devices are difficult to implement within the smaller structures of the International Space Station and future interplanetary flight vehicles. Simulation and

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[1] Harm, Deborah L. (1994) 'Preflight Adaptation Training for Spatial Orientation and Space Motion Sickness." *J Clin Pharmacol*, 34:618-627

[2] Kenney, Patrick J. (1994) 'Results of a Survey on the Use of Virtual Environment Technology in Training NASA Flight Controllers for the Hubble Space Telescope Servicing Mission' URL: http://www.vetl.uh.edu/Hubble/longpaper.html

adaptation devices will be necessary aboard these ships as astronauts practice emergency repairs and prepare themselves for altered-gravity conditions.

Environments with altering gravity also tend to induce disorientation and sickness as well as confusion; much remains unknown on how to alleviate this issue. For the astronauts, such devices as the Preflight Adaptation Trainer (PAT) are being developed to simulate the neurovestibular effects of microgravity in ways such that they will be able quickly adjust to the actual environment, even during their first flights[3]. Simulators such as the PAT, which use Virtual Reality, possess certain advantages as well as areas that are in need of further development.

Carnegie Mellon University's Human Computer Interaction Institute has created a unique Virtual Reality system that provides superior simulation of environments as well as an interface that allows for rapid creation of these "virtual worlds." It is our belief that this system has exceptional potential concerning the amelioration of current preflight simulation and adaptation methods. There are many aspects that remain unexplored concerning Virtual Reality training methods, as well as regarding the neurovestibular effects of altered-gravity environments.

IPAGE 1 and IPAGE 2 Virtual Reality Preflight Trainer
Carnegie Mellon's KC-135 IPAGE Virtual Reality preflight trainer was developed and consequently tested during two zero-g flights in March 2000. The IPAGE system was successful in depicting the rudimentary aspects of the KC-135 cabin and altered gravity, and we believe that the fundamental efficacy it displayed warrants further development and investigation of the system as a useful method for preparing RGSFOP participants for altered gravity flight.

The IPAGE Phase One preflight training system sought to prepare its four Carnegie Mellon subjects by giving them an intuitive understanding of the physics of an altered gravity environment; it did this by immersing them in an interactive Virtual KC-135, complete with an altered gravity effect similar to that which they would experience during their flight. As they practiced a simple task of coordination (throwing a ball at a target), the subjects trained with a tracked Head Mounted Display (HMD) and gloves. Within the team, half trained within the Virtual KC-135 environment complete with alternating zero-g and two-g effects, while the other half (as a constant) trained in a Virtual KC-135 possessing regular gravity characteristics. In flight, we tested and recorded our ability to accurately perform the same coordination task of throwing balls at a target.

Due to the small test subject pool, our collected data were not as conclusive as we would have liked. However, the test subjects' overall perceived level of comfort and preparedness – along with these factors' correlation to motion sickness – supported the assertion that the IPAGE 1 Virtual Reality system had strong potential for becoming an effective training tool for first-time KC-135 flyers.

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[3] Li, Marian (99). 'Preflight Adaptation Training (PAT) Facility.' URL: http://www.jsc.nasa.gov/sa/sd/facility/md19_pat.htm

With this in mind, many improvements were included in the IPAGE 2 Virtual Reality system. IPAGE-2's upgrades included a more sophisticated graphic rendering within the Virtual Reality scene, and exercises developed to give the users a greater sense of the necessary timing of experiments within the constructs of the KC-135's zero-g to two-g parabolic arcs. Also included in the training system was visual feedback discouraging trainees from moving their heads during periods of simulated two-g; this was to emphasize the general recommendation given to flyers not to move their heads during two-g periods of flight.

While these aspects of IPAGE 2 fostered a more realistic and sophisticated training environment for its subjects, the IPAGE 2 system did not possess any of the somatic (specifically neurovestibular) simulations of altered gravity that have been previously used for preflight adaptation purposes. Therefore, in evaluating IPAGE 2 training's correlation with motion sickness levels, we also sought to develop a negative control for virtual reality systems whose purpose is to effectively adapted flyers for altered gravity conditions through neurovestibular simulation.

METHODS AND MATERIALS:

Subjects

Approximately 57 pairs of undergraduate students flying aboard the KC-135 aircraft between the dates of February 8 and March 31, 2001 were used as test subjects to evaluate the IPAGE-2 Virtual Reality's effects on altered gravity motion sickness. The in-flight VR developer observations were conducted by Carnegie Mellon team members.

Instruments

IPAGE 2 Virtual Reality KC-135 Preflight Trainer
Our virtual reality system was developed in conjunction with members of the Stage 3 Research Group (http://www.cs.cmu.edu/~stage3). This group, under the direction of Professor Randy Pausch, has a long history of creating virtual environments showcasing novel interaction techniques. Stage Three has designed a software tool called Alice (http://www.alice.org), a rapid prototyping system for interactive 3D computer graphics that we intend to use to build our simulator. Alice offers high-level primitives for scripting animations, reading data from positional trackers, rendering 3D scenes, and broadcasting and receiving information over a network connection. Alice is also capable of running as a web browser plug-in, allowing remote users to be present in the virtual world.

Hardware System Architecture
The hardware required to drive our VR system was relatively inexpensive. A high-end Windows PC with a 3DFX Voodoo 2 graphics card provided the computing power. 3D position and orientation data were read from an Ascension Spacepad magnetic tracking system, and additional input was provided with a pair of Fakespace pinch gloves. Output was rendered to a Virtuality Visette HMD.

Figure 1: Hardware Configuration.
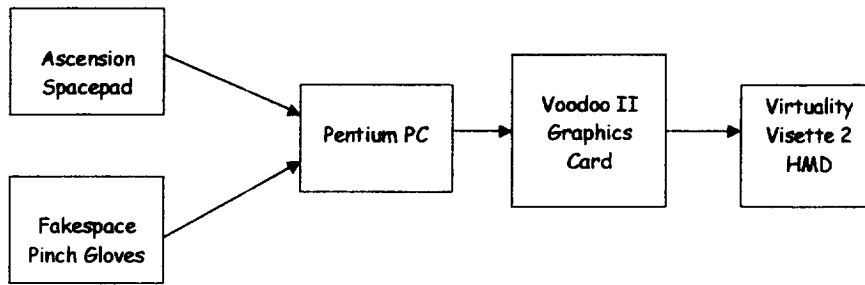
Software System Architecture

The simulation was programmed in Python (http://www.python.org), an interpreted, interactive, object-oriented scripting language. Python is the extension language that Alice uses as its programmable interface, and it offers a number of advantages to the development of VR content. Python combines remarkable power with very clear syntax. It has modules, classes, exceptions, very high level dynamic data types, and dynamic typing. There are interfaces to many system calls and libraries, and new built-in modules are easily written in C or C++. Our system took advantage of a number of such extension modules to perform the computationally intensive tasks of real-time physical simulation. These modules included the V-Collide package for polygon-level collision detection, developed at UNC-Chapel Hill, and Mathengine (http://www.mathengine.com), a physics engine for real-time rigid-body dynamics.

In-Flight Apparatus: the "Mission Toolkit"

The hardware used to test our flyers' coordination in the altered gravity environment consisted of a clear plastic divided glovebox containing checker pieces and several toy-sized outreach items anchored to our In Flight Mission Toolkit. This toolkit served as both an in-flight storage container as well as a platform for outreach demonstrations. In-flight observations were recorded on videotape as well as on tethered clipboards.

Procedures

Our experiment compared the motion sickness level of 57 pairs of students flying aboard the KC-135 aircraft between the dates of February 8 and March 31, 2001. In each pair, one of the flyers was trained prior to flight using the IPAGE-2 virtual reality preflight trainer (Treatment A). The second flyer was not given Virtual Reality training (Treatment B).

Assignment of student flyers to Treatment A or Group B was determined using a randomized number generator, which produced a series of 1's (Treatment A) and 0's (Treatment B) that were applied to a list of paired KC-135 flyers.[4] For Treatment A flyers,

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[4] http://www.randomizer.org/

preflight Virtual Reality training was conducted at NASA's Ellington Field Hangar 99B in Houston, Texas on February 9, February 22, March 9, and March 22, 2001. Each Treatment A subject underwent 5 minutes of training in the "Virtual KC-135."

IPAGE-2 virtual reality training involved immersion in a "Virtual KC-135A" cabin, complete with a simulated test director and undergraduate partner. A virtual "experiment box" within the cabin required trainees to practice the universal experiment task of pressing a series of buttons during the zero-g portions of simulated flight. During periods of two-g, visual feedback discouraging trainees from moving their heads helped to emphasize the general recommendation given to flyers not to move their heads during two-g periods of flight.

After each student's flight aboard the KC-135A aircraft, the students reported their perceived in-flight motion sickness level using a modification of the Kennedy Motion Sickness Questionnaire[5]. These questionnaires were prepared by the team and administered by NASA Reduced Gravity Office directors during post-flight debriefings for the flyers. For each flyer, the weighting algorithm table in Appendix B enabled the team to transform the flyers' questionnaire responses into a single number representing the flyer's overall motion sickness score as well as three motion sickness subscores (nausea, oculomotor, and disorientation).

For in-flight evaluation aboard the KC-135, we observed our effectiveness in completing simple tasks under altered gravity conditions. For each flight, Carnegie Mellon team members performed outreach tasks that involved winding, throwing, and retrieving a toy propeller plane. In addition, a clear plastic divided glovebox containing checker pieces was used to practice sorting red and black checkers in zero-gravity. In-flight observations concerning real KC-135A flight vs. the IPAGE 2's simulated KC-135A environment were recorded and used later to evaluate the virtual reality system's accuracy as well as to suggest further additions to virtual reality KC-135A simulators.

RESULTS/DISCUSSION:

Our results showed no significant difference ($p = .91$) between the trained group and the control group (no virtual reality training). We conducted a two sample t-test using train and not train as our subscripts and the total motion sickness score as our sample. Our null hypothesis was that they were equal, with the alternate hypothesis as not equal. As one can see, we could not reject the null hypothesis. We ended up with the following data:

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[5] R.S. Kennedy, N.E. Lane, K.S. Berbaum, and M.G. Lilienthal.
Simulator sickness questionnaire: an enhanced method for quantifying simulator sickness.
International Journal of Aviation Psychology, 3(3):203-220, 1993.

Table 1: Results

T/NT (1/0)	N	Mean	StDev	SE Mean
0	57	34.4	36.9	4.9
1	57	33.7	32.9	4.4

95% CI for mu (0) - mu (1): (-12.3, 13.7)
T-Test mu (0) = mu (1) (vs not =): T= 0.11 P=0.91
DF = 110

We also checked that the difference from the samples to their mean had a normal distribution. This is shown in the following two graphs, where the one on the right is for the not train condition and the one on the left is for train.
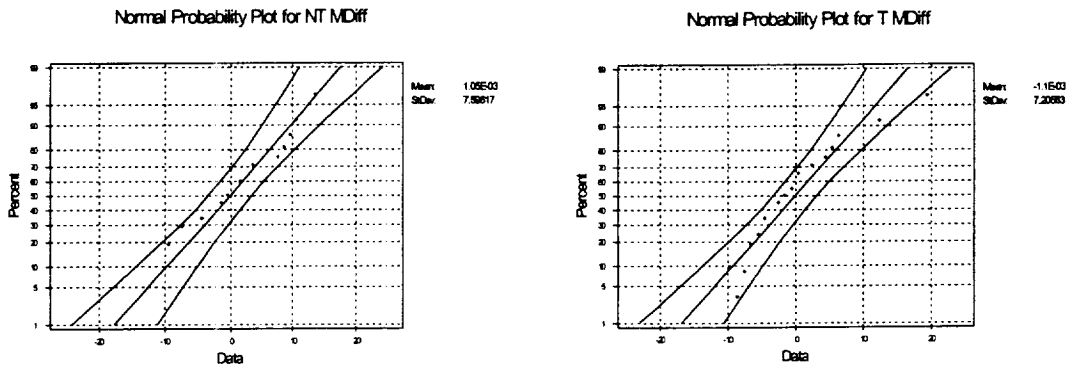
Our data was therefore normal, with no outliers. As one can see from the boxplot below, the medians were comparable, as were the spreads. The data for the not train set is on the left, with the train set on the right. One difference between the two would be that the no train data set had a more normal distribution (mean and median closer together, good spread) than the train set. In fact, the train set looks slightly left skewed due to the mean being higher than the median.
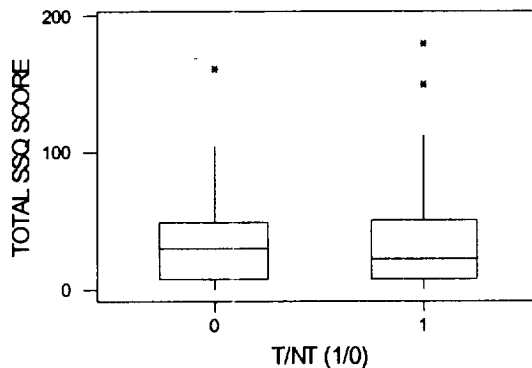
Figure 2: Boxplot of Motion Sickness Scores (Trained Group vs. Not Trained)

Subcategory motion sickness scores that represent nausea-specific, oculomotor-specific, and disorientation-specific motion sickness symptoms were also found to be statistically similar between the "Virtual KC-135" trained group and the control no-training group.

<u>In-Flight Observations</u>
In making specific in-flight comparisons of the KC-135 flight and the IPAGE "Virtual KC-135" system, Carnegie Mellon flyers found the most profound difference between the two to be the actual sensations of zero-g and two-g that they experienced in altered-gravity flight. The issues surrounding simulation of floating in a primarily visual system remain numerous, and probably any Virtual Reality simulation attempting to physically replicate a floating sensation would have to include suspension/neutral buoyancy components that are outside the immediate scope of the IPAGE system.

While replicating the physical sensation of floating might be a longer-term goal, an immediate improvement that the group noted would be to add a peripheral "navigation strap" to the IPAGE trainer. This strap would be equivalent in size and location to straps located in the actual KC-135, and—like a computer mouse enables one to scroll through a document—would enable training flyers to physically navigate through the "Virtual KC-135" in a way similar to cabin movement methods used during actual altered gravity flight.

Out of the several in-flight rudimentary tasks performed by Carnegie Mellon flyers, the checkers-sorting task was considered the most difficult in microgravity. Having to sort objects in three dimensions versus two dimensions was challenging enough to lead all four flyers to suggest that such a task be chosen for future trainers as an excellent example of the unique challenges of performing tasks in microgravity.

CONCLUSION:

Analysis and comparison of post-flight motion sickness questionnaires for both test groups showed no statistical difference between the IPAGE 2-trained and no virtual reality trained motion sickness profiles, supporting the conclusion that small increments of basic Virtual Reality training do not affect altered-gravity adaptation abilities for KC-135 flight.

Due to safety and time restraints, the IPAGE 2 system did not aim to induce the disorienting or nauseating effects of neurovestibular simulation of altered gravity. Because the IPAGE 2 system did not simulate the aspects of altered gravity that are commonly correlated with motion sickness, it was initially hypothesized that the system would not necessarily endow trained flyers with a heightened motion sickness resistance during their KC-135 altered gravity flights. The results of this experiment support this conjecture.

For future experiments involving evaluating motion sickness levels, a more direct and less objective test for in-flight motion sickness might be applied for greater precision. For example, motion sickness levels have found to have a direct correlation with skin

temperature,[6] which would produce a much more reliable and objective measure of motion sickness than a post-flight questionnaire. Such in-flight tests were out of the scope of this RGSFOP experiment due to its possible effect on flyers' performance, but might be more appropriate and precise than questionnaires for future experiments.

In-flight observations made by Carnegie Mellon team members (and IPAGE-2 developers) led to several possible improvements to the IPAGE system that would enable it to more accurately simulate and therefore prepare (especially first-time) flyers for successful flight aboard the KC-135 aircraft. While the IPAGE-2 simulator did not prove to affect overall motion sickness levels, it was still well received and appreciated by the undergraduate participants in the Reduced Gravity program.

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http://www.randomizer.org/

http://school.discovery.com/homeworkhelp/worldbook/atozscience/m/373580.html

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[6] http://school.discovery.com/homeworkhelp/worldbook/atozscience/m/373580.html

http://www.spacecheetah.net/kc135

PHOTOGRAPHS:

JSC2001E08470
JSC2001E08485
JSC2001E08487 to JSC2001E08489
JSC2001E08641
JSC2001E08647 to JSC2001E08648
JSC2001E08678

VIDEO:

- Student Campaign, Group A, March 27-28, 2001; Reference Master: 619326

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights - Using Active Controls to Improve Subject Loading
during Exercise in Microgravity

FLIGHT DATES:
March 29 – 30, 2001

PRINCIPAL INVESTIGATOR:
Bill Marshall, Penn State University (PSU)

CO-INVESTIGATORS:
John Halenar, PSU
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Ben Weber, PSU
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Dana Ahmed, PSU
Robyn Berridge, PSU

NASA Photo: JSC2001E08696

GOAL:

The goal of this project is to improve the subject load device (SLD) used by astronauts to load their bodies during exercise in microgravity by incorporating an active control system.

The experiment was flown aboard NASA's KC-135 aircraft in March 2001 as part of the Reduced Gravity Student Flight Opportunities Program.

OBJECTIVES:

This project seeks to accomplish the following experimental objectives:
- Build and test an active control system for subject loading during exercise in microgravity
- Capture quantitative load data for the active system
- Capture quantitative load data for the passive system
- Obtain qualitative data regarding the comfort, ease of use, and design of the active system

INTRODUCTION:

The loss of bone calcium has been noted as a major problem during space flight. The main factor believed to be responsible for this loss is the reduced use of and smaller loads on the load bearing bones (Vico, 1607). As a counter measure to this bone loss, astronauts currently engage in exercise while in space. However, the current protocols are ineffective in maintaining the proper bone mass (Vico, 1610). One possible reason for this is because the current exercise harness system is uncomfortable and cumbersome to use, and some astronauts do not load the harness to the appropriate loads (Pawelczyk).

While there have been many methods taken to improve the system, such as modifying the harness, one that seems to be lacking is the incorporation of a constant loading force to the astronaut during exercise. The Subject Load Device (SLD) system is a passive spring-loaded system, which will vary the load it applies based on the displacement of the astronaut (as in jumping or squatting).

As a means to provide a more constant loading force, this experiment seeks to incorporate an active feedback system into the passive SLD design, so that the SLD tether tension may be monitored and adjusted to maintain a constant loading force. The improved system will adjust the displacement of the spring system by use of a stepper motor and gearing system. Since the loading force will be constant for all displacements of the tether, the subject wearing the harness will have a much greater range of motion during exercise. This could potentially lead to new exercise protocols that could help reduce the occurrence of space flight osteoporosis (Sommer).

METHODS AND MATERIALS:

Subjects exercised in microgravity aboard NASA's KC-135 aircraft while wearing an exercise harness, which loaded the subject by means of two tethers attached to both hips of the subject. A laptop computer captured data from a force plate and two load cells, with each cell in-line with one of the tethers.

Subjects exercised while in a supine position relative to the floor of the aircraft. During microgravity, the subject floated just above the floor with room to exercise. During high-gravity portions of the flight, the subject was able to rest in a back-down, chest-up position. This position is highly encouraged by NASA as the ideal position for a person to take high-gravity loads while on the aircraft, as well as limiting the chances of succumbing to motion sickness. As noted in the Procedures section, exercises consisted of deep knee bends and stepping in place.

Subjects were initially loaded in the extended, or "standing" position to approximately 120 lb prior to exercise by adjusting the tension in each tether to 60 lbs and monitoring that tension via load cells. During exercise, data were captured and recorded from the force plate in a 10-second interval of each portion of microgravity. This provided 10 seconds of data for each period of microgravity. Data were then saved in the force plate software for post-flight analysis.

Active loading was not available during this experiment due to computer software difficulties. However, passive loading was performed to capture and analyze baseline data for future flights.

The force plate is 20"x20" and captures the forces acting on it in the x, y, and z coordinate axes, as well as the moments about those axes. The maximum capacity in the z-axis is 1,800 N (404 lbs) and 180 N (40.5 lbs) in the x and y-axes. The force plate is manufactured by Advance Mechanical Technology, Inc. and comes with its own interface software for capture and recording of data.

The load cells are in-line, strain gauge type load cells that are capable of loads up to 250 pounds full scale. Signals produced were in the millivolt range and were amplified to a 0-5 volt reading by means of signal conditioning circuits provided with the load cells. Data were captured with an A/D card and displayed on the laptop computer via a program written in Lab View.

Subjects
Subjects were chosen for this experiment based on their involvement on the project team. A total of four subjects were chosen by peer vote by members of the project team prior to proposal submission. Subjects were co-ed undergraduate students ranging in age from 19 to 23, and were all in good health at the time of flight. Each subject was required to sign an informed consent document as required by human subject testing protocols.

The sole criteria recorded for each subject was subject weight. For the four subjects weight ranged from 159 lbs to 192 lbs. The measured weight of the subject was used to load the subject to the proper amount during exercise. Subject height, or hip height, while linked to the amount of load supplied by the system, was not considered since the system could be adjusted to account for different sized subjects.

Instruments
Quantitative data were captured and recorded via computer software programs as discussed in the Methods and Materials section.

Qualitative data were recorded during flight using a hand-held tape recorder given to each subject. This provided data on the feelings and comfort of the subject during the experiment, as well as any suggestions for improvements in design or future procedures. Further data were recorded by post-flight interviews with the subjects. Due to concerns with subject anonymity, this qualitative data are not published other than as summarized in the Discussion section below.

Procedure
During flight one student flyer served as the exercising subject for ten microgravity parabolas while the second flyer worked with the computer to control data collection from the force plate with its software program, Swaywin95. A switch of roles was made during a turnaround mid-flight, and the second flyer then exercised for ten parabolas with the original subject collecting data with the computer.

Of the microgravity portions of the ten parabolas for each subject, the first two were used to zero the force plate and weigh the subject, the next four to record continuous deep knee bends by the subject, and the last four to record the subject stepping in place. All exercises were performed with the subject oriented horizontally to the floor of the aircraft about 6 inches off the floor with the subject's feet on the force plate.

RESULTS:

From careful inspection of our flight and ground based data, one can notice several interesting results. For our brief data analysis in this paper we will only elaborate on the few that we consider to be the most important. First, for our data analysis we chose to look at the force the subjects applied to the force plate (Force Z) and the subjects' balance while exercising on the force plate (95% Confidence Region). The Force Z plots give us a graphic representation of the amount of forces each subject applied to the force plate, whereas the balance graphs show the orientation of the subject's feet on the force plate while performing deep knee bends and stepping in place.

To help with the assessment of data, each subject was weighed on the force plate during ground testing. Table R1 shows these results.

Table R1

Subject	Weight (lbs)
1	191.68
2	165.05
3	158.91
4	165.93

One of our original intentions was to load each subject to his or her actual weight. However, due to safety concerns each subject only bore approximately 60 lbs per tether resulting in a total loading force of 120 lbs.

The most notable occurrences are the impulses at the peaks of the ground based Force Z plots (Figure R1). These impulses on our deep knee bends data appear sparsely or not at all on those Force Z plots taken during the micro gravity portions of the KC 135 flight. The data also show that the Force Z plot remains relatively constant, varying over a small range except for impulse spikes, for ground based tests, but the Force Z plot varies dramatically during microgravity passive tests.

Figure R1 — Subject 3 — Ground Test Plot of Force Z

Subject 3 — Zero G Plot of Force Z
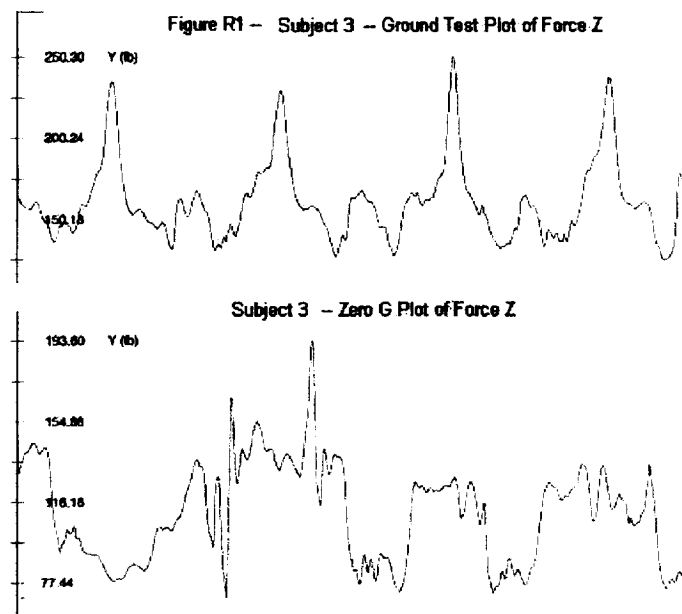
The Accusway force plate is also capable of recording balance in what it calls 95% Confidence Region. Our qualitative and quantitative data for deep knee bends revealed that the subjects had a few minor problems maintaining balance while exercising. Figure R2 compares this magnitude of sway. The cross of each region indicates the subjects XY placement compared to that of the force plates orientation. Note these data could easily be skewed by the subject not lining up correctly while exercising, however it was implemented to indicate if one tether was loading the subject more that the other.

Subject 1 – 95% Confidence Region plot of deep knee bends performed for ground testing

Subject 1 – 95% Confidence Region plot of deep knee bends performed onboard the KC 135 in Zero G

The 95% Confidence Region Graphs show a shift of the major axis from the Y axis during deep knee bends to the X axis while stepping in place. Figure R2 shows this for deep knee bends while Figure R3 shows this for stepping.

Figure R3

Subject 1– Ground Based Stepping In.Place Tests

Subject 1 – Zero G Stepping In Place Tests
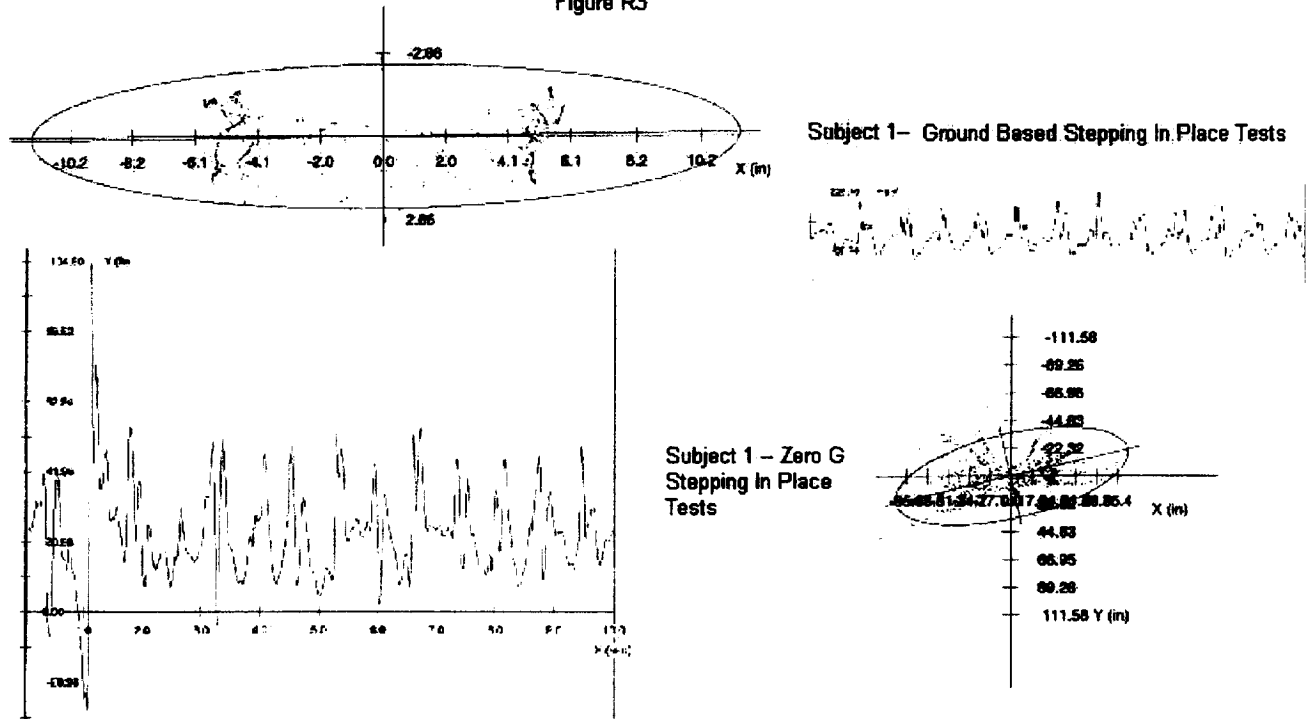
DISCUSSION:

The underlying problem associated with our experiment was at the time of flight our active system was not operational due to multiple computer problems. As a result, only the passive system data shown above were collected. However, the qualitative and quantitative data captured provides a baseline for ongoing research.

While the impulse spikes evident in Figure R1 initially caught our attention, further consideration leads us to believe that the subject pushing off as they go from a squatting to a standing position causes these spikes. These spikes are evidence of the body applying extra force to overcome the body's weight and fight against gravity. What is interesting, however, is that these spikes do not occur during microgravity flight. Two factors are believed to cause this result. The first factor is that the subject was not loaded to full body weight, and thus did not have to work as hard to lift him or herself. Also, in a squat position using the passive system, the subject is only loaded to a small fraction of body weight (approximately ¼ to ½ earth body weight). Since the body only weighs a small portion of its earth weight, the body does not need to work as hard to overcome this load. The second factor is due to balance. Since balance was much harder to control during microgravity, subjects performed exercises more slowly, reducing the amount of jerkiness in the movements.

As shown in Figure R2 above, balance was harder to maintain in microgravity as evidenced by the large deflections in the center of balance. Subjects often noted a drifting motion towards the ceiling of the aircraft. This drifting motion is believed to be caused by the resultant force of the subject rising off the floor of the aircraft and amplified by the

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subject acting to control his or her drift. One suggestion to improve the design of the experiment is to incorporate handles or similar devices for the subjects to control their balance.

The results given in this paper are not conclusive since active control results were not available for comparison. Future flights contributing to a more complete data set, however, could provide the knowledge needed to effectively modify the current SLD with active controls.

CONCLUSION:

- The incorporation of handles will provide the subject with more stability during exercise in microgravity.
- Impulse loads experienced on earth are not evidenced in a passive system in microgravity since the subject does not have to fight as hard against body weight.
- Future flights are required to obtain active control data.

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PHOTOGRAPHS:

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JSC2001E08696
JSC2001E08695 to JSC2001E08701
JSC2001E08744
JSC2001E08770 to JSC2001E08776

VIDEO:

- Student Campaign, Group B, March 29-30, 2001; Reference Master: 619324

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights - Autonomous Two-Phase Priming and Pressure Control System for Microgravity Porous Tube Hydroponics
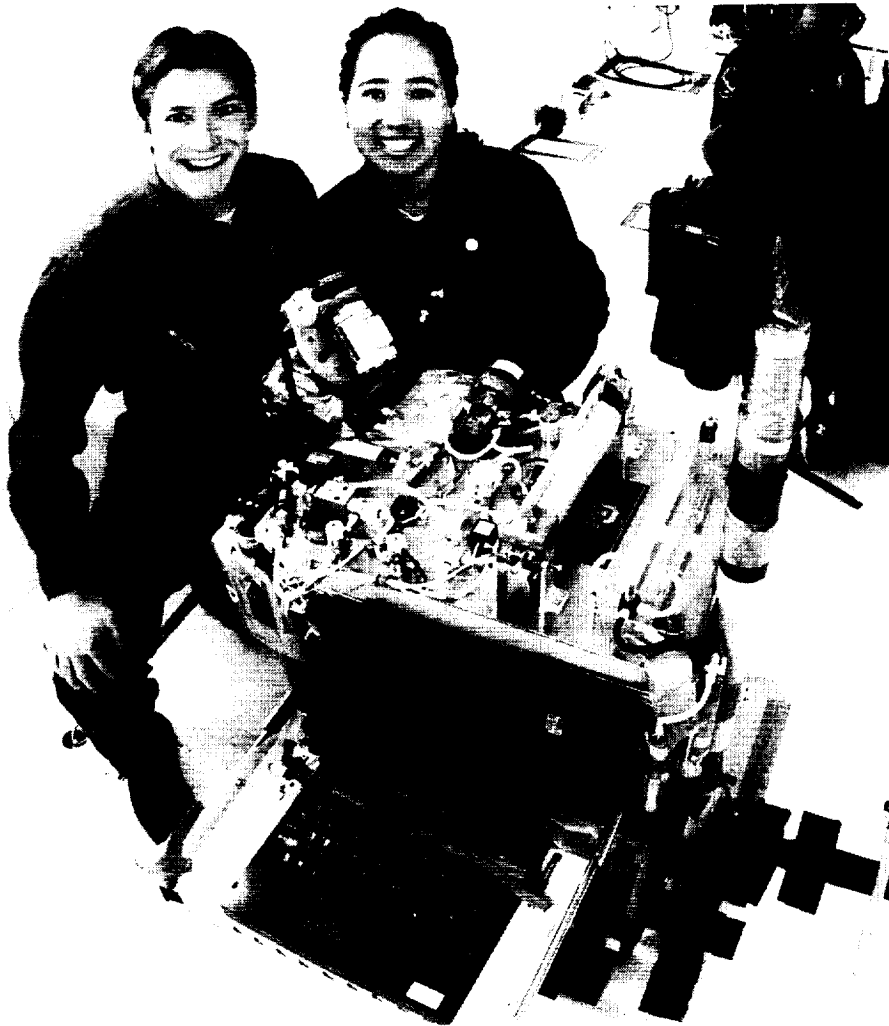
FLIGHT DATES:
March 27 – 28, 2001

PRINCIPAL INVESTIGATORS:
Jon Pineau, University of Colorado at Boulder
Bill Kalinowski, University of Colorado at Boulder
Dr. Alexander Hoehn, BioServe Space Technologies

CO-INVESTIGATORS:
Pauline Hwang, University of Colorado at Boulder
Victoria Scarffe, University of Colorado at Boulder

NASA Photo: JSC2001E08640

GOAL:

This experiment intends to contribute to the advancement of microgravity plant nutrient delivery systems and porous media behavior in reduced gravity.

OBJECTIVE:

To verify that the execution of an autonomous porous tube priming system allows the subsequent accurate pressure control and flow metering of a porous tube nutrient delivery system in a reduced gravity environment. This involves separating two-phase air/water flow and filling the matrix of a porous tube in order to achieve pressure control at slight negative pressures. The experiment identifies any differences between the behavior of the system on the ground and in reduced gravity, helping classify elements of such a system that may be verified without reduced gravity testing.

INTRODUCTION:

Although the cultivation of plant life in space is crucial for long-term space missions, plant growth technologies have not yet been optimized for spaceflight. Different systems have been formulated to deliver nutrients and water to growing plants, which are rooted in a soil or similar substrate. The substrate provides a finite supply of nutrients for the growing plant and presents the risk of soil-borne diseases. Hydroponic growth systems, on the other hand, have been shown to produce high yields and can be more accurately controlled. Liquid nutrients in hydroponic systems can be circulated and replenished over time, reducing the risks of contamination while increasing the duration of nutrient delivery

Delivery of such a liquid medium to plant roots in a microgravity environment presents a challenge. Liquid levels must be controlled such that roots are not water logged, but are supplied with an adequate amount of water. One previously tested microgravity hydroponic technology was the Porous Tube Plant Nutrient Delivery System (PTPNDS) developed at NASA's Kennedy Space Flight Center (Levine et al. 1998). In this system, plants were rooted on a ceramic porous tube. A liquid nutrient mixture was pumped through the tube and porous medium, reaching plant roots on the surface. The tubes are pressurized on the order of inches of H_2O) to control the amount of water available to the roots of plants growing on the surface.

Though plant-growth experimentation has been performed with such a system, the technology remains to be optimized and developed for space flight. In addition, there is no current technology that primes porous media on-orbit, a requirement for plant growth chambers during un-powered transfer from the Space Shuttle to the International Space Station (ISS). One open-loop system has been proposed for priming the PTNDS uses a purge bag that collects and stores the water and air that has exited the tubes during a "blow down" –like priming (Wells et al., 2000). In an attempt to reduce the amount of unusable air/water two-phase mixture produced by such a purge system, the authors have

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tested a closed-loop circulating system that both removes the air from the fluid lines and pressurizes the porous tube.

In March 2000, CU-Boulder students conducted KC-135 tests to individually validate key technology elements of a porous tube hydroponic system they had developed. These elements included fine pressure control within ceramic and stainless steel porous tubes (pore size: $0.2\mu m$) and effective two-phase flow separation in reduced gravity with a channeled membrane-based de-aerator. These component tests validated our ability to achieve steady state control of slight negative and positive pressures within the porous tubes in reduced gravity as well as dynamic control during the transitions between 0g and 2g phases of parabolic flight. Dynamic pressure control of this system would be required to prevent leakage during a cabin depressurization preceding Extra Vehicular Activity (EVA) on the Space Shuttle or International Space Station.

METHODS AND MATERIALS:

The autonomous priming and pressure control system functions in two steps. The first step primes the porous tube (0.4 in. OD, 0.3 in. ID, and 10 inch length) and circulates the two-phase flow through a channeled membrane-based de-aerator device. During this circulation, all the air is removed from the fluid lines and the porous tube matrix is filled with water. The second stage isolates the porous tube from the circulation system and connects it to a pressurization pump. Once the tube is dead-ended, a stepper motor actuated variable volume syringe pump is used to dispense or aspirate small volumes of water that in turn increase or decrease the system pressure. A block diagram of the system is found in Figure 1.

When the system initiates, water is injected into the porous tube loop until a pre-determined positive pressure is reached. This positive pressure in the tube results in the formation of small water droplets on the surface of the tube. Once this pressure is reached, the injection pump is automatically shut off. As the air and water mixture circulates through the de-aerator, air is removed and the pressure in the loop decreases. When the pressure decreases, the injection pump is toggled on and off to replace the displaced air volume. Once all the air bubbles are removed and there are no more rapid variations in pressure caused by exiting air, the system transitions into pressure control mode. Ground tests showed a full prime occurred after 50 seconds of continuous operation. To accurately assess the system's functionality in reduced gravity, accelerometer readings were used to command the software to only turn on the pumps (circulation and injection) when the vertical acceleration was less than 0.15 g.

The test procedure for the KC-135 was formulated to most accurately simulate the conditions that would be present during on-orbit priming following launch and cargo transfer to the ISS. The porous tube and the fluid loops past the circulation pump were completely dry. The fluid lines from the reservoir to the injection pump and the lines from the reservoir through the syringe pump up to the three-way valve that separates the syringe pump from the porous tube were pre-primed. This pre-priming of certain sections

would be performed prior to launch vehicle integration to assure that once the system is primed on-orbit, no air bubbles would be introduced into the porous tube during the pressurize control phase.

The key technology that enables this system to function is the channeled membrane-based de-aerator that was designed, built, and tested by aerospace engineering students at the University of Colorado at Boulder. This device operates by directing two-phase flow through shallow channels that are covered by a gas-permeable hydrophobic PTFE Teflon membrane. A suction pressure (~ 1 psi) is applied to the other side of the membrane. When air bubbles make contact with the membrane, they are sucked across the membrane and out of the fluid loop. Figure 2 shows a model of the de-aerator.
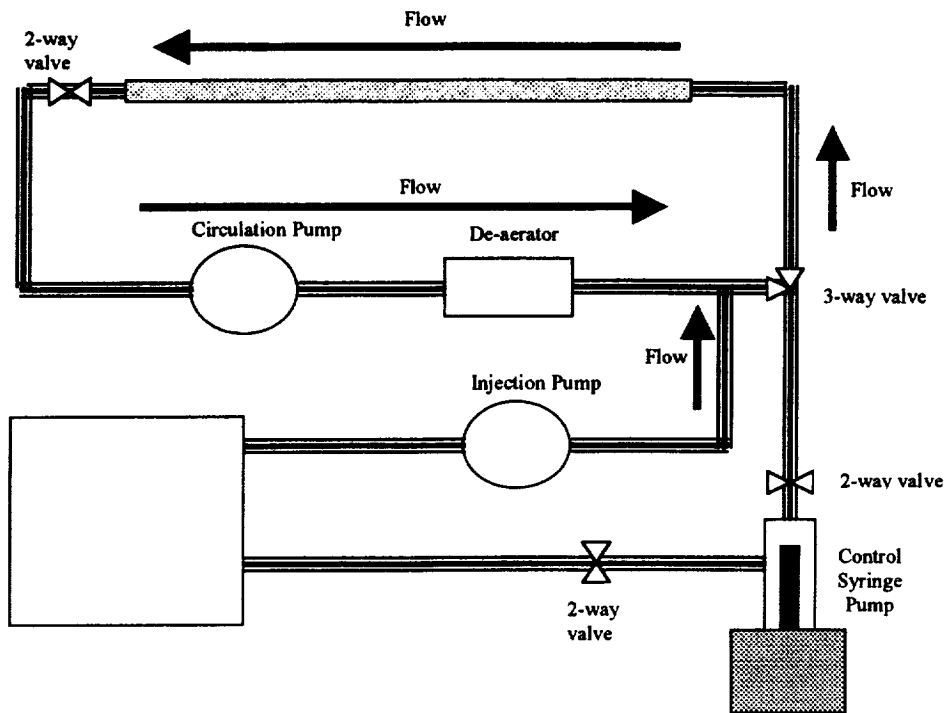
Figure 1. System block diagram during priming configuration. As air is removed from the system through the de-aerator, water is injected to replace the displaced air volume. Once priming is completed, the porous tube is dead-ended by a two-way valve and the three-way valve is switched to allow the control syringe pump access to the porous tube.
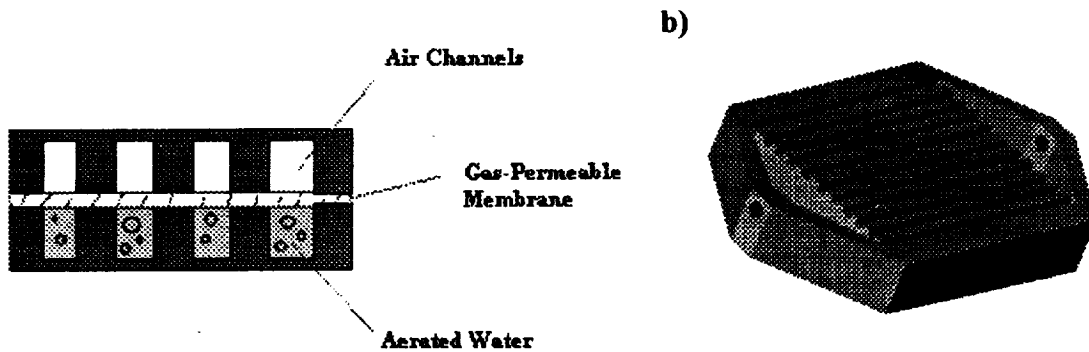
Figure 2. a) A cross section of the channel de-aerator concept showing a gas-permeable membrane sandwiched between one set of channels through which the two-phase air/water fluid flows and another set of channels on which suction is applied. **b)** A model of the fluid channel side of the de-aerator. The longest dimension of the actual device is 3.5 inches.

RESULTS:

A successful dry ceramic porous tube prime was only achieved during the second day of flight due to software errors during the first day. The system operated properly by shutting off all pumps during flight phases in which the measured acceleration was above 0.15g. Visual observation noted efficient and complete de-aeration during reduced gravity periods. Small water droplets on the surface of the tube (~ 3mm diameter) were visually confirmed to have been aspired by the tube when a negative pressure was applied to the inside of the tube.

The control system maintained pressure control of the tube during 10 parabolas following the completion of the priming phase. Pressure control was maintained at –6.0 +/- 0.3 inches H_2O during 1 and 2 g phases of the flight. During the 20 second 0 g phase of the flight, the ambient pressure within the KC-135 gradually dropped nearly 20 inches H_2O (~ 0.6 psi). The pressure control system maintained the pressure inside of the tube to within 3 inches H_2O of the set point (-6 inches H_2O) during this large pressure swing.

DISCUSSION:

The criteria to base a successful de-aeration during our test is a visual observation of small droplets receding into the tube when a negative pressure is applied to the inside of the tube. If the porous matrix of the tube was not fully primed and there existed air pathways between the outside air and the inside of the tube, a negative pressure within the tube would pull in air rather than the small droplets on the outside of the tube. As long as the pressure within the porous tube remains higher than the air inclusion pressure of the porous matrix, slight negative pressures can be maintained.

The pressure control system performance was nominal and behaved similar to ground tests during the steady 1 and 2 g flight phases. Further ground testing is required to compare the dynamic response of the pressure control system during flight under the relatively large ambient pressure swings that occur within the cabin. It is believed that through minor adjustments of the control gains and by implementing a true PID controller to the pressure control loop, the pressure control system could fully compensate to within 0.5 inches H_2O during the ambient pressure changes. The cabin pressure fluctuations were caused by the idling of the engines of the KC-135 that supply bleed air to the cabin air compressors. This is a standard feature of the KC-135 cabin environment. Future experiments that must maintain small differential pressures with respect to ambient should factor this into the experimental design to ensure that these effects to not interfere with science objectives.

In addition to compensating for changes of hydrostatic pressure (during 0, 1, and 2 g phases) and changing ambient pressure, the pressure control system must overcome pressure lost due to evaporation off the surface of the tube. Qualitative observations have been made that show a definite increase in control pump aspiration volume when the primed system is run at lower humidity levels. The evaporation rate is much less on the ground in Houston (60 to 90 % relative humidity (RH)) than it is in Colorado, where the

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hardware development and ground tests took place. In addition, the cabin of the KC-135 is filled with much drier air (15% RH) as it ascends to its 35,000 feet altitude than is present on the ground.

Although the porous tube was dry prior to the flight, there was still a small quantity of water inside of the porous matrix. Observations during ground testing showed that the success of our priming method was dependent on whether the tube had been primed within the last 24 hours. We attempted to use a heat gun to force evaporate the water from the inside of the porous matrix but did not achieve the same effect as letting the tube sit overnight. During our pre-flight activities the morning of our KC-135 flight days, we primed the system to verify system functionality. Therefore, this test may not have fully demonstrated the on-orbit priming capability of our system. The small number of tubes and available time were the limiting factors prohibiting us from waiting 24 hours between each ground test. We believe that the system can still effectively prime a completely dry porous tube with minor adjustments to control gains, pressure limits, and timing issues.

CONCLUSION:

This experiment verified the functionality of an autonomous porous tube priming and pressure control system. Although the system functioned autonomously, an autonomous method for verifying full prime has yet to be developed. Implementation of a more vigorous controller is needed to compensate for rapid changes in ambient pressure to avoid over pressurization within the porous tube and leaking (i.e., during a potential rapid decompression of the Space Shuttle or ISS cabin). More testing must be performed with completely dry tubes to fully simulate a true space mission, which may require several days between Space Shuttle integration and ISS power-on.

KC-135 environmental parameters such as ambient pressure and humidity should be taken into account when developing experiments that are dependent on these parameters. When these parameters fluctuate unexpectedly and affect an experiment, it is almost impossible to attribute any observed behavior completely to the effects of reduced gravity. We hope that future experimenters take this into account in preparation of future KC-135 payloads.

ACKNOWLEDGEMENTS:

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VIDEO:

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Videos available from Imagery and Publications Office (GS4), NASA/JSC.

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TITLE:
Undergraduate Program Flights – Airway Management in Space

FLIGHT DATES:
March 29 – 30, 2001

PRINCIPAL INVESTIGATORS:
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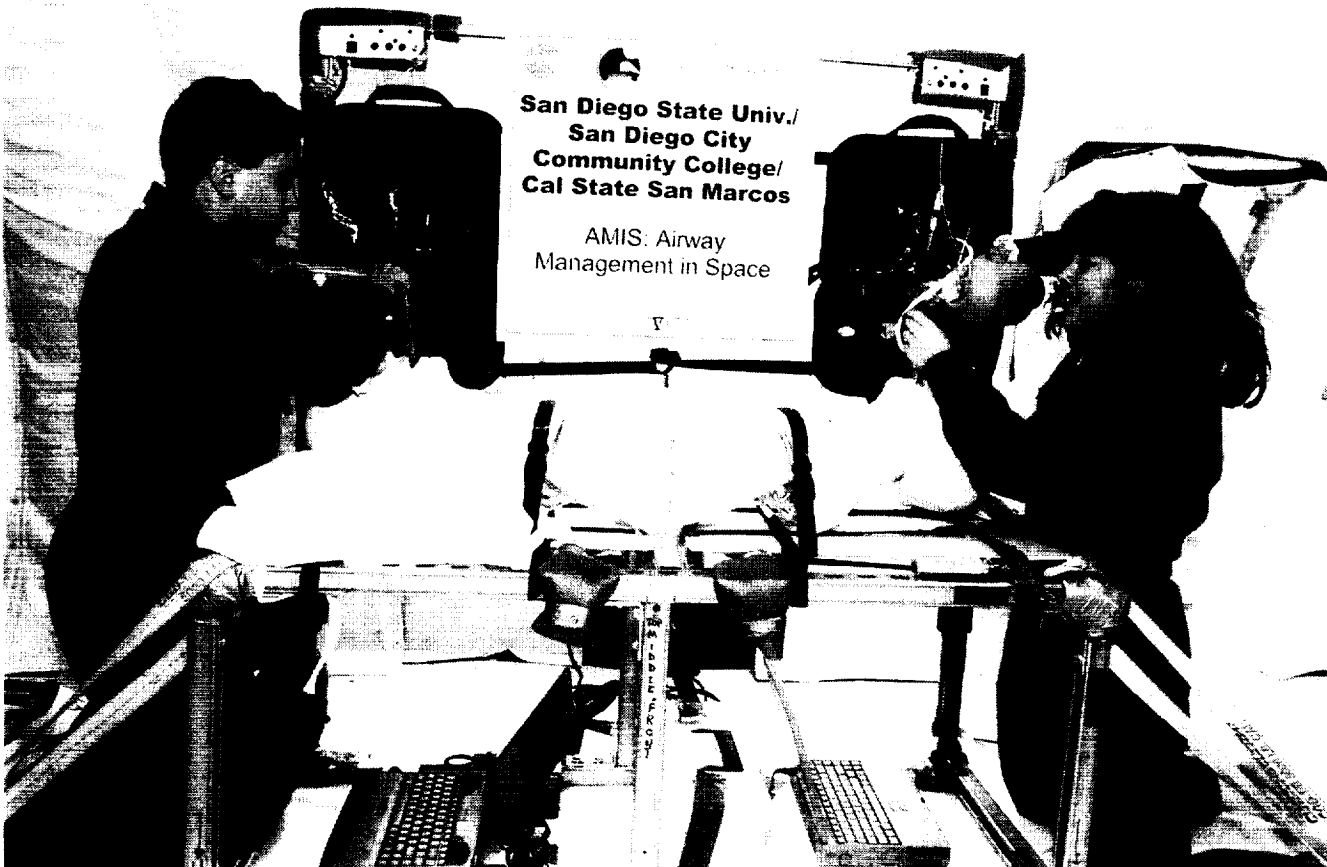
NASA Photo: JSC2001E08720

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GOAL:

To determine which medial airway device is most suitable for microgravity.

OBJECTIVE:

Current training of NASA space shuttle astronauts includes training for airway emergencies that may occur onboard the shuttle. With the increase of shuttle missions and long duration missions onboard the International Space Station there is an increased need for efficient airway emergency management due to injury or acute illness. In past studies utilizing simulated microgravity conditions, airway management was found to be extremely difficult. Airway Management in Space (A.M.I.S.) Team plans to do a randomized comparison study of two non-surgical airways: the traditional tracheal airway or "endotracheal tube", and the esophageal tracheal airway or "Combitube". We will determine which airway is easier to place effectively in an airway manikin while in microgravity, with the hopes of aiding in the development of future NASA protocols for airway emergencies while on space missions.

INTRODUCTION:

Since the beginnings of mankind, there has always been the need to explore. People have dreamed of leaving the earth and reaching for the stars and inhabiting unknown worlds. As astronaut Joseph Allen states in his book Entering Space, "The exploration and settlement of remote and unknown regions are elemental human activities." [1] The United States began its space journey with the Gemini, Mercury, and Apollo programs. It was those programs that led to today's Shuttle missions. Now, the focus is on long duration missions on the International Space Station and voyaging to Mars. With prospects such as these, it is apparent that there is a need for developing protocol for medical emergencies. One type of emergency is the "airway emergency." During spaceflight, there may be an increased risk of hypoxic cardiopulmonary arrest, aspiration of foreign bodies, and burns." [2] Events such as these disrupt normal breathing mechanisms and result in the loss of oxygen to the brain. It is known that if an airway emergency were to take place on such a mission, medical evacuation is not a suitable option because of distance and the need of the human brain to have oxygen within six minutes or else sustain brain tissue death. It is therefore imperative that immediate care be given while onboard the orbiter/station. Providing such care incurs many things. First, there must be the appropriate airway equipment onboard the orbiter/station to render care and then the crew must be adequately trained to perform such care.

Currently, the space shuttle carries endotracheal tubes that can be inserted into the trachea for breathing, and there is also a tracheostomy kit that can be used to perform a surgical incision into the trachea for the placement of a tracheostomy. [2] Then oxygen can be delivered to the patient. Both of these procedures are extremely difficult, invasive, risky and require lengthy training and experience to perform them. Recently published research indicates that anesthesiologists who are very competent at providing such airway care in normogravity had difficulties providing the same and similar airway adjuncts in simulated

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micrograyity. [2] The challenge is to find an airway device that is easy to insert, requires minimal training and provides optimal airway care while in micrograyity. Keller *et al* [2] concludes that airway management will probably be more difficult for astronauts. They recommend that "airway management training in anesthetized patients in normogravity and in manikins in simulated micrograyity would be useful adjuncts to the current program." They also indicated that "studies conducted during parabolic flight would probably yield sufficient information to construct evidence-based algorithms for airway management in micrograyity. Therefore A.M.I.S. proposes to do a comparative airway device study during parabolic flight aboard NASA's KC-135. In this experiment we will compare the current standard tracheal airway or "endotracheal tube" to an esophageal tracheal airway called the "Combitube." The latter device requires little effort to insert, no visualization with a laryngyscope, one tube to fit most patients, and works successfully regardless of whether it is placed in the esophagus or directly into the trachea. [3] To our knowledge, this airway has not been tested in micrograyity and therefore requires consideration. Comparing the two airways during parabolic flight will allow investigators to determine whether one is more advantageous over the other during micrograyity . It will also aid in developing future protocols for airway emergencies while on space missions. Our goal is to design, build, and test such a model on the ground and onboard NASA's KC-135 reduced gravity aircraft.

METHODS AND MATERIALS:

The experiment involved the comparison of speed, accuracy, and subjective ease of insertion of the endotracheal tube versus the Combitube. Each of the two flyers had an experimental station where they performed intubations on an airway manikin (see fig. 1).

FIG. 1: EXPERIMENTAL APPARATUS
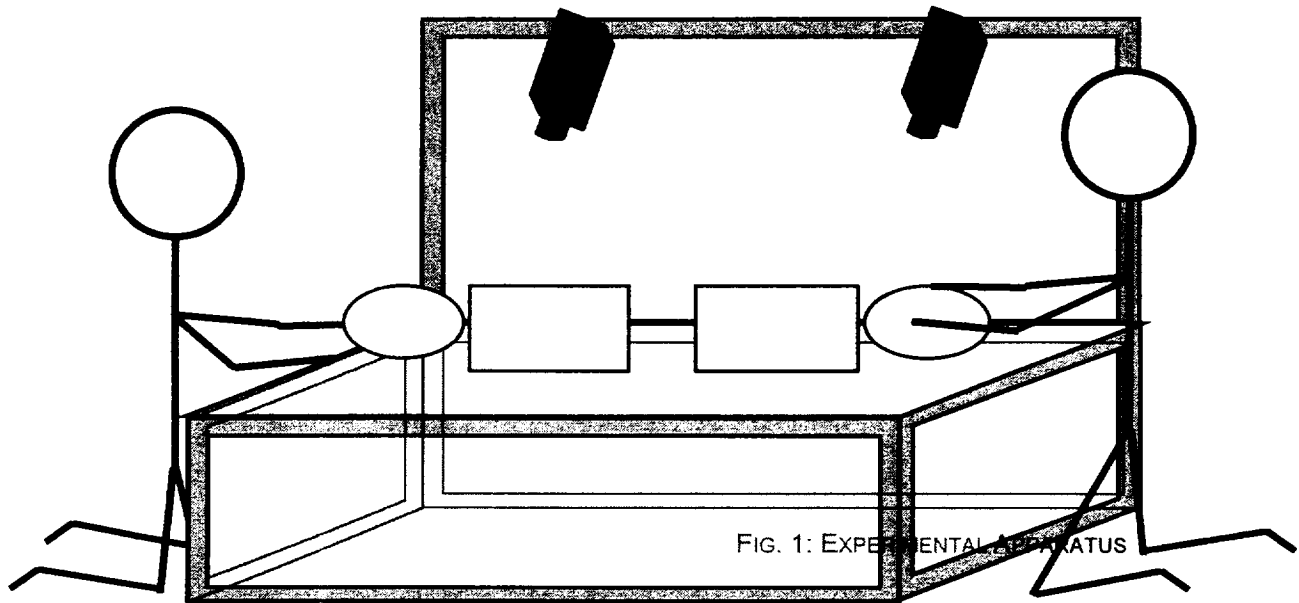
Two leg straps were utilized to maintain stabilization of the flyer. During the microgravity phase of the flight, each flyer intubated the manikin with one of the two airway devices. Although the number of intubations with each airway device was ultimately equal, the order was randomized. Each flyer performed one insertion per parabola. Each procedure started at the onset of microgravity with the flyer initiating a computer-controlled device hooked to two laptops that indicated which airway device to use and then started a timer.

The endotracheal intubation procedure (see fig.2) involved using a laryngoscope to visualize the glottic opening to directly place the endotracheal tube through the vocal cords into the trachea. This allowed direct ventilation to the lungs. After placement, the cuff was then inflated with 10cc of air from a blunt-tipped plastic syringe, which secured the airway. At this point the flyer stops the timer, and the computer recorded the elapsed procedural time. Verification of successful airway placement was then determined by using a bag-valve device (fig.3) that inflated the lungs bilaterally and equally. At this point the parabola was finished and the flyer then prepared the equipment for the next parabola. All equipment was kept in equipment pouches attached to the frame.
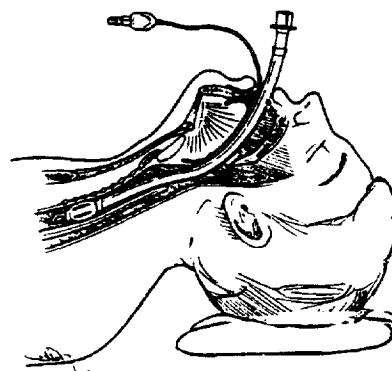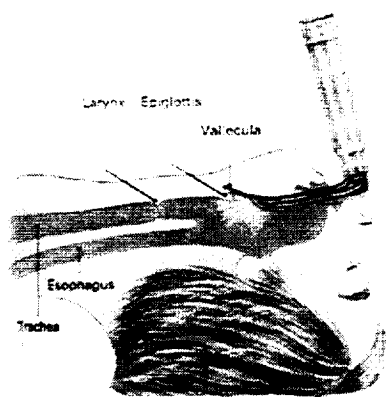
FIG. 2: ENDOTRACHEAL INTUBATION

The Combitube esophageal tracheal airway procedure involved inserting the airway directly into the oral pharynx without direct visualization. After placement, both cuffs were then inflated with air from blunt-tipped plastic syringes, which secured the airway. At this point, the flyer again stopped the timer, and the computer recorded the elapsed procedural time. Verification of successful airway placement was again determined using a bag-valve device (fig.3), and watching for equal rise and fall of the manikin lungs. At the end of the parabola, the flyer prepared the equipment for the next parabola.
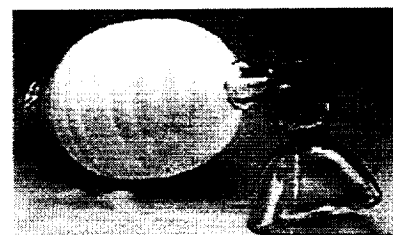
FIG. 3: BAG-VALVE DEVICE

The qualitative data consist of the elapsed time for intubation, and whether the intubation was a success or not. Success being defined as rise and fall of the lungs of the manikin with ventilation by the bag-valve device. Upon completion of the program, we analyzed the data and determined if there was a statistically significant difference between the time it took to place each device, and made comparisons in accuracy in placement by looking at the number of successes versus failures.

Each flyer has had considerable training and experience with intubation. Estimations have each flyer having about 150 successful intubations on manikins, three flyers with actual live intubations varying in number due to being licensed field paramedics and one flyer without live intubation experience. This variable occurred due to unforeseeable circumstances. The same exact experiment was performed on the ground to provide a control against which both procedures were compared. The only difference being that in the ground control, the investigators did not use Scop-Dex, an anti-nausea medication provided prior to KC-135 flights.

RESULTS:

Data were recovered from both laptops after each flight. Bar graphs were made showing each flyers average time per each procedure on the ground and in microgravity (graph 1).

graph 1

Comparison of Combitube vs. ET Tub
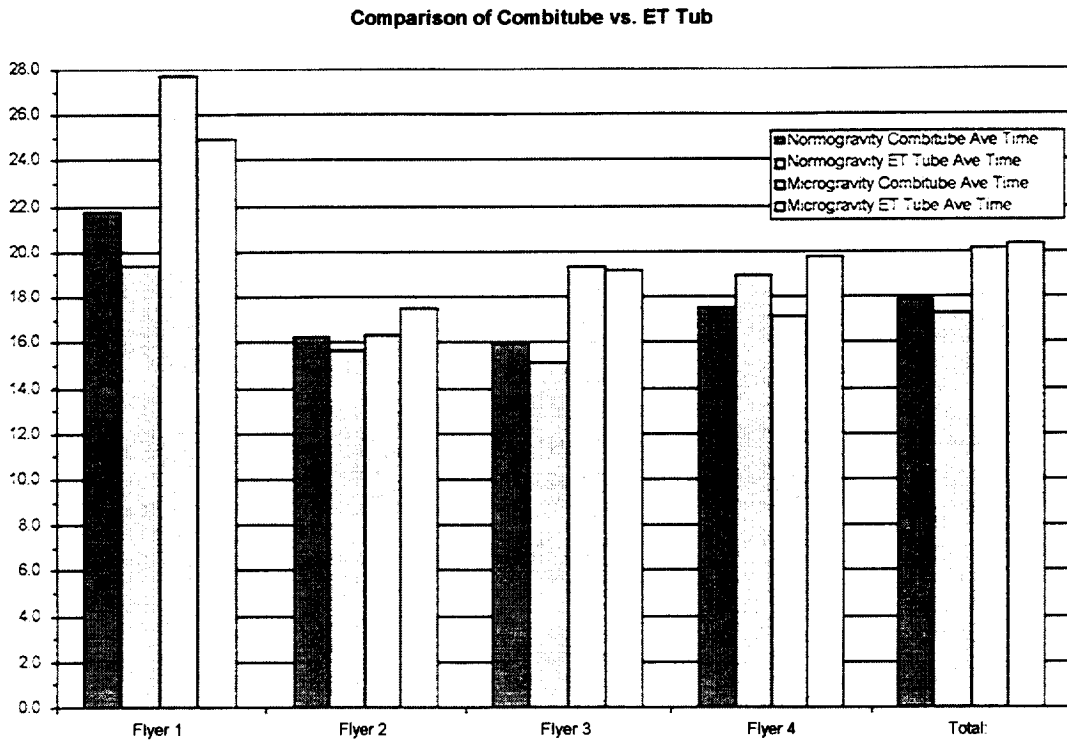
Graph 2 is a bar graph showing combitube success /attempts vs. ET tube success/attempts (graph 2).

Comparison of Attempts Vs. Successes

Legend:
- Microgravity ET attempts
- Microgravity ET Successes
- Microgravity Combitube attempts
- Microgravity Combitube Successes

X-axis: Flyer 1, Flyer 2, Flyer 3, Flyer 4, Total (Flyer)
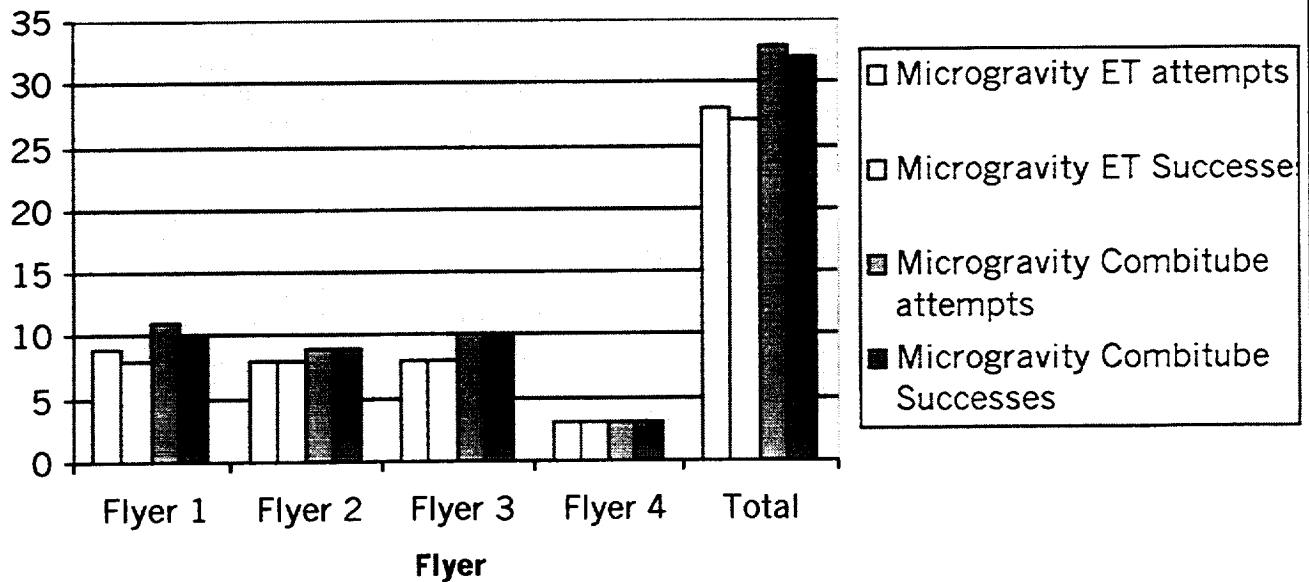
Graph 2

DISCUSSION:

Graph 1 indicates that on average the combitube performed as well as the ET tube. On average approximately 20 seconds was necessary for inserting both. Some flyers were faster than others which may be due to their level of experience or due to medication effects. Two flyers claimed that their performance was hampered by the medication effects/motion sickness, while the other pair of flyers felt little to no effect. This could account for the higher average performance time overall. The second graph indicates that there is a variance in the number of attempts of combitube vs. ET. The reason for this was that two flyers were unable to finish the experiment due to motion sickness. This offset the equal number of randomized tubes that the computers were indicating. Had each flyer successfully completed the experiment, there would have been an equal number of each tube attempted. Therefore, further data analysis must be done. Graph 2 also indicates a few failures. Flyers admittedly claimed that the "newness" of microgravity was a distraction and may have played a role in these failures. Overall, the flyers felt that both airways were easy to insert. However, they remarked that much more skill and concentration was needed to perform the ET procedure than with the Combitube. The leg restraints were subjectively graded as "adequate" restraining devices for this procedure in this type of set up.

CONCLUSION:

It is apparent that both airways can be inserted successfully during microgravity. Both the Combitube and ET tube performed equally well. Since this is the first experiment utilizing the Combitube on the KC 135, it is shown that there is enough time to perform the insertion procedure. Therefore further testing on the KC 135 is reasonable. Because the Combitube airway requires less training, is easier to insert, and requires no surgical procedure, it is recommended for further study as an alternative airway to what is currently on the shuttle. Another recommendation would be to utilize flyers with the same airway training as the astronauts and then make comparisons. It is also recommended that the flyers have experience on the KC 135 so that motion sickness, the distraction of "floating" and aircraft operation don't play a role in the outcome of the experiment. The overall equipment set up was optimal for flyer performance.

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VIDEO:

- Student Campaign, Group B, March 29-30, 2001; Reference Master: 619324

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Undergraduate Program Flights - (H.E.R.D.) Human Eye Responses to Decreased
Gravity; a Study of Intraocular Pressure and Corneal Curvature in the KC-135

FLIGHT DATES:
March 29 – 30, 2001

PRINCIPAL INVESTIGATOR:
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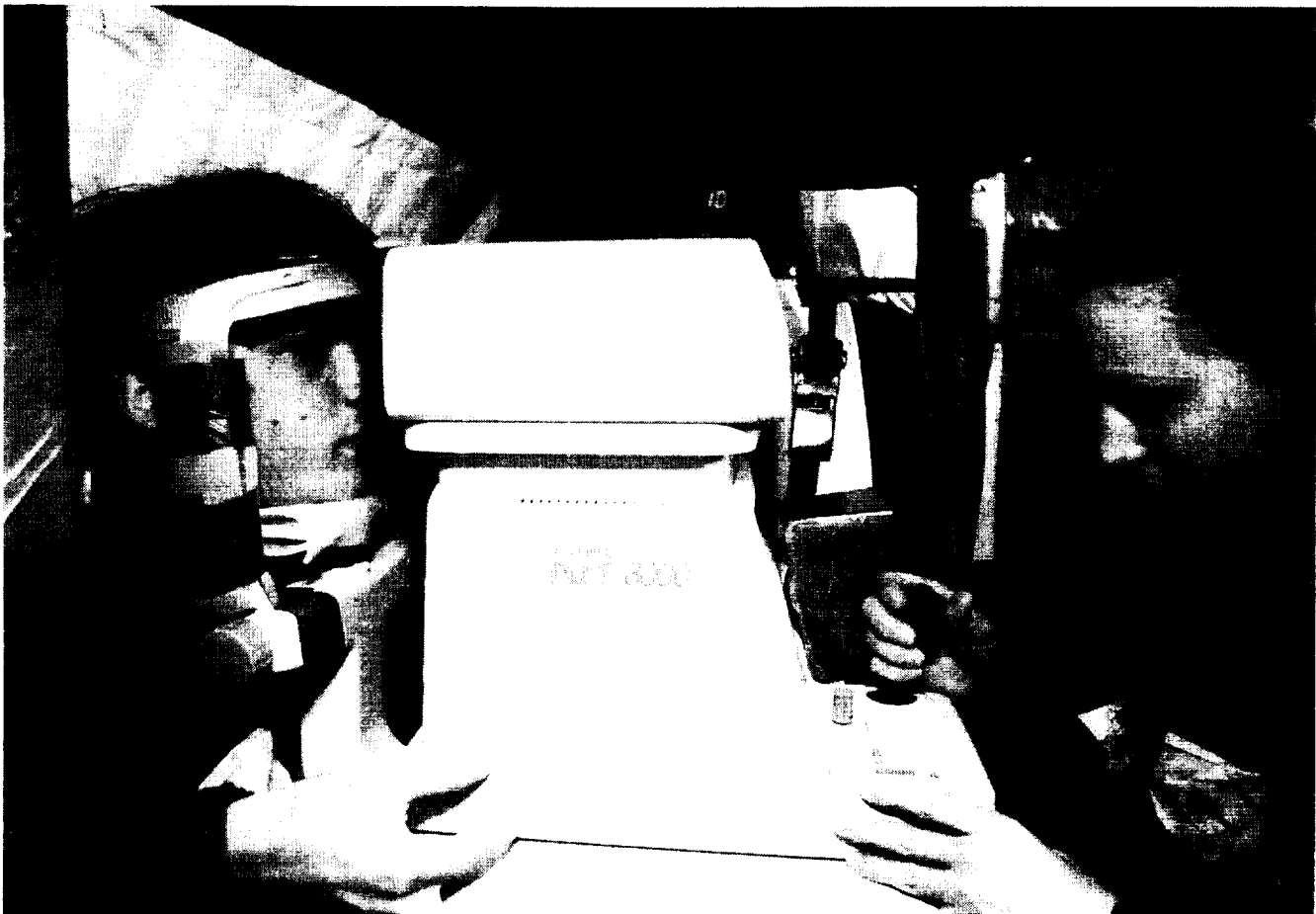
NASA Photo: JSC2001E08719

GOAL:

As human beings contemplate extended stays in space, understanding the physiological effects of microgravity on the body is crucial. In this light, the focus of our study is the human eye. It is well known that terrestrial influences, such as atmospheric pressure and elevation, can affect both corneal curvature (CC) and intraocular pressure (IOP) (1). Variation in CC can lead to vision problems such as myopia (near-sightedness) and hyperopia (far-sightedness) (9). Furthermore, fluctuations in IOP are risk factors associated with glaucoma, a leading cause of preventable blindness in the United States. Increased ocular pressure can lead to optical nerve damage and, in the extreme, loss of sight. For these reasons, the Marshall KC-135 team investigated the effects of reduced gravity on these two physiological properties.

OBJECTIVES:

As humans continue to probe deeper into space and spend longer periods of time in decreased gravity environments, it is of utmost importance to determine exactly what physiological effects these different conditions have on the body. It has been shown that microgravity causes an increase in intraocular pressure (4). However, there has not been a previous study to determine if a correlation exists between intraocular pressure and corneal curvature. Our team investigated this by using a non-contact tonometer to measure IOP and a kerato-refractometer to measure the corresponding corneal curvature under conditions of microgravity. The geometric shape of the eye is maintained by the pressure of intraocular fluid (3); therefore we hypothesized that as the IOP changed with microgravity, so would the CC.

The motivation for these studies was two-fold. First, increases in intraocular pressure (20+ mmHg) are known to cause nerve damage and glaucoma-like symptoms that may lead to short-term sight loss, permanent blindness, or conditions such as myopia and hyperopia. Further, we suspected that there might be a direct correlation between IOP and CC and/or gravitational conditions and CC. The cornea is one structure used by the eye to focus an image on the retina. Thus, if gravitational and IOP conditions cause fluctuations in CC, the vision may be distorted as a consequence, and long-term exposure to these conditions may lead to more serious effects. By studying the effects that gravity has on IOP and CC, we hope to better understand the physiological changes that occur in the human eye and how damage to the eye can be prevented during explorations into environments that contain gravitational conditions different from normal terrestrial influences.

INTRODUCTION:

On-ground measurements of intraocular pressure and corneal curvature were taken preceding the KC-135 flight. A TOPCON KR-8000 kerato-refractometer was used to determine CC. IOP was measured using a non-contact tonometer (AT550 manufactured by Reichert).

In-flight measurements of intraocular pressure and corneal curvature were taken with the same equipment as on-ground measurements. The kerato-refractometer and non-contact tonometer were housed within a well-padded superstructure. Velcro foot-straps were available to keep the team members from floating too far from the equipment. Foam facial molds allowed for quick and safe placement of the subject's eyes in front of both instruments.

During the two KC-135 flight days, two team members were able to fly at a time. The jet followed a parabolic flight pattern, providing alternating periods of 0 g and + g. Our experimental plan utilized 30 parabolas. The number of accurate readings was dependent on the ability of both team members to function efficiently in the fluctuating g environment. Any noted necessary changes were made to the equipment setup and procedure for the second flight, which involved two different team members.

In-flight measurements were transferred to an on-board computer via software written by our team that utilized the RS-232 ports of each instrument. Statistical analysis and comparative conclusions of the data were made after returning to the ground. Intraocular pressure had a significant increase of approximately 51.5% ($p < 0.05$) while no significant changes in corneal curvature were noted ($p > 0.05$).

METHODS AND MATERIALS:

Subjects
Two investigators participated as test subjects each flight.

Instruments
Measurements of intraocular pressure were made using the AT550 Auto Non-Contact Tonometer from Reichert. The auto non-contact tonometer only requires that the "patient" is stationary while in the proper position. A padded facial molding in front of the instrument ensured proper alignment. The AT550 non-contact tonometer directs a slight puff of air toward the eye followed immediately by a brief flash of light. The instrument then determines IOP by measuring the angle of the reflected light.
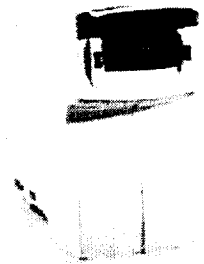
Figure 3 Non-Contact Tonometer

Corneal curvature readings were made with the KR-8000 Auto Kerato-refractometer manufactured by TOPCON. The kerato-refractometer requires some alignment with a joystick before it will take readings. To minimize problems associated with realigning for each measurement in micro-gravity a facial molding ensured the team member being tested was in the proper position. This instrument directs a series of concentric infrared circles onto the surface of the cornea. Each ring has a successively larger diameter and together these circles are used to make a corneal map.
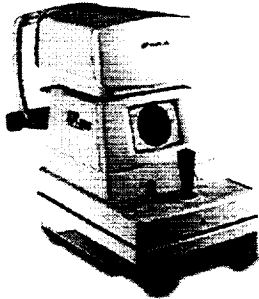
Figure 4 Auto Kerato-Refractometer

Data were downloaded immediately to a Gateway Solo 2500 Laptop through RS-232 connections.
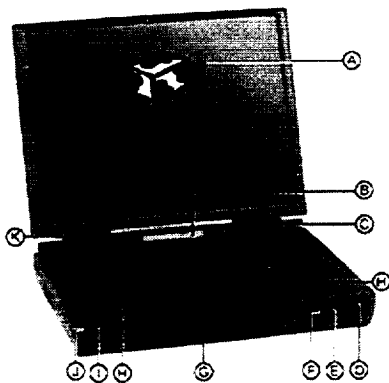
Figure 5 Gateway Solo 2500

The patient and data-taker were located on opposite sides of the instruments. The structure itself was sufficient to use for steadying throughout the flight.

Procedure
On-ground measurements of all team members were taken approximately two weeks prior to flight, and again 1 day prior to flight. This measurement was to determine if changes had taken place. Baseline data were taken in the plane at altitude in 1 g, to correct for cabin pressure. In-flight measurements were planned to follow the procedure below, but changes were made according to each experimenter's ability.

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Parabola(s)	Procedure
1	Acclimatization
2	Experimenters move into place
3	Remove straps from the instruments
4-6	Left eye tonometry data collected
7-9	Right eye tonometry data collected
10-12	Left eye keratometry data collected
13	Adjust keratometer
14-16	Right eye keratometry data collected
17	Experimenters switch positions and keratometer adjustment
18-20	Right eye keratometry data collected
21	Adjust keratometer
22-24	Left eye keratometry data collected
25-27	Right eye tonometry data collected
28-30	Left eye tonometry data collected
Lunar-Martian	Secure straps on the instrumentation for landing

RESULTS:

The intraocular pressure of subjects 1 and 2 changed significantly when comparing zero-g to 1-g measurements ($p < 0.05$). The differences ranged from 24.9 to 58.5 percent. From subjects 3 and 4, we were unable to obtain any useful data. There was no significant change in corneal curvature in zero-g compared to 1-g ($p > 0.05$) for any of the test subjects.

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Tonometry
Measurements are in mm-Hg

Subject 1

	Ground	Plane at 1-G	Plane at 0-G
R	12	12	20
R	13	14	19
R	12	12	
Average	12.33333	12.66667	19.5
Stdev	0.57735	1.154701	0.707107

				Percent difference
Ttest	0.342799	<--Ground vs Plane at 1-G		2.9
	0.004196	<--Ground vs Plane at 0-G	*	58.5
	0.00192	<--Plane at 1-G vs Plane at 0-G	*	53.9

	Ground	Plane at 1-G	Plane at 0-G
L	13	13	19
L	14	16	18
L	12	15	18
Average	13	14.66667	18.33333
Stdev	1	1.527525	0.57735

				Percent Difference
Ttest	0.100087	<--Ground vs Plane at 1-G		12.8
	0.001606	<--Ground vs Plane at 0-G	*	40.8
	0.019936	<--Plane at 1-G vs Plane at 0-G	*	24.9

Subject 2

	Ground	Plane at 0-G
R	13	22
R	14	18
R	14	24
Average	13.66667	21.33333
Stdev	0.57735	3.05505

				Percent Difference
Ttest	0.022411	<--Ground vs Plane at 0-G	*	56

	Ground	Plane at 0-G
L	16	23

L	15	26
L	16	22
Average	15.66667	23.66667
Stdev	0.57735	2.081666

Percent Difference

Ttest	0.008124 <--Ground vs Plane at 0-G	*		51.1

DISCUSSION:

Upon collection and analysis of the flight data, it was determined that there were significant physiological changes that occurred in the eye with respect to changing gravitational conditions. From the collected tonometry flight data of the flight crew, it was found that there was an increase in intraocular pressure of approximately 51.5%. Although there was only useful data from one flight day, the tonometer was easy to use in the zero-g environment. The kerato-refractometer was difficult to use in microgravity. The top portion of the equipment sits on rollers and has a joystick for alignment purposes. In free-fall, the top portion floats above the base, and in order to make measurements the experimenters had to hold down the instrument while making adjustments. This method of taking measurements proved to be inadequate, and a different approach may provide quicker, easier readings.

CONCLUSION:

It was hypothesized that as the intraocular pressure changed with microgravity, so would the corneal curvature. From the experiment results, this hypothesis can not be supported. Upon collection of ground data from each of the flight crew members and comparing it to the data collected in zero gravity, it was determined that physiological changes of the eye occurred in each of the test subjects. From this collected data, it was found that an increase in the intraocular pressure occurred with changing gravitational conditions ($p < 0.05$), but no significant changes in curvature of the cornea occurred ($p > 0.05$). The pressure readings from this experiment were similar to those from experiments using other instruments (4). This confirms that intraocular pressure changes in zero-g, and the AT550 Reichert Non-Contact Tonometer gives accurate and valid readings in microgravity. Due to difficulties using Topcon's KR8000 Auto Kerato-Refractometer, there were few usable measurements. The data are therefore unreliable, and future studies must be made to obtain any conclusive result of changes in corneal curvature. A method of stabilizing the instrument must be created, or a different instrument must be used, in order to accurately study corneal curvature changes. The ~25 seconds of free fall were enough to take measurements, but may only represent the eye pressure and eye curvature immediately after the onset of weightlessness. Future studies including longer periods of weightlessness must be done to determine the effects of spending any substantial amount of time in microgravity.

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JSC2001E08762 to JSC2001E08768
JSC2001E08715 to JSC2001E08719
JSC2001E08727 to JSC2001E08731
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VIDEO:

- Student Campaign, Group B, March 29-30, 2001; Reference Master: 619324

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Evaluation of Treadmill with Vibration Isolation System Contingency Exercise Surface

FLIGHT DATES:
April 17 – 18, 2001

PRINCIPAL INVESTIGATORS:
Charlie Lundquist, NASA/Johnson Space Center

CO-INVESTIGATORS:
Stuart Lee, Wyle Life Sciences
Jim Loehr, Wyle Life Sciences
Mike Rapley, Wyle Life Sciences
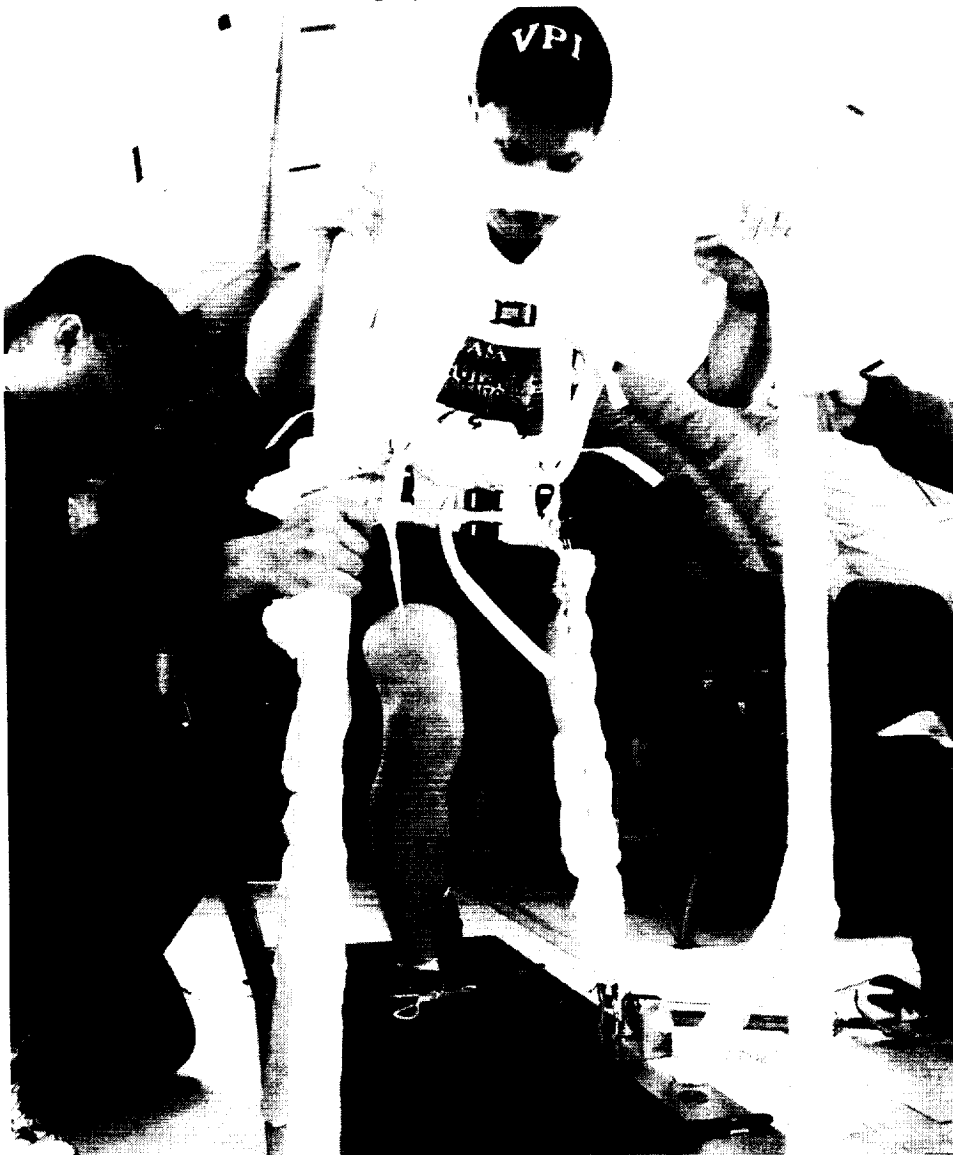
NASA Photo: JSC2001E11970

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INTRODUCTION:

A treadmill with vibration isolation system (TVIS) is currently being flown on the International Space Station (ISS) as an exercise countermeasure to space flight deconditioning, including loss of bone and muscle mass, decreased aerobic capacity, and neurovestibular disturbances associated with ambulation. The purpose of this evaluation was to investigate potential exercise procedures for use of a slick-surface plate by ISS crewmembers for contingency operations in case of TVIS failure.

METHODS AND MATERIALS:

Attachment points for constraining the crewmembers during exercise, specifically the Subject Load Devices (SLD's) and the Subject Positioning Devices (SPD's), were evaluated to determine if they were in an appropriate configuration for crew comfort and countermeasure performance. Additionally, subjects evaluated the surface to be used (Teflon versus aluminum), the need for a handle to perform the exercise (handle versus no handle), and the footwear to be worn (nylon booties versus cotton socks).

Four flights, with 40 parabolas completed per flight, were flown to evaluate the TVIS contingency exercise surface (CES).

RESULTS:

Preliminary results indicate the SLD's are properly configured and the SPD's are necessary for performance of TVIS contingency exercise.

DISCUSSION/CONCLUSION:

The aluminum plate provided a slicker surface than the teflon plate, a handle was necessary for performance of the contingency exercise and nylon booties should be worn.

PHOTOGRAPHS:

JSC2001E11897 to JSC2001E11898
JSC2001E11908 to JSC2001E11910
JSC2001E11913 to JSC2001E11913
JSC2001E11917 to JSC2001E11919
JSC2001E11927 to JSC2001E11928
JSC2001E11968 to JSC2001E1174
JSC2001E11976 to JSC2001E11977
JSC2001E11979
JSC2001E11981 to JSC2001E11983
JSC2001E12744
JSC2001E12746
JSC2001E12752 to JSC2001E12754

JSC2001E12760
JSC2001E13224 to JSC2001E13226
JSC2001E13211
JSC2001E13213
JSC2001E13230

VIDEO:

- KC-135 Flights April 17 & 18, 2001, Reference Master provided

TITLE:
Plant Growth Investigations in Microgravity (PGIM-02)

FLIGHT DATES:
April 17 – 18, 2001

PRINCIPAL INVESTIGATORS:
Robert Ferl, University of Florida
Anna-Lisa Paul, University of Florida
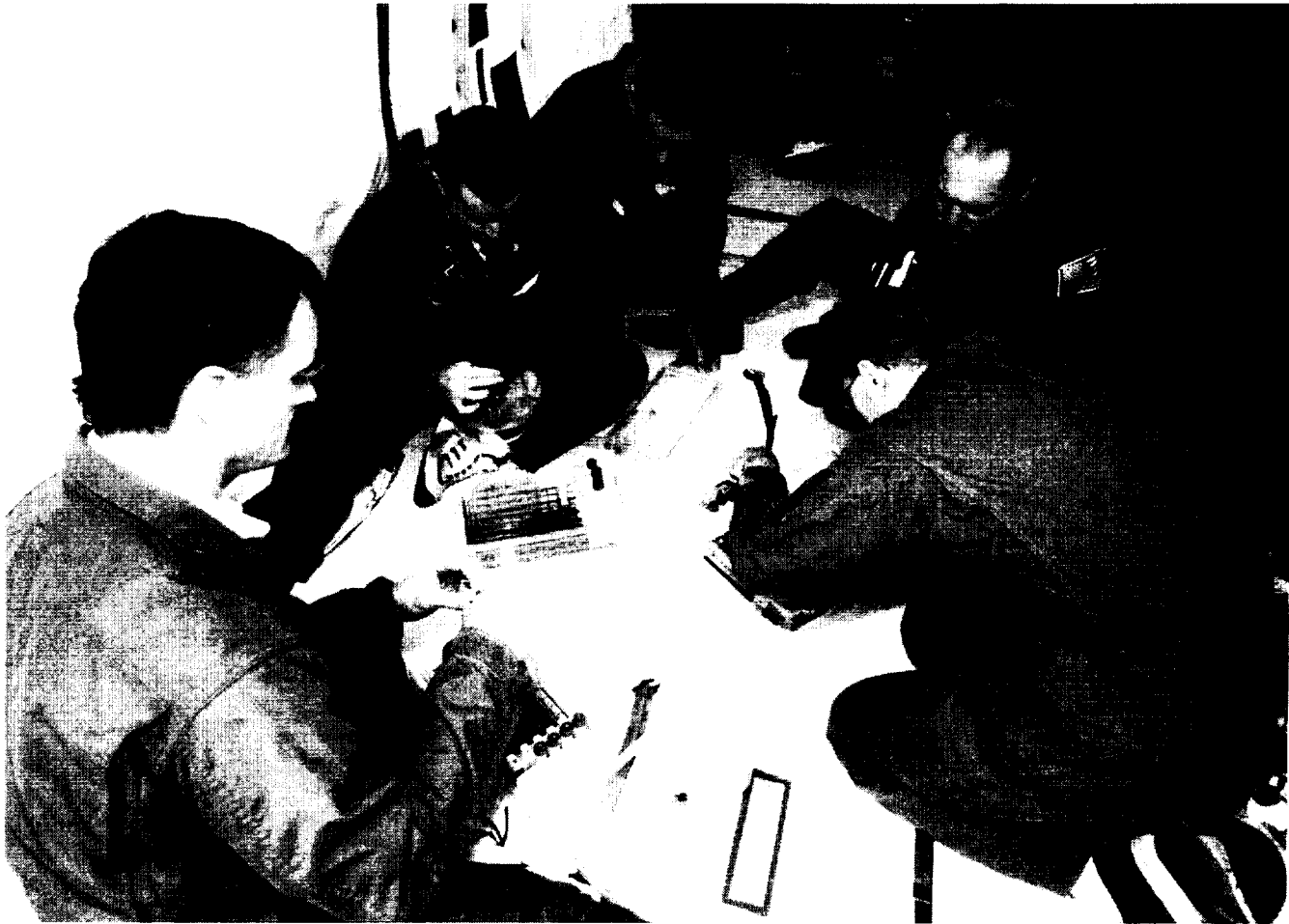
NASA Photo: JSC2001E11963

GOAL:

The overall goal of this flight experiment payload is to answer questions regarding plant biology in microgravity environments.

OBJECTIVES:

- The first major objective is the observation and quantitation of reporter gene detection of stress during KC-135 parabolic flight.
- The second objective is the preliminary characterization of Green Fluorescent Protein (GFP) reporter gene constructions.
- The third objective is the fixation of plants of both GUS and GFP for microscopic analysis using immunological whole mount procedures.

INTRODUCTION:

The guiding tenet of this project is that plants experience many forms of stress in current plant space biology applications, yet mechanical engineering is limited in its ability to monitor those stresses. In addition, the microgravity environment of space flight may affect the ability of plants to process critical biological signals, such that the perception of certain signals may be inappropriately processed into a stress response.

These experiments are set to repeat previous observations of flight induced Adh/GUS expression in shoots, and to extend those observations by staining plants of various ages and at various times in the flights.

METHODS AND MATERIALS:

This project involves genetically engineered plants as monitors and reporters of their environment. The main axis of experimental approach is to genetically modify plants to be capable of reporting the actual occurrence of stress situations, or even their inappropriate perception of stress. This has been accomplished by engineering arabidopsis plants to contain specific stress response and reporter gene combinations designed to register the perception of certain stresses during space flight. These stress reporter plants are referred to as TAGES, for Transgenic Arabidopsis Gene Expression System.

RESULTS/DISCUSSION:

The experiment team was able to complete the test protocols successfully aboard the KC-135. Tissue harvested postflight is still undergoing analysis.

PHOTOGRAPHS:

JSC2001E11904 to JSC2001E11906
JSC2001E11922 to JSC2001E11925
JSC2001E11953 to JSC2001E11954
JSC2001E11959
JSC2001E11962 to JSC2001E1163
JSC2001E12094
JSC2001E12743

JSC2001E12745
JSC2001E12747 to JSC2001E12751
JSC2001E12757 to JSC2001E12759
JSC2001E12761
JSC2001E12765
JSC2001E13215 to JSC2001E13223
JSC2001E13227
JSC2001E13231

VIDEO:

- KC-135 Flights April 17 & 18, 2001, Reference Master provided

TITLE:
Water Offset Nutrient Delivery Experiment (WONDER)

FLIGHT DATES:
April 17 – 18, 2001

PRINCIPAL INVESTIGATOR:
Kevin Burtness, The Bionetics Corporation
Howard Levine, Dynamac Corporation

NASA Photo: JSC2001E11955

OBJECTIVE:

One of the payload objectives is to develop a plant growth unit that delivers water/nutrients to plants via porous tubes.

INTRODUCTION:

For this KC-135 experiment, moisture sensors were investigated for potential use within a spaceflight payload termed the Water Offset Nutrient Delivery Experiment (WONDER). The payload is being developed in response to an NRA grant, 98-HEDS-01-036, which was selected for development and assigned to the Advanced Human Support Technology (AHST) program in 1998.

METHODS AND MATERIALS:

Within some of the plant compartments, water delivery will require use of moisture sensors to detect the level of wetness of the plant growth substrate materials which surround the porous tube. This test is being flown to characterize moisture sensors obtained from Dr. Gale Bingham (Space Dynamics Laboratory, Utah State University) in a microgravity environment via the KC-135. The moisture sensors that are being flown have been calibrated for use in ground-based applications. The intention for this KC-135 flight is to make comparisons and identify offsets from ground calibrations of these sensors. In a microgravity environment it is unknown whether these moisture sensors will behave differently due to separation of the plant growth substrate material in which the sensors are embedded. It is possible that the substrate may separate enough in microgravity to give a biased measurement and lead to a "drier" reading. If this were the case it would lead to higher fluid injection and wetter than expected substrate during the actual space flight. These sensors operate by sending a heat pulse to the sensor and calculating the temperature differential after a known decay time.

RESULTS/DISCUSSION:

Analysis of the sensor readings taken during the KC-135 flights are still in work, but preliminary observations indicate little difference between moisture sensor readings taken on the ground on those taken during 0-g.

PHOTOGRAPHS:

JSC2001E11955 to JSC2001E11958
JSC2001E12094

VIDEO:

- KC-135 Flights April 17 & 18, 2001, Reference Master provided

TITLE:
Measuring Disinfectant Concentrations in Spacecraft Drinking Water

FLIGHT DATES:
April 17 – 18, 2001

PRINCIPAL INVESTIGATORS:
Marc Porter, Iowa State University
Matteo Arena, Iowa State University
Duane Weisshaar, Iowa State University
Paul Mudgett, Wyle Life Sciences
Jeff Rutz, Wyle Life Sciences
Mickie Benoit, Wyle Life Sciences
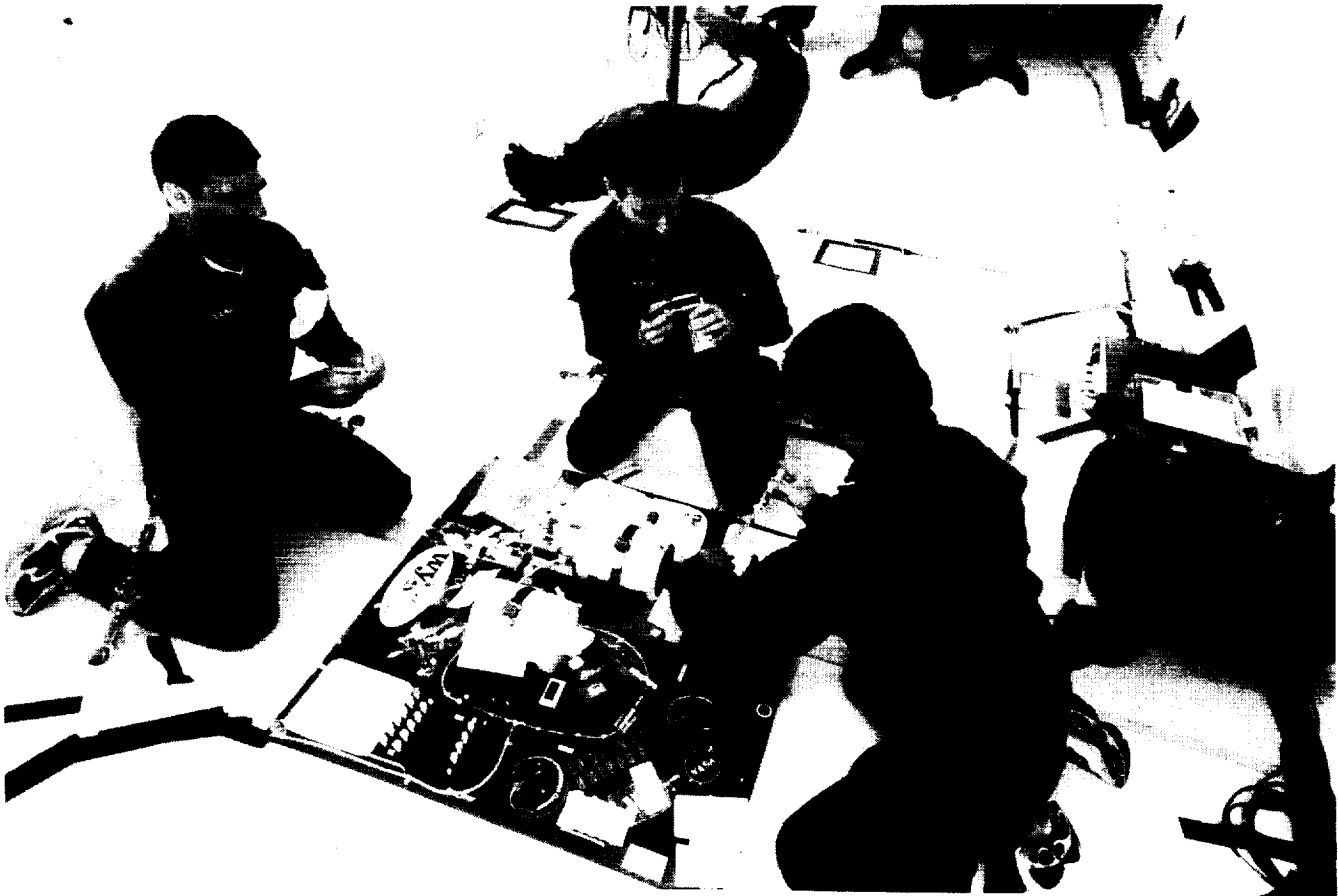
NASA Photo: JSC2001E11964

OBJECTIVES:

1. Simulate USOS galley water system dispensing iodinated water
2. Simulate Russian galley water system dispensing "silverized" water
3. Simulate water sample collection from ISS galleys
4. Test ISU developed Solid Phase Extraction colorimetric method for aqueous iodine
5. Test ISU developed Solid Phase Extraction colorimetric method for aqueous silver
6. Test a commercial off-the-shelf (COTS) mini pH meter, a component of a prototype Fluids Test Kit
7. Test a COTS mini conductivity meter, a component of the prototype Fluids Test Kit
8. Test a chemical test strip bag system developed for Thermal Control System monitoring

METHODS AND MATERIALS:

Experiment Platform

The spacecraft galley water systems were emulated using 4-liter bladder tanks (Bag-in-a-Bottle P/N 17000-0040 from Berghof/America, Concord, CA) mounted on a 40-inch square sheet of 0.75-inch thick painted plywood. Each tank has a PTFE bladder. The high-density polyethylene shell of the tank was modified to accept a compression fitting such that the bladder could be pressurized to expel the contents, and the cap was modified to accept a 0.25-inch NPT fitting to plumb a line to the dispenser. Thus, the operation of the water tanks would be gravity independent. Breathing air from a K-size bottle with a gas regulator, relief valve and manifold system was used to pressurize the tanks. The relief valve was set at 10 psig, but no more than 5 psig pressure was applied during operations. The tanks are pressure rated to 15 psig by the manufacturer, although the burst pressure is much greater (63 psig). Valves to control the air and water flow were mounted on the plywood. Teflon lines and valves were used for water distribution and polyethylene lines with brass valves for air distribution. Dispense port fittings were stainless steel male Luer-lock (P/N SSA-1305, S4J Manufacturing, Cape Coral, FL), similar to sampling interfaces used on the International Space Station. Eight handles were mounted to the platform, two on each edge for ease of transport. The platform was secured to the KC-135 aircraft floor by 4 bolts, one through each corner of the platform. All ancillary equipment was mounted directly to the platform surrounding the tanks or was secured by Velcro or elastic loops. The equipment included the Reflectance Spectrophotometer (Colorimeter), Solid Phase Extraction Cartridges, Fluids Test Kit, and custom pouches fabricated by the Softgoods Department of Wyle Laboratories to hold Teflon bags and syringes.

Spacecraft Drinking Water Simulants

Water containing iodine at normal Shuttle flight-like concentration (2-4 mg/L I_2) was obtained by flowing Milli-Q (Millipore Corporation, Bedford, MA) deionized water through a flight-like Microbial Check Valve (MCV) cartridge packed with room temperature grade iodinated resin (resin P/N 90021-69 Umpqua Research Co., Myrtle Creek, OR). Approximately 4 liters of water were flushed through prior to filling the bladder tank. The flow rate through the cartridge was 1.04 L/min. A total volume of

4200 ml was placed in the bladder tank, and then the tank was capped, mixed and "burped" to minimize air in the tank by pressurizing the bladder slightly with air pressure and opening the water outlet. Samples of the iodinated water were obtained directly from the MCV outlet and from the bladder tank dispense port after the full tank was connected to the experiment platform plumbing. Effluent water from a depleted MCV cartridge (used for 5 years in a water disinfection system test bed at NASA Johnson Space Center) was also placed in an 800 ml Teflon bag (P/N 2P-0800, American Fluoroseal Corp) to serve as a low iodine test point. The flow rate was 1.09 L/min. Samples were collected for laboratory analyses, which included iodine by UV/Visible spectrometry, pH and conductivity.

Water containing silver at 0.5 mg/L was prepared using Milli-Q deionized water and 1100 mg/L silver (I) stock solution, which was prepared from silver fluoride powder and Milli-Q deionized water. A volume of 1.9 ml concentrate was added to the bladder tank while it was being filled with Milli-Q deionized water (4200 ml total volume). The tank was capped, mixed, "burped" and then connected to the experiment platform. Samples were collected immediately after that for laboratory analysis.

Flush, Sample and Standards bags
Teflon bags of various sizes were obtained from American Fluoroseal Corporation (Gaithersburg, MD) and were fitted with either Luer quick-disconnect fittings (P/N 415067 Reflux valves from B. Braun, Bethlehem,PA) or Luer check valves P/N 80040, obtained from Qosina (Edgewood, NY), each with a tethered cap from Qosina (P/N 65600). For flushing the dispense ports prior to sampling, P/N 1P-0030 was selected with a nominal capacity of 30 ml (50 ml maximum). For obtaining samples from the water storage system, a 150 ml Teflon bag (P/N 2P-0150) was selected. These bags are scaled down from what is currently used on ISS for flushing and archive sampling (300 ml and 1000 ml bags, respectively). Milli-Q deionized water was also supplied for the KC-135 flight experiment in appropriately labeled 150 ml bags to serve as analytical blanks. All-plastic, air-tight, Luer-lock syringes, 3 ml and 10 ml sizes (Henke Sass Wolf, GmbH, Tuttlingen, Germany) were used to draw water from the sample bag and gauge the volume used for each test. Waste bags for receiving cartridge effluent were also 150 ml Teflon bags fitted with check valves to prevent back flow and contamination. Silver (I) standards at 0.1, 0.3, 0.6 and 1.0 mg/L concentrations were prepared from an 1100 mg/L silver stock solution. These solutions were analyzed by Inductively Coupled Plasma-Mass Spectrometry to verify the silver concentration, and then were placed in appropriately labeled 30 ml Teflon bags for the flight experiment.

SPE cartridge system
The extraction membranes were prepared by modifying Empore SDB-XC (polystyrene-divinylbenzene) 47mm extraction disks (3M, St. Paul, MN). Each membrane was placed in a Millipore 47mm All-Glass Vacuum Filter Holder. For the Iodine determination 10 mL of a 30 g/L polyvinyl pyrolidone solution were pulled through a membrane. For the Silver (I) determination a membrane was treated with 10 mL of a 300 mg/L 5-(4-(dimethylamino)benzylidene)rhodanine (DMABR) solution. After the membranes were

conditioned, the residual solution on the membrane was removed by applying vacuum to dry the disk for 1-2 minutes. The membranes were then cut into 13 mm disks by means of a cork borer. Each 13mm disk was preloaded into a 13mm polypropylene Swinnex® Filter Holder (Millipore Corporation) for use during the KC-135 flight. These filter cartridges have Luer fittings for connection to a syringe (inlet) and waste bag (outlet), and an O-ring internal seal.

Spectrophotometer
A BIK-Gardner color-guide sphere d/8° diffuse reflectance spectrophotometer, Cat. No. LCB-6830 (BIK-Gardner USA, Rivers Park II, Columbia, MD) was used for the flight experiment. This instrument is a hand-held (3.2 x 7 x 3.7 inches) spectrophotometer of low mass (1.1 lbs.) and battery operated. Reflectance measurements require 1.5 s and cover the entire visible spectral range (400-700 nm) in 20-nm increments. The entire spectrum is plotted on the instrument's display panel and stored in memory. Individual wavelengths are accessible only after the data are downloaded to a standard personal computer (PC). The small aperture of the instrument enables reflectance readings to be made on a 13-mm diameter disk. The instrument was mounted on the board by means of a custom-designed, padded bracket attached to the platform with screws.

After the KC-135 flight, the spectra were transferred to a PC and analyzed with the color-guide MS-Excel worksheet to record the reflectance data from 400 to 700 nm. The data were then transferred to another Excel worksheet designed to calculate the Kubelka-Munk function and plot the calibration graphs.

SPE Analysis Procedures
The necessary equipment was arranged on the experiment platform for two investigators to have access to common items. A pouch holding syringes was placed along one edge of the board and the SPE cartridges (filter holders) on an adjacent edge. The spectrophotometer and the 150 mL waste bag were placed at the corner near one water sample port. The basic procedure involves the following steps: 1) Flush the water sampling port using a 30 ml Teflon bag; 2) Collect a sample in a 150 ml Teflon bag; 3) Withdraw a measured volume from the sample bag into a syringe; 4) Attach the syringe to the appropriate cartridge and inject the water through the cartridge; 5) Detach the syringe from the cartridge, withdraw the plunger to fill the syringe with air; 6) Attach the air-filled syringe back onto the cartridge and inject ~ 3 ml air to expel residual water; 7) Disassemble the cartridge (unscrew the two halves) to expose the membrane; 8) Place the membrane side of the bottom half of the cartridge in contact with the spectrophotometer aperture and collect a reflectance spectrum (normally in duplicate); and 9) Log the sample type, volume and cartridge identification number.

Silver treated water was analyzed by SPE on the first Flight Day and iodinated water on the second. For each Flight Day, the first measurement was on a blank, consisting of 1ml of deionized water. Each subsequent measurement used a fresh cartridge. For silver treated water, a sample volume of 1.5 ml was used for each concentration; for the iodinated water, the volumes were 1 mL, 3 mL, 6 mL and 10 mL. The procedure was

divided over 2-3 parabolas: sampling during the microgravity fraction of one parabola, and extraction and spectral analysis during the microgravity fraction of the succeeding several parabolas.

Water Test Kit containing COTS pH & conductivity meters
A compact Contingency Fluids Test Kit is being developed at NASA-Johnson Space Center for potential use on International Space Station (ISS). The prototype kit contains a commercial-off-the-shelf (COTS) hand-held mini pH meter (Model B-213, Horiba Ltd, Kyoto, Japan) and a mini conductivity meter (Model B-173, Horiba), several 3 ml syringes for collecting fluid, standard solutions for calibration, deionized water for rinsing the sensor cell, spare batteries, cue cards and a small logbook. In its closed configuration, the kit measures 8 x 7 x 1.5 inch. The purpose of the kit would be to help identify spilled or leaked fluids on ISS but could also be used to support the ISS experimental program in general. The KC-135 flight test was conducted to verify whether the COTS pH and conductivity meters are suitable for flight, especially with respect to contact of fluid (water) with the sensor in the measurement cell of each meter.

Test strip bag
Special Teflon bags have been designed to temporarily house chemical test strips and minimize free fluid escape when the test strip is withdrawn from the bag. The strips are inserted into the bag, clamped in place and, once wetted with fluid, are removed and read in air against an appropriate color chart. Two types of test strip bags have been implemented to date: one with pH test paper and the other for ammonium ion. These two are currently in use on the ISS for testing thermal control system coolant. The KC-135 flight experiment included two brief interface tests of the test strip bag.

RESULTS/DISCUSSION:

Preflight SPE Test Results
The flight experiments were preceded by a ground-based analysis as comparison standards (one for iodinated water and one for silver-treated water) to check performance against those obtained in microgravity. Reflectance measurements were made after passing 1 mL, 3 mL, 6 mL and 10 mL iodinated water (at ~ 3 mg/L I_2) through individual membrane disks. The pre-flight plot for iodinated water is shown in Figure 1 consisting of the calculated Kubelka-Munk reflectance function at 440 nm vs. volume of sample through the cartridge. For the silver calibration curve (pre-flight plot, Figure 2) 3 mL of 0.1, 0.3, 0.6 and 1mg/L silver water solutions were pushed through individual cartridges and analyzed at 580 nm. The silver fluoride treated water changes the color of the membranes to shades of pink and the iodinated water gave shades of yellow.
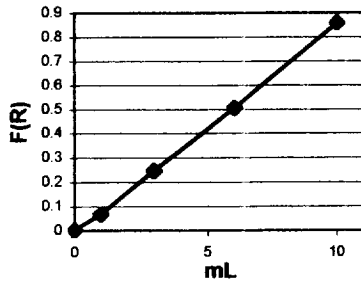
Figure 1. Iodine Calibration Curve
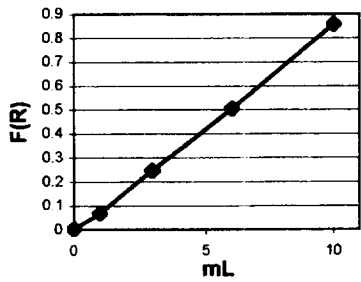
Figure 2. Silver (I) Calibration Curve

Flight SPE Results

Complete calibration curves for either iodine or silver were not obtained during the KC-135 flight, therefore individual points rather than calibration curves were compared to the ground-based results. Tables 1 and 2 present those comparisons. It was difficult in the microgravity environment to accurately measure volumes using syringes because of unavoidable air bubbles. Because the signal intensity is proportional to sample volume, an uncertainty of 10-15% in the result is not unexpected. One of the in-flight measurements exhibited an error greater than 15%. The 1 mL sample of iodinated water gave a low response during the flight. The likely cause is this particular cartridge leaked some water through the O-ring seal, causing incomplete filtration and yielding the -23% difference. Another factor could be incomplete filtration of the 1ml aliquot due to hold up and sublimation of the iodine from the membrane. Sublimation is not expected to be significant at the cool temperature (14 C). The positive error observed for the other iodine samples indicates the low temperature (14 C) inside the KC-135 decreased iodine sublimation vs. what is observed in the laboratory at 25C.

Table 1. Silver water analyses--ground vs. flight results

	F(R) (on ground)	F(R) (in flight)	% Error
Blank	0.0127	0.0132	+ 4
0.1 mg/L	0.0219	0.0213	- 3
0.5 mg/L	0.0851	0.0919	+ 8

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Table 2. Iodinated water analyses--ground vs. flight results

	F(R) (on ground)	F(R) (in flight)	% Error
Blank	0.0025	0.0023	- 8
1 mL (~ 3 mg/L)	0.0681	0.0522	- 23
3 mL (~ 3 mg/L)	0.2473	0.2822	+ 14
6 mL (~ 3 mg/L)	0.5058	0.5827	+ 15
10 mL (~ 0.4 mg/L)	0.1193	0.1359	+ 14

Preflight/In-flight/Postflight pH and Conductivity Measurements

Preflight activity included a 2-point calibration of the Horiba Twin pH meter using pH 4.00 and pH 7.00 standard buffers supplied with the meter. The Horiba Twin Conductivity meter was calibrated using the 1.41 mS/cm standard supplied with the meter. Sample measurements were made after a deionized water rinse of the sensors. The sensor area was also rinsed with sample prior to the actual sample measurements, which were normally done in duplicate or triplicate. Each replicate used a fresh portion of the sample. The flight procedure involved checking the calibration with the pH 7 standard or 1.41 mS/cm standard (the pH 4 buffer was not flown). The minimum volume required for the conductivity meter is 3 drops (~ 0.15 ml) both on the ground and in microgravity. In fact its plastic sensor cavity retains the fluid by surface tension so the conductivity can be read in any orientation on the ground. The pH sensor cell is larger and requires a minimum 0.25 ml on the ground (0.5 ml preferred). During the microgravity testing, the water tended to "boule" in the sensor well and to bridge or contact both parts of the pH sensor, a minimum 1 ml was required (the sensor well with its lid closed holds 2 ml). Once placed in the well, however, the water in microgravity was held by surface tension and did not tend to escape, so closing the lid was not necessary. In both the ground and flight tests, the water in the sensor well was removed by tapping the meter with one hand against a Kimwipe in the other hand. Data collected during both flight-days were compiled with the preflight and postflight data and appears in Tables 3 and 4. Because of obvious scatter in the measurements, the last digit displayed by the pH meter is not significant, so the average value is rounded to the first digit after the decimal.

Table 3. pH data set

Sample Description	Preflight pH	Preflight Average	In-flight pH	In-flight Average	Post-flight pH	Post-flight Average
Normal iodinated water	5.46, 5.73	5.6	5.42,7.09,7.01,6.8	6.6	5.73,5.45	5.6
Low iodinated water -	5.45,4.99,4.99	5.1	4.94, 5.04	5.0	5.18, 5.08	5.1
Tap water, JSC Bldg 37	7.72, 7.73	7.7	7.37,7.74,7.83	7.6	7.83,8.18,8.21	8.1
Silver treated water	6.54, 6.27	6.4	5.69, 7.46, 7.19	6.8	7.00,6.00,5.90	6.3
External Check Std (8.44)						8.38

Notes: Multiple values in a cell are duplicate measurements on fresh sample portions from the syringe.
Preflight and postflight laboratory temperature was 24-26C.
Temperature on KC-135 dropped during flight from approximately 25C at take off to 13C during the parabolas.

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Table 4. Conductivity data set

Sample Description	Preflight Conductivity (uS or mS/cm)	Preflight Average (uS or mS/cm)	In-flight Conductivity (uS or mS/cm)	In-flight Average (uS or mS/cm)	Post-flight Conductivity (uS or mS/cm)	Post-flight Average (uS or mS/cm)
Normal iodinated water	3, 2 uS	2.5 uS/cm	4, 3, 3 uS	3.3 uS/cm	2, 2 uS	2 uS/cm
Low iodinated water	5, 5 uS	5 uS/cm	7, 9 uS	8 uS/cm	6, 6 uS	6 uS/cm
Tap water, JSC Bldg 37	0.28, 0.28 mS	0.28 mS/cm	0.27, 0.32 mS	0.30 mS/cm	0.32, 0.32 mS	0.32 mS
Silver treated water	12 uS	12 uS/cm	8, 67*, 27, 14 uS	16 uS/cm	4, 4, 4 uS	4 uS/cm
External Check Std (0.45)						0.44 mS/cm

Notes: Multiple values in a cell are duplicate measurements on fresh sample portions from the syringe.

Preflight and postflight laboratory temperature was 24-26C.
Temperature on KC-135 dropped during flight from approximately 25C at take off to 13C during the parabolas.
*Suspect inadequate rinse of sensor after calibration check with 1.41 mS/cm Std caused initial high conductivity value on Flight Day 2. Outlier omitted in computing the average.

Generally, the inflight pH values agreed with preflight and postflight data, except for inflight data for the "normal" (~ 3 mg/L) iodinated water collected on Flight Day 2 that showed a significantly higher pH. Significant scatter in the values for silver treated water were also observed and a trend toward higher values the second day vs. the first. Both iodinated and silver treated water are of low ionic strength making pH measurements difficult and susceptible to contamination (such as calibration buffer that is not thoroughly rinsed out of the well). Contamination is the probably cause for the high readings on the second Flight Day. Postflight measurements of pH and conductivity check standard obtained from Analytical Products Group (Belpre, OH) confirm the accuracy of the meters on the ground. Each meter has built-in temperature compensation, so the cool temperature measured in-flight (14C) should not have affected the performance.

The inflight conductivity measurements were also generally comparable to the preflight and postflight data. One result obtained during Flight Day 2 indicated a conductivity of 67 uS/cm, much larger than the ground based. Contamination is suspected and this result (statistical outlier) was omitted when computing the average. As with pH, measurements of low ionic strength water samples are difficult and susceptible to contamination.

Test Strip Bag

Two investigators independently evaluated test strip bags. The bag was connected to the water supply and the valve was "cracked" open allowing the test strip to be wetted without pressurizing the bag with water. Once the test strip was wetted, the valve was closed and the test strip clamp removed while the bag remained attached to the port. The

test strip was then withdrawn from the bag while pinching the outlet. During one of the tests approximately 1 ml escaped from the bag when the test strip was withdrawn, but this small quantity is easily handled with a dry wipe. The bag outlet was reclamped to prevent escape of the water remaining in the bag. Postflight weight measurements indicated approximately 4 milliliters of fluid are required to wet the test strip. Results of the interface and fill tests demonstrated that the design is sound and allows the test strip to be wetted and removed for inspection without release of a significant volume of liquid.

CONCLUSION:

The simulated spacecraft water system on the experiment platform successfully supported all planned water tests. Water sampling similar to that performed on International Space Station was adequately emulated on the KC-135 flights, although on a smaller scale. The SPE results obtained during this initial microgravity environment testing were satisfactory: the in-flight data are generally consistent with the ground-based test data. Results indicate the method works efficiently and reliably and would thus be a candidate for spacecraft application. One problem is the air bubbles or residual air from the interface drawn into the syringe when withdrawing water from the sample bag; this phenomenon reduces the reproducibility of the measurement, because of uncertainty in the volume. The introduction of a screen or other phase separator inside the syringe might solve the problem. A device to mitigate unavoidable bubbles would be advantageous in order improve linearity and accuracy, but this may complicate the hardware. Also, water residue on SPE membrane may scatter light. Removal of water from the membrane prior to reading the color is important but only if analyte is not removed in the process. Efforts to minimize residual water will be explored. Another problem occasionally observed was leakage out of the SPE filter housing. Most likely this was the result of the two halves of the cartridge not being screwed together tightly. A new, customized cartridge to eliminate the leaking problem and simplify is being designed. Although the existing method is easy and rapid, it is completely manual. Development of an automated or semi-automated system is desirable to make implementation of the method more convenient (less labor intensive) and to increase reproducibility particularly in the volume measurement.

KC-135 testing indicates the COTS pH and conductivity meters would be useful and workable in spaceflight without modification. Concerns such as contact of the sensor area with water and fluids handling in general were demonstrated to be controllable. This matter, however, proved difficult to document photographically during the flight. The evaluations of the test strip bags were also positive, indicating their straightforward design is adequate for rapid screening applications.

PHOTOGRAPHS:

JSC2001E11911 to JSC2001E11912
JSC2001E11916
JSC2001E11920 to JSC2001E11921
JSC2001E11926

JSC2001E11929
JSC2001E11960 to JSC2001E11961
JSC2001E11964 to JSC2001E11967
JSC2001E11975
JSC2001E11978
JSC2001E11980
JSC2001E11984
JSC2001E12094

VIDEO:

- KC-135 Flights April 17 & 18, 2001, Reference Master provided

TITLE:
Community College Program Flights – Effects of Reduced Gravity on Structure and Tonic
Responses of Elodea Leaves

FLIGHT DATES:
April 19 – 20, 2001

PRINCIPAL INVESTIGATORS:
Pam McMullen, Houston Community College-Northwest (HCC-NW)
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NASA Photo: JSC2001E11993

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GOAL:

This project was designed to test the effects of 0G and 1.8G on the tonic responses of plant cells.

INTRODUCTION:

Elodea canadensis, an aquatic perennial, was used for the purpose of this experiment. *Elodea* typically has a thin leaf that is easily observed under a microscope. Chloroplast and cytoplasmic streaming also known as cyclosis are easily observed in this plant.

Parts of this project were extensions of observations from last year's experiences with the reduced gravity program. Some changes were implemented that were designed to overcome some of the problems that occurred in last year's experiments. The apparatus used to gather part of the information during the flights consisted of a microscope connected to a video camera and video tape recorder.

METHODS AND MATERIALS:

For the purpose of these experiments fresh samples of an individual *Elodea* leaf was mounted on several slides prior to the flight. After takeoff of the KC-135 plane, the slide was placed on the microscope stage for direct observation during the flight. Since the microscope was attached to a video camera and recorder, the morphology of the *Elodea* leaf was taped for further analysis at a later time. The same apparatus was used both days and no changes were made to the equipment. Control experiments were conducted simultaneously on the ground using a similar apparatus. All results were recorded and observed on the day of the flight.

In addition to the leaf being observed under the microscope, fresh *Elodea* plants were flown in three separate containers of isotonic, hypertonic and hypotonic solutions. These containers were placed in the flight bag and observed after the flight for any changes.

RESULTS:

Due to the large amount of information collected on both flights we will provide preliminary observations of the material that we have analyzed.

Experiment 1 Day 1
Based on the observation of the slides with the microscope, it appears that the G forces associated with takeoff of the plane were sufficient to cause some changes in the cellular morphology of the Elodea leaf. There was a redistribution of chloroplasts in the cells. Some were clustered in the center while others were spread out toward the periphery. This was accompanied by visible gaps within the cell. Additionally, there were changes in the sizes of the individual cells within the leaf. There was a minimum of cytoplasmic streaming. When this characteristic was observed, it was very slow. Also, there were

morphological changes in the cell in response to gravitational forces between 0G and 1.8G. Observations of ground control *Elodea* leaves revealed even distribution of the chloroplasts with moderate to rapid cytoplasmic steaming and homogenous cell size within the leaf.

Experiment 2 Day 1

Isotonic solution
Post-flight and control samples of *Elodea* in isotonic solution were compared. Some of the morphological differences noted above were observed in the post-flight samples. The control samples exhibited the same properties as mentioned above.

Hypertonic solution
Post-flight and control samples of *Elodea* in hypertonic solution were compared. Both appeared similar. In both samples the cell membranes had separated from the cell wall. Chloroplast and organelles had moved to the center of the plant cell. Fewer chloroplasts could be identified. Considerable internal rearrangement of cellular contents was observed in both samples.

Hypotonic solution
Post-flight and control samples of *Elodea* in hypotonic solution were compared. Both samples appeared turgid. Fewer chloroplasts and organelles were observed in both samples. Although both exhibited cytoplasmic streaming, the post-flight sample appeared slower than the ground control sample. There were differences in the cell wall of control and experimental *Elodea* leaves.

Experiment 1 Day 2

On day 2, flight 2, three different slides were observed.

The first slide was observed for the first ten parabolas. Similar morphological changes that were observed on day 1 were exhibited on this flight. There was also cellular changes in response to gravitational variations. Evidence of some lysis of cellular structures was evident.

Experiment 2 day 2

Isotonic solution
Both the plant samples from the post-flight and control samples were examined. Similarities with day 1 samples were noted.

Hypertonic solution
Both the samples appeared to be affected by the hypertonic environment. Cellular rearrangement was evident in these *Elodea* leaves and appeared similar to the day 1 specimen.

<u>Hypotonic solution</u>
Turgidity was noted in both the post-flight and the ground samples. The appearance of both specimens were similar to those of day 1.

Equipment Function
The apparatus functioned very well both days providing adequate data. Some plane vibrations made observations difficult. The student flyers did an excellent job in refocusing the samples as needed.

CONCLUSION:

It was clearly apparent based on reviewing the experimental and control data that gravitational forces generated during takeoff of the flight were able to cause morphological changes in the cells of *Elodea* under isotonic conditions. Moreover, the in-flight changes in the gravitational environment further altered cellular morphology. These changes appeared to be more prominent in the slide specimens than leaves transported in the containers. It should be noted that in spite of morphological changes in the experimental *Elodea*, the cells were viable. Changes in cell shape during the flights might be attributed to the chemical nature of the cell wall. Plant cell walls are made of cellulose which shows a considerable amount of resilience which could change in response to varying gravitational environments. The effects of normal gravity on the orientation of plants are well established. The results of marked changes in gravity on plants are not as clearly defined. The results from these experiments provide some initial information on cellular alterations resulting from changing gravitational conditions.

The observations of the hypertonic control and experimental leaves were fairly similar. The cellular changes were more pronounced in the experimental leaves transported in the hypotonic solution when compared to control specimens.

Whether the overall changes in the experimental cells, particularly in the isotonic solutions, are permanent or reversible are yet to be determined. This In addition, there is a need to correlate these structural changes due to gravitational variations with physiological responses such as photosynthetic capabilities of the *Elodea* leaf. Such information could be possibly useful in sustaining plant life in long term space travel.

OUTREACH ACTIVITIES:

The outreach activities will utilize the numerous partnerships that HCCS has with area High Schools including the Houston Independent, Spring Branch Independent and Katy Independent School Districts. Currently, we have specifically developed an outreach project with Spring Woods High School in the Spring Branch Independent School District. The reduced gravity experiences were shared with students in Ms. Virgina Tucker's senior biology class Students in the reduced Gravity program will present their experiences to high school students involved in these partnerships. These presentations may also be extended to area Middle Schools within the various School Districts. This

presentation is also available to other 2 and 4-year institutions of higher learning in the immediate Houston area.

Our system journalist is currently writing articles concerning the reduced gravity projects for publication in academic periodicals.

Web Site Information
A web site has been established to post information about the Texas Community College Reduced Gravity Campaign. A description of this year's project will be posted. Results of last year's experiment can be found, as well as results from this year's experiments. There is also a graphic showing of the parabolic maneuvers of the KC-135 as well as a link to NASA's Texas Community College Reduced Gravity Student Flight web site. Although our web site is currently incomplete, we expect to have it completed soon to post the results of this year's collected data. To access our web site please go to http://nwc.hccs.cc.tx.us/zerog/index.html. Or you may go to www.hccs.cc.tx.us/nwcollege/index.html and click on" Programs and Departments", then click "Biological Sciences", then go to "Zero Gravity Experiments".

ACKNOWLEDGEMENTS:

The Students and Faculty Mentors wish to thank and express their appreciation to Ms. Lucia Brimer, Project Director,TSGC, Mr. Bob Stuckey and Ms. Sally Nash, NASA mentors, Dr. Donn Sickorez, the Pilots and Flight Crew at Ellington Air Force Base for the help and efforts that contributed to the success of this project.

PHOTOGRAPHS:

JSC2001E11844
JSC2001E11858 to JSC2001E11861
JSC2001E11864 to JSC2001E11866
JSC2001E11877 to JSC2001E11878
JSC2001E118993

VIDEO:

- 2001 Student Campaign 04/19 – 04/20, Reference Master: 619332

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Community College Program Flights – Vital Signs in Microgravity

FLIGHT DATES:
April 19 – 20, 2001

PRINCIPAL INVESTIGATORS:
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CO-INVESTIGATORS:
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NASA Photo: JSC2001E11995

GOAL:

Collect and analyze physiological data on human test subjects under variable gravitational conditions.

OBJECTIVE:

To prove or disprove the hypothesis as explained in the introduction.

INTRODUCTION:

The hypothesis is that the human body will show increased effects of stress during 1.8G compared to 0G; conversely, 0G will produce decreased effects on the human body as compared to 1G (control) in a seated relaxed state.

The purpose of this experiment is to observe and compare the physiological effects of microgravity (0G) and increased gravity (1.8G) on the human body in varying positions (sitting, standing, and laying) during flight. The effects being observed during the experiment and control are heart rate (ECG), respiration rate and depth, and galvanic skin response (GSR).

METHODS AND MATERIALS:

Subjects:	Human (1male, 1female)
Instruments:	Dell laptop computer
	Biopac transducer
	Galvanometer
	Electrocardiogram
	Disposable vinyl electrodes
	Electrode gel
	Pulse sensors
	Respiratory sensors
	Surge protector outlet

Procedure
Control data were obtained from the subjects several weeks prior to the flights. The procedures were the same for the control and the flight. The subject was connected to three sensors that monitored the above stated physiological responses. These sensors led into a transducer that relays the information into the computer. An observer monitored the subject and operated the apparatus. The test subject was outfitted with the leads prior to flight. The observer on the flight set up the Biopac software and readied the computer to record the data after calibration. Data were recorded on the test subject in various positions during 0G and 1.8G. The observer marked gravitational changes via the computer. The data were analyzed post flight.

RESULTS:

NOTE: Due to software and hardware difficulties, it was not possible to obtain data from the male subject on the first flight day. Therefore, the results and analysis of the physiological changes during standing and sitting positions are those obtained from the female subject.

Table of Ranges

	ECG in BPM	**Respiration in mV**	**GSR in Δ μMho**
0G	~50.0 to 150.0	-10.0 to 6.0	-0.5 to 5.5
1.8G	~70.0 to 150.0	$\cong$ 0	-0.5 to 5.5
Ground Control	~30.0 to 150.0	-1.0 to 2.0	$\cong$ 0

NOTE: In the discussion of results, refer to the table when ranges are needed.

In general, the ECG was elevated during the entire flight, as compared to the normal (1G) control readings. The subjects pulse rate was elevated during the 1.8G and 0G segments. The 1.0G control data showed lower pulse levels.

The subject's respiration was depressed to the point of a flat line at times (0-volume exchange), during the 1.8G phases. However, the 0G phases produced a wide and exaggerated respiration spectrum. The control data of the respiration were a rhythmic pattern.

During both the 0G and 1.8G, the galvanic response showed a wider range with the occurrence of peaks on comparison, the control data seemed to stay at a constant level.

DISCUSSION:

Variations in the physiological responses of the subject could be due to several other factors, such as:

> Age
> Flight experience
> Level of apprehension
> Effect of medication
> Amount of rest
> Intake of food
> Environmental variables in flight (e.g. temperature)
> Hardware sensitivity

The respiratory responses measuring 0.0 mV could be due to the gravitational force pulling the sensor away from the body or the forces applied to the subject could have suppressed respiration resulting in very shallow breathing.

CONCLUSION:

The effects of gravitational conditions on physiological responses were markedly varied from control recordings. The hypothesis presented in the introduction was not completely substantiated. During the 1.8G conditions there appeared to be an accentuation of the physiological stresses when compared to 1.0G. The presumption that 0G would be less stressful than 1.0G was not correct. Based on these preliminary observations of one subject it appears that different gravitational conditions do alter the physiological responses measured in this experiment. Further experimentation with more subjects is needed to more precisely analyze these responses. Moreover, the effects of prolonged exposure to changes in the gravitational environment are as yet to be determined.

PHOTOGRAPHS:

JSC2001E11844 to JSC2001E11845
JSC2001E11849 to JSC2001E11857
JSC2001E11862 to JSC2001E11863
JSC2001E11879 to JSC2001E1180
JSC2001E11895
JSC2001E11999 to JSC2001E12002
JSC2001E12010 to JSC2001E12011

VIDEO:

- 2001 Student Campaign 04/19 – 04/20, Reference Master: 619332

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Community College Program Flights – An Investigation of the Effect of Gravity on the
Molecular Headspace Composition of Fruit

FLIGHT DATES:
April 19 – 20, 2001

PRINCIPAL INVESTIGATORS:
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Shana Schreiber, GC
Catalina Schultze-Craft, GC
Thomas Shimer IV, GC
Kelly Steemke, GC
Michelle Swearer, GC
Jayne Vidas, GC

NASA Photo: JSC2001E12016

GOAL:

The goal of the investigation is to determine whether the aromas of foods such as fruits are affected by gravity. Are the aromas stronger, weaker or unaffected in microgravity as compared to normal gravity or 1.8G gravity?

OBJECTIVE:

The objective is to measure the headspace composition of a fruit such as an apple by absorbing the molecules on a micro-fiber, desorbing the molecules into the injector of a gas chromatograph, and analyzing the molecular composition. Since the experimental conditions on the flight involve microgravity and 1.8G gravity under similar conditions of temperature and pressure, the samples are assumed to experience comparable treatment except for the effect of gravity.

METHODS AND MATERIALS:

Equipment
A gas chromatograph (Hewlett-Packard 5890A) equipped with a capillary column (RTX-5, 30m) and Turbochrom Navigator (TCNav2) interface was used for the analysis. Six Supelco SPME Portable Field Samplers with 65 μm PDMS/DVB stationary phase fibers were used to collect the headspace samples. We arbitrarily chose apples of the golden delicious variety because of their easy availability year round and their noted aromas. A container made of wood and plexiglas, designed by high school students in the CAD class in the workforce department of Galveston College, was used to confine the syringes in a safe manner and to confine the experiment into a portable enclosure.

Procedure
Apples were packed tightly into a plastic bag with a short stem funnel covering the top of the apple to provide a small volume of headspace and to protect the microfiber from damage through contact with the solid apple. The package was closed with tape and positioned on a heating pad on the floor of the container. The purpose of the heating pad was used to optimize the production of aroma molecules from the apple. The syringe with micro-fiber was mounted with a clamp and secured to the container. The tip of the syringe was inserted into the headspace of the apple package. During the brief window of exposure to zero gravity, the microfiber was exposed to the headspace of the apple. Since a single exposure is insufficient for sufficient sample collection, the process of exposing the sample during the multiple parabolas at zero gravity was repeated every time that the sample experienced the gravity condition. When the condition changed, the microfiber was withdrawn into the protective needle of the syringe. The total time of exposure that we obtained is therefore the summation of many brief times of exposure. At the end of the flight the syringes were removed and transported to our lab for immediate analysis by gas chromatography. The gas chromatography procedure is based on the procedure described by Jun Song, Department of Agriculture, Michigan State University (Supelco Bulletin 869A). The micro-fiber was inserted into the injector at 250 °C and exposed for 5

minutes with purge "off". The column temperature was at 40C. At the end of desorption, the purge was turned "on", and the column temperature was maintained at 40C for 3 additional minutes, followed by a temperature program of 10 °C/minutes until a column temperature of 200C was reached and maintained for 5 minutes. The fiber was then removed from the injector. Each sample was handled by a similar protocol.

RESULTS:

Two sets of experiments were collected on two flights on consecutive days. A total of 12 experiments were performed (Table 1).

Table 1				
Experimental Design				
First Flight - 42 Parabolas-04/19/01				
Sample Label	Sample	Gravity Condition	Sample Status	Total Time of Exposure (min)
1	Control	Zero G	Fiber damage	13
2	*Apple	Zero G	Fiber damage	13
25	Apple	Zero G	OK	13
26	Control	1.8 G	OK	18
27	Repeat Sample 26	----	--	--
24	Apple	1.8 G	OK	18
7	Apple	1.8 G	Fiber damage	18
Temperature of apple on heating pad 35 deg, head space 21 deg				
Second Flight - 32 Parabolas - 4/20/01				
Sample Label	Sample	Gravity Condition	Sample Status	Total Time of Exposure(min)
28	Apple	Zero G	OK	12
6	Apple	Zero G	Fiber damage	12
3	Apple	Zero G	Fiber damage	12
29	Apple	1.8 G	OK	17
30	Apple	1.8 G	OK	17
31	Apple	1.8 G	OK	17
Temperature of apple on heating pad 40 deg, head space 24 deg				

Seven of these experiments yielded analyzable data. The total time that samples were collected in zero G added up to 13 minutes on the first flight and 12 minutes on the second flight. The collection time at 1.8 G lasted a total of 18 minutes and 17 minutes respectively. Even though that the first flight consisted of 42 parabolas and the second flight consisted of only 30 parabolas, the total time of sampling for the two flights is about the same. Samples were not collected on every parabola.

The retention time of the peaks with electronic area integration and corresponding percentages are listed in Table 2.

Table 2							
Peak Area and Percentage							
Retention Time	Sample 25(Apple,Zero)		Sample 24(Apple,1.8)		Sample 26(Control,1.8)		Sample 27(Repeat 26)	
(minutes)	Area	%	Area	%	Area	%	Area	%
13.998	0	0	0	0	0	0	0	0
16.623	10,423	3	5,383	2	0	0	0	0
18.462	10,333	3	4,158	2	0	0	0	0
20.009	24,996	8	12,164	5	225	0	225	0
20.786	12,650	4	4,663	2	867	1	0	0
22.889	11,949	4	37,508	14	53,489	65	50,738	76
23.102	64,012	20	41,896	16	0	0	3,928	6
23.762	5,463	2	11,695	4	15,051	18	11,453	17
25.016	180,246	56	149,711	56	525	1	0	0
26.755	2,609	1	2,121	1	12,022	15	0	0
27.904	0	0	0	0	0	0	0	0
	322,681	100	269,299	100	82,179	100	66,344	100
Retention Time	Sample 28(Apple,Zero)		Sample 29(Apple,1.8)		Sample 30(Apple,1.8)		Sample 31(Apple,1.8)	
(minutes)	Area	%	Area	%	Area	%	Area	%
13.998	0	0	588	0	0	0	0	0
16.623	3,526	3	0	0	3,183	2	3,166	1
18.462	564	1	0	0	1,318	1	1,948	1
20.009	1,410	1	4,266	0	7,120	4	6,040	3
20.786	1,142	1	10,900	1	7,667	4	6,247	3
22.889	46,590	44	49,845	6	71,359	35	44,983	21
23.102	5,653	5	30,802	4	21,333	11	20,757	10
23.762	13,453	13	13,865	2	17,328	9	10,493	5
25.016	32,403	31	749,278	87	72,699	36	117,802	55
26.755	1,445	1	1,543	0	731	0	397	0
27.904	0	0	0	0	0	0	697	0
	106,186	100	861,087	100	202,738	100	212,530	100

On the first flight, the total integration of the area from the zero G sample is greater than the area of the 1.8 G sample. The values are 323,000 vs 268,000 or about 20%. On the second flight the relationship is reversed. The 1.8 G samples even have about twice the values of the zero G sample. Two dominant peaks with retention times of 23 and 25 minutes appear in all the apple samples under both gravity conditions. Other peaks of minor intensity also appear in the chromatograms. The ratio of the two major peaks varies between 1 to 2.8 for one sample and 1 to 5.7 for another sample. The pattern between the gravity conditions is not consistent enough to detect a trend. The major peak at 25 minutes has integration values ranging from 32,000 to 749,000 suggesting that the samples have widely different quantities of the same component. The control sample (26), without apple, also displayed two peaks at 22.889 min. and at 23.762 min. A repeat of the procedure with the same fiber generated a similar chromatogram with integration values of 53,489 and 50,738 for the first peak and 15,051and 11,453 for the second peak for samples 26 and 27. The pattern is consistent but suggests that it doesn't relate to the headspace composition but might be related to a component generated by the conditions of the procedure. These peaks appear in minor amounts in all the samples.

DISCUSSION:

The loss of five samples in these experiments is a problem that we did not anticipate. We were aware of the delicate nature of the fibers and had trained the participants in the procedure to handle them. The brief window of time in the sampling while the participants are floating in space provides a challenge to maintain a stable environment. We presume that the sequence of extending the fiber and retracting the fiber in its sleeve and then in the syringe got reversed and thereby broke or damaged the tip. The variation in intensity of the g.c. peaks among duplicate samples is fairly large. A possible source for this effect might be the severe temperature condition (250C) recommended for desorbing the molecules from the fiber. Some of the heavy molecular weight aroma molecules reported in apples such as pentyl hexanoate, hexyl hexanoate might decompose and polymerize and explain the erratic results in the duplicate samples. The control sample, absence of apple, and its repeat demonstrates the reproducibility of our technique but it also suggests that we are observing peaks in the chromatogram that might not be sample related. The literature (Supelco bulletin 869) reports the elution of sample within 6 minutes after desorption while our samples elute after 26 minutes.

CONCLUSION:

We conclude that the analysis of the samples at zero G and 1.8 G does not show a reproducible difference in the headspace composition of the samples. We obtained variable results but they are not consistent to establish a difference due to the effect of gravity. The variation in composition of replicates suggests that the experimental conditions need to be investigated further to determine if these variations are due to sample differences or to other phenomena like molecular decomposition of products or breakdown of the microfiber, the column, or the septa.

ACKNOWLEDGMENT:

PHOTOGRAPHS:

JSC2001E11843
JSC2001E11846 to JSC2001E11853
JSC2001E11867 to JSC2001E11869
JSC2001E11881 to JSC2001E11882
JSC2001E11992
JSC2001E11998
JSC2001E12003 to JSC2001E12005
JSC2001E12012
JSC2001E12015
JSC2001E12016

VIDEO:

- 2001 Student Campaign 04/19 – 04/20, Reference Master: 619332

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
KC-135 Investigation of the Contingency Water Container Strap Volume Indication
Device

FLIGHT DATES:
April 19 – 20 , 2001
May 10 – 11, 2001

PRINCIPAL INVESTIGATORS:
Nigel J. Packham, NASA/Johnson Space Center
Ketan.S. Chhipwadia, NASA/Johnson Space Center

NASA Photo: JSC2001E13838

OBJECTIVE:

The objective of the KC-135 flight will be to effectively calibrate the volume indication
strap so that modifications to flight hardware can be made to support upcoming flights.

INTRODUCTION:

A recent modification of the contingency water container (CWC) included the addition of a strap which is placed around the circumference of the restraint. This strap is designed to expand and contract depending on the volume of water within the CWC (the strap includes an elastic section). A color scheme has been applied to the strap to give a rough indication of the volume of water within the CWC. A recent KC-135 flight provided the first zero-g data on the performance of this strap for volume indication. An unexpected result was that even though the bag was filled to the nominal volume, the intended indication on the strap was not observed. Additionally, in-flight photographs from STS-100, which was the first flight of the new design that incorporates the strap, gave the same unexpected result.

METHODS AND MATERIALS:

A CWC filled with up to 115 lbs of deionized water was removed from the KC stowage box during the first parabola in zero-g. The position of the strap was photodocumented. During the pull out and climb portions of the parabola, test personnel removed a known volume from the CWC using a "needleless" syringe and re-injected the water into a second (empty) CWC. During the second parabola, photodocumentation was recorded. This process was repeated until the range of volumes (and hence volumes indications on the strap) was completed.

All hardware was either class III flight hardware, or hardware that had been previously used on-board the KC-135 aircraft.

Hardware was stowed in the KC stowage box during the last test parabola. During the zero-g portions of the flight, test personnel maintained contact with the CWC at all times, without exerting a force on the bag that could affect the volume indication. A log of volume of water removed (per parabola and cumulative) was maintained by the test personnel.

RESULTS:

Photodocumentation of the performance of the strap during parabolic flight confirmed the need for a modification of the flight hardware. The flights were used to essentially calibrate a development strap, the results of which will be transferred to existing and future flight units.

DISCUSSION/CONCLUSION:

Testing of the CWC and strap aboard the KC-135 was useful. We anticipate additional testing aboard the KC-135 as engineering modifications are completed.

PHOTOGRAPHS:

JSC2001E13788to JSC2001E13838
JSC2001E15846
JSC2001E15858 to JSC2001E15860
JSC2001E15889 to JSC2001E15890

VIDEO:

- 2001 Student Campaign 04/19 – 04/20, Reference Master: 619332

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Texas "Fly High" Program - Effects of Microgravity Culture on F-actin
Polymerization in Activated T-cells

FLIGHT DATE:
April 27, 2001

PRINCIPAL INVESTIGATOR:
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John E. McClure, Ph.D., BCM/NASA-JSC

NASA Photo: JSC2001E12775

GOAL:

To investigate the role of cytoskeletal systems in gravity sensitivity of T-cell activation.

BACKGROUND:

Research has shown that changes in the gravity environment of cells can affect their behavior. Specifically, tissue culture experiments during space flight indicate that stimulation of T-cells in microgravity culture fails to activate T-cells as measured by the expression of CD69 and the receptor for IL-2 (CD25); two primary responses which are necessary for T-cell proliferation (1).

T-cells, a type of white blood cell critical to the immune system, function in response to foreign invaders and abnormal cells found in the body. T-cells, also called T-lymphocytes, can be found throughout the body, particularly in peripheral blood and the lymphatic system. T-cells remain in a quiescent state (G0 of the cell cycle) as they roam the body in search of foreign protein fragments on the surface of other cells. T-cells recognize the proteins of antigens as foreign invaders via the T-cell receptors (TCRs) on their surface. The engagement and aggregation of TCR results in activation of many signaling pathways inside the T-cell including the polymerization of actin cytoskeleton, which is required for activation of T-cells. T-cell activation and subsequent proliferation are necessary in order to efficiently eliminate foreign or abnormal cells in the body.

The cell's cytoskeleton is not only responsible for the cell's morphology and signal transduction, but also for maintaining the force balance inside the cell. The actin cytoskeleton consists of globular (G-) and filamentous (F-) actin. These two types of actin maintain a dynamic equilibrium through polymerization and depolymerization as required by the cell at any particular time. The actin cytoskeleton performs various functions within the cell including changes in the cell's morphology, locomotion, and organization and transport of intracellular organelles. In T-cells, the engagement and aggregation of the TCR results in rapid polymerization of G-actin into F-actin within seconds of activation. In view of the fact that actin polymerization plays a key role in T-cell signal transduction and activation response, our hypothesis is that altered actin polymerization may be responsible for the lack of T-cell responsiveness in microgravity culture. In the current experiment, we investigate gravity sensitivity of the actin cytoskeleton in T-cells under different gravitational loading during parabolic flight.

OBJECTIVES:

1. To characterize the adaptation and response of the T-cell actin cytoskeleton in microgravity and hypergravity phases of parabolic flight.
2. To develop the equipment and methodology necessary for performing the above.
3. To provide hands-on experience in microgravity life science research to the team of high school AP students through the Texas Fly High Program.

METHODS AND MATERIALS:

Cells
The Jurkat T-cell line was used for tissue culture of T-cells in parabolic flight and measurement of intracellular F-Actin levels.

Flight Hardware
A C-2000 Infant Isolette (generously provided by the Hill-Rom AirShields Corporation) was used as a 37°C isolation chamber for the experiment. The C-2000 was modified for parabolic flights by securing all unattached parts to prohibit floating during the microgravity phase of the parabolas. The table portion of the isolette was lined with plastic backed absorptive paper to contain any liquid spills, and a pattern of Velcro attachment was used to secure syringes, caps, timer, and pen inside the isolette. A box of Kim-Wipe tissue was attached on the inside of the isolette hood along with Ziploc bags for absorption and containment of any liquid spills during the experiment.

The glove port doors handles and support plates were padded with pipe insulation and Velcro to protect flight crew from sharp edges. In addition, all opening to the isolette were sealed to create a closed chamber for containment of all biological reagents.

Pre-flight Procedure:
This experiment was designed using syringes for incubation of cells and injection of activator, fixative and buffer solutions during flight. Each experiment contained 2 T-cell syringes, 2 activator syringes (+/-), 2 fixative syringes, and 2 buffer syringes. The (+) set contained activator in the activation syringe and the (-) set contained buffer for determination of baseline F-actin levels. Syringes for each experiment were secured using Velcro inside Zip-Lock bags which were designed for attachment inside the C-2000 isolette hood for 37 °C incubation prior to flight.

Approximately 3 hours before each flight, experiment sets were prepared by filing the syringes with the appropriate solutions in the Microbiology laboratory at NASA – Johnson Space Center (JSC). The syringes were then transported to Ellington Field using a portable 37 °C incubator and transferred to the C-2000 isolette prior to flight.

In-flight Procedure
Each flight team consisted of three individuals: two student experiment operators stationed on either side of the C-2000 Isolette, and one experiment coordinator. The duties of the experiment coordinator included initiation of testing sequence upon attainment of the correct gravity level (0g or 1.8g), record keeping of pertinent information, and ensuring safety of experiment procedures and flight crews.

Prior to entering a parabola, the experiments were prepared by the operators by removing the syringes from the bags and securing them at their designated location on the C-2000 platform using Velcro. Two operators were required for each experiment; one for the (+) set and the other for the (-) baseline control. Each operator prepared for his/her

experiment by removal of the caps from the syringes and connection of the T-cell syringe to the activator syringe with a Luër-lock. Immediately upon entry into the microgravity phase of the parabola, both operators injected the activator into the T-cell syringe simultaneously. The activation phase of the experiment was timed to exactly 10 seconds after which the fixation syringe was used to inject a fixative solution to stabilize the cells for post-flight analysis. After 20 seconds of fixation, the buffer syringe was utilized to dilute the fixative to avoid over-fixation of the samples. Similar experiment procedures were carried out during the 1.8g phase of the parabolas.

A total of 18 in-flight experiments were performed during two flights, with 10 experiments performed during the microgravity phase of parabolas and 8 experiments performed during the 1.8g phase of the parabolas for comparison. Upon completion of the flights, the samples were transferred from Ellington Field to the Microbiology laboratory at JSC on ice for post-flight analysis.

Post-flight Analysis
Upon return to the laboratory, the samples were washed to remove the fixatives and stained with Bodippy-Phallacidin for measurement of intracellular F-Actin by flow cytometry.

RESULTS:

To examine the effects of microgravity on F-actin polymerization in activated T-cells, cultured Jurkat T-cells were activated in-vitro using anti-TCR antibodies in both 0 and 1.8g segments of parabolic flight. Tests were performed on two separate flights of NASA's KC-135. The C-2000 isolette performed extremely well as it maintained the desired temperature during all phases of parabolic flight while providing an isolation chamber for second level containment of samples.

Post-flight analysis of samples indicates that the percent F-actin polymerization was dramatically reduced in 0g compared to 1.8g (Figure 1). The standard error of means indicate moderate error, and this error was expected due to small number of samples and operator variability.
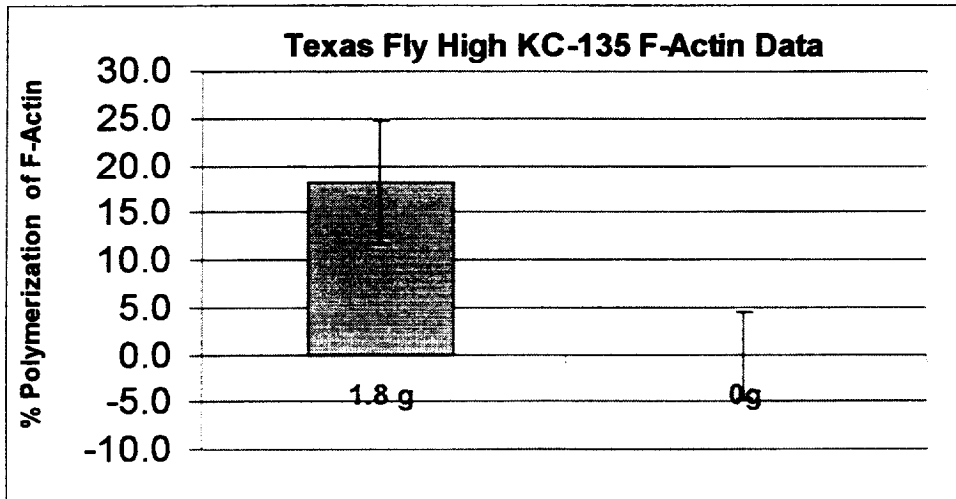
FIGURE 1

Another interesting finding was that the baseline for F-Actin shifted to lower levels in 1.8 g compared to 0g (Figure 2). These data are consistent with other laboratory data indicating that exposure of T-cells to higher gravitational loading results in lower levels of F-Actin.
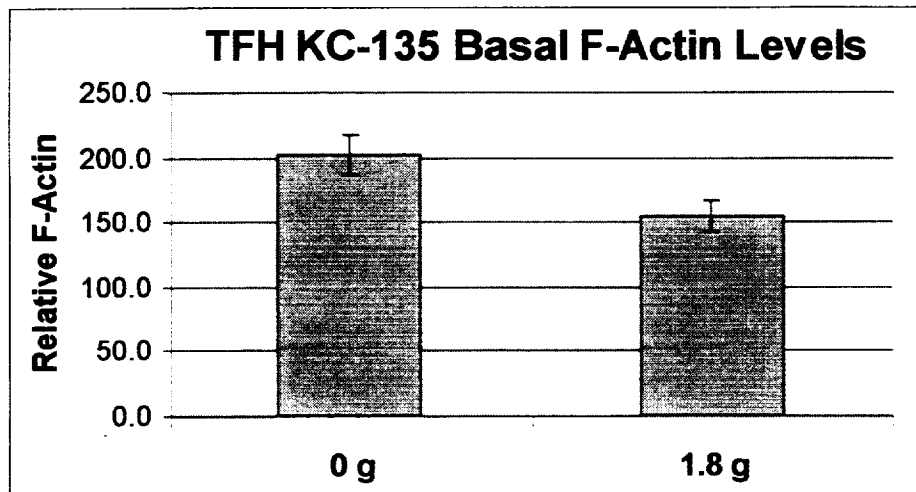
FIGURE 2

DISCUSSION/CONCLUSION:

The purpose of this experiment was to investigate the polymerization of intracellular F-actin in T-cells during microgravity culture. Results from this experiment indicate that the actin cytoskeleton does not polymerize upon stimulation in microgravity culture as compared to the 1.8g control. Furthermore, the baseline shift of F-Actin to lower levels in

1.8 g suggests that increase in gravitational loading on cells results in depolymerization of the actin cytoskeleton at higher g-levels. These data are the first evidence of the inhibition of actin polymerization in microgravity culture.

In view of the challenging nature of microgravity life science experiments, we are very pleased that during the first flight of these experiments we were able to obtain new insights into the adaptation and response of the actin cytoskeleton in microgravity culture. Future experiments are currently being planned to further improve both the quality and quantity of the data for characterization of the actin cytoskeletal response in microgravity culture.

REFERENCES:

B.B. Hashemi et. al., 1999, "T-cell activation responses are differentially regulated during clinorotation and in space flight", FASEB J. 13, 2071-2082.

ACKNOWLEDGEMENTS:

PHOTOGRAPHS:

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JSC2001E12783
JSC2001E12785
JSC2001E13129
JSC2001E13132 to JSC2001E13134
JSC2001E13155
JSC2001E13175 to JSC2001E13176

VIDEO:

• 2001 Student Campaign High School-Flight Group 1&2, Reference Master: 619330

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Texas "Fly High" Program – CPR Evaluation of Cardiopulmonary Resuscitation
Technique in Microgravity

FLIGHT DATE:
April 27, 2001

PRINCIPAL INVESTIGATORS:
Elena Coddington, Mayfield High School (MHS), Las Cruces, NM
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Mary Burke, mentor, White Sands Test Facility

NASA Photo: JSC2001E12774

GOAL:

To evaluate the depth compressions and timing of three different CPR techniques in microgravity conditions.

OBJECTIVES:

- To test the effectiveness (timing and depth compressions) of a mechanical CPR compression unit to be used in microgravity and 2 G environments.

- To measure the timing and depth of compressions using a straddle and inverted position to administer CPR.

- To compare timing and depth compression of manual CPR and mechanical CPR methods in microgravity and on earth's environment.

INTRODUCTION:

Onboard the KC-135 research aircraft, experiments will be performed under simulated zero-gravity to study the American Heart Association's CPR technique and test the operation of a mechanical CPR unit (a.k.a. Thumper).

There are two parts to the experiment. Part one is to test and evaluate the timing and depth compression of a mechanical CPR unit. The second part is to measure the timing and depth compression of several manual CPR techniques. The manual CPR techniques utilizes several different positions to apply force onto the heart. The first position is to straddle the patient at the waist line and hold on with one's legs under the patient. The second position is an inverted position. This position requires the operator to position themselves into a handstand; placing their hands on the patient's chest and their feet at the top of the aircraft. The force to compress the heart is achieved by pushing off the top of the aircraft with the push of the legs.

The proper depth compression is from 1.5 - 2 inches and compression rate is 80-100 compressions per minute. These data are used to compare the effectiveness of each technique applied.

This data will be useful to NASA for the potential construction of a mechanical CPR unit to be used in a life-threatening situation. We hope it has future applications on earth as well. This data will also further develop a CPR technique that will be successful in a zero gravity environment.

Students have gained an understanding of CPR, human anatomy and physiology, and engineering. Students at Mayfield High School were trying to provide a practical application of a potential problem in space travel and space life.

METHODS AND MATERIALS:

Equipment Description

Board
The board is provided by Wyle Laboratories, part of the Life Sciences Section. The board has flown several times before on the KC-135 and is identical to the board that currently flies on the Space Shuttle. The board is equipped with straps to secure the "patient" and the interface has the required bolt pattern to attach to the aircraft floor. Mounted to this wooden interface will be a support for the board hinge joint and a mount for the mechanical device.

Thumper® CPR System Model 1007

Input
Compressed gas at 3.515 to 6.327 kgf/cm2 (50.0 to 90.0 psi)
Gas Consumption: Maximum 45 LPM (11.88 gal/min.)
Adequate input pressure indicator set at 3.515 kgf/cm2 ± 0.211 kgf/cm2 (50.0±3.0 psi)
Pressure relief valve set at 7.030 ± 3.515 kgf/cm2 (100.0 ± 5.0 psi)
Filter to prevent contamination
Oxygen checked quick connector (oxygen will not be the gas used – BA instead)
Input supply hose

Compression
Compression Frequency: 90.0 ± 4.0 cycles per minute
Compression Stroke Range: Continuously Adjustable, 0.0 to 8.0 cm (0.0 to 3.15in)
Compression to Ventilation Ratio: 5:1
Relaxation Force Range: Upstroke force of at least 1.361 kg (3.0 lbs.)
Duty Cycle: Preset for 50% of cycle
               Chest Compression Waveform: Exponential wave with time constant of
less than 60.0 msec

Size (Assembled)
Width: 22.86 ± 0.254 cm (9 ± 0.1 in.)
Length: 48.26 ± 0.254 cm (19 ± 0.1in.)
Height: 55.88 ± 0.254 cm (22 ± 0.1 in.)
Weight 20 lbs.

Mannequin
Resuscitation Annie standard CPR class model.

Tools
A wrench will be used to tighten the bolts that mount the wooden interface board to the KC-135 bolt pattern. Other tools may be used to attach the camera to the requested support mount and to connect to the BA cylinder. The tools will be used to mount the board and connect the equipment prior to flight.

Experimental Procedures

- **Parabola Assignment/Activity**

  Flight (same activities for each day):

1-2	Adjust to microgravity
3-6	First student performs straddle method
7-10	Second student performs straddle method
break	
11-15	First student performs inverted method
16-20	Second student performs inverted method
break	Setup Thumper
21-26	Monitor Thumper
Break	Modifications to Thumper setup if needed
27-30+2	Monitor Thumper

- **Preflight Procedures**
  1. Setup wooden interface board and bolt to aircraft.
  2. Verify manual valve closed, then connect to BA supply (verify everything vented prior to connecting)
  3. Mount/Setup board. Ensure support installed under hinge.
  4. Strap down mannequin on board.

- **Straddle Position Procedures**
  1. During the period of weightlessness the operator situates himself/herself in a straddling position over the lower abdomen. A straddle position is achieved by placing both legs on either side of the mannequin's torso, while not directly on the mannequin. If necessary the operator may receive assistance from their partner in order to situate himself/herself on the board.
  2. The operator must squeeze the mannequin/board with their legs in order to remain in position over the mannequin.
  3. Once in the straddle position, the operator will begin to perform CPR on the mannequin. The operator will administer 15 hand compressions (1 compression per second) with hand placed directly upon the mannequin's sternum area.
  4. The operator will perform compressions until receiving the command "30 Low" to prepare for 2g environment which involves removing himself/herself from the CPR board and at "Feet Down Coming Out" he/she will ensure that they are oriented such that both feet are on the floor of the aircraft.

- **Inverted Position Procedures**

  1. During the period of weightlessness the operator positions their body directly over the mannequin in an inverted (handstand) orientation.
  2. The operator uses the top of the aircraft as a push-off platform as they push themselves down on the mannequin, enough to achieve the necessary 2-inch compression depth.

3. The operator continues the process to complete 15 compressions.
4. The operator will perform compressions until receiving the command "30 Low" to prepare for 2g environment which involves re-orienting himself/herself from the inverted position, and at "Feet Down Coming Out" he/she will ensure that they are oriented such that both feet are on the floor of the aircraft

- **Mechanical Device Operation Procedures:**
1. During the break to turn southward (after parabola 20), the students will setup the mechanical device, open the BA isolation valve, and turn on the unit.

2. Monitor operation of device.
Note: The device will remain in operation throughout the parabola.

- **Emergency Procedure:**
1. In the event of a board or restraint failure, the operation will be halted in order to assess the impact of the failure. Only with concurrence from both student flyers and the teacher/mentor will operations recommence once the safety of participants can be ensured.
2. In the event of a camera failure, the operation will continue. Observations will be recorded at the completion of the flight. The team will then still be able to give "lessons learned" type information to the next day's crew.

RESULTS:

Operator 1 – Straddle Position – Flight #1

Parabola	# of compressions	Time (sec)	Number of compressions where 1.5" – 2" depth achieved
1	0	20	
2	18	20	0
3	22	20	0
4	21	20	0
5	20	20	0

Operator 2 – Straddle Position – Flight #1

Parabola	# of compressions	Time (sec)	Number of compressions where 1.5" – 2" depth achieved
1	24	20	0
2	21	20	0
3	20	20	0
4	21	20	0
5	15	20	0

Operator 3 – Straddle Position – Flight #2

Parabola	# of compressions	Time (sec)	Number of compressions where 1.5" – 2" depth achieved
1	16	20	0
2	21	20	0
3	24	20	0
4	23	20	0
5	16	20	3

Operator 4 – Straddle Position – Flight #2

Parabola	# of compressions	Time (sec)	Number of compressions where 1.5" – 2" depth achieved
1	26	20	16
2	18	20	15
3	23	20	12
4	19	16	12
5	20	20	16

Inverted Position – Flight #1 – No data available

Inverted Position – Flight #2 –

Data taken, but due to uncontrollable circumstances we cannot determine who was in position. We are currently awaiting a video tape to help us.

Trial	# of compressions	Time (sec)	Number of compression where 1.5" – 2" depth achieved
1	12	9	12
2	13	14	1
3	17	13	17
4	16	12	15
5	13	13	10
6	14	15	12
7	23	16	23
8	20	18	19
9	18	18	14
10	24	18	16
11	19	17	14
12	19	14	19
13	17	13	4

Thumper – Flight #1 - Microgravity

Trial	# of compressions	Time (sec)	Number of compressions where 1.5" – 2" depth achieved
1	20	20	20
2	20	20	20
3	20	20	20
4	20	20	20
5	20	20	20

Thumper – Flight #2 - Microgravity

Trial	# of compressions	Time (sec)	Number of compressions where 1.5" – 2" depth achieved
1	20	20	20
2	20	20	20
3	20	20	20
4	20	20	20
5	20	20	20

Thumper – Flight #1 – Zero Gravity

Trial	# of compressions	Time (sec)	Number of compressions where 1.5" – 2" depth achieved
1	20	20	20
2	20	20	20
3	20	20	20
4	20	20	20
5	20	20	20

Thumper – Flight #2 – Zero Gravity

Trial	# of compressions	Time (sec)	Number of compressions where 1.5" – 2" depth achieved
1	20	20	20
2	20	20	20
3	20	20	20
4	20	20	20
5	20	20	20

DISCUSSION:

One conclusion was evident after reviewing the data and discussing the experience with the flyers. The Thumper was very successful in achieving the proper depth and consistent timing for the resuscitation of a heart attack victim in microgravity and 2 G environments.

The straddle method was very difficult to perform. It took a great deal of energy to maintain position and apply a force sufficient enough to obtain the proper depth. The operators became physically exhausted. We also believe that due to all the physical positioning, our crew got motion sickness very early into the parabolas. The first flight crew were unable to perform the inverted position because they were physically incapable. The second flight crew experienced the same physically demanding aspect of the straddle position, but were able to perform the inverted method. This method was effective in obtaining the force to achieve the proper depth for compressions. The timing could be corrected with more practice on the technique. However; this method requires that an operator be with the patient at all times. It is our belief that having a crew member free to perform other duties is very critical. The success of the mechanical CPR unit is that not only is it perfect in depth compression and timing, but it also allows the freedom of another crew member to perform other tasks.

Finally, body weight and size also made a difference in achieving the correct force necessary for the proper depth. One flyer was able to achieve more successful compression depths than the other flyers. It was evident that his size, and muscle mass contributed to his results.

CONCLUSION:

Our data indicate that the straddle method is ineffective in obtaining proper depth and maintaining correct timing of compressions. This technique requires an enormous amount of energy to sustain the compression rate and proper depth for effective resuscitation. The inverted method, with practice, is effective at maintaining depth and compression timing. The Thumper CPR instrument provides not only proper depth and consistent timing, but freedom for crew members to perform other tasks while a patient is being administered CPR.

REFERENCES:

www.michiganinstruments.com, webpage, Michigan Instruments, Inc., 4717 Talon Ct SE, Grand Rapids MI 49512; Tel: 616-554-9696 or 800-530-9939; Fax: 616-554-3067; manufacturer of Thumper® CPR System Model 1007, March 2001.

American Red Cross CPR training class and handbook material.

PHOTOGRAPHS:

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JSC2001E12791 to JSC2001E12792
JSC2001E12795
JSC2001E13127
JSC2001E13137 to JSC2001E13140
JSC2001E13168
JSC2001E13172
JSC2001E13180 to JSC2001E13181

VIDEO:

- 2001 Student Campaign High School-Flight Group 1&2, Reference Master: 619330

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Texas "Fly High" Program – Lower Body Cooling to Raise Mean Arterial Pressure

FLIGHT DATES:
May 8 – 9, 2001

PRINCIPAL INVESTIGATORS:
Lisa Sanford, Westwood High School (WHS), Palestine, TX
Alex Anderson, WHS
Greg Peterson, WHS
Randy Shipper, WHS
Rhonda Stockton, WHS
Michelle Kavetski, WHS
Angela Adair, WHS
Renae Berry, WHS
Misty Starkey, WHS
Matt McCurdy, NASA/Johnson Space Center
Laura Shaw, Purdue University

NASA Photo: JSC2001E15843

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INTRODUCTION:

Applying cold packs to the lower body is a novel way to attempt to lessen the effects of orthostatic hypotension in humans leaving microgravity and entering terrestrial gravity. Orthostatic hypotension results from an insufficient mean arterial pressure to the brain. Numerous human and animal studies have shown that humans prone to orthostatic hypotension after weightlessness have a diminished ability to constrict blood vessels in the periphery.

Mean arterial pressure is a function of cardiac output and total peripheral resistance:

Mean Arterial Pressure = Cardiac Output x Total Peripheral Resistance

The proposed countermeasure (heat removal from the lower body) will attempt to trigger vasoconstriction in the lower body, which will subsequently cause an increase in total peripheral resistance. Since mean arterial pressure and total peripheral resistance are directly proportional, the cold-induced vasoconstriction in the legs during hyper gravity may prevent hypotension in the subject.

The data collected during hypergravity will simulate the aggravated effects of returning to 1 G after a stay in weightlessness after several days. The data collected during weightlessness will be an additional variable that will help characterize the effects of parabolic flight on total peripheral resistance and heart rate.

This project proposes to remove heat from the lower body to elevate total peripheral resistance and prevent orthostatic hypotension. In the skeletal muscle vascular system, heat causes blood vessels to dilate and cold causes blood vessels to constrict. It is hypothesized that the removal of heat will cause the arterioles in the lower body skeletal muscle to constrict, subsequently increasing resistance in the vascular bed and increasing total peripheral resistance. Cold packs will be applied to the lower body of the subject while taking beat-to-beat blood pressure data to determine the effectiveness of the cold packs in increasing the amount of blood returned to the heart.

METHODS AND MATERIALS:

- Finapres™ BP Monitor (Ohmeda) – a noninvasive finger-photoplethysmographic device (wraps around index finger) used to estimate beat-to-beat mean arterial pressure

- Teac MR-30 Cassette Data Recorder

- Cold compress (Painstopper Therapeutic Ice Pack, Hill Country Manufacturing, Kerrville, Texas) - strapped onto quadriceps and gastrocnemius muscles of both legs of subject

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Pre-flight

Collect data – subject's blood pressure will be measured without cold packs and with cold packs applied.

In-flight

Finapres will be applied to subject's finger and a monitor will be attached to the hand and a data-recorder.

Subject's blood pressure will be checked and recorded for 10 parabolas during weightlessness without the cold packs.

Subject's blood pressure will be checked and recorded for 10 parabolas with the cold packs applied.

RESULTS:

Ground Control

	Diastolic	Systolic	Mean (MAP)	Sec	R-R Interval
Average	96.86	165.64	116.00	0.53	114.58
Count	180.00	180.00	180.00	180.00	180.00
Std Dev	6.39	12.26	6.82	0.12	11.97
Std Error	0.48	0.92	0.51	0.01	0.89

Ground Cold Packs

	Diastolic	Systolic	Mean (MAP)	Sec	R-R Interval
Average	101.62	177.52	121.17	0.56	107.32
Count	175.00	175.00	175.00	175.00	175.00
Std Dev	3.91	7.39	4.08	0.03	5.76
Std Error	0.30	0.56	0.31	0.00	0.44

Flight Control

	Diastolic	Systolic	Mean (MAP)	Sec	R-R Interval
Average	100.09	154.83	117.52	0.38	161.75
Count	52.00	52.00	52.00	52.00	52.00
Std Dev	10.55	13.52	8.85	0.06	24.66
Std Error	1.48	1.89	1.24	0.01	3.45

Flight Cold Packs

	Diastolic	Systolic	Mean (MAP)	Sec	R-R Interval
Average	106.26	166.37	127.47	0.43	144.52
Count	126.00	126.00	126.00	126.00	126.00
Std Dev	6.92	11.68	7.73	0.12	19.87
Std Error	0.62	1.04	0.69	0.01	1.78

Mean Arterial Pressure
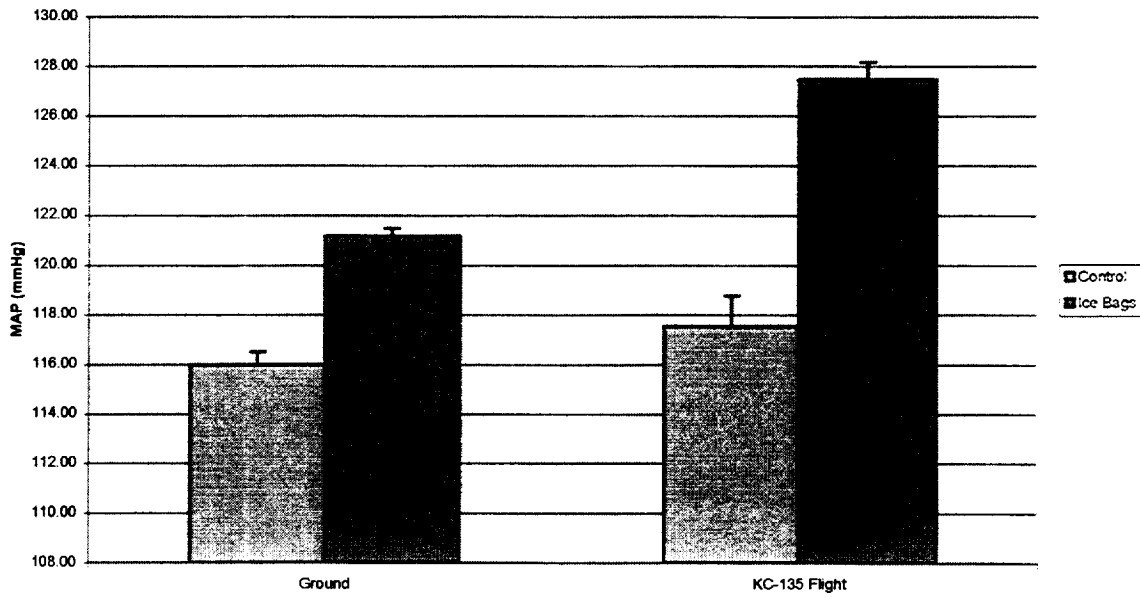
R-R Interval
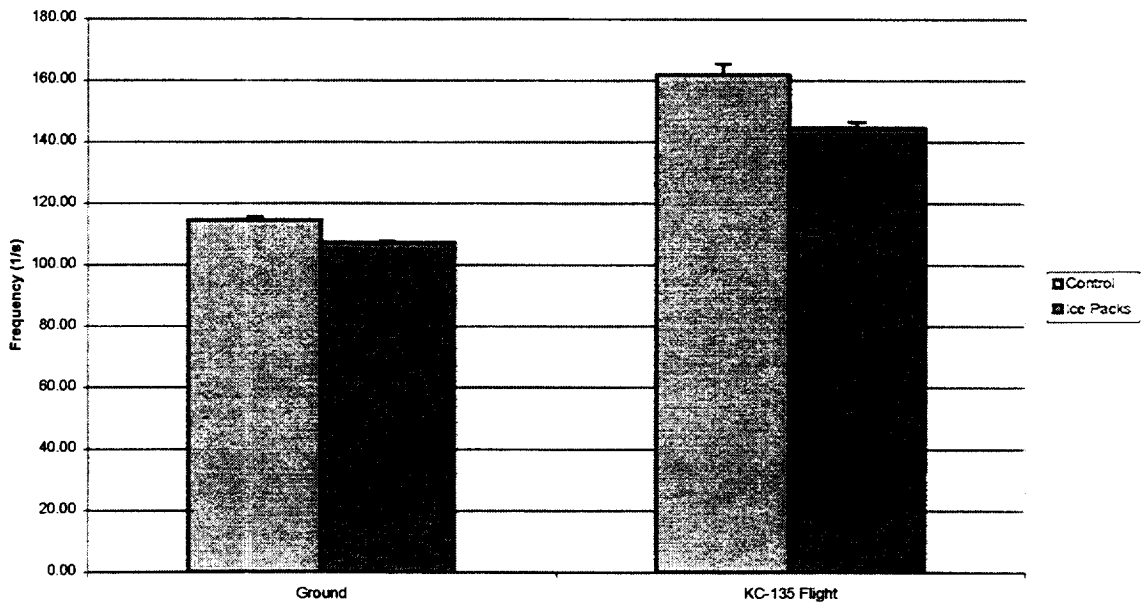
Only data from the first flight data were analyzable, and so we have data for one subject (n=1). Consequently, only descriptive statistics (mean, standard deviation) and the standard error of the mean for mean arterial pressure within a length of time were computed. The null hypothesis (H_o) could not be accepted or rejected.

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CONCLUSION:

The KC-135 flight data suggest that the cold packs may cause an increase in arterial pressure in the upper body. This technique may be useful to astronauts experiencing orthostatic hypotension after a space mission.

PHOTOGRAPHS:

JSC2001E15797 to JSC2001E15804
JSC2001E15825
JSC2001E15843
JSC2001E15850 to JSC2001E15857

VIDEO:

Video footage provided directly to investigators.

TITLE:
Texas "Fly High" Program - Zero-G Hand Wash Experiment

FLIGHT DATES:
May 8 – 9, 2001

PRINCIPAL INVESTIGATORS:
Bruce Sauser, NASA/Johnson Space Center
Laura Shaw; Purdue University
Daniel Taylor, Van Alstyne High School (VAHS), Van Alstyne, TX
Criss Martin, VAHS
Michael Dail, VAHS
Carrie Coley, VAHS
Carol Smith, VAHS
Jessica Haddox, VAHS

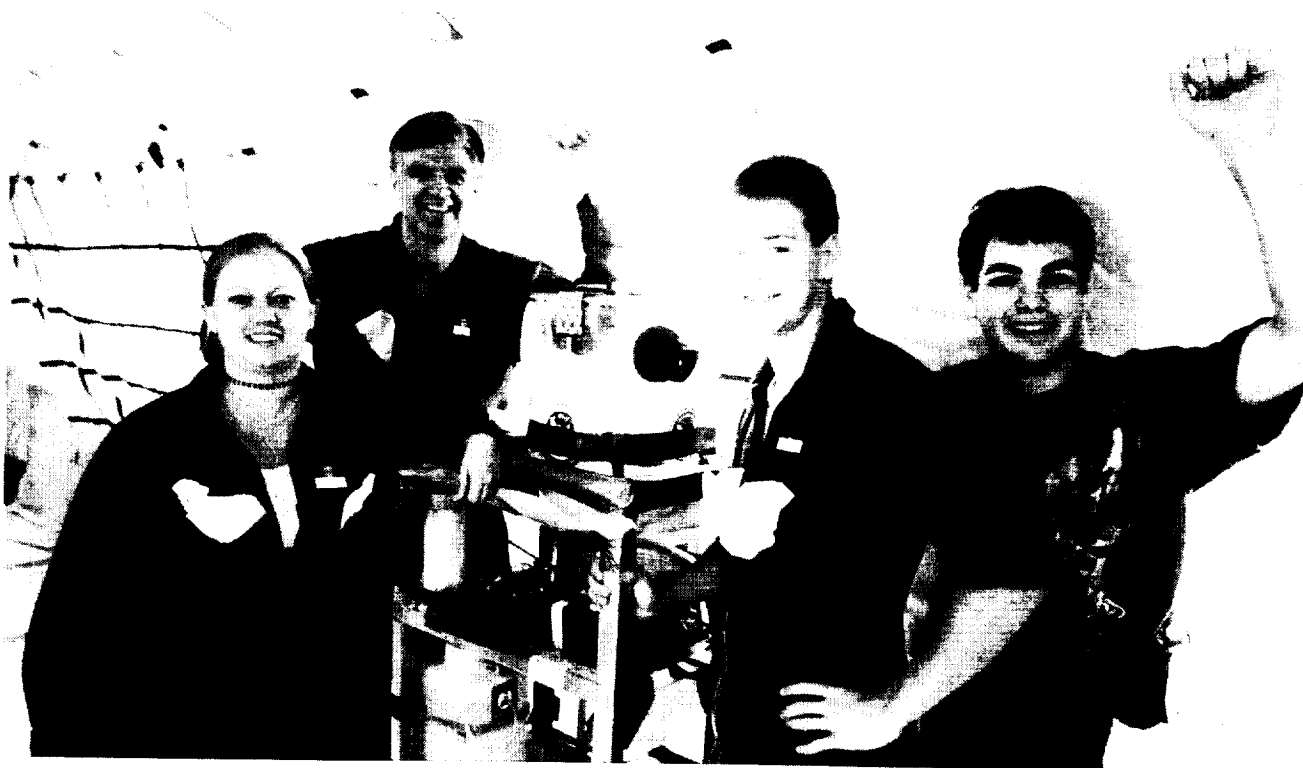## CO-INVESTIGATORS:
Nathan Murray, VAHS
Sean Taylor, VAHS
H.R. Sweat, VAHS
Alan King, VAHS
Heather McCormack, VAHS
Mack Hunter, VAHS

NASA Photo: JSC2001E15796

GOAL:

To create a safe and effective way to wash hands on the Space Station

OBJECTIVE:

- Evaluate different approaches to accomplishing the hygiene functions associated with hand washing in a microgravity environment.
- Evaluate effectiveness of rinsing soap off the hands.
- Obtain data to further support flight hardware design.

INTRODUCTION:

The Johnson Space Center's Engineering Directorate has implemented a redesign phase for the International Space Station (ISS) waste and hygiene compartment (W&HC).

Functions to be carried out inside the W&HC include urination and defecation, and hygiene functions such as washing, oral hygiene, shaving and hair cutting. In order to support these functions, equipment will be designed, fabricated and tested in both one gravity and microgravity environments.

One of the functions that is being heavily investigated at present is that of hand washing. A method needs to be developed to allow crewmembers to wash their hands. Since water management, especially in the two-phase situation (i.e., a mixture of water and gas) in microgravity can be troublesome, it is necessary to perform parabolic flights to evaluate the different approaches. Data from these flights will be used to further refine hardware for flight purposes. Optimized hardware will be tested again in parabolic flight prior to flight hardware design and fabrication.

METHODS AND MATERIALS:

Subjects
Four flyers participated as test subjects

Instruments
Aluminum Experiment Rack containing the following- Flexible Water Reservoir, Wastewater Reservoir, Brass Nozzle, 12V Positive Displacement Pump, Wastewater Pump, Power Supplies, Hand Wash Basin, Soap Container

Procedure

a. Before take-off, secure all equipment and other items in designated places (the water supply should be secured and watched at all times during take-off and landing.)

b. Seal the openings of the hand washing basin with the chip clips and plug in the power supplies.

c. After take-off, attach the water supply and remove chip clips and place them in the test subject's pockets.

d. During the first few parabolas, adjust to the 0-G environment.

e. In the following parabola, begin the experiment as follows:

    i. The test subject shall insert their hands into the hand washing basin.

    ii. The equipment operator shall turn the power supplies and flow meter on.

    iii. The equipment operator shall then turn the input switch located on the top level of the device to the "on" position so water can begin pumping into the basin.

    iv. The test subject shall begin the motions of washing their hands while the equipment operator times the action of doing so with a stopwatch.

    v. Once the test subject's hands are sufficiently wet, the equipment operator shall turn the input switch to "off" when indicated to do so by the test subject stating "done."

    vi. The test subject shall lather their hands with the soap provided in the soap dispenser on the side of the hand washing basin.

    vii. When the hands have been lathered, the equipment operator shall turn the input switch back on.

    viii. The test subject should then rinse hands as well as possible.

    ix. The equipment operator shall then turn the input switch off when again indicated by the test subject and stop timing with the stopwatch.

f. When 2-G is reached perform the following steps:

    i. Remove hands from the hand washing basin being very careful not to allow any water to escape into the plane.

    ii. The equipment operator shall secure the openings of the basin with the chip clips from the test subject's pocket immediately following step 6a while the test subject dries their hands with a paper towel provided.

    iii. Both check the pressure of the water container. If there is pressure, relieve that pressure by twisting the lid of the container filled with paper towels on the second level of the device and then tightening it again once the pressure has been relieved.

    iv. The equipment operator shall turn the output switch located on the third level of the device to the "on" position.

    v. Once the basin is drained, the equipment operator shall turn the output switch off.

  vi. The test subject shall record time, flow rate, and observations on the chart provided using H.R.'s Zero Gravity pen.
 g. Repeat steps 5-6 for each additional parabola.

RESULTS:

The performance of the water flow was unaffected by how fast the water was coming out. There is not enough force in the pump we used to make a significant difference to the water. The rate did increase as voltage did, but there was no difference in the efficiency of washing our hands.

DISCUSSION:

The hand wash basin should probably have more secure openings for the hands. Whenever, someone would remove their hands, water would be projected into the cabin of the plane. A possible solution to this would be a type of lid that could automatically flip down over the openings whenever there were no hands in the basin. A more efficient way to drain water also needs to be designed. We could only drain the water in 2-G, which will not be an option on the Space Station. Our drainage pump also had a slight leak during the second day of flight.

CONCLUSION:

The previously mentioned improvements are a necessary commodity if this device is to be placed on the Space Station. This experiment was a difficult one to run on the KC-135 due to the water hazards it presented in the cabin of the plane. Timing and the amount of water did not create any problems for us in the ability to wash our hands sufficiently clean in the given amount of time.

PHOTOGRAPHS:

JSC2001E15795 to JSC2001E15796
JSC2001E15813 to JSC2001E15817
JSC2001E15847

VIDEO:

Video footage provided directly to investigators.

TITLE:
Texas "Fly High" Program - The Coriolis Effect, Centrifugal Acceleration, and Artificial Gravity in Space

FLIGHT DATES:
May 10 – 11, 2001

PRINCIPAL INVESTIGATORS:
Salina Morrow, Jefferson High School (JHS)
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Amanda Powell, JHS
Charlie Lawrence, JHS

NASA Photo: JSC2001E16405

GOAL:

Our goal is to test an apparatus we have built to demonstrate the Coriolis and centrifugal accelerations within the normal pull of Earth's gravity. We hypothesis that weightlessness will not significantly affect the lead angle of the fluid within our device.

OBJECTIVES:

- Demonstrate the Coriolis effect and centrifugal force on the ground
- Characterize the angle of lag (in centrifugal acceleration) and lead (in Coriolis acceleration) of the liquid exiting the rotating tubes. These are the control measurements.
- Investigate the effects of weightlessness on the Coriolis and centrifugal forces.
- Characterize the angle of lag (in centrifugal acceleration) and lead (in Coriolis acceleration) of the liquid exiting the rotating tubes in weightlessness.
- Analyze the in-flight data and determine the effects of weightlessness on liquid flow in centrifugal and Coriolis acceleration.
- Obtain data that can be used to help characterize fluid flow in a rotating frame of reference.

INTRODUCTION:

Artificial gravity on long-duration missions in space would lessen the effects of many physiological problems, including bone loss, cardiac muscle atrophy, skeletal muscle atrophy, alterations in the circulatory system, and a host of neurovestibular, endocrine, and cellular adaptations. The major potential problem with using artificial gravity is the effects of the rotation-induced centrifugal and Coriolis-coupled accelerations on the crew. Centrifugal and Coriolis acceleration in a rotating spacecraft will potentially cause disorientation and nausea symptoms in the crew. When a crewmember turns his/her head out of the plane of rotation, fluid will continue to flow in the ear in the direction of rotation, producing a false sense of rotation. The behavior of rotating fluids is characterized under centrifugal and Coriolis acceleration. Direct applications include modeling fluid flow in the balance organs of the middle ear and phase flow in the life support system.

METHODS AND MATERIALS:

The test apparatus contains two straight tubes and two bent tubes that extend from a rotating axis. The direction of the water from each different tube is measured on the ground (as a control) and on the KC-135 (experimental). These measurements demonstrate the effect of weightlessness on the lead and lag angles of the fluid exiting the tubes.

Procedures
The Coriolis and centrifugal acceleration apparatus will be dry during takeoff. After takeoff, the pump will be turned on, filling the apparatus tubes with colored fluid. Next, the motor will be turned on, turning a belt that will rotate the central axis of the setup. During the 0-g portions of the experiment, the lag and lead angles of the fluid exiting the tubes will be measured with a compass. During the 1.8-g portions of the flight, the fluid will drain back into the reservoir so the water can flow back through the apparatus. Results will be recorded by video camera and may be recorded with written notes during the experiment.

Pre-Flight Preparation
1. Assemble all hardware components on the centrifugal and Coriolis acceleration apparatus.
2. Check all fasteners to verify tightness and stability of hardware.
3. Load the experiment apparatus and any other experiment hardware (duct tape, scissors, compass, etc.) onto the aircraft.
4. Fasten apparatus to "tiedown" grid on the floor of the KC-135.
5. Verify that the apparatus is securely fastened to the aircraft floor.

In-Flight Preparation for Experiment
1. Position all power cords so as to not become entangled with personnel during weightless periods. Using duct tape, affix cords to cabin floor.
2. Verify all cords remain fastened securely.

In-Flight Experiment
1. Set voltage (unless batteries are used).
2. Fill water reservoir.
3. Power bilge pump.
4. Power motor.
5. Analyze the lag and lead angles of fluid exiting the tubes.
6. Measure the lag and lead angles of fluid with a compass.

In-Flight Preparation for Landing
1. Stow all cables into the location dictated by the flight crew.
2. Stow all non-mounted hardware in pre-designated position (ex. in a duffel bag)

Post-Flight Close-Out
1. Remove "tie down" bolts fastening the experiment apparatus to the aircraft floor.
2. Unload the apparatus and non-mounted hardware from the aircraft.
3. Store all experiment hardware and equipment in the locker provided by flight operations personnel in JSC Building 993.

RESULTS/DISCUSSION:

Difficulties with the motor "power on" prevented the hardware from working as anticipated. Very few data points were able to be collected. Our main observation was that the water inside bubbled up and floated to the top of the apparatus.

CONCLUSION:

The experience of weightlessness aboard the KC-135 was truly a unique opportunity for the investigators. We hope to improve the hardware design and look forward to another opportunity to fly. Hardware that works successfully in a 1-G environment may not work at all in a 0-G environment.

PHOTOGRAPHS:

JSC2001E15790
JSC2001E16405
JSC2001E16411
JSC2001E16439

VIDEO:

- Student Campaign May 10 – 11, 2001, Group B flight footage, Reference Master: 619336

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
Texas "Fly High" Program - Ocular Motion in Micro-Gravity

FLIGHT DATES:
May 10 – 11, 2001

PRINCIPAL INVESTIGATORS:
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Windy Griffin, PHS
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Julie McKenzie, Mt. Pleasant Radio station KALK 97.7

NASA Photo: JSC2001E15749

GOAL:

To use NASA's KC 135 to create a micro gravity environment for determining the effect of micro gravity on eye muscle control.

OBJECTIVE:

To test the effects of micro gravity on ocular motion using a Visagraph.

INTRODUCTION:

The students and advisors of the Texas Fly High are performing an experiment using a Visagraph in micro gravity to test the eye movements, of the reader. This is an unprecedented experiment because although the Visagraph has been used readily on earth it has never been used in a zero gravity environment.

Background

The Taylor Visagraph II is a relatively new device designed to evaluate eye movements made during reading. It uses goggles with infrared optics to detect the eye movements and computer software to determine the number of fixations, regressions, and other characteristics of the eye movements.

METHODS AND MATERIALS:

Four high-school students and four adults served as subjects. During each parabola two subjects performed the experiment over a ten-parabola period. The Visagraph is used to test fixations, motility, and tracking of the human eye. Software for the Visagraph collected their eye movements data. The information collected during the level-flight 1 G portion of the flight was compared to the data collected during the 0 G flight time. The contrast showed the effect of gravity on the eye muscles of the subjects. This information, which was the basis of this experiment, indicates if there is a true effect of gravity on eye muscles.

Ground Operations

Ground facilities/equipment was not needed to operate our experiment.

Subjects

Eight flyers, (4 students 4 adults), were tested in 1 G and while in micro-gravity.

Instruments

We are using a Visagraph, safety goggles, a laptop computer, and the software program associated with the Visagraph.

Experiment Procedure

- ❑ NASA personnel deliver equipment from storage.
- ❑ Laptop is placed securely onto Velcro lap-strips and booted.
- ❑ Visagraph interface cable is connected to laptop.
- ❑ Visagraph power supply is plugged into plane 110-volt supply.
- ❑ Test operator starts Visagraph program.
- ❑ Test subject puts on safety goggles and Visagraph.
- ❑ Visagraph is adjusted to test subject's pupil settings.
- ❑ Subject is instructed to stare at the top of the first test page.
- ❑ The subject is signaled to begin the test.
- ❑ After test subject remains in testing position until next test is ready.
- ❑ Test operator conducts second test and then third test for test subject.
- ❑ Tests are conducted in 1 G on flight out to Gulf of Mexico.
- ❑ All subjects are tested in 1 G for use as control data.
- ❑ Parabolic flight begins.
- ❑ At the beginning of the parabola, subject is instructed to stare at the top of the first test page.
- ❑ The subject is signaled to begin the test.
- ❑ After test subject remains in testing position until top of next parabola is reached.
- ❑ Begin second test on next parabola.
- ❑ Begin third test on next parabola.
- ❑ This process of testing over a three-parabola period is repeated twice with each of the subjects.
- ❑ NASA stores gear for return to Ellington.

If at anytime in the flight there is a complication such as sickness, there is a chain of command set up within the flyers. If one is incapacitated, the experiment will continue with everyone adjusting to fulfill their predetermined roles. In the worst-case scenario, two people can run this experiment.

Definitions

Below are the definitions for the physiologic parameters which were of interest in this investigation:

- Fixations: Number of eye stops.

- Saccade: A rapid intermittent eye movement, as that which occurs when the eyes fix on one point after another in the visual field.

- Excursion: A movement from and back to a mean position or axis in an oscillating or alternating motion.

- Duration of Fixation: Average Length of eye pauses.

- Regressions: Number of reverse eye movements.

- Rate of Completion: How long it takes to finish the tracking test.

RESULTS:

Included are the averages of the data collected for flights one and two.

Fixation Maintenance (test one)
    Fixations (Number of eye stops)
        1g Left: 7.875   1g Right: 8.75
        0g Left: 11.45   0g Right: 12.27

Saccades %
        1g Left: 3.5   1g Right: 2
        0g Left: 8.36   0g Right: 8.27

Excursions
        1g: 37.64   0g: 30.76

Motility (Test two)
    Fixations (Number of eye stops.)
        1g Left: 56.13   1g Right: 58.00
        0g Left: 52.14   0g Right: 51.55

    Average Duration in seconds between fixations:
        1g Left: 0.28   1g Right: 0.27
        0g Left: 0.27   0g Right: 0.29

Tracking (Test three)
    Fixations: (Number of eye stops.)
        1g Left: 14.63   1g Right: 15.00
        0g Left: 10.68   0g Right: 10.68   with 0's*
        0g Left: 17.46   0g Right: 17.36   without 0's*

    Regressions (Number of reverse eye movements.)
        1g Left: 0.5   1g Right: 0.5
        0g Left: 1.45   0g Right: 1.14

    Duration of Fixations in seconds (Average Length of eye pauses.)
        1g Left: 0.24   1g Right: 0.19
        0g Left: 0.13   0g Right: 0.13   with 0's*
        0g Left: 0.25   0g Right: 0.25   without 0's*

    Rate of Completion in seconds:
        1g: 3.43
        0g: 4.12

*Data collected showed zeroes. We were unclear if these were truly data collected or if there was an error in the testing procedure. In preliminary tests on the ground there were no zeroes in our data. To accommodate this data, we averaged the zeroes in and also left them out.

DISCUSSION:

From our data we can make no absolute finding other than there is a significant difference in the way the eyes work with or without gravity. In some cases the ability to perform seemed easier but in others more difficult. Summarization of the facts bring this group to the conclusion that further testing is needed and that this was only the beginning to a window of information not yet opened. From the numbers gathered we know that fixation is easier when only staring or moving back and forth but when the eyes are put in to a reading motion, fixation seems to become harder. There are significant increases in the number of saccades the greater amount being in micro-gravity. The left and right eyes do not seem to move with the same difference of speed whether in gravity or micro-gravity but they do, as units take longer to fixate in both the motility and the tracking tests. In the motility test the number of regressions increased more than double the rate of regressions in gravity. The rate of completion in the third test takes almost a second longer while in micro gravity. These conclusions are only a rough draft of what further research could lead to. We as a group would like to continue in our research of ocular motion in micro-gravity with further testing possibly aboard the KC-135 or the International Space Station.

CONCLUSION:

This team concludes there is a significant difference in the way that eyes function in micro-gravity. Since this is the first test of its kind we have no information but our own data to compare so our results are vague but as accurate as possible. We believe that there is a significant need for further research in this field and we would like to conduct this research in the future.

PHOTOGRAPHS:

JSC2001E15745
JSC2001E15749
JSC2001E15790
JSC2001E16406 to JSC2001E16407
JSC2001E16415
JSC2001E16422
JSC2001E16425
JSC2001E16439

VIDEO:

- Student Campaign May 10 – 11, 2001, Group B flight footage, Reference Master: 619336
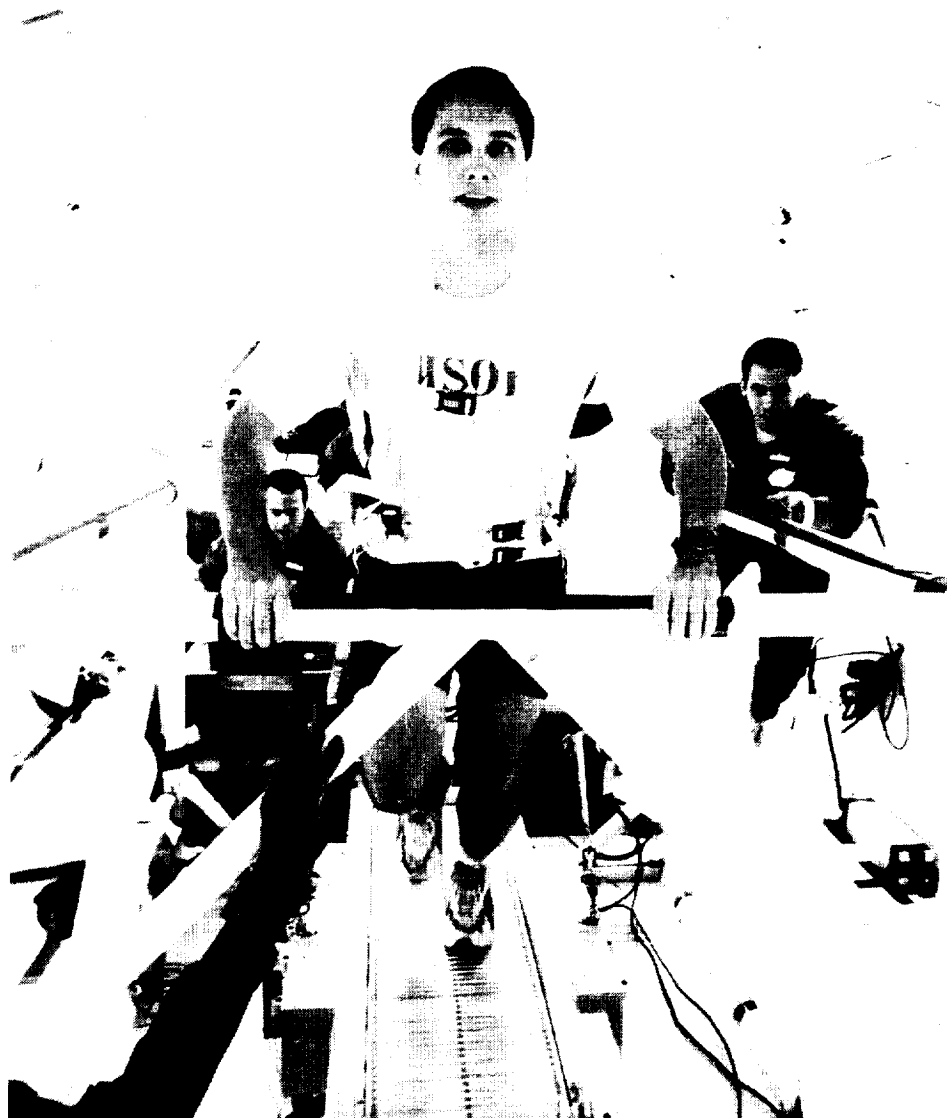
Videos available from Imagery and Publications Office (GS4), NASA/JSC.

TITLE:
TVIS Micro-Gravity Loads Determination

FLIGHT DATES:
May 10 – 11 2001

PRINCIPAL INVESTIGATOR:
Raul Blanco, NASA/Johnson Space Center

CO-INVESTIGATOR:
Horacio De la Fuente, NASA/Johnson Space Center

NASA Photo: JSC2001E16473

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GOAL:

Determine the maximum stresses in the structure of the treadmill with vibration isolation system (TVIS) chassis as to validate the current design or to drive future design modifications.

INTRODUCTION:

The original TVIS slats were failing on orbit due to fatigue. Aluminum slats have now replace the original non-metallic ones. The aluminum slats are much stiffer than the non-metallic, thereby changing the load path into the inner structure. Since modeling a runner on this treadmill would be very complex and have a high level of uncertainty, testing was chosen as the method of determining the structural stresses. Knowledge of the actual loads and stresses will provide information on the adequacy of the rest of the treadmill design.

METHODS AND MATERIALS:

Twenty-two strain gages were attached to the inner structure of the treadmill to measure the strain in the main truss and cross member. The treadmill was connected to the aircraft floor via four load cells. Load cells were also placed in line with the Subject Loading Devices. Acceleration data were acquired directly from the aircraft three axis accelerometers. 28 VDC power was supplied to the treadmill via two GSE power supplies. The data system consisted of a National Instruments SCXI setup that was sending the data via PCMCIA to a laptop computer. Variations included runner weight, subject loading device setting, runner speed, and treadmill active vs. passive modes.

RESULTS:

The data are currently being analyzed to determine design adequacy. The data are also being used for finite element model correlation.

DISCUSSION/CONCLUSION:

The TVIS KC flight experiments were conducted to determine the similarity between earth based and ISS based treadmill running. Thus far, evaluation of the data shows a lot of similarity between the two events.

PHOTOGRAPHS:

JSC2001E15756
JSC2001E15761 to JSC2001E15762
JSC2001E16466 to JSC2001E16476

VIDEO:

- KC-135 flights, May 10 am, May 10 pm, May 10 am/pm edited, and May 11 copies provided to investigator.

Appendix

Background Information about the KC-135 and the 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 the earth's orbit. Given the frequency of Space Shuttle missions and the anticipated construction and eventual habitation of the New International Space Station, the Reduced-Gravity Program provides a truly ideal environment to test and evaluate space hardware and experimental procedures prior to 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 KC-135 turbojet (KC-135A), flying parabolic arcs, produces periodic episodes of weightlessness lasting 20-25 secs. The KC-135 is sometimes also flown to provide short periods of lunar (1/6) and Martian (1/3) gravity. Over the last 35 years, approximately 100,000 parabolas have been flown in support of the Mercury, Gemini, Apollo, Skylab, Space Shuttle, and Space Station programs.

Excluding the KC-135 Flight Crew and the Reduced Gravity Program Test Directors, the KC-135 accommodates seating for a maximum of 21 other passengers. The KC-135's cargo bay provides a test area that is approximately 60 feet long, 10 feet wide, and 7 feet high. The aircraft is equipped with electrical power, overboard venting system, and photographic lights. When requested and available, professional photography and video support can be scheduled to document activities inflight.

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 reconfiguring test equipment.

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

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Telephone: (281) 244-9875

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