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Reduced Gravity Education Flight Program Overview

The Reduced Gravity Education Flight Program provides a unique academic experience for undergraduate students and educators to successfully propose, design, fabricate, fly, and evaluate a reduced gravity experiment of their choice over the course of six months. The overall experience includes scientific research, hands-on experimental design, test operations, and educational/public outreach activities.

Objectives

- To provide students and educators with an outstanding educational opportunity to explore microgravity.
- To attract outstanding young scholars to careers in math, science, and engineering in general.
- To introduce young scholars to careers with NASA and in the Space Program in particular.
- To provide a platform for students and educators to understand how microgravity affects research and testing of serious science and engineering ideas.
- To provide an opportunity for both the general public and school children to discover educational and professional opportunities available at NASA.

Significant Outcomes

- This year, two additional programs were added: Network of Educator Astronaut Teachers (NEAT) and the Systems Engineering Educational Discovery Program (SEED).
- Over 220 college undergraduates from 23 states (representing 31 different institutions) participated in the 2008 program. Forty proposals were selected for the 2008 flight year. Twenty-seven projects focused on engineering concepts, nine were physical science experiments, and three were life science (including biology) experiments.
- Over 65 college undergraduates and faculty in the System Engineering Educational Discovery (SEED) programs representing 9 states and 10 different institutions participated in the 2008 program. The projects in this flight week were all system engineering based.
- Over 70 K-12 educators from NASA Explorer Schools (NES) from 13 states and Puerto Rico (representing 14 different institutions) participated in the 2008 program. Twenty-two applications were submitted for the 2008 flight year.
- Over 60 K-12 educators from Network of Educator Astronaut Teachers (NEAT) from 9 states and American International School in Ecuador (representing 11 different institutions) participated in the 2008 program. Fourteen applications were submitted for the 2008 flight year.
- Four members of the Portland State University microgravity team were the featured speakers at the Evergreen Aviation and Space Museum in McMinnville, OR. They discussed the challenges involved with designing an experiment for microgravity, their experiment, the Microgravity University program, their results, and NASA opportunities.
- On March 25, 2008, one team from Missouri University Institute of Science and Technology presented at the St. Louis Science Center during NASA's 50th anniversary Future Forum. Students had a chance to educate the public on microgravity, and how it plays a key roll in research.
- Lamar University's proposal the "Study of Vibrational Damping Effects of Grass-like Crops in a Microgravity Environment" was presented at American Society of Mechanical Engineers (ASME)
- Team DPX from The College of New Jersey ran a 4 week program at West Windsor-Plainsboro High School South entitled, 'Energy in the 21st Century', was designed to complement the preexisting curriculum at these schools and get young scientists more involved.
- Students from the University of Michigan submitted a paper to the American Institute of Aeromautics and Astronautics entitled, "Reduced Gravity Teasting of the Nanoparticle Field Extraction Thruster".

Program Overviews

Undergraduate Student Program

The Reduced Gravity Education Flight Program allows teams of undergraduate science and engineering students nationwide to propose, design, and fly a reduced gravity experiment.

The 2008 flights came from all over the United States, with participants from 23 states representing 31 different institutions. Forty proposals were selected for the 2008 flight year. Twenty-seven projects focused on engineering concepts, nine were physical science experiments, and three were life science (including biology) experiments.

Overall, 39 of the 40 selected teams were able to complete their projects for flight. This included the first teams from the University of Alaska at Fairbanks, University of the Ozarks, University of Arizona (teamed with University of Florida), University of Sothern Maine, The College of New Jersey, and the University of Pittsburgh. This year's participants in the NASA Reduced Gravity Education Flight Program Student Program reported to Ellington Field during April, June, and July. The following pages contain abstracts about each project. Full final reports are available upon request.

To date, student teams from 49 states have flown. These include more than 2,600 undergraduate students from 165 universities.

Systems Engineering Education Discovery (SEED)

For the first time, the Education Office offered a nationwide solicitation of student applications aimed at addressing systems engineering challenges within both microgravity and lunar gravity environments. Unlike the traditional reduced gravity flight program where students propose the research to be carried out, the NASA technical workforce identified ongoing projects that are systems engineering and reduced gravity related. Selected student groups were then paired with NASA research projects under the leadership of a NASA Principle Investigator to carry out scientific research, hands-on investigational design, test operations, and educational/public outreach activities.

In addition to student involvement, one university/college faculty member was invited to fly with each team. This helped to provide faculty members with teaching materials in their classroom and is used as a motivator to increase their students' interest in systems engineering.

Outreach Programs connected with high school students, special program students, newspapers that reached the general public and students, middle school students, museum goers, engineering showcase participants, elementary school students, university students, robotics teams, and state fair attendees. It is expected that several thousand members of the general public will have access to these outreach displays. The outreach programs extended to at least 10 different states and two countries.

The 2008 flights came from all over the United States, with participants from 9 states representing 10 different institutions. Twenty projects were submitted from NASA Johnson Space Center, Marshall Space Flight Center, and Glenn Research Center. Ten proposals were selected for the 2008 flight year. Overall, all 10 selected teams were able to complete their projects for flight. This included the first teams from the University of Nebraska at Lincoln, Polytechnic University, and Carthage College. This year's participants in

the SEED Program reported to Ellington Field during April. The following pages contain abstracts about each project. Full final reports are available upon request.

NASA Explorer Schools (NES)

This "pipeline" strategic initiative promotes and supports the incorporation of NASA content and programs into science, technology, and mathematics curricula in classroom grades 4-9 across the United States. Targeting underserved populations in diverse geographic locations, NASA Explorer Schools will bring together educators, administrators, students and families in sustained involvement with NASA's education programs.

Teams composed of full-time teachers and a school administrator develop and implement a three-year action plan to address local challenges in science, technology, and mathematics education. This customized professional development plan will be available based on needs assessments and delivered through on-site school services and via distance-learning networks. The Reduced Gravity Flight Program is one of the special opportunities offered to NES teams.

The 2008 flights came from all over the United States, with participants from 13 states and Puerto Rico representing 14 different institutions. Twenty-two applications were submitted to NASA Johnson Space Center. Fifteen applications were selected for the 2008 flight year. Overall, 14 selected teams were able to complete their projects for flight. This year's participants in the NES Program reported to Ellington Field in February. The following pages contain abstracts about each project. Full final reports are available upon request.

Network of Educator Astronaut Teachers (NEAT)

The NASA Educator Astronaut Project teamed with JSC's Reduced Gravity Education Flight Program to provide an opportunity for K-12 NEAT members. Interested teams developed reduced gravity proposals through teamwork between teachers and students within the classroom. Each selected team was assigned a NASA technical mentor to assist the team with the flight and education specialist to help integrate the project and related NASA materials into the classrooms.

Digital Learning Network events were used as an integral part of this opportunity to keep the students involved in the entire process. The first videoconference event included an introduction to microgravity and the Reduced Gravity Education Flight Program. Then, several months into the program students and teachers connected back to NASA to present their hardware to our technical panel. A third connection was coordinated allowing teachers to connect back to their students in the classroom from Ellington Field immediately following their research flight. The teachers finished the program by having their students analyze the data collected and conduct outreach events to share the experience with their local communities.

The 2008 flights came from all over the United States, with participants from 9 states and American International School in Ecuador representing 11 different institutions. Thirteen applications were submitted to NASA Johnson Space Center. Eleven applications were selected for the 2008 flight year. Overall, all 11 selected teams were able to complete their projects for flight. This year's participants in the NEAT Program reported to Ellington Field in March. The following pages contain abstracts about each project. Full final reports are available upon request.

Abstracts

Top: Educator getting fitted for oxygen mask as a part of the Hyperbaric Chamber Training. Left: Student working with satellite experiment on the aircraft. Right, top: Educator makes adjustments to camera position during flight. Right, bottom: Student team explains their experiment to the Test Readiness Review (TRR) Committee.

Undergraduate Student Program
Participating Universities – By State
* First Time Participant (institution)

State	Institution	Page	State	Institution	Page
AK	University of Alaska Fairbanks*	14	NC	University of North Carolina at Pembroke	14
AR	University of the Ozarks*	22	NJ	The College of New Jersey*	13
AZ	The University of Arizona*/University of Florida	13	NM	New Mexico State University	9
CA	University of California San Diego	15	NM	University of New Mexico	19
CA	University of Southern California	20	NY	Rochester Institute of Technology	11
CO	University of Colorado at Boulder	15	NY	Cornell University	7
CT	Yale University	23	OR	Portland State University	10
FL	Embry-Riddle Aeronautical University	7	PA	Pennsylvania State University	9
FL	The University of Arizona*/University of Florida	13	PA	University of Pittsburgh*	19
IN	Purdue University	10	RI	Brown University	6
KS	University of Kansas	16	TN	Rhodes College	11
ME	University of Southern Maine*	20	TX	Lamar University	8
MI	Michigan Technological University	8	TX	Texas A & M University	12
MI	University of Michigan	17	TX	University of Texas @ Austin	21
MO	Washington University in Saint Louis	22	WI	University of Wisconsin @ Madison	22
MO	Missouri University of Science and Technology	17, 18	WV	West Virginia University	23

Brown University: Providence, Rhode Island

The Application of Sound Waves on the Control of Fluid Behavior in Microgravity

Proposal ID: 2008-2049

A major challenge created by a microgravity environment is the difficulty of controlling the movement of fluids. Our experiment is intended to further the understanding of how sound waves affect the movement of fluids in a zero gravity environment. In years past, Brown Space Club experienced firsthand the difficulty of forming and controlling the behavior of fluids in microgravity. Additionally, previous studies have shown that fluid control is a complicated process because fluids can move freely throughout the environment without the influence of other forces. This creates problems in almost any application of fluids in microgravity, ranging from fuel tanks to waste containment and disposal. By investigating the movement and control of fluids in microgravity using sound waves, we hope to be able to devise a method for the precise control of fluids in zero gravity.

Cornell University: Ithaca, New York

Haptically Controlled, Power-Efficient Space Robotics

Proposal ID: 2008-2060

We are creating a prototype remote manipulator that features a unique user interface. The robotic arm will include three links to investigate how maneuvers typical of in-orbit construction will affect the momentum of the other links and the power consumption of the whole arm. To gather this data, we are constructing a three-link robotic arm actuated by six control-moment gyroscopes (CMGs). A CMG consists of a constant-speed rotor and a gimbal that changes the direction of the rotor's angular momentum. CMGs consume less power than traditional methods of actuation such as a reaction wheel assembly (RWA). RWAs are used on currently used on spacecraft but they offer very low torque for the amount of electrical power they consume. When the CMGs are arranged in a scissored pair and gimbaled in opposite directions (see figure below), they produce a torque along a single axis. Because the change in angular momentum produces a gyroscopic torque, no work is done if we discount losses due to friction and if the gimbaled inertia were zero. CMGs theoretically produce much higher torque output for input power and subsequently are a more efficient way to actuate space robotics. The Microgravity Research Team proposes an experiment that will gather power consumption data to compare with power data of other means of actuation. In addition to this low-power operation, our design includes another innovation: a haptic interface will allow an astronaut to control the arm, giving it a range of motion similar to that of a human arm. There is a scissored pair of CMGs for each joint of the human arm – shoulder, elbow, and wrist. Each scissored pair produces a torque that moves a segment of the arm about an axis. The torque produced, however, cannot overcome gravity for long, and it is for this reason that these tests must be performed in a microgravity environment.

Embry-Riddle Aeronautical University: Daytona Beach, Florida

Project FuSSION(Fuel Slosh Simulation of Induced Oscillatory Nutation)

Proposal ID: 2008-2051

Fuel slosh in propellant tanks is an essential component for spacecraft stability design criteria and has been responsible for mission failure in several instances. Although NASA currently employs three-axis gyroscopic stability designs, spin stabilization continues to be implemented on the upper stage of many Multi-Stage-To-Orbit (MSTO) launch vehicles to stabilize the payload for deployment and could be used aboard gravity generating crafts for long-duration spaceflights in the future. The purpose of Project FuSSION is to experimentally predict and determine the effects of fuel slosh in off-axis, cylindrical fuel tanks aboard spinning spacecraft. The experimental design will use an automated system to release a dynamically scaled spacecraft on board NASA's C-9 aircraft. As the pilots fly parabolic arcs, the occupants inside experience a simulated microgravity environment that is ideal for researching fuel slosh, as it simulates the minimal effects of gravity in space. The spacecraft will house a three-axis accelerometer that will be used to analyze the energy absorption by the propellant as it sloshes within the tanks. This dissipation of energy causes the spacecraft to nutate around its minor axis. The mock spacecraft is designed to induce a severe nutation growth by creating a resonance between the fluid's natural frequency and the nutation frequency of the spacecraft. The system will utilize two off-axis cylindrical tanks within the spacecraft. Three geometrically similar tank

Student Dillon Sances from Embry-Riddle Aeronautical University work with their experiement on the aircraft.

configurations will be tested: a partially filled configuration, a set of solid masses to act as control, and a partially filled set containing a semi-rigid diaphragm. This variety will provide sufficient empirical data to either verify or disprove a Matlab Simulink3 simulation of the same phenomenon. Team FuSSION expects to find a practical correlation between the Matlab computerized simulation and the actual experimental data observed during the flight aboard the C-9 aircraft. This can then be used as a cost effective method of predicting fuel slosh in similar propellant tank systems.

Lamar University: Beaumont, Texas

Bounded Meniscus Geometry in Reduced Gravity

Proposal ID: 2008-2098

The experiments will study the geometry of a bounded meniscus during reduced gravity. The results may provide support for the hypothesis that in reduced gravity the geometry of a meniscus can be controlled to form a reduced gravity variable focus reflective surface. A sealed cylindrical container shall provide a boundary that will stop the capillary rise of water contained in the cylindrical container. Then, by altering the volume of water in the container, the curvature of the meniscus may be varied. Camcorders will record images of the meniscus so that the various curvatures of the meniscus during reduced gravity can be plotted and mapped. This technique of producing a reduced gravity variable focus reflective surface may have various space science applications such as use in a liquid space telescope.

Lamar University: Beaumont, Texas

Study of Vibrational Damping Effects of Grass-like Crops in a Microgravity Environment

Proposal ID: 2008-2072

There are two essential requirements for extended duration manned spacecraft. The first one is the suppression of very low frequency space vehicle structural vibration, and the second is the sustainable production of the clean air, water and food needed by the human crew. We envision a biology-inspired technology which provides a novel solution to both requirements and also reduces the energy required to maintain these critical functions. The hypothesis is that a crop-based life support system would suppress low-frequency structural vibrations, and simultaneously, the vibrations would enhance crop growth in microgravity. The living grass-like crops may become the key component in a new technology which extract and make use of unwanted energy associated with structural vibration of the spacecraft. The proposed project is to evaluate the energy dissipation of the selected grass-like crops in a microgravity environment. The experiment of dynamic structural frequency response will be performed on a grass-like crop colony. Energy dissipation and the damping loss factor will be measured to show that grass-like crops allow the colony to dissipate substantial amounts of energy over a frequency band centered at 0.1 to 4 Hz. The purpose of the project is to prove that grass-like crops provide useful damping of low frequency structural vibrations in a microgravity environment.

Michigan Technological University: Houghton, Michigan

Metal Nanotip Formation in Zero Gravity

Proposal ID: 2008-2042

Liquid metal ion sources (LMIS) have been widely used and studied because of the extremely bright, focused ion beam that they produce. Liquid metal ion sources can be used for both ion emission when heated and electron emission when cooled. This is possible due to the Taylor cone formed during ion emission which is frozen when the heat is removed and proceeds to act as the sharp tip required for electron emission. When used in electron emission mode, the primary failure mechanism is damage to the fragile tip. Using a concept recently developed at Michigan Tech, damaged tips can be reformed. Such

emitter tips are essentially regenerable and can be reused again and again for interchanging ion and electron emission. Recently, research has been focused on applying this technology to electric space propulsion: ion emission would be used for propulsion, and electron emission would be used to balance out the overall electric charge of the device. Our team's goal is to test this technology in zero gravity to simulate actual outer space operating conditions. Emitter tips, fabricated by coating sharp tungsten tips with indium, will be used for ion emission during flight and will be subsequently quenched in zero gravity. The geometry of frozen Taylor cones will be studied using scanning electron microscopy and by inducing electron emission from each tip to estimate the tip radius. The results from zero gravity testing will be compared with results from equivalent tests carried out in the laboratory, allowing us to determine the effect of gravity on the final structure of the frozen Taylor cones before they are used for electron emission.

New Mexico State University: Las Cruces, New Mexico

Inertial Property Algorithm Verification

Proposal ID: 2008-2101

As on-orbit servicing and operations of spacecraft become increasingly aggressive and complex (such as satellite on-orbit refueling, docking, repairing, etc.), the need to identify their changed inertial properties is becoming a critical task. The importance of this task stems from a spacecraft control system's effectiveness and accuracy, relying on its knowledge of spacecraft's inertial distribution. A currently proposed method to obtain altered inertial properties of a space system requires only moving a robotic arm and measuring the system's resulting velocity changes. The acquired velocity readings are introduced into a series of momentum conservation equations, and a solution set is generated that provides the altered inertial properties of the space system. Due to on-board robotic arms typically being powered by restorable energy, the need to consume fuel in order to obtain dynamic measurements by firing thrusters is eliminated. The proposed shift in methods will be extremely beneficial considering the important issue of conserving propulsion fuel for more critical mission objectives. The Inertial Property Algorithm Verification (IPAV) experiment utilizes a single-axis robotic arm that is pre-programmed to go from one position to another in order to induce a change in angular velocity of a mockup hosting satellite body. Various parameters, such as the final orientation of the robotic arm relative to the hosting body, the initial angular velocity of the system, and the masses of attached secondary bodies can be varied in specified intervals to enhance the test performance and help team members to understand the dynamic principles involved. This will allow for a wide range of variables to be tested, which will strengthen the acquired data set. Cameras, gyroscopes, and accelerometers will by used to measure the dynamic behavior of the system. In addition to the IPAV experiment's benefits to the dynamics and control aspects of spaceflight, it will also positively impact the lives of young adults that are exposed to its development and success.

Pennsylvania State University: University Park, Pennsylvania

A Study of Interparticle Forces within a Complex Plasma-II

Proposal ID: 2008-2082

A collection of disassociated electrons and nuclei are known as plasma, or an ionized gas. A unique category of plasmas are the dusty plasmas, which contain microparticles (of about 1 to 10 microns in size) that become charged when introduced into the plasma and form into crystalline structures. This is a relatively young field of research with many opportunities for application including silicon wafer fabrication. Further understanding of complex plasmas could also aid in the understanding of astrophysical phenomena including planetary rings. The formation of these crystals is governed by several forces including gravity, the thermophoretic force, and the ion drag force. When studying dusty plasmas on the ground, the gravitational force is significant and suppresses the formation of 3D crystals. In microgravity, however, the ion drag force becomes the dominant force in crystal formation. In such an environment, a void in the center of the dusty plasma is also observed. This phenomenon is not yet understood. Dusty plasma can be created by applying radiofrequency (RF) power to two parallel plate electrodes. This technique will be employed along with

many experiment improvements to continue last year's study of the ion drag force and void length in relation to the RF power applied.

Portland State University: Portland, Oregon

Passive Separation of Two-Phase Flows using Conduit Geometry II

Proposal ID: 2008-2105

The control of fluids in spacecraft is essential for the design of many on-board flight systems including water recovery, biological processes, fuel storage, and coolants. As the new flight vehicles, Ares I and V are launched back to the moon and on to Mars, reliable, lightweight, compact, and inexpensive fluid separation systems will be crucial for long-term mission success. The objective of this experiment is to provide relevant and readily applicable, quantitative results that can be used in the design of passive, redundant fluid separation systems. A bubbly flow will be delivered to two separate test cells used to separate the liquid and gas phases of the flow simply by using the geometry of the fluid containers. The primary goal of the flight is to acquire a complete and reproducible data set enabling quantitative analysis and leading to a conclusive publishable result. Data will be generalized and compared to theory where possible. Expected results will produce clear qualitative visual data that demonstrate bubble separation as well as a quantitative analysis applicable to the design of a variety of fluid systems aboard spacecraft.

Purdue University: West Lafayette, Indiana

Electrolysis in Microgravity using Porous Metal Foam Electrodes

Proposal ID: 2008-2079

The transportation of hydrogen and oxygen in the form of water allows for a safe and efficient supply of resources for both life support and energy systems. Electrolysis is the process which separates the hydrogen and oxygen in water allowing the safe compound to be split into its more volatile, but useful, elements. With the limited power available in space systems, efficiency of electrolysis is important to maintain adequate levels of oxygen with minimal power input. Because microgravity present in orbit negates buoyancy, further power consumption is required to remove bubbles from the electrode and separate gases from the system. The use of metallic foams as the electrodes in electrolysis could increase efficiency of the systems in multiple ways. Metallic foam is a porous metal structure, typically with over 80% of the volume being void space. Research in 1G electrolysis yielded results showing that metallic foams have a larger current density and higher efficiency than a solid metal. Microgravity tests need to be conducted on the efficiency capabilities of the metallic foams because all previous studies have used buoyancy as the main driver for the removal of bubbles. The lack of buoyancy would undoubtedly affect data, and these effects need to be documented. A metallic foam electrode could simplify the problem of phase separation in electrolysis systems. The capillary effects inside a partly submerged metallic foam structure draws water into the foam like a sponge. Once drawn in, the water inside the metallic foam electrode would be separated into its gaseous parts. The ongoing capillary effects that continuously displace gasses in the foam would push out the hydrogen/oxygen gases without the need of a powered phase separator.

Purdue University: West Lafayette, Indiana

Wicking in a Groove Network

Proposal ID: 2008-2070

There are several applications which would greatly benefit from improved knowledge of the wicking of liquids. Controlling propellants through valves, fuel pumps, and the like is crucial to the safe and efficient operation of spacecraft. Likewise, managing condensation aboard spacecraft in order to protect critical components is of the utmost importance. Furthermore, with the rapid increase in the use of high performance electronics, the need to efficiently cool them has become a concern. One possible solution to the aforementioned problems is to use a liquid filled capillary network to wick materials to and from the

system. A capillary network might also be useful to model the advance of liquid across a microscopically rough surface. Experiments must be conducted to test predictions of theoretical models, and most of these theories require a zero gravity environment. Fittingly, many of the applications of capillary wicking take place in zero gravity. Previous land based research on this subject has required the use of nanoscopic capillaries in order to obtain a reasonable liquid Bond number. By bringing the experiment into microgravity, the capillaries can be made several orders of magnitude larger. The advantages of this are twofold. First, observation of the wicking becomes much easier, as no microscopes or other expensive instruments are required. Second, the manufacturing of these capillaries becomes much simpler, allowing for greater repeatability.

Rhodes College: Memphis, Tennessee

Binary Orbital Motion of Electrically Charged Spheres

Proposal ID: 2008-2046

Student Jennifer Thompson and her team from Rhodes College present to the TRR Committee.

The similar mathematical forms of Coulomb's Law of Electrostatics and Newton's Law of Gravitation suggest that two oppositely charged spheres should be able to move in a binary orbit about their center of mass using only the electric force as the force of attraction. To test this idea, we will attempt to achieve a binary orbit between oppositely charged graphite coated Styrofoam spheres. The spheres will have a mass of 5 grams and a radius of 1.5 cm. They will be charged to a surface voltage of 20 kV (one positively and one negatively) using a precisely controlled, current-limited, bipolar power supply. Initially, the spheres will be separated by a center to center distance of 20 cm. Once charged, the spheres will be launched in opposite directions (perpendicular to the line adjoining their centers). A successful orbital attempt will result in the two spheres orbiting one another about their center of mass. The microgravity environment will minimize the effects of frictional and gravitational forces, allowing the orbit to be purely electrostatic in nature.

Rochester Institute of Technology: Rochester, New York

Characterization of Thermal and Piezo-Electric Print Heads in a Microgravity Setting

Proposal ID: 2008-2059

We propose to demonstrate the feasibility of inkjet printing in a microgravity environment. To our knowledge, inkjet printing research has not been conducted under microgravity conditions. Printhead technology applications have been expanding rapidly; advances include: circuit board tracings (Cooley; Hayes; Yoshioka), biomedical research (Ilkhanizadeh; Lange), and three-dimensional prototyping (Cho; Cooley; Hayes). With the constant progression towards long-term space travel, the use of inkjet printers to fabricate essential equipment in space becomes a possibility. These printer functions require a study of the performance of the device components. The experiment will focus only on printheads in a microgravity setting, the ink drop characteristics, ink drop flight, and printing accuracy. Two different types of printhead technologies will be tested using an Epson C120 piezo-electric printhead and a Kodak EasyShare 5100 thermal printhead (Kin; Yang). Two printers, a laptop computer, and a drop analysis device (DAD) will be included in the testing apparatus. The DAD will contain thermal and piezo printheads, a microcontroller, high speed camera, and optics to capture ink drop ejection. The DAD will provide imagery to analyze the shape, pattern, size, and velocity of liquid expelled by the printheads. Commercial inkjet inks will be used to simulate the various applications of inkjet printheads in microgravity. High speed camera images will be

collected and analyzed for drop quality and velocity. The experimentation will also yield a study of fluid dynamics on a nano-volume scale.

Texas A & M University: College Station, Texas

Analyte Detection Via Protein Nanopores in a Microgravity Environment

Proposal ID: 2008-2112

Texas A&M University researchers have developed a storable chip that can be used to detect life, as well as to detect harmful substances in an enclosed environment. This chip can identify numerous substances based on the identification of various analytes (i.e. molecules, proteins, DNA, etc) (Kang, "Storable" 4701; Kang, "Stochastic Detection" 10684). This system uses a lipid bilayer suspended on a Teflon chip to house a single protein nanopore, and an electrical current sent through the protein is monitored for fluctuations (Kang, "Storable" 4702). A change in the current flow indicates that one of the targeted analytes has passed through the nanopore; the change in current flow is specific for each analyte (Kang, "Storable" 4703). The current system works well in the lab, but it is bulky and not suitable for space applications. The team proposes to redesign the current system to provide additional functionality to make it suitable for space applications and to reduce its size and weight. In particular, due to the sensor's sensitivity to vibration and acoustic excitations, the team proposes to design and test an isolation system that will eliminate test data contamination due to these external disturbances. The proposed experiment is a proof-of-concept to verify that the protein nanopore chip works in a reduced-gravity environment. The data collected from this experiment will be compared to the results of similar ground-based tests to determine the effectiveness of such a sensor in microgravity and thus its potential use for space applications. A successful test of this sensor in microgravity will provide NASA engineers another approach to aid in the further development of technologies used in future roles in space endeavors.

Texas A & M University: College Station, Texas

Gravity Independent Boiler Experiment

Proposal ID: 2008-2073

Boiling is a well understood phenomena within the confines of terrestrial applications. The presence of the earth's gravity creates buoyancy forces which cause vapor formed by nucleation to detach from the heating surface and rise. This motion of the vapor bubble within the heated fluid induces fluid convection and facilitates heat transfer. However, in microgravity environments the absence of these buoyancy forces results in reduced bubble detachment and decreased heat transfer. The Aggie Boilers, a multidisciplinary team of undergraduate students from Texas A&M University, is dedicated to demonstrating the capability of a vortex boiler to create a radial acceleration field through the intrinsic momentum of the incoming fluid, which will allow bubble detachment to occur independent of outside gravitational fields. The momentum of this incoming fluid will also produce shear along the heated surface and offer an additional method of bubble detachment. Successful demonstration of this technology will have broad implications for future space missions including possible applications in thermal control, reclamation of waste water, and potential use in a space-based Rankine power cycle.

Texas A & M University: College Station, Texas

Investigation into the Effects of Fluid Motion on the Rotation About the Unstable Axis of a Body

Proposal ID: 2008-2081

The Bacon-Wrapped Scientists are proposing an experiment to research the stability of rotation about an object's principal axes. The experiment seeks to observe the effect that a liquid, isolated from any external forces (including gravity), inside a rotating prism will have on the stability of its rotation about its intermediate

axis. Each principal axis of rotation has a corresponding moment of inertia I1, I2, and I3. The two axes of rotation with the highest and lowest moments of inertia are called the major and minor axes, respectively. Rotation about the major and minor axes is stable, but rotation around the intermediate axis (corresponding to the median value of moment of inertia) is unstable (Thomson 130-131). These principles are true for objects with a fixed mass distribution. This experiment intends to observe how this behavior will be affected (and hopefully dampened or reduced) by a variable mass distribution—and thus a variable moment of inertia IE.

The College of New Jersey: Ewing, New Jersey

Using Fluorescent Dust to Obtain a Three-Dimensional Analysis of a Dusty Plasma

Proposal ID: 2008-2043

Dusty plasmas are an important part of astrophysical and ground-based sciences with applications ranging from planetary rings to fusion reactors [1-5]. As this field continues to rapidly grow, microgravity experiments involving dusty plasmas are occurring more frequently [6-8]. These microgravity experiments are yielding new and exciting dusty plasma phenomena that cannot be replicated in ground-based studies [9, 10, 11]. However, as dusty plasma research continues to evolve, the primary imaging technique used in these cutting-edge experiments has not changed since 1994. The traditional laser-sheet method, the defacto method in most dusty plasma studies, is currently restricting three-dimensional dust clouds made in microgravity environments to two-dimensional analyses [12-16]. As an alternative to the laser-sheet technique, Team DPX is proposing the implementation of a new imaging method incorporating fluorescent dust. By making the dust fluoresce through exposure to ultraviolet (UV) radiation, we can brightly and uniformly illuminate entire three-dimensional structures within our ground-based experiments. We hope that this method can be successfully incorporated in future microgravity studies of dusty plasmas and produce better results than a laser-sheet. The first part of our experiment is designed to compare the results obtained with the laser-sheet technique to those obtained by inducing fluorescence. In this section particular attention will be given to interparticle spacing and particle velocity as a function of UV intensity. The second part will build upon our previous student-directed work at Princeton Plasma Physics Lab (PPPL) by attempting to prove a linear correlation between UV intensity and particle rotational velocity in a direct current (DC)-glow discharge plasma.

The University of Arizona/University of Florida: Tucson, Arizona and Gainesville, Florida

Applications and Limitations of Ionic Polymer-Metal Composite Sensors and Actuators in Space

Proposal ID: 2008-2106

Students Andrew McDonald and Anthony Licari from University of Florida and Yuridia Robeson from University of Arizona present to the TRR Committee.

Advancing scientific knowledge of the universe requires human exploration and thus development of space vehicles. NASA's advancing aeronautics and space technologies commonly have constraints on power consumption, mass, and cost. Ionic Polymer-Metal Composite (IPMC) strips are inexpensive, low-mass, and low-power consuming actuators and sensors that can be used to effectively address these constraints. There has been a significant amount of research done on IPMC strips' rate of response with varying voltages, frequencies, and times of exposure. Studies show that IPMC strips' highly dynamic sensing

characteristics were remarkable in accuracy and repeatability. IPMC strips are desirable sensors and actuators since they show very large deformation in the presence of low voltage applied and can operate in very low temperatures. The proposed experiment will examine the effects of microgravity and hypergravity on IPMC strips for various voltages and times of exposure with fixed frequencies. Investigating the gravity dependence of IPMC strips' rate of response at various voltages is of significant importance since IPMC mechanical devices are capable of automating numerous tasks for use in microgravity/hypergravity environments encountered by the Space Shuttle Program (SSP), International Space Station Program (ISSP), and the next-generation Constellation Program (CxP). Space mechanisms that require actuators include robotic arms, miniature rovers, and release mechanisms. Many sensor applications require precise pointing control mechanisms that can be enabled by the use of IPMC strips. Lastly, IPMC strips can be incorporated into spacecraft as smart motion sensors to measure launch and on-orbit vibrations.

The University of North Carolina at Pembroke: Pembroke, North Carolina

Gravitational Effects on Human Immune Complexes and Flame Dynamics

Proposal ID: 2008-2095

The space program of today is multifaceted. Many of the programs with which NASA is involved include human exposure to the reduced gravity of space. As more astronauts take flight for longer periods, the reality of impaired immune functions associated with the microgravity experience is becoming an area of great interest. It is important to understand what factors are related to changes in the immune system processes. Our goal is to identify the significance of gravitational forces on antigen-antibody reactions within the human body by studying them in-vitro. We will observe the reaction rates between human Immuno Globulin G (IgG) and Goat derived Anti-Immuno Globulin G (A-IgG) in a Sodium Phosphate Buffer. The absorbance rates obtained during flight will be compared to the rates measured for an identical solution mixed in the lab. These ground truth samples will be obtained in 1-g post flight to verify the increase and/or decrease in rate of absorbance. In our second experiment, which will serve as an outreach demonstration, we will study the dynamics of a candle flame in 0-g and 2-g as they differ from the standard 1-g flame.

University of Alaska Fairbanks: Fairbanks, Alaska

Investigation of Small Satellite Attitude Control Systems

Proposal ID: 2008-2113

Current aerospace trends encourage satellites to be smaller, faster, and cheaper. However, the physical limitations of such small satellites create unique design challenges. To define one of these challenges for future small satellite missions built by students at the University of Alaska Fairbanks, a team of mechanical and electrical engineering students will study the accuracy and stability of small satellite attitude control systems (ACS). This experiment will focus on the challenge of reaching an attitude position quickly and efficiently. Many small satellites experience oscillations as their attitude control system stabilizes in the desired orientation. This oscillation reduces the efficiency of an attitude control system and imposes a greater draw on the satellite's already limited power supply. This project's mission is to investigate such instability and characterize it with the objective of overcoming the problem on future missions. After designing and constructing two control systems, one mechanical and one electromagnetic, the students will evaluate the pointing accuracy and short-term stability of platforms employing these systems in zero gravity. Because the platforms cannot realistically "hover" while maintaining a reasonable 3-axis test environment, this evaluation is not possible in a one-g environment. Zero-g flights through the Reduced Gravity Student Flight Program will allow investigation of the ACS platforms in a three-dimensional environment similar to space, where the systems will eventually be required to function, without relying on a costly in-situ evaluation of attitude control systems in orbit. Further evaluation of the platforms based on small satellite requirements such as mass, volume, and power will provide a research and design foundation for future missions.

University of California San Diego: La Jolla, California

Deployable Tensegrity in Space

Proposal ID: 2008-2117

Deployable structures in space pose special problems. The stiction and friction of the controlled deployment in micro-gravity cannot be accurately simulated in a 1g environment. We propose an experiment to design and test a deployable structure concept and a deployment strategy. The structural concept is a type of "tensegrity" structure composed of tendons and rods in a special chosen topology. We will test the concept of a tensegrity deployable structure in microgravity and accurately model its deployment behavior based on its deployment behavior in terrestrial gravity. Models testing different deployment strategies of the same tensegrity structures will be built to help aide in design of final deployment strategy. The deployment strategies in terrestrial gravity include different stowed configurations and different actuator and tendon configurations. Recent results at UCSD have derived minimal mass tensegrity designs, and this experiment will test these designs. This will be the first deployable tensegrity structure tested in microgravity. The shape and internal geometry we are proposing minimizes mass and maximizes strength which would minimize cost aboard NASA launch vehicles. The specific dome-like structure we are proposing could be utilized in various microgravity applications such as a space habitat, a solar collector/or reflector, or a radar dish. In the second part of our experiment, we will build and test the design in our lab. Using our lab tests, we will predict the deployment behavior of the microgravity test, and then we will conduct the microgravity test using the same deployment method as in the terrestrial part of the experiment.

University of Colorado at Boulder: Boulder, Colorado

DANDE Microgravity Separation System Demonstration

Proposal ID: 2008-2094

The Drag and Neutral Density Explorer (DANDE) is part of the University Nanosat 5 Program (UNP), sponsored by Air Force Office of Scientific Research (AFOSR) and organized by the Air Force Research Laboratory (AFRL). The program is a student competition among 11 schools to design, integrate, and fly a 50kg satellite as a secondary payload on a government mission. Given the constraints of the science objectives and AFRL guidelines, the DANDE student team has designed a unique separation system which will be activated on orbit during the commissioning phase of the mission. This allows the spacecraft to be spherical which is required to characterize its cross-sectional area and coefficient of drag. It is our goal to thoroughly test this separation system in the microgravity environment aboard NASA's C-9 aircraft to demonstrate and improve the reliability of our design. The separation system is designed to release the 'lightband adapter bracket (LAB)' which acts as an interface between the launch vehicle and the satellite bus. The interface uses two StarsysTM release mechanisms and kinematic mounts designed by students to restrain motion between the system components when in the un-deployed state. It is the goal of this test to determine ejection speeds, accelerations, tip-off rates, and the redundancy of the system in its realistic environment. This will be determined by acceleration data and video footage taken during the flight. The DANDE microgravity team is working to ensure that this test is performed safely and will work with NASA to mitigate risk. In addition, a series of outreach lectures are planned to raise public awareness of this NASA sponsored test. This microgravity deployment demonstration will improve our system reliability models when presenting our finished payload to the Air Force in January of 2009. If selected for launch, this system will be used by students for several additional years as it is integrated and launched in the 2011 timeframe.

University of Kansas: Lawrence, Kansas

Assembly of Spacecraft Systems by Electro-Magnetic Binding and Locking Equipment

Proposal ID: 2008-2086

In order to make manned missions to Mars and elsewhere possible, it is necessary to develop low-energy, highly adaptable means of manufacturing components for spacecraft in a microgravity environment. Assembly of Spacecraft Systems by ElectroMagnetic Binding and Locking Equipment (ASSEMBLE) is an experiment testing a new approach to the orbital docking process. The key components of the experiment are the electromagnets. Placed on the ends of the modules, these electromagnets will have a male-female locking systems for the final connection. Once within a range of a few meters, it will be possible to initialize an electromagnetic attraction between a series of points on each pod. Just before contact, the polarity of the electromagnets will be reversed to produce a negative acceleration. Upon contact, a secondary system of electromagnets will allow the locking system of the pods to rotate and lock into position.

University of Kansas: Lawrence, Kansas

Effects of Energy Dissipation for Communication Satellites

Proposal ID: 2008-2102

Internal energy dissipation effects have been a phenomenon occurring in satellites since America's first satellite launch. Since the specific energy state of a satellite governs its motion, it seems evident that energy dissipation of a satellite could also govern its stability. These effects have been studied, and the relationships between the rate of energy dissipation and satellite stability have been derived. Designers now have the benefit of designing around such instability risks when designing systems which affect the energy rates. However, no beneficial application has been determined taking advantage from this relationship. This proposal discusses a University of Kansas MicroGravity Team (MGT) experiment involving design and testing of internal energy dissipation effects in microgravity for a mock satellite designed to be similar to a communication satellite. This testing will measure the change in angular velocities and the amount of time required to change the axes of rotation during energy dissipation and will measure varying amounts of energy dissipation needed to manipulate the mock satellite as prescribed. Additional qualitative data will be obtained to record the direction of spin of the final rotation, the number of times the satellite spins in either direction, and see if a trend can be developed that can accurately predict final satellite orientation. Through microgravity flight testing of this experiment, the team hopes that the results recorded meet the following goal of this project: to aid developers in future satellite attitude control design. Results from this project will be documented and presented in a formal report that will have the ability to be presented to personnel within satellite industry and related areas of aerospace academia and also have the ability to be presented to varying levels of elementary and secondary level school children and those who do not have a background in engineering and astrodynamics, as proposed by our outreach program provided in this proposal.

University of Kansas: Lawrence, Kansas

SMART-HAWKER: A Smart Wire Actuated Robotic Arm

Proposal ID: 2008-2100

In 2006, our team from the University of Kansas designed a space docking prototype that used shape memory alloy (SMA) as the main actuating mechanism. We completed the design and were accepted into NASA's Reduced Gravity Student Flight Opportunities Program (RGSFOP). Our team conducted in-flight microgravity testing on the prototype. The information acquired from those results has been utilized to create a new, improved design. This year, we are moving on from the docking mechanism concept and have chosen instead to apply our experience with SMA actuation to the design of a robotic arm for use in

microgravity environments. The new design, named SMART-HAWKER, is based on its predecessor but will incorporate three independently moving sections. Two of the sections will be capable of bending in 4 different directions. The third segment will incorporate the torsional design from last year, allowing it to twist in both a clockwise and counter-clockwise direction. This proposed prototype is the next logical phase in the development of robotic SMA technology. By giving our device the ability to move in three different directions at three different locations along its length, the mechanical arm's maneuverability will increase significantly. With further development, our design could potentially lead to a mechanical arm with the capability to move like a snake in all directions. Such a device would be a significant advancement over many technologies currently available. Over the coming months, our team will be testing various characteristics of our new system, such as its accuracy, precision, and load-bearing capabilities. However, since the SMART-HAWKER is being engineered for space application, the device must be tested in a controlled zero gravity environment. NASA's RGSFOP is the ideal testing environment for collecting the desired data. The SMART-HAWKER team will use this microgravity data to further enhance their design concept.

University of Michigan: Ann Arbor, Michigan

Determining Zero-G Feasibility of the Nanoparticle Field Extraction Thruster Reflight

Proposal ID: 2008-2061

The Nanoparticle Field Extraction Thruster (NanoFET) is an electric propulsion system being developed at the University of Michigan. It has the potential to create low power, high efficiency thrust for spacecraft applications. Our goal is to examine how aspects of the NanoFET design behave in a microgravity environment via a more robust and sophisticated experiment using lessons learned from last year's flight. There will be two types of tests conducted over the course of the flight days. These are liquid instability and particle extraction tests. At least 13 unique tests will be conducted each flight day – ten of liquid instability and three of particle extraction. Liquid instability tests will involve testing the electrohydrodynamic behavior of a controlled liquid in polycarbonate test cell reservoirs with knife-edged orifices of different shapes and sizes. No particles will be used during these tests. The particle extraction tests involve observing if particle extraction can be achieved for different test cell configurations. The spherical aluminum particles will be on the millimeter-diameter size scale. The same experiment will be run on both flight days but with a different liquid (water or soybean oil) each day. The voltage in the test cells are provided by a high-voltage power supply controlled via a LabVIEW interface. The LabVIEW program will also be used to synchronize and operate video cameras, voltmeters, ammeters, and an accelerometer to collect data from our experiments. Flight test results will be used to validate NanoFET physics models in microgravity, suggest improvements for future NanoFET designs, and compile lessons learned for future ground and microgravity tests.

Missouri University of Science and Technology: Rolla, Missouri

Reduced Gravity Testing of a Refrigerant-Based Cold Gas Thruster

Proposal ID: 2008-2077

Missouri University of Science and Technology was formerly the University of Missouri at Rolla. With space becoming evermore popular, technological advancements are occurring more frequently. Several breakthroughs are starting to occur within the small satellite community where developments in distributed space systems are reducing cost and introducing more redundancies in satellites. To be advantageous, distributed space systems require control of relative dynamics to maintain the formation and orientation of the satellites in orbit. One method utilized for these operations is a propulsion system to conduct the necessary attitude and orbit corrections. These systems may be restricted by physical design constraints or safety regulations and restrictions when integrated into the design of the satellite. Various types of propulsion systems exist that could potentially be utilized onboard a small satellite including electrical and chemical systems. However, many of these systems can introduce additional complexities, interferences, or safety concerns. One of the simplest and safest systems that exist is a cold gas system. Generally, cold gas systems utilize inert, nontoxic, non-flammable gases (e.g. nitrogen, carbon dioxide, xenon, etc.) as

propellants, which require high pressure and large volume storage. One possible alternative is the use of saturated liquids which can be stored at much lower pressures and in smaller volumes. However, saturated liquids have not been widely utilized. Butane, which is flammable and therefore undesirable, has been one of the few saturated liquids used as a propellant and then only in a few designs. Refrigerants offer a non-flammable solution but have only been used as heat transfer fluid in space. To utilize refrigerants as propellants, further development is required. This development can be accomplished by further analyses of the fluid, modeling the fluid within a system, and flying a refrigerant system onboard student-built satellites. For this experiment, a cold gas thruster system, utilizing the refrigerant, R-134a as the propellant, will be mounted and tested in a sealed chamber onboard NASA's C-9 aircraft. The experiment will simulate conditions that cannot be duplicated in a university laboratory. Temperature, pressure, and thrust data will be used to evaluate the performance of the thruster system. After the experiment, the results of the zero gravity flight and ground testing will be compared to determine the effects that sloshing has on the performance of the system. These results will further the understanding of refrigerant-based cold gas systems and support the implementation of cold gas system in a future UMR designed satellite.

Missouri University of Science and Technology: Rolla, Missouri

Studying Arc Welding in Microgravity Conditions

Proposal ID: 2008-2062

Missouri University of Science and Technology was formerly the University of Missouri at Rolla. The Miners in Space Weld Team has been working to refine a welder that will provide a safe and effective way to weld in microgravity. One of the main keys to achieving this is to understand how gravity affects the formation of a weld. Gravity appears to have an effect on the shape of a weld pool and also its microstructure (Blackwell-Synergy), thus having an effect on the characteristics of the weld. The Weld Team has been studying and evaluating the strength of welds performed by conventional techniques in the presence of reduced gravity. The experiment being used was designed to test the micro and lunar gravity effects on welds. The type of welder chosen for the experiment is a Gas Metal Arc Welder (GMAW), while the metal chosen to produce the welds on is aluminum. Due to the wide use of aluminum in the aerospace industry and because of weight and cost, it has also been chosen for this experiment. The welder is attached to an automated arm that moves on a lead-screw system controlled by a computer. Attaching a spool gun to the automated arm along with the welder eliminates the risk of wire feed jams. By eliminating this risk the quality of the collected data is improved. The arc used to create the weld is formed with the help of argon gas. Once the arc is formed, the automated arm moves across the test plate containing the aluminum strips for welding. The arm travels down the strip, creating the weld. After the weld has formed, the arm returns to its initial starting point and proceeds to a fresh test strip and is ready to weld again. Because safety is of the highest importance, the entire welding process is contained inside a sealed metal box, which prevents the welding sparks from interacting with anything other than the aluminum. Once the welds are completed and the data are collected, the samples will be run through an array of tests to determine the characteristics of each weld. Weld strength and the welds' endurance to extreme temperature changes will be tested. The purpose of this experiment is to make it possible to weld in space. To do this, the results of the past experiments are used to gain further insight. By testing the effects of lunar gravity, microgravity, and increased gravity on welds and comparing that data to weld formations developed at normal-gravity conditions, it should be possible to find trends in the effects of gravity on the welds. These trends will help determine what the necessary conditions for welding in space are. Once the data are obtained, it will be possible to further modify the welder and continue researching.

University of New Mexico: Albuquerque, New Mexico

The Effects of Gravity on Fibroblast Inactivation due to Ionizing Gamma Radiation

Proposal ID: 2008-2096

Students Veronica Padilla and Allison Miller from University of New Mexico present to the TRR Committee.

All cells, whether in the body or in another living organism, will eventually be exposed to environmental hazards that will cause them to inactivate. We know that exposure of cells to ionizing can cause their death rate to increase. When cells are exposed to radiation, their death rate is well understood within Earth's standard gravitational environment, but not much is known how cells will react to radiation when taken out of this situation. Research has shown that when cells are placed into a different environment other than what they are used to, the stress induced upon the cells causes them to operate ineffectively and eventually die. A study of this nature will help us better understand the mechanisms that control cell repair in microgravity, as well as the deleterious effects of radiation to cells in microgravity. Obtaining information on this subject will give us insight on how to control or prevent such an effect, if there is such a consequence. This research is crucial in determining health standards for astronauts on future manned deep spaceflights. Our research will determine the effect of gravity on death rate of cells when exposed to radiation.

University of Pittsburgh: Pittsburgh, Pennsylvania

Investigation of Bubble Topology in Tubes with Constant Bend Radii in a Microgravity Environment

Proposal ID: 2008-2087

While in orbit, a satellite must maintain the orbit consistent with its task through station keeping. A popular method for station keeping is using hydrazine arc-jet thrusters for the reaction control system. The use of pressurized helium to control propellant flow to the thrusters introduces an interesting two phase problem where helium bubbles have the potential to follow the propellant into tubing which prefaces the main thrust chamber. Depending on the volume of the helium and contact angle formed by the two-phase system, the bubbles can equilibrate (statically) into one of three different topologies: a wall-bound bubble, annulus, and a fully occluding plug. Current industry-leading satellite designs employ either long straight tubes or sharply bent tubes, but current numerical research shows that with increasing bend radii in the fuel piping, incidence of bubble plug formation is reduced. Introducing constant bend radii tubing as replacements for typical zero-gravity piping is therefore a logical next step. The intent of this project is to contribute experimental data about constant bend radii tubing used in fuel piping. To achieve this goal, tubes with different bend radii will be tested to observe the topology of bubbles created at specified contact angles. These results will then be compared to our numerical analysis performed using Surface Evolver, a liquid-surface modeling program created by Susquehanna University's Dr. K.A. Brakke. The results of a successful experiment will suggest whether implementing constant bend radii in fuel piping is a viable solution to prevent bubble formation from critically hindering fluid flow. References: Braun, J.P., Collicot, S. H., Zero-Gravity Solutions of Droplets in a Bent Circular Cylinder, American Institute of Aeronautics and Astronautics, 2007

University of Southern California: Los Angeles, California

The Study of Radiative Effects on Burning Rate for Improved Flame Suppression in Microgravity - Part 2

Proposal ID: 2008-2089

Many factors can effect combustion reactions and flame behavior. In terrestrial gravity, the effect that buoyancy induced convection has on these reactions greatly outweighs other combustion effects. In microgravity, where buoyancy is no longer present, other effects become the driving force of combustion reactions. The influence of radiative electromagnetic waves on the burning rate of the reaction is the most prevalent factor. The two notable waves are radiative loss, which is the transfer of radiative heat away from the flame, and radiative reabsorbtion, which is the absorption of waves that were once emitted by the flame that have bounced back and reentered the combustion sequence. A flame will continue to burn if and only if the heat loss due to radiation is less than the heat gained through radiative reabsorbtion. It is hypothesized that these two factors are governed solely by the atmospheric composition surrounding the flame. The proposed experiment hypothesizes that a radiatively active gas, such as carbon dioxide, will increase radiative reabsorbtion and reduce radiative losses, resulting in a hotter flame and an increased burning rate. Likewise, it is believed that a radiatively inactive gas, such as helium, will produce the opposite effect, leading to flame extinction. This hypothesis will be tested by igniting small wax balls inside of three sealed chambers where the atmospheric compositions will be high molarity carbon dioxide, helium, and nitrogen, respectively. Modifications to the data collection system and igniter setup from last year's experiment will result in a much better understanding of radiative effects. The end goal of this project is to prove that the current use of carbon dioxide based fire extinguishers in human space missions, without a thorough proof of their effectiveness when compared to helium based fire extinguishers, is ill advised and places an unnecessary risk on the flight crew.

University of Southern Maine: Portland, Maine

Effects of Hypergravity and Microgravity on DNA Damage, Repair, and Cellular Uptake in Lung Cells

Proposal ID: 2008-2103

The President announced a "Vision for U.S. Space Exploration," which will take us back to the moon and beyond. The plan included the development of a permanent manned moon base with trips lasting up to six months for the purposes of exploring the surface of the moon, learning more about the history of the earth and the Solar System, and eventually sending astronauts to Mars. It has been observed that microgravity causes changes in the morphology of cells and results in the loss of muscle and bone mass. Based on this information, we hypothesize that normal cell function will change in microgravity and hypergravity such that toxic chemicals have a greater damaging effect on cells and DNA. To test this hypothesis, we will study cells treated with chemicals known to damage DNA (lead chromate and sodium chromate) and an emerging public health concern (silver nanoparticles) on human lung cells in hyper- and microgravity. The results from these experiments will show us if there are differences in cellular uptake of chemicals, the amount of DNA damage induced by chemicals, or effects on damage repair in microgravity and hypergravity. Thus, in addition to providing an excellent educational opportunity for us as students, if the tests prove there is a harmful difference, the results will have the added benefit of providing NASA with information necessary to consider steps to reduce the possibility of exposure toward toxic chemicals while astronauts are in microgravity. We would then take the experiments further to test the effects of other chemicals such as lunar dusts in microgravity, to which astronauts traveling to the moon will be exposed.

University of Texas @ Austin: Austin, Texas

Nanosatellite Separation Experiment Using a P-POD Deployment Mechanism

Proposal ID: 2008-2092

Nanosatellites are becoming increasingly common in the aerospace industry due to their reduced size, small mass, and economical cost. These small satellites will often operate in groups rather than as single satellites and, once they are clear of the carrier, separate from one another. One topic of immense interest is the characterization of the separation dynamics of such satellites. Our team's experiment involves testing a separation method that has never been performed before. Our proposal is to observe and characterize the separation of two satellites by ejecting a 3-unit CubeSat (picosatellite) from the Mk II Poly Picosatellite Orbital Deployer (P-POD). This separation is unique because it will occur orthogonal to the axis of motion. A larger satellite, termed the "Chaser", will have a P-POD mounted to it, while a smaller satellite, termed the "Target", will be initially located inside of the P-POD and will be ejected from the Mk II. One practical use of this separation system in space would be to deploy the Target from the Chaser and then perform autonomous rendezvous by using a propulsion system on the Chaser. The objective of our experiment is to obtain data related to the dynamics of this separation, which includes rotations, accelerations, and translations of both the Target and Chaser satellites during and shortly after the separation event. This data will then be examined in order to determine the validity of this separation system. A microgravity environment is required since motion in six degrees of freedom (translation and rotation) are necessary for the experiment to most nearly approximate the conditions that the satellites will be subject to while in orbit. Our experiment will provide direct observation of the separation dynamics through the use of accelerometers, inertial measurement units, and visual representation through cameras. We will also have immediate access to the data analysis through our wireless data acquisition systems.

University of Texas @ Austin: Austin, Texas

The Effects of Microgravity on the Heating of Two-Phase, Cold-Gas Propellant using R-134a

Proposal ID: 2008-2115

A major obstacle for two-phase cold-gas propulsion systems in space is the unique fluid flow phenomena associated with microgravity and its effect on propellant heating in the two-phase regime. The purpose of using a two-phase system is to take advantage of the higher specific volume inherent in liquids. However, in order to create effective thrust, the stored liquid propellant must first be vaporized through heating. Research suggests that different types of microgravity fluid flows will require different amounts of heat energy to vaporize. We propose to test the efficiency of different heating methods to determine the heating energy required for vaporization in the microgravity environment onboard the C-9. This experiment will involve releasing R-134a, a commercial refrigerant, in a two-phase state from a pressurized holding tank. First, the R-134a will flow into a plenum, where one of three different heating configurations will be applied. The first configuration will use externally applied resistive heating elements. The second configuration will consist of baffles and resistive heating meshes inside the plenum. The third configuration will incorporate a combination of the previously described arrangements. A camera will also be used to observe the fluid flow patterns which occur during each test run. Temperature and pressure sensors will be used to confirm propellant vaporization. Upon completion of the experiment, the efficiency of each method will be evaluated by examining the power and time required to achieve vaporization. Fluid flow patterns will also be compared to determine the effects they have on the heating of the propellant.

University of the Ozarks: Clarksville, Arkansas

The Effect of Microgravity on Water Absorption of Polyelectrolytes

Proposal ID: 2008-2097

Sodium polyacrylate is a highly absorbent polymer, commonly used in a variety of ways. In general, it is valued for its ability to retain water, a quality that makes it useful in diapers and potting soil; its nontoxic nature also makes it an ideal compound for use in some children's toys that "grow" when placed in water. Sodium polyacrylate is a polyelectrolyte; that is, it belongs to a class of polymers that contain positively or negatively charged side chains. When added to an aqueous solution, the polymer chain of the polyelectrolyte can become less coiled, allowing the polymer to fully expand due to electronic repulsion. (Holliday 20-21) The mechanism by which sodium polyacrylate absorbs and retains water is known as the polyelectrolyte effect. During this process, the addition of counter-ions to the solution allows the polymer to recoil due to the shielding of like charges on the side chains of the polymer. (Dautzenberg et al. 1-2) The precise influence of gravity on the polyelectrolyte effect is not known, but it is speculated that the presence or reduction of gravity may have an impact on the behavior of the polymer in an aqueous solution. Gravity may affect the rotation of the atoms around carbon-carbon single bonds, thus affecting the alignment of the side chains. It may also affect the formation of solvent cages, a primary factor in the solubility of a molecule in a solution. The solubility of the polymer will be measured using turbidity of the solution once the polymer is added to water.

University of Wisconsin @ Madison: Madison, Wisconsin

The Efficiency of Linear Spray Cooling Under Varying Gravity

Proposal ID: 2008-2050

Thermal management is an increasingly important factor in the design of next generation electronic systems, and the limits of current technologies are quickly becoming apparent. This experiment will investigate the method of linear spray impingement cooling under varying gravity conditions to allow determination of a quantitative relationship between gravity and spray cooling performance. The results could be a major step forward in the efforts concerning thermal management in space.

Washington University in Saint Louis: Saint Louis, Missouri

Reduced Gravity Bandit Propulsion: An Automated Vision-Navigated Inspector Spacecraft

Proposal ID: 2008-2041

Washington University (WU) is one of eleven schools developing a student-built nanosatellite for the NASA / Air Force Research Laboratory (AFRL) University Nanosat-5 competition. Students are directly responsible for all aspects of design: concept, manufacture, integration, testing, and operations. The mission of the WU spacecraft, Bandit/Akoya, is proximity operations and automated repeatable docking of very small spacecraft in microgravity. The 3kg "Bandit" inspector free-flyer detaches from the 29 kg "Akoya" host spacecraft, maneuvers in 6DOF at close range, and redocks using an extremely error-tolerant docking mechanism. Though the ability to dock in space has been previously demonstrated, the scale of Bandit/Akoya is unique; at 3kg and $15,000 per "Bandit" inspector free-flyer, Bandit has numerous low-cost, light-weight space applications. Small, autonomous service or inspector vehicles such as Bandit may be applied to on-orbit inspection, repair, and anomaly resolution. A vehicle with Bandit's camera capabilities would be deployed as a probe to investigate and photograph another spacecraft at close range. These photographs would be used to check for damage or to verify position. At low cost, the vehicle may be recaptured or expendable. Several advances have been made in inspection, relative maneuvering, and docking technology in the past decade. In 2000, Surrey Satellite Technology's SNAP-1 separated from its launch vehicle and transmitted images back to Earth. AFRL's 28kg XXS-11 demonstrated line-of-sight

guidance to within 100m of a target. In 2007, the United States Defense Advanced Research Projects Agency (DARPA) / NASA Marshall Space Flight Center's Orbital Express demonstrated autonomous separation, hard-docking, and refueling. Bandit is a further contribution to these missions: repeatable and extremely error-tolerant soft-docking. Bandit's primary features are a 6DOF propulsion system and a visual navigation / inspection system. The visual system includes a camera and image-processing. Bandit photographs an array of LEDs on Akoya, analyzes the position of the LEDs, and determines its pose. WU's goal is to flight-test Bandit's propulsion and visual navigation systems through the C-9 Reduced Gravity Student Flight Opportunities Program. Two tests are included: 1. Orient (detumble) Bandit in 6DOF using on-board inertial sensors and propulsion system. 2. Navigate Bandit towards the simulated dock using visual sensing / processing and the 6DOF propulsion system.

West Virginia University: Morgantown, West Virginia

Investigation of Viscous and Capillary Fingering Through a Hele-Shaw Cell in Microgravity

Proposal ID: 2008-2093

The proposed experiment will test the phenomena of capillary fingering and viscous fingering in a two-phase immiscible flow under the conditions of microgravity and hypergravity. Capillary fingering occurs at low injection rates and is dominated by capillary forces at the interface between the two immiscible fluids. In comparison, viscous fingering is a fingerlike growth displacement pattern that results from injecting a less viscous fluid into a more viscous fluid at a high injection rate. Under the conditions of gravity and a high injection velocity, viscous fingering has been shown to form a fractal growth pattern, commonly referred to as a Brownian tree. A Hele-Shaw cell (HSC) can be used to visualize this fractal growth pattern. A HSC is created from two parallel plates with an extremely small plate separation relative to its length. This apparatus constrains 3-D fluid motion to a simplified essentially 2-D form. To analyze capillary and viscous fingering, the proposed experiment consists of two separate parts. The first part of the experiment utilizes two pairs of HSCs. Each HSC contains two immiscible fluids of different viscosities, resulting in a unique viscosity ratio, M, for each HSC pair. Each pair consists of two test sections, one HSC with porous media (HSC-PM) and one without (HSC). During microgravity, the two pairs will be flipped 180 degrees about a fixed central axis. This portion of the experiment will model a capillary driven fingering flow for two different viscosity ratios under different gravitational conditions. The second part of the experiment utilizes a high velocity injection of a lower viscosity fluid into a HSC saturated by a fluid of higher viscosity. This test will analyze viscous fingering at varying flow rates and gravitational conditions. The information gained from this research can be beneficial for physical applications such as oil extraction, carbon sequestration, filtration, and flame propagation. It also may have applications to possible underground fluid storage for a lunar base.

Yale University: New Haven, Connecticut

Void Deformation in a Complex Plasma in Sub- and Super-terrestrial Gravity

Proposal ID: 2008-2090

Complex, or dusty, plasmas are plasmas containing microparticles. In experiments conducted under Earth conditions the dust particles form a 2-dimensional crystalline structure. However, in microgravity dusty plasmas have a complex 3-dimensional structure that is characterized by a dust free central region or void. In our experiment, we intend to characterize the deformation of this void between sub- and super-terrestrial gravity in a complex argon plasma by analyzing a series of CCD images. We plan to calculate and characterize the net change in the distance between dust particles as the gravitational field changes. With this calculation, we aim to estimate an effective spring constant for the system and gain insight into how dusty plasmas behave in dynamic environments. Comparison with calculated values may give a method to estimate charge and Debye length thereby giving a glimpse into the behavior of the dusty plasmas that make up the interstellar medium.

SEED Undergraduate Students
Participating Universities – By State
* First Time Participant (institution)

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Auburn University: Auburn, Alabama

Multimission Space Suit EVA Drink Bag Filling Process

Gravity Type: Microgravity

A multimission space suit drink bag filling process that removed air in the drinking water quickly and could be used in both the 0-G and 1/6 G surface EVA would be evaluated. Time overhead and crew workload to fill and remove air from the drinking water prior to installing in the suit is a major time consuming item that affects Work Efficiency Index. This is mainly a 0-G problem, and I am not sure if it is a lunar 1/6 G problem. EVA drink bags will definitely be required during surface EVAs due to the expected work loads.

This will be a systems engineering challenge on Shuttle, International Space Station, and lunar surface EVAs. Requires mechanical engineering, physics knowledge of fluids and gases, integration with Shuttle, ISS, and lunar surface systems and knowledge of EVA systems and space suits. CEV EVAs will be of short duration and may not require an installed drink bag.

NASA Technical Contact(s): Jessica Vos, Robert Trevino – JSC Space Suit and Crew Survival Systems Branch

Carthage College: Kenosha, Wisconsin

Inertial Filtration in Lunar Gravity

Gravity Type: Lunar

NASA Mentor, Juan Agui from GRC and a student from Carthage College monitor their experiment.

Life support systems on lunar habitats will inevitably have to handle the additional loading due to airborne lunar regolith dust that is introduced in the pressurized environment. Regenerable filters or filters that can be cleaned will be desirable, over disposal filters, as well as filters that can handle dust fines and ultrafines. Inertial filtration technology which relies on inertial separation such as cyclone filters (often seen on vacuum cleaner systems) could meet this demand. The separation relies on centrifugal effects and gravitational settling to remove the solid particulate matter. This usually captures the bulk of the particulates, although the smallest particles still have a chance to remain entrained in the gas phase. In the lunar gravity environment, 1/6th of that on Earth, this effect is diminished, and as a consequence there is a chance that more of the particles may evade the settling chamber.

Therefore, the feasibility of using inertial filtration to capture a broad size range of particulates in lunar gravity has to be demonstrated. An experiment can be conducted on NASA's reduced gravity aircraft to show feasibility.

The experiment needs to demonstrate and provide data on the capturing efficiency of a broad size range of particulates in an inertial separator in normal and lunar gravity. Standard test particles and lunar simulant can be used for testing. The Atmospheric Revitalization element of the Exploration Life Support project is developing air filtration systems to handle airborne lunar dust in habitats.

NASA Technical Contact(s): Juan Agui – GRC Office of Biological and Physical Research

Ohio State University: Columbus, Ohio

Lunar Regolith Simulant Hopper Interface Feasibility Tests (LRSHIFT)

Gravity Type: Lunar

According to NASA's Exploration Architecture Requirements Document (EARD) "By 2023, the Constellation Architecture should provide from lunar in-situ resources, no less than 1 metric ton of oxygen per year." Currently, JSC personnel are collaborating with multiple NASA centers as well as contractors and universities to demonstrate the capability of extracting oxygen from lunar regolith simulant at rate consistent with the EARD requirement of 1 metric ton per year. Methods for extracting oxygen from lunar simulant and Apollo samples have already been demonstrated on a small scale. The JSC lead OPTIMA program (Outpost Precursor Testbed based on ISRU & a Modular Architecture) is funded through ISRU (In-Situ Resource Utilization) and has a goal of demonstrating an end-to-end oxygen production plant by November 2008. This demonstration would take lunar simulant from the ground, transfer it into a hopper, and feed it into a reactor chamber where it is then reduced with hydrogen in order to extract oxygen in the form of water. The water is then electrolyzed into hydrogen and oxygen gas. The hydrogen is recycled, and oxygen gas is stored for human consumption.

The OPTIMA program incorporates multiple subsystems that all have to work together in order to demonstrate an end-to-end process. Assuming that NASA personnel are able to successfully demonstrate the capability of producing 1000 kg of oxygen per year from simulated lunar materials on Earth, the question would still remain as to how the overall system would function in a reduced gravity environment. The best way to answer that question is to identify the mechanisms within the system that would be the most vulnerable to reduced gravity and test them under such conditions. The results of the reduced gravity tests being proposed here would feed into the larger OPTIMA program in order to determine the best methods for transferring lunar regolith to and from an oxygen production reactor chamber.

NASA Technical Contact(s): Aaron Paz, Lara Oryschyn – JSC Energy Systems Division

Polytechnic University: Brooklyn, New York

Investigation of Propellant Transfer Systems For Spacecraft

Gravity Type: Microgravity

One of the challenges in the design of spacecraft with complex, liquid propellant systems is selecting the best method of transferring propellant from one tank to another by means of a compressed gas pressurant and is especially interesting with orbital refueling stations proposed for the NASA Constellation program. There is much theory about how the fluids will react in microgravity; however, the gap between theory and reality is still wide due to insufficient empirical data. It is proposed that a systems engineering approach be used to conduct a hardware trade study of at least four propellant transfer methods in microgravity to determine which has the least pressure drop (head loss), the greatest propellant mass exchange rate, and

is the most efficient. In addition, an examination of the flow of the propellant is essential to determine if phenomena detrimental to spacecraft, such as vortices or sloshing, occur in the system.

It is believed that water would make an excellent surrogate for the propellant. Although traditionally gaseous nitrogen would be used as the pressurant, compressed air would better suit the task for risk mitigation while operating in a sealed aircraft.

NASA Technical Contact(s): Mike Brennison – MSFC Stress Analysis

Portland State University: Portland, Oregon

Droplet Coalescence

Gravity Type: Microgravity

This project would complement the data obtained from an International Space Station experiment that measured the coalescence rate of 2 spherical droplets in low gravity. Low gravity permitted the experimentation with large spherical droplets (up to 1 cm diameter) confined on strings. The coalescence of 2 drops over a period of time was measured. The purpose of the experiment was to develop a method for determining the viscosity of a liquid based on the time it took to coalesce 2 drops, hence the experiment is called, "Fluid Merging Viscosity Measurement" (FMVM). Liquids observed were honey, cornsyrup, glycerin, and silicone oils (viscosity calibration standards). Terrestrial experiments were also performed by placing small drops of liquid on thread (<1mm), manually bringing the droplets together till they touch, and recording with a home video recorder. Clips of the video were captured as AVI files analyzed to determine the time it took for coalescence.

System Engineering principles could be used to translate scientific experiment requirements into engineering requirements and hardware designs to permit the experiment to be performed during the low gravity parabola on the aircraft. The specific change in design from terrestrial or ISS experiments is to perform the experiment in the short time period of the parabola. For example deploy 2 drops (1 to 4mm diameter) on 2 strings, bring into contact, and record the coalescence time (1 to 10 sec).

NASA Technical Contact(s): Edwin Ethridge – MSFC Ceramic Materials

Purdue University: West Lafayette, Indiana

Angle of Repose of Lunar Regolith Simulant JSC-1A in 1/6 g

Gravity Type: Lunar

Student and Faculty from Purdue University make adjustments to their hardware in- flight.

This project would measure the angle of repose of lunar regolith (soil) simulant JSC-1A during 1/6g parabolic flights on the NASA aircraft. The angle of repose is the slope angle at which a pile or berm of material will begin to flow (landslide). The construction of berms (walls) of regolith on the moon will be useful for several applications. Radiation protection of the lunar outpost from nuclear fuel cells on the moon could be provided by a wall of regolith (berm). Berms could also protect the outpost from the blast of lunar soil during landing and departure vehicles. The measurement of the angle of repose for lunar regolith stimulant JSC-1A would be useful for design studies. Dr. Ethridge is involved with the

production of the new lunar regolith simulants.

System Engineering concepts could be used to translate user (science) requirements into engineering solutions and hardware concepts to achieve the desired measurements and results.

NASA Technical Contact(s): Edwin Ethridge – MSFC Ceramic Materials

University of Cincinnati: Cincinnati, Ohio

Mini AERCam Docking in Microgravity

Gravity Type: Microgravity

Students from the University of Cincinnati working on capturing Mini AERCam.

The Autonomous Extravehicular Robotic Camera (AERCam) program is developing a small, free flying vehicle capable of performing inspection and viewing missions in support of International Space Station (ISS) operations. The anticipated AERCam configuration for a future ISS implementation is an externally based free-flyer with recharge capability. However, in order to recharge itself, the vehicle needs to dock to a recharging station. Due to its low mass and small size, traditional docking systems are not viable options for the vehicle. As a result, a novel magnetic docking system was developed in order to guide AERCam to a soft-docking configuration that captures the vehicle. Once the vehicle is captured by the magnetic docking system, hardware secures AERCam in place and the recharge process can commence.

For the flight, the team will design and build a mechanism that will impart a constant linear velocity to AERCam as it approaches the magnetic docking system. The magnetic docking system will be placed on a movable platform that will allow the researchers to vary the incidence angle of the vehicle upon docking. The ultimate goal is to characterize the docking envelope for position, rotation, and velocity of the vehicle relative to the docking station.

As part of the systems integration of the docking mechanism and the flying vehicle, ground tests have evaluated the effective docking envelope for the magnetic capture. Although useful as an initial engineering evaluation, these tests produced limited results due to the constraints imparted by gravity. The microgravity environment allows for a detailed systems engineering evaluation of the hardware. First, it will provide an environment to evaluate the integration of the docking mechanism and the vehicle, a pivotal step into hardware's ultimate success. In addition, it will allow for a comparison between the engineering calculations and a more realistic simulation of the operational environment than ground testing. Finally, a microgravity flight serves as an evaluation of the ground testing results. If microgravity results prove to be similar to observations on the ground, engineers can perform tests quickly and accurately with current ground testing equipment. Thus, a realistic testing environment allows for a more holistic systems engineering approach that includes design, system integration, testing, and hardware evaluation.

NASA Technical Contact(s): Fernando Zumbado, Nathan Howard – JSC Automation, Robotics, and Simulation Division, Dynamic Systems Test Branch

University of Colorado at Boulder: Boulder, Colorado

Application of Developing World Terrestrial Water Treatment to the Lunar Outpost

Gravity Type: Lunar

Terrestrial water treatment systems and spacecraft water treatment systems share similar requirements and methods. While spacecraft treatment systems are often designed to process urine to potable standards, there are technologies terrestrially designed to address ground and ocean water contamination with similar requirements. Such treatment systems appropriate for the developing world may also be appropriate for the lunar outpost, given that the Outpost will require rugged equipment operating in a harsh environment with limited local resources. This project proposal may include scaled versions of terrestrial water treatment systems for treating brine water in developing countries applied to the lunar outpost in a 1/6th gravity environment using local resources such as lunar regolith simulant.

Life support on the moon will have to take advantage of in-situ resources and consist of a fully integrated system with humans, habitat, and environment playing system roles. Additionally, terrestrial water treatment systems are feats of systems engineering that can be applied to the lunar outpost.

NASA Technical Contact(s): Evan Thomas – JSC Life Support & Habitability Systems Branch

University of Kentucky: Lexington, Kentucky

Impact Ground Reaction Force on Different Surface Types in a Lunar Gravitational Environment

Gravity Type: Lunar

In order to determine the risk of bone fracture in space, the NASA Integrated Medical Model (IMM) Project has developed a bone fracture risk analysis module which provides an estimate of the probability of bone fracture during specific normal activities and off-nominal events that may occur during future space exploration missions. To determine the probability of fracture, the load experienced by the lumbar spine and the femoral neck during an activity is estimated using mathematical biomechanical models. To validate and reduce the uncertainty in the model, it is desirable to know the ground reaction forces (GRF) resulting from a known mass impacting different surface types in the lunar or Martian gravitational environment. It is desirable to know how the GRF changes as a known mass lands on different surface types, such as, sand, gravel, rocks, water, ice, and lunar regolith simulant (if possible). The scope of the work for this project includes experimental design, experimental equipment development and set up, data collection, and data analysis.

Systems engineering is a process comprised of tasks which include 1) state the problem, 2) investigate alternatives, 3) model the system, 4) integrate, 5) launch the system, 6) assess performance, and 7) re-evaluation. Although small, the proposed project will be a contribution to the overall engineering system that is under development and necessary for long-duration space exploration to occur. The IMM Project is tasked with developing models to predict how the human system will perform in space. These models are very important for determining the limits of human capabilities within the unique environment of space. The information gained through this project will provide valuable input to the IMM model about the time response of impact force in a lunar environment, information that can be used to increase the accuracy and decrease the uncertainty of the model.

NASA Technical Contact(s): Beth Lewandoski – GRC Bio Science and Technology Branch

University of Nebraska at Lincoln: Lincoln, Nebraska

Effects of 0G on Radio Frequency Identification (RFID) Data Accuracy

Gravity Type: Microgravity

To test the effects of 1/6G and/or 0G on the read rate/accuracy of RFID reading capabilities of items contained in Cargo Transfer Bags (CTBs) using a portable reader and/or the accuracy of read rates of CTBs/tagged items translating through a vehicle using stationary readers. The ISS Program is currently investing Surface Acoustic Wave (SAW) RFID technology to augment the current barcode-based inventory system on ISS to track loose and stowed cargo. Ground-based tests have been performed, but there is no RFID test data available for either a 0G and 1/6G environment. Constellation is also pursuing RFID for future missions, vehicles, lunar base, and an inflatable station. We are interested in investigating SAW and/or Gen 2 technology.

NASA Mentor, Amy Schellhase and UNL Student, Dustin Dam, experience microgravity for the first time.

NASA Technical Contact(s): Amy Schellhase – JSC Orion Project Office

NES Educators – By State
* First Time Participant (institution)

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Clara Barton Elementary School: Chicago, Illinois

The Effect of Gravity on Fluid Flow through Permeable Materials

This experiment will test the effect of gravity on the flow of fluids through permeable materials. Experimental hardware will consist of a clear, subdivided hanging box filled with a selection of light colored materials in which a dark-colored water-based dye will be introduced. The resulting high contrast will allow for simple measurement of the distance the liquid traveled during differing amounts of gravitational force. Results from corresponding experimental work in the classroom will be compared to results obtained during the reduced gravity flight.

Crossroads Elementary School: St. Paul, Minnesota

Force and Form

Crossroads Elementary School is teaching 6th grade students the concept of rotational motion and moment of inertia. The moment of inertia for a spinning body depends on the mass distribution relative to the axis of rotation. The moment of inertia equals the sum of the mass times the square of the distance from the axis of spin for each particle in the body. The moment of inertia is greater for spinning objects with their mass distributed farther from the axis of rotation. Gyroscopes and tops are designed on this principle. In this process of studying rotational motion and moment of inertia, the students have been determining characteristics of objects that spin. The students formed groups of approximately 6-7 students and discussed possible experiments they could develop to be tested in microgravity. The students came up with how weight placement, height, and shape affect rotational motion as topics of experimentation. The question of how gravity affects magnetic force has come up as well. The students are in the process of developing designs for these experiments such as rotating a pencil with an attached weight. They will perform ground tests in an environment with gravity and record data such as the length of time the object spins. This data will be compared with data taken in a microgravity environment to demonstrate how rotational motion and moment of inertia are affected in microgravity.

Franke Park Elementary School: Fort Wayne, Indiana
Falling Spheres Through Liquids

Six graduated cylinders will be filled with two sets of liquids of three different viscosities. Two sets of spheres of different densities will be placed in each cylinder. The cylinders will be attached to a rotisserie device inside of a glove box for containment. The experiment will be conducted by observing and filming the motion of the spheres going through the different fluids while the cylinders are rotated at different angles on the rotisserie device. In 1g, the spheres are expected to fall at different speeds. In 2g, the spheres are expected to fall faster, and in 0g, they are expected to stay where they are at the moment of entering 0g unless a force acts upon them.

Johnson Junior High School: Cheyenne, Wyoming
Bubble Inquiries

This study involves liquid control in a zero gravity environment and will investigate bubble formation patterns in liquids of differing densities. This investigation will include examining the results of bubbles formed from liquids of various densities and surface tensions contacting each other. Through this investigation fluid interaction and emulsion formation in reduced gravity will be examined. The results will allow the students to study the concepts of surface tension and fluid density. The investigation will utilize an apparatus that will provide varying degrees of mechanical force and the capability to introduce multiple fluid bubbles into the test volume to measure changes in bubble formation patterns within the liquids after reaching an initialization point. The test apparatus will include a clear canister to hold equal amounts of each liquid and enable viewing. Several fluid introduction tubes will be located in a radial pattern around the circumference of the canister, each with tubing attached to a syringe containing a different test fluid and suctioning device. The syringes will be used to introduce predetermined volumes of fluid. A video camera will be used to record the test volume from above the canister in which the amount of mechanical force applied can be varied. At the completion of each parabola, the return of gravitational force will pull the liquid tested through a mesh screen into a containment volume at the bottom of the canister. The mesh screen will ensure that the tested fluids do not interfere with additional testing.

Key Peninsula Middle School: Lakebay, Washington
Reaction Time

The purpose of this experiment is to determine the effect of gravity on the reaction rate between baking soda and vinegar. The reaction rate is dependent on how often the reactants collide. The reactants will be combined in normal gravity by students at Key Peninsula Middle School and then by their teachers in microgravity on board the C-9. A previous microgravity flight experiment forced mixing of the reactants by using a syringe; however, this follow-up experiment will not force the mixing with the syringe. The relative rate of the reactions will be determined by measuring how quickly one of the products, carbon dioxide, is made by measuring the pressure produced from the reaction. It is expected that there will be fewer collisions between the reactants in microgravity and therefore, less carbon dioxide will be produced in microgravity than in the classroom.

Luis Munoz Marin: Cleveland, Ohio
Free Falling ROVeRs

The experiment chosen by the students is an evaluation of a LEGO Robotic Transporter. The Robotic Transporter will run along a ramp carrying different size weights. The evaluation will consist of measuring the time it takes the robot to carry each of the weights across the ramp as well as if there is a limit on the amount of weight it can carry. This will be carried out both in Earth gravity ground testing and in DC9B zero-g testing and the results will be compared. It is expected that for Earth gravity ground testing the time to carry the weights will decrease as the weights get heavier, eventually resulting in a limit for which the Robotic Transporter can no longer carry the weight. However, in the absence of gravity, there is expected to be no practical limit for which the robot will be able to carry a weight across the ramp.

Lorraine Hansberry Academy: Bronx, New York
Staying on Track: Creating Artificial Gravity

In this experiment we will attempt to understand how we can create artificial gravity during microgravity, a concept that will have great relevance as we send our astronauts on long-duration missions through space. We will fly an apparatus that will hold a mass that is allowed to spin about a shaft whose speed can be varied. The mass will be attached to the end of spring with a known spring constant, and when the mass is spun about the shaft, the deflection of the spring will be measured. Given the distance from the shaft (radius), the angular speed, and the deflection of the spring, we can verify the equations for centrifugal acceleration and calculate the amount of gravitational force we have applied to our mass. We will vary the radius, spring constant, and speed over the course of the two flights to produce the necessary data. We can use this data to project what size radius and speed would be needed to create an Earth-gravity environment for an average astronaut mass.

Marcelino Canino Canino Middle School: Dorado, Puerto Rico
Flying Colors

Marcelino classroom teacher, Gladys Munoz demonstrates her students experiment to camera.

This experiment studies the effects of gravitational acceleration on the behavior of mixing fluids. Since fluid properties such as viscosity and surface tension have an effect on diffusion properties, the objective is to determine how different gravity conditions (more or less than 1g) affect the rate at which fluids of different colors and types mix. Three separate assemblies will be prepared, each with three different cylinders where different colored fluids will be placed separately in the experimental apparatus. The fluids will then be put in contact while in hyper gravity, another while in microgravity, and a third was used as control. It is expected for the reduced gravity mixtures to take longer due to the liquids' surface tensions than the hyper gravity mixtures with the control providing intermediate times. This experiment will be conducted in phases. The students will research scientific information relating to this topic, design and build the investigation apparatus in the laboratory, help plan the trip to Houston, analyze experimental results, and help disseminate results to their classmates and the general community. They will work on this dissemination through oral and written presentations.

Middle School at Parkside: Jackson, Michigan
Electromagnets in Microgravity

Our experiment that we plan on flying in the micro-gravity plane involves electromagnets. The theory that we plan on testing in our experiment involves the effects various degrees of gravitational forces exert on metal objects, specifically in terms of electromagnetic forces of those metal objects. The experiment will be student driven and teacher supported. The main student involvement in the experiment implementation will come out of our after-school program. However, we plan on involving the whole student body in various parts of the process.

North Ridge Magnet Elementary School: Moreno Valley, California
Water Streams and Droplets

The 4th and 5th grade science club students at North Ridge Elementary School have been questioning the properties of water in relation to microgravity. They have become interested in water streams and how the stream will change when sprayed into an environment where gravity does not pull the liquid down. The students have discussed the trajectory path of a water stream, the composition of a water stream, and the cohesiveness and variance of water droplets. In both microgravity and hyper gravity, the students anticipate the trajectory will affect the rate in which the water stream breaks apart into individual droplets. Experiments with water streams will enable the students to come up with many different hypothesis in the search for what happens to the stream of water in microgravity.

Oak Hills Terrace Elementary: San Antonio, Texas
Roller Coaster Enthusiast of OHT

This experiment will study the exchange between potential and kinetic energy by studying the physics of roller coasters. The Oak Hills students started investigating roller coaster physics during school. This led to the students creating roller coaster structures using vinyl tubing and small metal balls. The experiment will be made up of three parts: a ball moving down a ramp, a ball moving up a ramp, and a loop. The students will study how gravity affects the motion of the balls (roller coaster "car") in these simplified roller coasters. The experiment will measure the distance traveled by the ball when a constant force is applied and the ball is "launched" through the roller coaster in 0-G, 1-G, and 2-G environments. These experiments were used to help discuss the principles of energy exchange and gravity with the students.

Piedmont Elementary School: Charleston, West Virginia
Firing in Space

Piedmont Elementary School will explore Newton's first law of motion, the law of inertia, in an experiment which will fly onboard NASA's Weightless Wonder in February of 2008. The law of inertia is commonly stated as: "an object at rest tends stay at rest, or an object in motion tends to stay in motion with the same speed and direction, unless acted on by a force." This experiment observes the effect of the force due to gravity on the path and range of a projectile, a foam dart. The team will launch the projectile parallel to the aircraft floor and record the position of the projectile in both microgravity and hypergravity. The launcher will be attached to a camera pole, and the motion of the projectile will be recorded with a video camera. Grid paper and a timer will be placed behind the path of the projectile for easy observation of each projectile's position in time. The team predicts that in microgravity the projectile will continue to move in the direction it was deployed until it hits a net, opposite the launcher, because the force of gravity is not exerting a force on the projectile and, therefore, can not change the projectile's path. During hypergravity, the force acting on the projectiles is almost twice that on the surface of the earth. In this phase of flight, the team hypothesizes

that the projectile will travel half the distance the same projectile would travel in normal Earth gravity. Additionally, the experiment will observe four different masses as they are dropped from the same height in both microgravity and hypergravity. This demonstration will be used in the classroom to compare to the projectile flight in two dimensions and reinforce the concepts of mass and weight.

Sioux City Community Middle Schools: Sioux City, Iowa

How Does Gravity Affect Convection?

The experiment will investigate the rate of movement of airflow due to thermal convection and measure the spatial variation of temperature in micro-gravity, hyper-gravity, and normal terrestrial gravity. The equipment was comprised two interconnected tubes; one tube has a thermal source and the other a thermal sink. Under normal gravity conditions, gas will rise from the source in the warmer tube, transfer to the cooler tube, and fall to the sink, thereby completing a convection cycle and transporting thermal energy from the source to the sink. A vapor can be introduced to the gas to provide a visualization tool for observing this phenomenon. The efficiency of this thermal transfer process will be investigated by using the vapor tracer to measure airflow rates and using multiple temperature sensors to measure relative thermal energy concentrations within the system.

South Plantation High School: Plantation, Florida

Mass Determination in Microgravity with an Inertial Balance

Microgravity presents unique problems for space travelers in the realm of mass measurement. One known method of accomplishing this task is the use of an Inertial Balance. Relying on the period and/or frequency of vibration, it is possible to calculate an unknown mass compared to a known mass in a mathematical proportion. Our experiment will consist of a mass of no more than five pounds placed in the holding pan of a two bladed balance that will be clamped to a pole. Visual counts of the oscillations will be conducted during the flight and calculations made with the various test masses upon landing. Percentage of error will also be calculated using values obtained on land based triple beams or digital balances. An electronic motion detector may also be employed to ascertain the certainty of the visual data. As an additional experiment, we propose to use a pendulum consisting of a string and a plumb bob. The pendulum will be started at normal gravity values and then observed as the flight reaches the peak of the parabola. A video camera will record the results of the experiment.

NASA Mentor, Mark Pape and teacher from South Plantation High School make final adjustments to their team's hardware before take-off.

NEAT Educators – By State
* First Time Participant (institution)

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MN	Mayo High School*	37			

Academia Cotopaxi American International School: Quito, Ecuador

Studying Rates of Solvation by Measuring Temperature Changes

Solubility is a key chemical concept in our everyday lives. It influences how our bodies absorb nutrients, how we cook our food, how we clean our dishes, and myriad other activities. Substances dissolve through a process known as solvation. In water, solvation occurs when the polar H2O molecule (the solvent) attracts other polar particles (the solute); in this study, those other particles will be the ions in calcium chloride and sodium bicarbonate. The solvation process can be either exothermic, meaning that it releases heat and increases the temperature of the system, or endothermic, meaning that it absorbs heat and decreases the temperature of the system. The team from Academia Cotopaxi has designed an experiment to measure the rates of solvation of calcium chloride and sodium bicarbonate in 1G and in microgravity by measuring temperature changes. Twenty-four small (60-125mL) bottles will be preloaded with a fixed amount of solute (12 each with calcium chloride and sodium bicarbonate.) These bottles will be grouped in units of 8 for each set of 10 parabolae, and each group will be secured to the bottom of a Lexan-80/20 glovebox that may be opened from the top. The active set of bottles will be capped with three-hole rubber stoppers: one hole will contain a temperature probe connected to a laptop computer, one will hold a syringe filled with water, and the third will hold a compressed syringe. The inactive sets will be capped with screw caps to contain their contents. As the C-9 goes over the top of a parabola, water will be injected into one bottle (alternating between the two solutes from one parabola to the next), while the air is removed with the second syringe. The temperature probe will record the temperature change as the solute dissolves, and each trial will be videotaped for qualitative evaluation. For subsequent parabolae in the set of 10, other bottles/probes/syringes will be used so that no equipment needs to be changed out in micro- or hypergravity. During level flight between sets of parabolae, we will open the glovebox, move the stoppers with probes/syringes to a new set of bottles, refill the syringes with water, and cap the used bottles with screw caps. We hypothesize that the solvation process will occur more rapidly in microgravity, as the solute

Educators from Academia Cotopaxi explain their students experiment to the TRR Committee.

and solvent particles will be more free to interact without gravity forcing the solute to settle. Therefore, we predict that we will see more rapid changes in temperature on the C-9 than in our ground trials.

Alice Worsley School: Fresno, California

Nutrient Delivery System for Plant Growth Chambers in Microgravity

Watering techniques on Earth rely on proper percolation of the water through the soil. This process is dependent on gravity. In a microgravity environment, proper water dispersal throughout the soil becomes a complex issue (Personal Communication, Dr. Robert N. Bowman Senior Scientist, Lockheed Martin Mission Services, NASA Ames, 10/14/2007). This study is addressing the issue of delivering nutrients to plants in a microgravity environment and the protocols that will be developed to support these systems. Several delivery systems will be tested to evaluate the systems operation and ability to effectively saturate the soil within a plant growth chamber while in microgravity. All systems will be tested using water with non-toxic food coloring. Those systems being tested for soil saturation will use moisture trapping cat litter. The nutrient delivery system's structural design and operation will be evaluated using digital video. Soil saturation will be measured by weighing the amount of water trapped in the soil (cat litter). A secondary question being addressed focuses on protocol development for testing and conducting nutrient delivery. Two to three systems will be developed and tested at 1G in Fresno, California, and compared to test results conducted in micro G aboard NASA's reduced gravity C-9 aircraft. The results of this study will add to the body of knowledge concerning the complex issue of plant growth in microgravity.

Carlisle High School: Price, Texas

Soil Compaction Evaluations as a Precursor to Construction and Agriculture on the Moon and Mars

The purpose of this series of experiments is to determine the effects of gravity on soil compaction and porosity. Soil compaction and porosity must be considered before cultivating plants and are also important factors to evaluate before constructing buildings. When soil is disturbed, i.e. tilled, moved, etc, there are a number of factors involved in the subsequent compaction that will occur. A primary factor is gravity. Since Mars has a surface gravity that is 38% of the earth, and the moon's gravity is only 1/6 that of the earth, soil compaction will be affected. We plan to use overall soil density determined from mass and volume measurements in combination with soil particle density to calculate soil porosity and compaction. This information in addition to measurements of relative gravity will be used to study short-term soil compaction in anhydrous simulated martian and lunar soils. We hope to determine the percent soil porosity at Earth gravity, moon gravity, Mars gravity, and microgravity in lunar and martian soil simulants.

Columbus High School: Columbus, Georgia

Physics of Plant Growth in Micro, Lunar, and Martian Gravity

Growing plants on the moon and Mars will be critical to the long-term survival of human explorers as well as for long-term space travel. Understanding differences in how plants work in the gravity of these environments is an important investigation to anyone seriously trying to leave the earth for extended periods of time. This open-ended investigation addresses a series of small-scope research questions regarding cellular respiration, water and nutrient transportation, and the effects of thermal radiation on plant growth in microgravity. To address the research questions derived by students at three different schools (grades K-12), a suite of sensors will be employed. A 42 channel 16-bit data logger will collect up to 2GB data during ground trials and in flight. The analog sensors include a CO2 sensor, an O2 sensor, temperature sensors, light sensors, a leaf wetness sensor, and relative humidity sensors. Sensors that will collect data on the environment include a 3-axis magnetometer, 3-axis accelerometer, and a 3-axis gyroscope that are all time-stamped with the other data. Students will complete exercises to analyze data graphically and look for linear

and nonlinear trends. Though the reduced gravity flight only affords multiple short durations of microgravity, if we can show measurable changes with a suite of sensors in a 1g environment, we can begin to model the difference in behavior in these various gravity environments using physics heat flow models or numerical models. These will then be offered as the basis for new theories and investigations. Ultimately, continued experiments may be designed to further understand the physics of plants in microgravity, specifically on Mars and the moon.

Lakeview Middle School: Warsaw, Indiana

The Absorption of Water by Various Growth Substrates in a Microgravity Environment

Gravity, or a lack of gravity, will continue to be a force that needs to be better understood as astronauts continue to live and work in space. As the time draws near for people to spend extended time in reduced gravity for long-duration missions to the moon, Mars, and beyond, the ability to grow food in reduced gravity environments must be perfected. Therefore, all aspects of plant growth will need to be understood, and technologies that optimize plant growth in microgravity environments must be perfected. Since gravity plays a roll in how water soaks into soil on Earth, the lack of gravity may impact plant growth and root formation as astronauts attempt to grow plants for food in space. Through testing a variety of plant growth substrates for water absorbtion in microgravity, we will determine which substrate absorbs water faster and may be most conducive to normal plant growth. Several Plant Growth Chambers will be constructed and filled with substrates consisting of various amounts of sphagnum peat moss. During the microgravity portion of the flight , quantitative data (temperature readings) will be used to determine the depth of water absorption into the substrate. We hypothesize that the containers that contain the greatest percentage of sphagnum peat moss will absorb water faster. In addition, since there is no "up" in space, it is hypothesized that the absorption rate will be the same whether the water is applied to the "top" of the container or the "bottom" of the container in the watering process used for containers with the same substrate composition. This data will be used to assess which substrate would perform better in a reduced gravity environment and, thus, support plant growth in space environments.

Lubbock High School: Lubbock, Texas

Project M.E.G.A. (Microgravity Experimental Growth Activity)

Crystals grown in microgravity will have few defects than those grown on Earth or in hypergravity. Although the types of crystals we are growing are food grade, chosen because of toxicity and containment concerns, the growth of crystals without defects is important to the production of microchips, video cameras, digital watches, flat-panel televisions, and many other electronic applications. A lower number of impurities and defects create a higher quality crystal which, in turn, produces higher quality electronic equipment.

Mayo High School: Rochester, Minnesota

Heat Flow, Sedimentation, and Standing Waves

Experiment 1 - 3-D Standing Waves: In a traditional Kundt's Tube, a speaker is placed at the end of a closed tube containing a fine powder or dust. When the appropriate frequency is reached to produce a standing wave in the tube, the fine particles are pushed away from the antinodes and collect in the nodes of the wave. This gives a distinct pattern that can be used to measure the wavelength of the standing wave. A fine structure of ripples and dust walls are also produced that reflect the vortex patterns that are generated as the air in the tube vibrates with the waves. All of this, of course, is found along the bottom of the tube due to gravity. We wish to investigate the pattern that is formed in both the zero-g and the hyper-g environment. In zero-g we hope to produce a node/antinode pattern that fills the volume of the tube and not just its bottom. We also hope to record the small patterns that form in both zero and hyper-g and investigate

the role gravity plays in the vortex patterns that develop. We have built a prototype tube and have been experimenting with frequency, lengths, and types of powder. We have also experimented with a video camera attached to a computer that simultaneously records the video, 3-axis acceleration data, and temperature data. The software we are using allows us to make time and distance measurements directly from the video. This will be our main mode of data collection during the flight. At a basic level, our experiment will provide video that can be used by almost any teacher to supplement a demonstration that is often done in physics classes. In talking with experts, we have received a wide range of opinions on what will happen with the experiment in zero-g. At a more technical level, we hope to shed some light on the role of gravity in producing the fine structure seen in the tube.

Experiment 2 - Sedimentation Rate: As a particle falls through a fluid, gravity, buoyancy, and frictional forces combine to determine the terminal velocity the particle will reach. Other variables including the diameter of the container and Reynolds number will also vary the terminal velocity. In this experiment we wish to look at some of the variables that affect the rate at which a particle falls through a viscous fluid. Using a standard viscosity fluid, we will investigate different size particles and different diameter tubes. We hope to take measurements in zero and hyper-g environments, and we would also like to attempt measurements during transitions from one to the other. In developing the experiment, we have built several prototypes and have experimented with a variety of fluids and particle types and sizes. We have built spreadsheets to help us determine the appropriate values to use in our final design. We have also looked at different methods of resetting the experiment and keeping it aligned with the gravitational field. We have also experimented with a video camera attached to a computer that simultaneously records the video, 3-axis acceleration data, and temperature data. This will be our main mode of data collection and will be shared with the other experiment. Once again, at a basic level we hope to provide video that can be played alongside a similar experiment done in a typical physics classroom. We also wish to use the equations that describe this type of motion to see if our results match those predicted.

Menomonie High School: Menomonie, Wisconsin

Effect of Microgravity on Nutrient Uptake by Algae

Educators from Menomonie explain their students experiment to the TRR Committee.

In order to achieve the maximum effects of long-duration spaceflight on plants, optimum growing conditions of light, water, and nutrients must be obtained. This experiment looks specifically at a plant's ability to take in nutrients in a microgravity environment. We believe that in a microgravity environment, nutrient uptake will decrease as compared to that of plants grown on Earth. Plant roots absorb nutrients from soil or water using passive transport (diffusion) across the plant cell membranes of root tissue. In an experiment testing the rate of diffusion in a simulated hyper-gravity, using a turntable, we found that the rate of diffusion increased. Extrapolating that data to a microgravity environment, we believe the reverse will be true; the rate of diffusion will decrease. Similarly, we would expect to see a decrease in nutrient uptake in lunar and Martian parabolic flights since they also have a reduced gravity compared to Earth gravity (1/6 and 3/8, respectively). Water and nutrients will move through the plant by capillary action, which has been shown to increase in microgravity, but this will not affect the extent to which the nutrients are brought into the plant initially.

Our experiment will be enclosed in a customized housing design yet to be finalized. It will contain a chamber for water with an opening for the stem of a plant. The hole will be sealed to avoid leakage of water. The water chamber will have a rubber stopper through which a syringe can be inserted to withdraw samples of the water. Food coloring will be added to the water. Since nutrient uptake is by simple diffusion, we can utilize the diffusion of the food coloring to represent individual nutrients essential to the plant. Samples of the colored water will be drawn from the chamber at the beginning and end of each microgravity opportunity during parabolic flight. These samples will be injected into sealed collection vials for later analysis. Using a colorimeter, the concentration of the food coloring in each sample can be determined. On the ground, we will take similar measurements in a controlled experiment to serve as a source of comparison to our flight data.

This research is vital not only to space-based research but ground based as well. The use of plants in long-duration spaceflight has many applications. Growing a variety of plants will provide food and oxygen for astronauts as well as act in bioremediation of wastes. Furthermore, plants will be an integral part in maintaining crew morale. Being in a room with plants reduces stress and promotes a sense of calm by reducing blood pressure and heart rate. Additionally, we have recognized that research done in space can greatly improve life on Earth. As technologies have advanced, agricultural practices have benefited. Living in a semi-agricultural community, we feel it is important to look at various impacts on plant growth in a variety of environs. One problem associated with agricultural practices in our community and surrounding locations is agricultural runoff which has led to severely eutrophic conditions in our waterways. We hope to apply findings of our research to this dilemma.

Milan High School: Milan, Michigan
Capillary Conundrum

For long-duration spaceflight the ability to grow food is a major concern. Simple processes like supplying aqueous nutrients to the root structure of plants cannot be taken for granted. In a reduced gravity environment, the containment and distribution of aqueous nutrients will be dominated by surface tension, the adhesion of the liquid to the root structure and the potting material. Our experiment is designed to evaluate the effects of a reduced gravity environment on capillary action (highest fluid column) in a series of tubes of different inside diameters. We will also analyze the effect of varying the surface tension of water on capillary action, by comparing the results for water and a solution of water and dissolved granulated plant food.

North Carolina School of Science and Mathematics: Durham, North Carolina
Calcite in the Ear's Role in Dizziness/Wind Energy for Mars Colony

Space adaptation syndrome is a problem facing many astronauts and is poorly understood. This research focuses on the vestibular system located in the inner ear that provides the body with a sense of balance and direction by relaying information about rotation and tilt to the brain. The system is separated into two independent parts. The semicircular canals, which convey positions in all three planes of movement, and the macula and saccule in the utricle, which measure linear acceleration. The movement of endolymph against the cilia in the semicircular canals results in the release of neurotransmitters that inform the brain of the body's position in its environment. To better understand how altered gravitational fields affect the vestibular system, a scaled model of the semicircular canals will be constructed and placed in a microgravity environment so that the effect can be quantitatively measured. By examining the movement of the artificial endolymph against the synthetic polymer crista and fiber-optic cilia, the resulting phenomena under microgravity may be more thoroughly understood. Additionally, a model of the otolith organs has been constructed in two parts. Two separate boxes, which represent the utricle and the saccule, are filled with two layers of crosslinking copolymer of polyacrylamide, polyacrylate, and N,N'-methylenebisacrylamide of two different densities. Fiber optic hair bundles protrude into the gel layers and are illuminated by a laser. Their

movement is recorded through image capture. On top of the gel is a layer of pseudocalcite, with a density of about 2.9 g/cm3, partly synthesized in vitro; this material adds weight to the gel and amplifies its motion.

This project seeks to determine whether or not gravity has an effect on the output voltage of a wind turbine (possible applications for wind power on Mars). The team will examine this research question by measuring the output of an actual turbine during each flight parabola. As the parabola simulates hyper gravity on the way up and microgravity on the way down, the team will examine the effects of both increased and decreased gravitational pull on the turbine. In addition to voltage measurements, the team will also measure the apparent gravitational pull inside the plane. Using this data, our team will produce two graphs (voltage vs. time, gravitational pull vs. time) necessary to answer the research question. Ideally, the team will develop a mathematical model of the relationship between output voltage and gravitational pull.

Timberlane Regional High School: Plaistow, New Hampshire

Vibration of Musical Instrument Soundboard in Microgravity

The problem we are examining is whether a musical instrument soundboard – specifically a guitar soundboard – will vibrate differently in a microgravity or hyper gravity environment than in a standard (1 G) environment. The group feels that this experiment may have applications for the long-term exploration of space. From what both the mentors and students have read, much effort has been spent on limiting vibration in space on satellites and other craft, with the resulting technology being applied from stopping vibration on satellite solar panels to a vibration damping system on alpine skis. All the while, little has been said about systems that are deliberately placed into vibration, like that of a musical instrument soundboard.

Appendixes

Left, top: Students working on the experiment during a parabola. Left, middle: Educator trying to reset experiement between parabolas. Left, bottom: Group of educators learning about their breathing equipment before the. Right, top: Group pf Educators in hyperbaric chamber experiences the effects hypoxia. Right, middle: Flight team recording data from the flight. Right, bottom: NASA mentor in hyperbaric chamber experiences the effects hypoxia.

Appendix 1 – Undergraduate Student Program Proposals at a Glance

Selected Engineering Proposals

Institution	Proposal Title	Page
Cornell University	Haptically Controlled, Power-Efficient Space Robotics	7
Embry-Riddle Aeronautical University	Project FuSSION(Fuel Slosh Simulation of Induced Oscillatory Nutation)	7
Lamar University	Study of Vibrational Damping Effects of Grass-like Crops in a Microgravity Environment	8
Michigan Technological University	Metal Nanotip Formation in Zero Gravity	8
New Mexico State University	Inertial Property Algorithm Verification	9
Portland State University	Passive Separation of Two-Phase Flows using Conduit Geometry II	10
Purdue University	Electrolysis in Microgravity using Porous Metal Foam Electrodes	10
Purdue University	Wicking in a Groove Network	10
Rochester Institute of Technology	Characterization of Thermal and Piezo-Electric Print Heads in a Microgravity Setting	11
Texas A & M University	Analyte Detection Via Protein Nanopores in a Microgravity Environment	12
Texas A & M University	Gravity Independent Boiler Experiment	12
The University of Arizona/University of Florida	Applications and Limitations of Ionic Polymer-Metal Composite Sensors and Actuators in Space	13
University of Alaska Fairbanks	Investigation of Small Satellite Attitude Control Systems	14
University of California San Diego	Deployable Tensegrity in Space	15
University of Colorado at Boulder	DANDE Microgravity Separation System Demonstration	15
University of Kansas	Assembly of Spacecraft Systems by Electro-Magnetic Binding and Locking Equipment	16
University of Kansas	Effects of Energy Dissipation for Communication Satellites	16
University of Kansas	SMART-HAWKER: A Smart Wire Actuated Robotic Arm	16
University of Michigan	Determining Zero-G Feasibility of the Nanoparticle Field Extraction Thruster Reflight	17
Missouri University of Science and Technology	Reduced Gravity Testing of a Refrigerant-Based Cold Gas Thruster	17
Missouri University of Science and Technology	Studying Arc Welding in Microgravity Conditions	18
University of Pittsburgh	"Investigation of Bubble Topology in Tubes with Constant Bend Radii in a Microgravity Environment"	19
University of Texas @ Austin	Nanosatellite Separation Experiment Using a P-POD Deployment Mechanism	21
University of Texas @ Austin	The Effects of Microgravity on the Heating of Two-Phase, Cold-Gas Propellant using R-134a	21
University of Wisconsin @ Madison	The Efficiency of Linear Spray Cooling	22
Washington University in Saint Louis	Reduced Gravity Bandit Propulsion: An Automated Vision-Navigated Inspector Spacecraft	22
West Virginia University	Investigation of Viscous and Capillary Fingering Through a Hele-Shaw Cell in Microgravity	23

Selected Physical Science Proposals

Institution	Proposal Title	Page
Brown University	The Application of Sound Waves on the Control of Fluid Behavior in Microgravity	6
Lamar University	Bounded Meniscus Geometry in Reduced Gravity	8
Pennsylvania State University	A Study of Interparticle Forces within a Complex Plasma-II	9
Rhodes College	Binary Orbital Motion of Electrically Charged Spheres	11
Texas A & M University	Investigation into the Effects of Fluid Motion on the Rotation About the Unstable Axis of a Body	12
The College of New Jersey	Using Fluorescent Dust to Obtain a Three-Dimensional Analysis of a Dusty Plasma	13
University of Southern California	The Study of Radiative Effects on Burning Rate for Improved Flame Suppression in Microgravity - Part 2	20
University of the Ozarks	The Effect of Microgravity on Water Absorption of Polyelectrolytes	22
Yale University	Void Deformation in a Complex Plasma in Sub- and Super-terrestrial Gravity	23

Selected Life Science (Including Biology) Proposals

Institution	Proposal Title	Page
The University of North Carolina at Pembroke	Gravitational Effects on Human Immune Complexes and Flame Dynamics	14
University of New Mexico	The Effects of Gravity on Fibroblast Inactivation due to Ionizing Gamma Radiation	19
University of Southern Maine	Effects of Hypergravity and Microgravity on DNA Damage, Repair, and Cellular Uptake in Lung Cells	20

Appendix 2 – SEED Program Proposals at a Glance

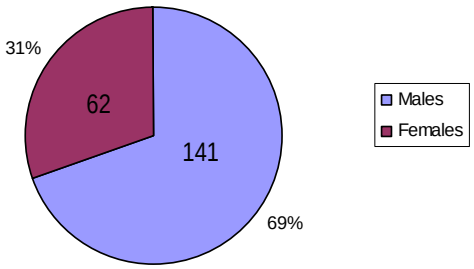
Selected Engineering Proposals

Institution	Proposal Title	Page
Auburn University	Multimission Space Suit EVA Drink Bag Filling Process	24
Carthage College	Inertial Filtration in Lunar Gravity	24
Ohio State University	Lunar Regolith Simulant Hopper Interface Feasibility Tests (LRSHIFT)	25
Polytechnic University	Investigation of Propellant Transfer Systems For Spacecraft	25
Portland State University	Droplet Coalescence	26
Purdue University	Angle of Repose of Lunar Regolith Simulant JSC-1A in 1/6 g	26
University of Cincinnati	Mini AERCam Docking in Microgravity	27
University of Colorado at Boulder	Application of Developing World Terrestrial Water Treatment to the Lunar Outpost	28
University of Kentucky	Impact Ground Reaction Force on Different Surface Types in a Lunar Gravitational Environment	28
University of Nebraska at Lincoln	Effects of 0G on Radio Frequency Identification (RFID) Data Accuracy	29

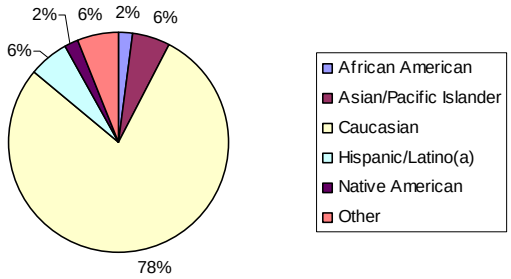
Appendix 3 – Demographic Data

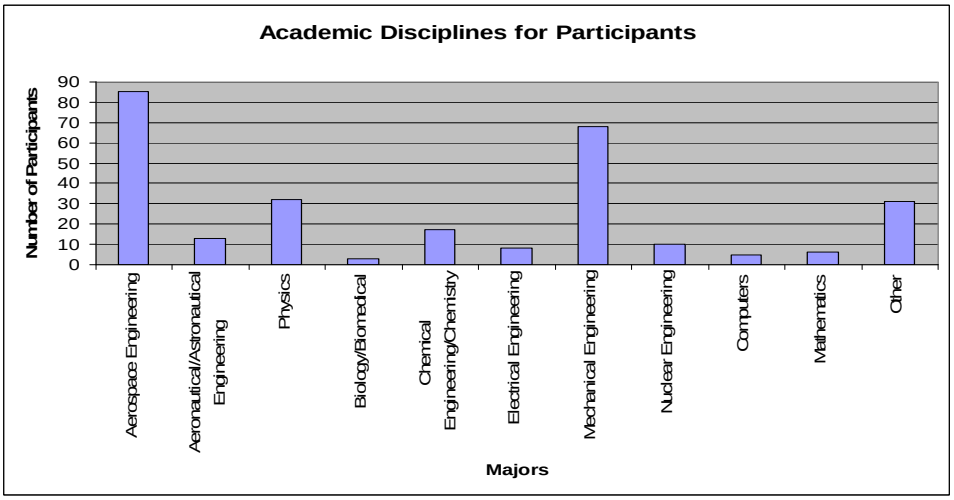
Combined Undergraduate Students Demographic Information (UG & SEED)

Program Participants by Gender



Participants by Ethnicity





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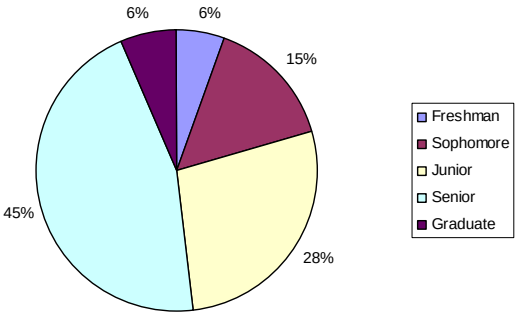
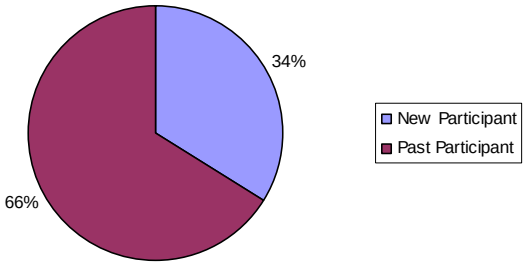
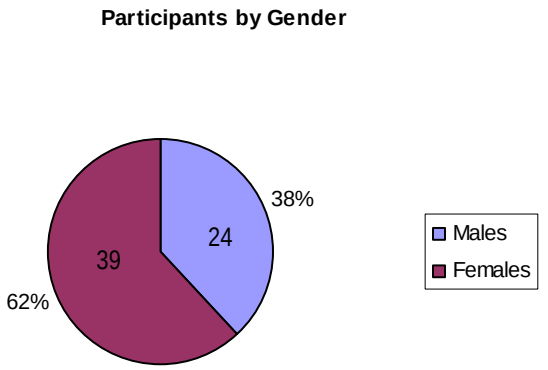
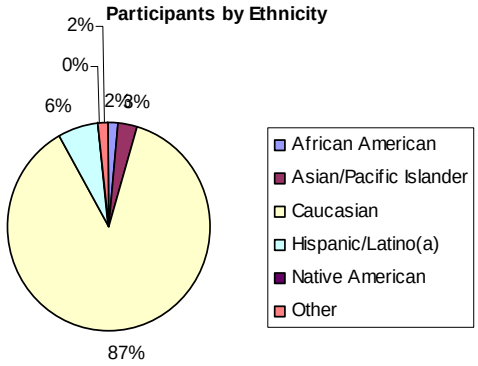


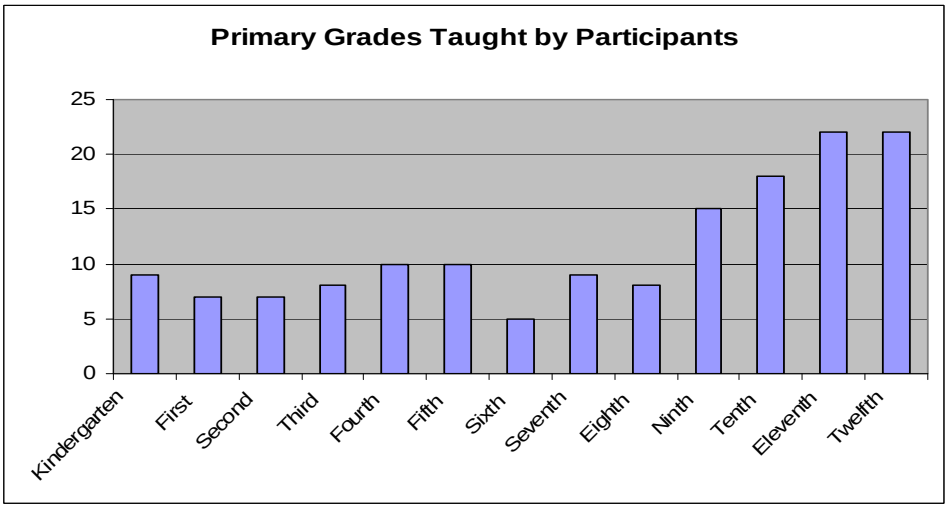
Program Experience for Participants

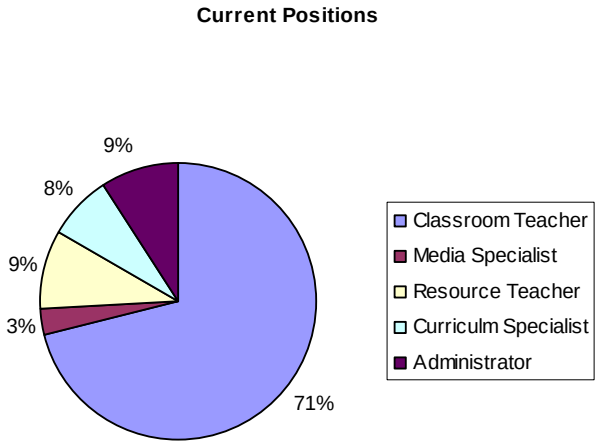


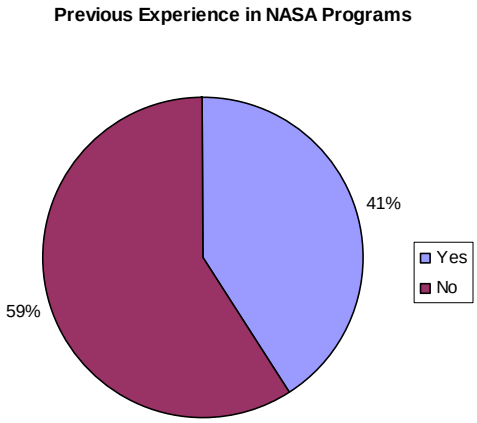
Combined Educators Programs Demographic Information (NES & NEAT)



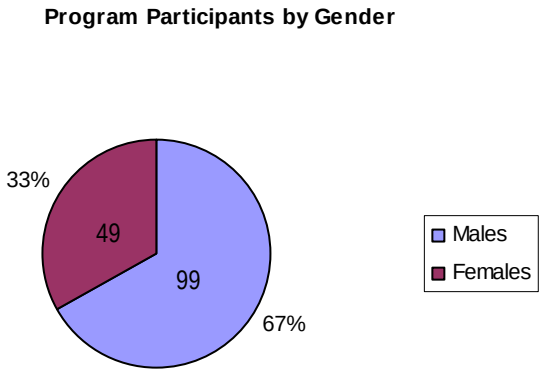


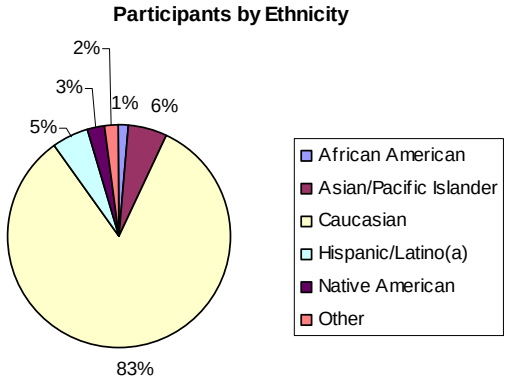


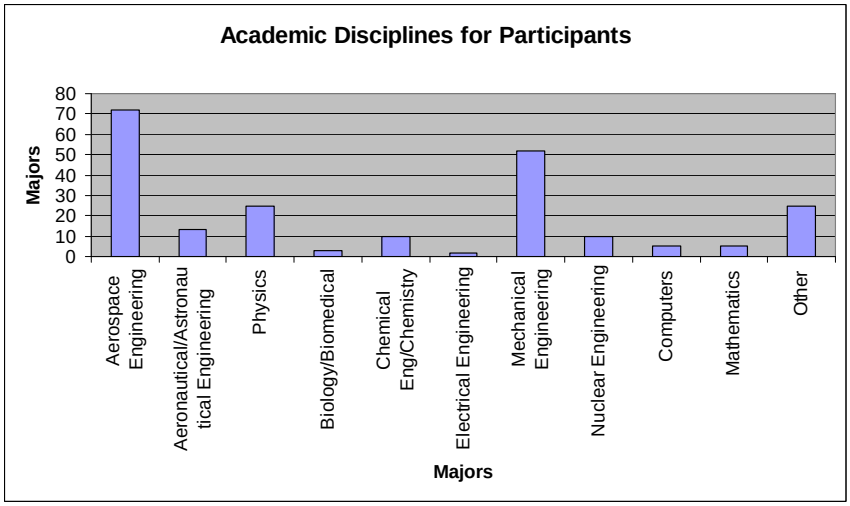


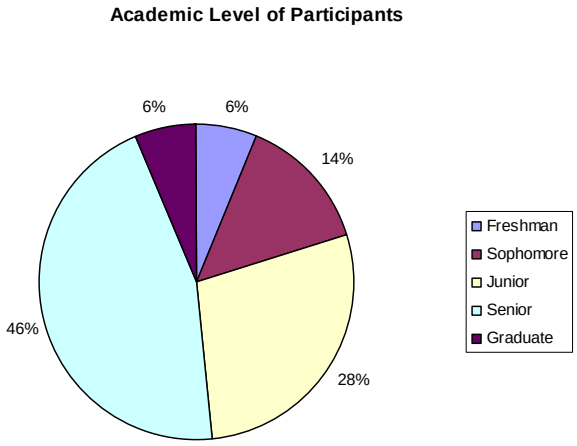


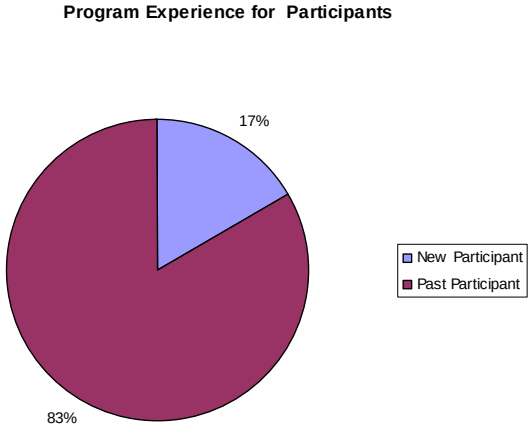
Undergraduate Student Program Demographic Information





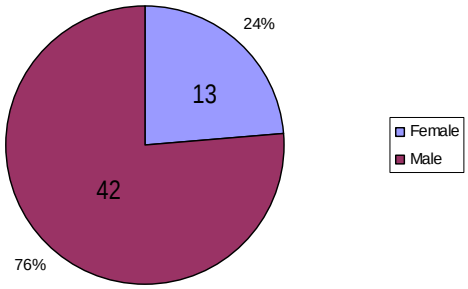




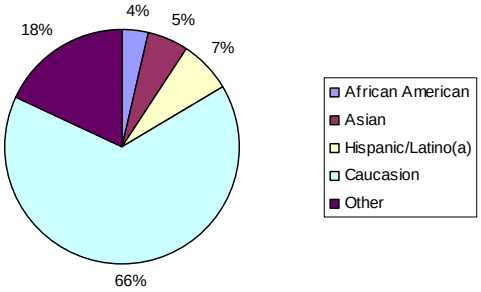


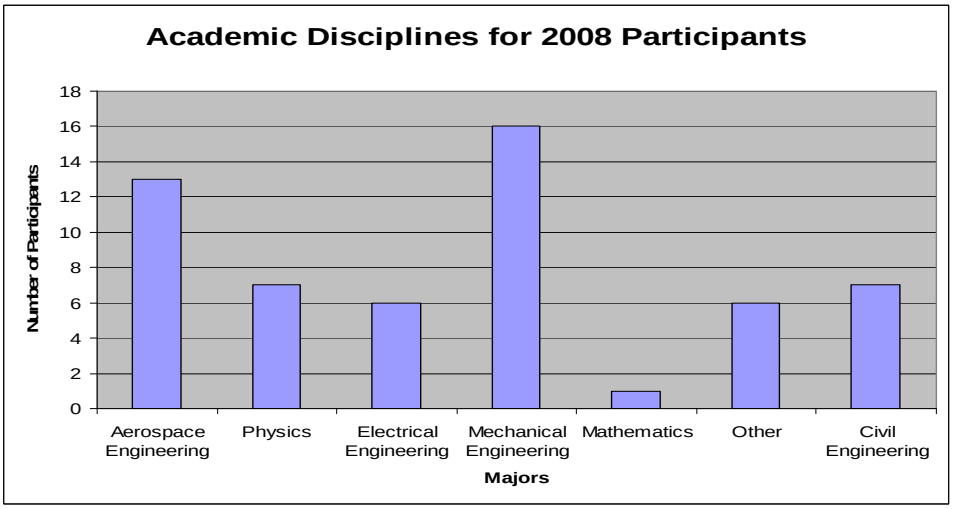
Systems Engineering Educational Discovery Demographic Information

Participants by Gender



Participants by Ethnicity





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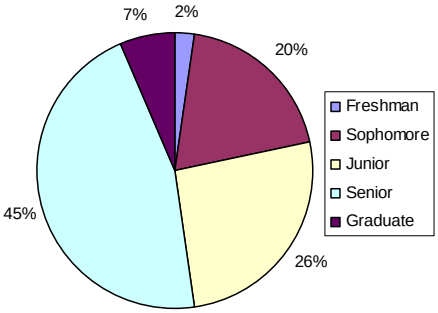
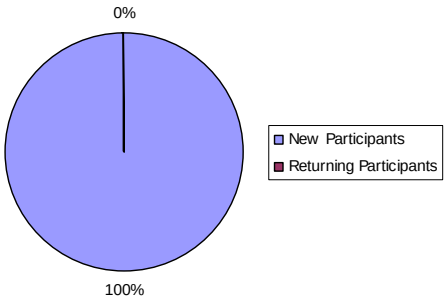
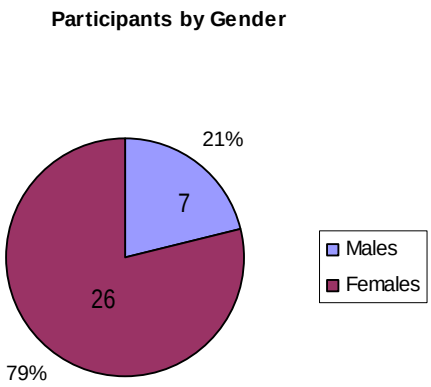
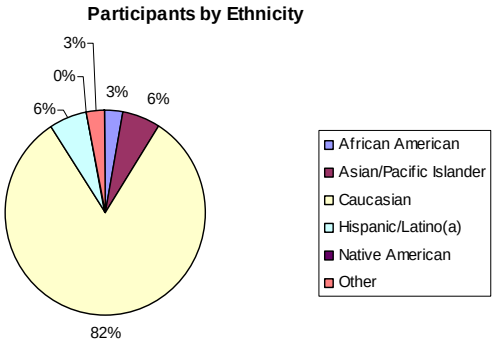


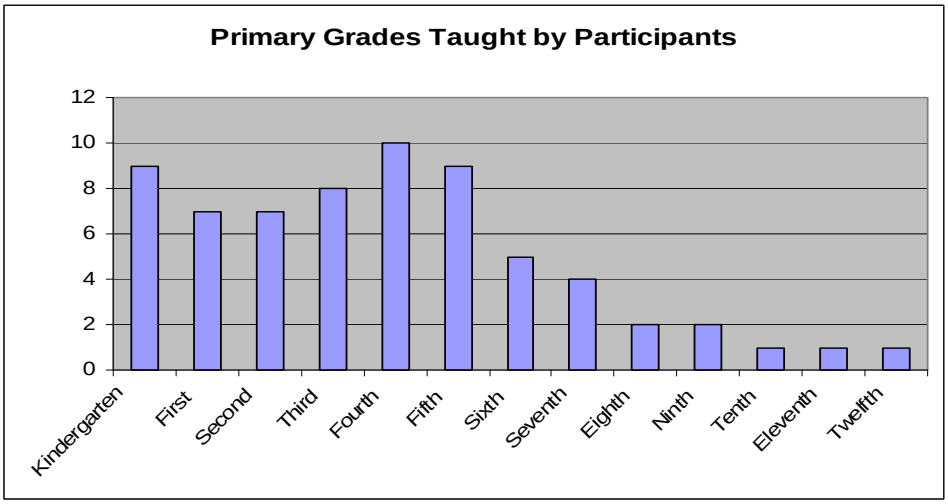
Program Experience for 2008 Participants

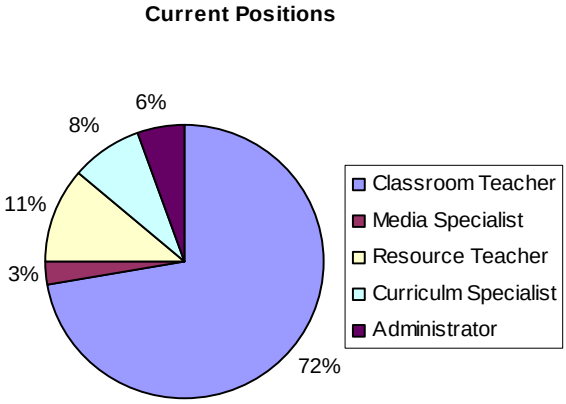


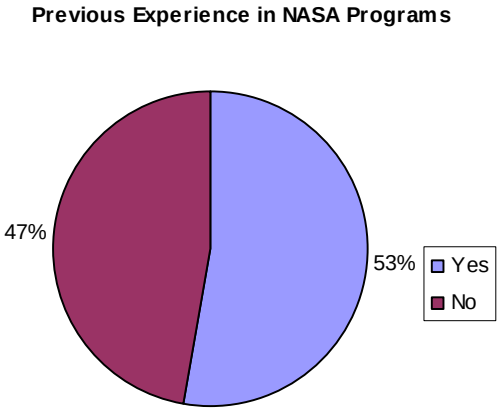
NASA Explorer School Educators Demographic Information





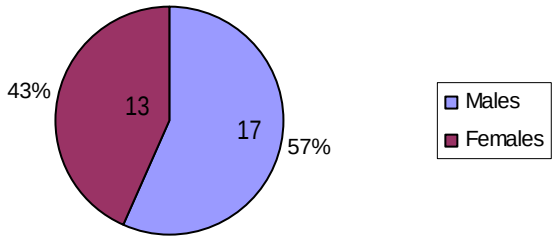




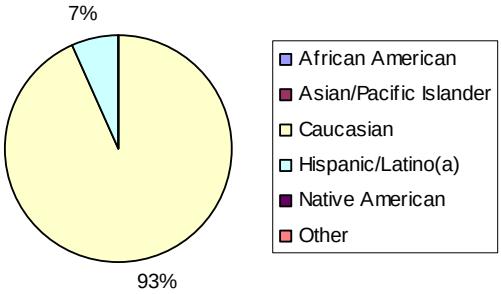


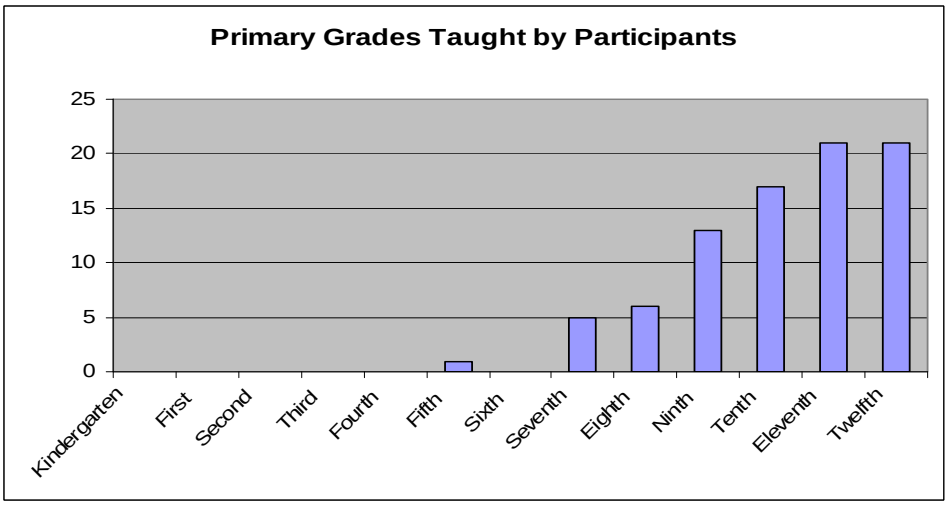
Network of Educator Astronaut Teachers Demographic Information

Participants by Gender

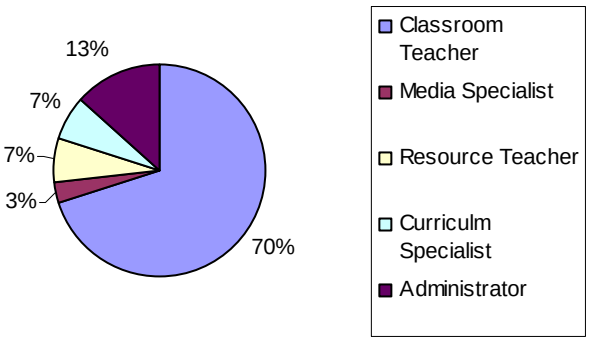


Participants by Ethnicity

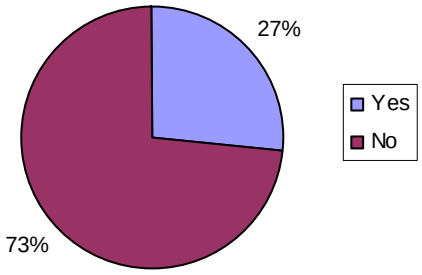




Current Positions



Previous Experience in NASA Program



Appendix 4 – Participant Comments

Program evaluations were collected by NASA Education Evaluation Information Systems (NEEIS). Educators, students, and faculty overwhelmingly praised the program for providing a rare real world hands-on engineering experience for K-12 and undergraduate students. A few of the educator and student responses follow.

- "I appreciate the fact that NASA makes this experience available to teachers, as I've seen the value it gives our students. For us, it's a truly unique physiological experience, which I certainly enjoyed. Thank you for the opportunity"
- "I hope that NASA understands how important thier programs are to teachers and students. The United States is in a global competition for students in all career fields, and this program allows students to see what careers NASA could provide. This interest starts in elementry school and needs to be continued until college."

"This program provides a very good and rare opportunity to practice practical engineering. This is important to an engineer as the experience is rare to find."

- "What a great opportunity for me as a teacher to leave my daily work environment and rub shoulders with scientists, mathematicians and engineers at NASA. I loved talking with the mechanics, other educators, NASA mentors and office staff about the program. They are universally positive and supportive of the RGO Program. We were welcomed wherever we went. Staff were gracious and helpful from providing us with bullnose clips to patches. It was a friendly, yet professional atmosphere and well worth the ten days spent here. As a child of the 50's the opportunity to test myself in the hypobaric chamber and later on the C9 in reduced gravity and 2 G's was a once in a lifetime experience. The experiment for my students and school, the communication with our school colleagues and the projects we completed aboard is the icing on the cake. My enthusiasm for stretching and testing myself and the students has invigorated my teaching for the remainder of the school year and for many years to come. I am pumped!!! Thank you!"
- "It was so inspiring to meet and talk with so many young NASA engineers, scientists, and astronauts. The behind the scenes tours, physiological training, and hypobaric training were an awesome experience to be shared with students and others. Even though I had a adverse reaction to the RGO flight, I am so excited that I was able to experience zero gravity! The feeling is so incredible. I want to go back and talk for a week about this with my students! I always tell them that attitude is everything. I want to sow those seeds of hope and inspiration in all of my students!"
- "I have acquired a new appreciation about how vast NASA reaches in all areas of our lives. This program specifically is an active way of reaching to our youth who are the future, and future leaders of science. It makes me also realize, that teachers are instructing students in science, and probably students are being educated for careers that do not even exist now but will exist within ten years from now. NASA is facilitating the process of educating for the future."
- "I cannot stress enough how much our ground crew students were inspired by all they saw and experienced this week. I know at least one, and possibly all 3 of them, are already talking about studying engineering in college and are so excited about the opportunity to participate in the Reduced Gravity Student Program at that level. Those that could not come to Houston with us were thrilled to see us in the DLN event after our flight and cannot wait to hear all about our experiment and our experience when we return home. If we can use programs such as this one with NEAT to hook kids on these subjects early, we'll be able to keep them for life."
- "It's hard to put this experience in words. The time spent in reduced gravity was unbelieveable and opportunity to tour NASA facilities that many others don't get to see was awsome. The whole experience made me think of quitting my job, going back to school for engineering, and trying to get a job at NASA. Then I thought more realisitically. I have the opportunity to inspire my students to do this. I

can help my students to develop better understanding of why working on science can be important and what they need to do to get access to these types of opportunities."

- "I just want to take the time to thank NASA for this program. It was a once in a lifetime experience and I am grateful for the opportunity. I cannot stress enough the importance of continuing this program in the future. I can only hope that future students can gain as much from this program as I did this past week. Thank you so much."
- "I landed from the C9 on a very different Earth. As I experienced zero-g, then Moon, then Mars, then 1-g, I felt the mass of the "body beneath me" increasing. For the first time in my life I tangibly understood the relative scale of my universe, and the weight of this planet I live on. I could not have achieved that perspective in any other way. It has forever changed the way I know this world. Thank you."
- "Never in a millions years did I ever think I would be able to experience microgravity. This helped me not only accomplish an impossible dream, but it help make me feel as if I can accomplish anything I put my mind to. Creating an experiment from scratch helped me learn the background to fractals, formulas, chaos theory, and many other topics. More importantly, it helped me learn a lot about myself, and working with others."
- "The Reduced Gravity program was an amazing opportunity to put real-life engineering skills to the test. Through proposing, designing, building, and finally flying our experiment, we learned countless lessons related to the processes and standards required in a "real-life" research project. We were able to take our classroom skills and apply them to a project which was held to professional standards. We also gained valuable experience in overcoming engineering design and construction obstacles throughout each phase of our project. In all, the Reduced Gravity Program opened my eyes to the world beyond school and taught me many lessons about relating the classroom to the real world. The ability to experience the design environment of my hardware will also greatly contribute to the effectiveness of future designs. Lastly, the Reduced Gravity program got me addicted to zero-g. So my team will be back for another flight!"
- "As a team we looked at the map that outlines the states that have participated in the Microgravity University program before and noticed that Nebraska was not among the participants. It was our goal to put together a proposal that would inspire confidence in our team's ablities. At the end of this week and a half it has been our team that has been inspired by the stories, acomplishments, and history of NASA and programs like this. It makes me proud to be an engineer."
- "I can't say that many people get to experience zero-gravity. Being around NASA and the space environment is inspiring because it is a fantastic reminder of our constant need to explore, learn, and create new opportunities and potentials unforseen without a space program."
- "I have never imagined in my wildest dreams that I would have an opportunity to work at a NASA site, but this experience has helped to make my dreams come true. All of the tours and interesting insider tidbits truly gave me a new appreciation for NASA. Working in a close environment with such amazing NASA employees also helped to give me an added appreciation. It has helped to inspire me to look further into the opportunities NASA has to offer."

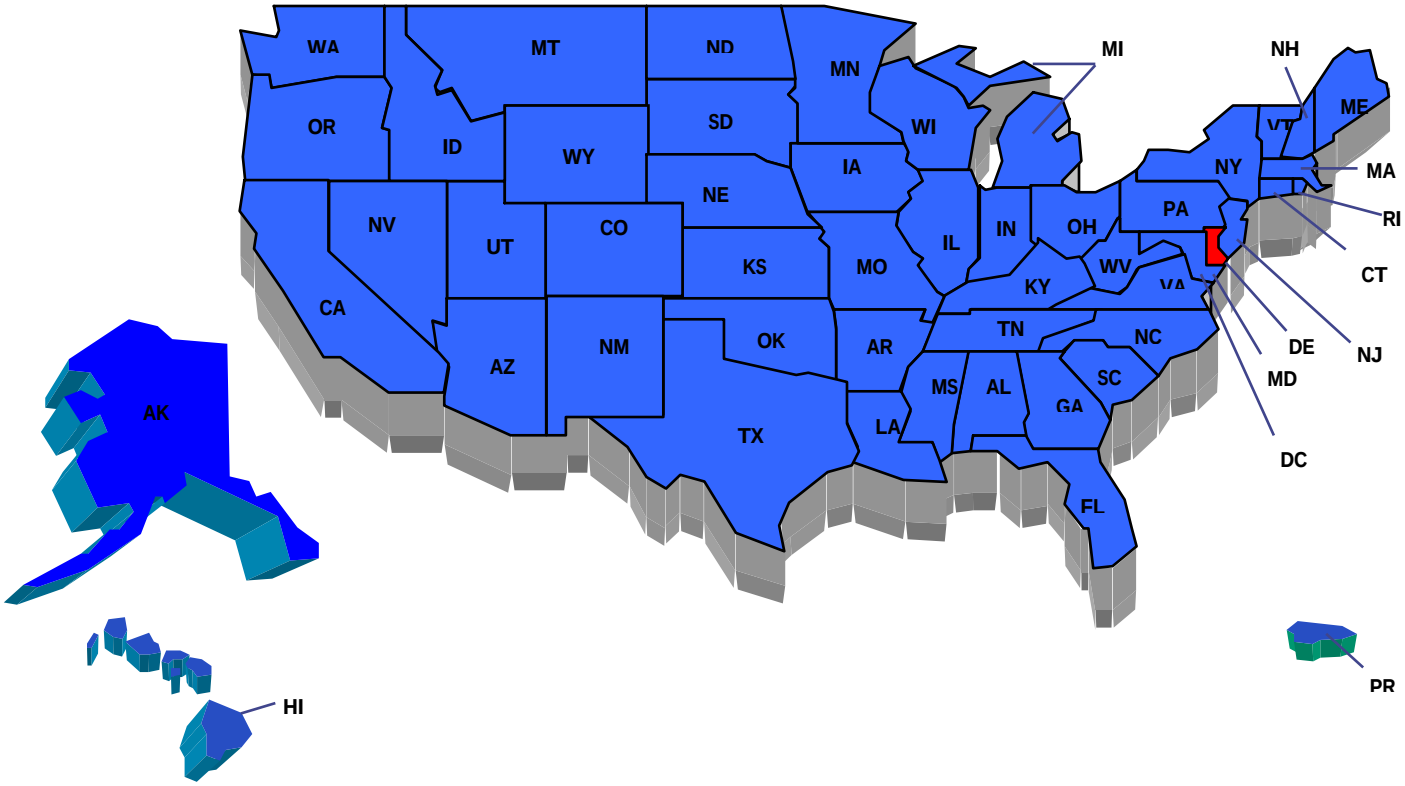
> *"This environment is not something that can be communicated verbally or even on film. It's something that needs to be experienced and the fact that this program is providing that opportunity to college students is outstanding!"*

- "What I hope will be the climax of all the work and education that I participate in during my lifetime will be to join the astronaut corps. and travel to outer space and perhaps further with the Constellation program. Therefore, being in microgravity at such a young age has only reinforced my desire and I feel I have jumped somewhat of a hurdle...I know I can handle zero-g with no problem and that I actually enjoy it and would love to do it everyday. I also was really impressed by the quality of the engineers working here especially those reviewing our experiment and on the TEDP committee. If that is what interacting with engineers in Houston is like, then sign me up. It cannot be just dumb luck that everyone we met was not only polite, but they were also constructive and supportive. Moreover, the organization of the program was top notch and I really admire the time and attention that is given to safety. "

Appendix 5 – Summary Participation

PARTICIPATING STATES: 1997 – 2008

Forty-nine (49) states have participated in the RGSFOP plus DC and Puerto Rico. The one state that has yet to participate is Delaware.



States Flown	49*	
States Never Flown	1	

*plus DC & Puerto Rico

Appendix 6 – 1997-2008 Participating University Status

2,630 Student Flyers (does not include ground crew)

165 Institutions / 600 Teams / 49 States (plus DC & Puerto Rico)

Institution Participation:

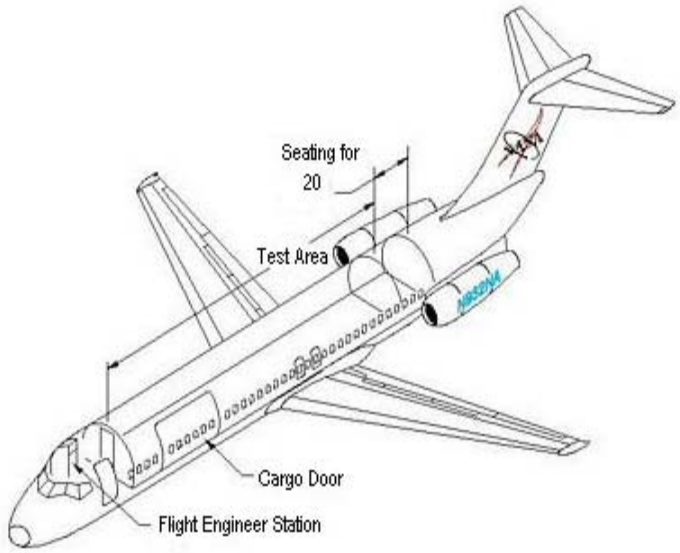
AK	Univ of Alaska Fairbanks	FL	Florida State Univ	MI	Michigan Technological University
AL	Alabama A&M	FL	Saint Leo College	MI	Univ of Michigan
AL	Auburn Univ.	FL	Univ of Miami	MI	Univ of Michigan-Dearborn
AL	Univ of Alabama-Birmingham	GA	Georgia Institute of Technology	MN	Univ of Minnesota-Minneapolis
AL	Univ of Alabama-Huntsville	GA	Morehouse School of Med.	MO	Drury College
AL	Univ of Alabama-Tuscaloosa	GA	State Univ of West Georgia	MO	Missouri University of Science and Technology
AR	Univ of Arkansas	GA	Univ of Georgia	MO	University of Missouri-Rolla
AR	University of the Ozarks	HI	Windward CC	MS	Mississippi State Univ
AZ	Arizona State Univ	IA	Iowa State	MO	Washington Univ-St. Louis
AZ	No Arizona Univ	IA	University of Iowa	MS	Univ of Southern Mississippi
AZ	Univ of Arizona/Florida	IA	University of Northern Iowa	MT	Dull Knife Mem Tribal College
CA	Cal State-San Marcos	ID	Shonshone-Bannock	MT	Montana State Univ-Billings
CA	California Institute of Technology	ID	University of Idaho	MT	Montana State Univ-Bozeman
CA	California Polytechnic Institute	IL	Univ of Illinois-Chicago	NC	Duke University
CA	Foothill College	IL	Univ of Illinois-Urbana/Champaign	NC	North Carolina A&T State Univ
CA	Harvey Mudd College	IN	Purdue Univ	NC	North Carolina State
CA	Pomona College	IN	Rose-Hulman Inst	NC	University of North Carolina-Charlotte & Pembroke
CA	San Diego City College	IN	Taylor University	ND	North Dakota State Univ
CA	San Diego State Univ	KS	Pittsburg State	ND	Univ of North Dakota
CA	San Francisco Art Institute	KS	University of Kansas	NE	Univ of Nebraska – Lincoln
CA	UC-Berkeley	KS	Wichita State University	NH	Dartmouth College
CA	UC-San Diego	KY	Eastern Kentucky University	NJ	College of New Jersey
CA	Univ of San Diego	LA	Univ of Kentucky	NJ	Princeton Univ
CA	Univ of Southern California	LA	Louisiana State Univ	NJ	Rowan University
CO	Colorado School of Mines	MA	Louisiana Tech Univ	NM	New Mexico State
CO	Colorado State Univ	MA	Harvard University	NM	New Mexico Tech
CO	United States Air Force Academy	MA	Massachusetts Inst of Tech	NM	Univ of New Mexico
CO	Univ of Colorado-Boulder	MA	Smith College	NV	Univ of Nevada-Reno
CT	Fairfield University	MA	Tufts Univ	NY	Alfred University
CT	Wesleyan Univ	MA	U Massachusetts-Lowell	NY	Cornell University
CT	Yale University	MA	Wellesley College	NY	Fordham University
DC	George Washington Univ	MD	Johns Hopkins University	NY	Polytechnic University
FL	Broward Community College	MD	United States Naval Academy	NY	Rochester Inst of Technology
FL	Embry-Riddle Aeronautical Univ	MD	Univ of Maryland-College Pk	NY	State Univ of New York Buffalo
FL	Florida A&M Univ	ME	Univ of Southern Maine	NY	Syracuse Univ
FL	Florida Institute of Technology	MI	Hope College	UT	Brigham Young
NY	United States Military Academy	RI	Univ of Rhode Island		

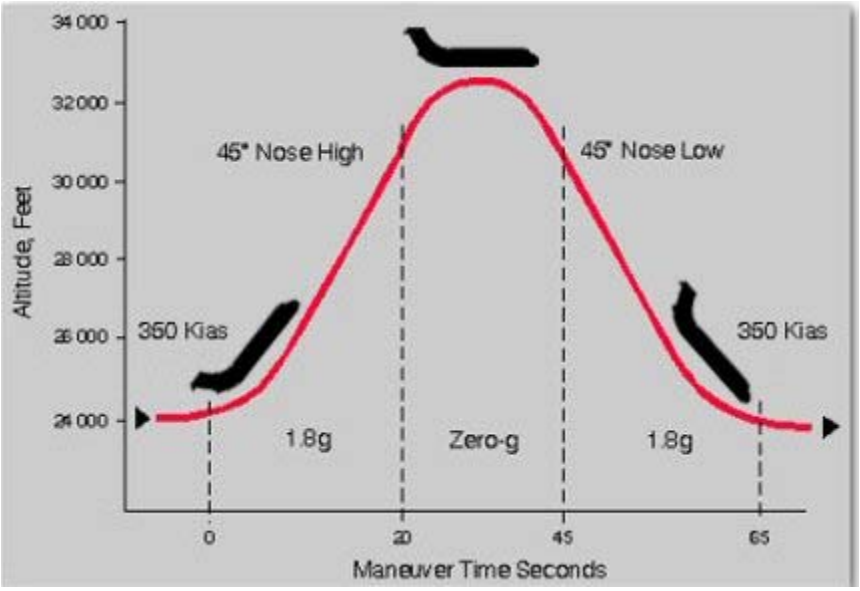
OH	Case Western Reserve Univ	SC	Clemson University	UT	Univ of Utah
OH	Ohio Northern Univ	TX	Austin Community College	UT	Utah State Univ
OH	Ohio State Univ	TX	Collin County Community College	VA	Virginia Tech
OH	Univ of Cincinnati	TX	El Paso Community College	VT	Norwich Univ
OH	Univ of Toledo	TX	Lamar Univ	VT	Univ of Vermont
OK	Univ of Oklahoma	TX	Prairie View A & M Univ	WA	Seattle Central Community College
OK	Univ of Tulsa	TX	Rice Univ	WA	Seattle Univ
OR	Oregon Inst of Technology	TX	S.F. Austin St Univ	WA	Univ of Washington
OR	Oregon State Univ	TX	Texas A&M Univ	WA	Washington State
OR	Portland State University	TX	Texas Christian Univ	WI	Carthage College
OR	Western Oregon University	TX	Texas Southern University	WI	Ripon College
PA	Carnegie Mellon	TX	Texas Tech	WI	Univ of Wisconsin-Madison
PA	Drexel Univ	TX	Univ of Houston	WV	Bethany College
PA	Penn State Univ	TX	Univ of Houston-Clear Lake	WV	Marshall Univ
PA	University of Pittsburgh	TX	UT-Austin	WV	West Virginia University
PR	Univ of Puerto Rico-Mayaguez	TX	UT-Dallas	WY	Univ of Wyoming
RI	Brown Univ	TX	UT-El Paso		
RI	Community College of Rhode Island	TX	UT-San Antonio		

Carthage College students and faculty working on their experiment during a lunar parabola.

Appendix 7 – About the "Weightless Wonder"

The NASA-JSC Reduced Gravity Research Program flies on a modified McDonnell-Douglas C-9B aircraft. The aircraft is crewed by a pilot, a copilot, a flight engineer, and two reduced gravity test directors. For the student campaign, a flight doctor, two video crew members and a photographer are also on board. Most test equipment is bolted to the floor using 20-inch tiedown grid attachment points.





The reduced gravity aircraft generally flies 30 parabolic maneuvers over the Gulf of Mexico. This parabolic pattern provides about 30 seconds of hypergravity (about 1.8G-2G) as the plane climbs to the top of the parabola. Once the plane starts to "nose over" the top of the parabola to descend toward Earth, the plane experiences about 25 seconds of microgravity (0G). At the very top and bottom of the parabola, flyers experience a mix of partial G's between 0 and 1.8 (called "dirty air").

Appendix 8 – Program History

Reduced Gravity Program Beginnings: In 1995, Ellington Field's Aircraft Operations Chief, Bob Naughton, accompanied NASA's reduced gravity aircraft to Europe to fly the European Space Agency's student parabolic flight campaign. Mr. Naughton, impressed with the success of ESA's flights, discussed the idea of a US parabolic flight campaign with NASA Headquarters and Johnson Space Center managers. Headquarters Education Chief Frank Owens liked the idea, as did (then) Deputy JSC Director George Abbey. In the summer of 1995, Abbey and Owens (with the support of the Texas Space Grant) prototyped the first US student parabolic flights.

1995 A pilot program was designed to provide a reduced gravity research opportunity for four teams of college seniors and graduate students from Texas' Rice and Texas A&M universities. The pilot program was called SURF (Students Understanding Reduced Gravity Flight).

1996 The program was repeated during the summer of 1996, again with four teams from Texas institutions: Lamar University, Rice University, Texas A&M University and the University of Houston. In the fall of 1996, SURF was renamed "Reduced Gravity Student Flight Opportunities Program (RGSFOP)" and expanded to include universities nationwide.

1997 Spring 1997 flights provided research opportunities for twenty-three teams from fifteen states. For the first time, journalists were permitted to fly as "team members."

1998 The RGSFOP doubled program "slots" in 1998 to include forty-seven participating teams from thirty-seven institutions in twenty-four states.

1999 A second yearly competition was born in 1999, which allowed for flights in both spring and summer. Forty-four teams from thirty-three institutions in twenty-one states participated during summer 1999.

2000 RGSGOP hosted 48 teams in March 2000. Because of KC-135 maintenance delays, 34 teams selected to participate in the Summer 2000 program were shifted into Spring 2001 program slots.

2001 Forty-eight teams participated in the Spring 2001 RGSFOP. Thirty-three teams were those shifted from the Summer 2000 program; the remaining fifteen teams were selected during the Spring 2001 competition.

2002 The Aerospace Academy (a division of San Jacinto College) accepted administrative responsibilities for the Reduced Gravity Student Flight Opportunity Program. The Microgravity University Office was born. A program coordinator and deputy coordinator, under the direction of Dr. Donn Sickorez, assisted the fifty-one teams who participated in the Spring and Summer flight weeks for the 2002 campaign.

2003 A record number of seventy-two teams were chosen to participate. Among these were seventeen first-time institutions and eleven minority teams. In addition, the program experienced an increase in minority participation.

2004 The RGSFOP extended offers to participate to sixty-nine student teams. Three NASA Explorer Schools and one Informal Education team were also invited to participate as part of a pilot program. Although the student program has been in existence in some form for nearly a decade, it is continuing to reach new audiences. This year, six new institutions and seven minority institutions were among the selected teams. This was also the last student group to experience reduced gravity on the KC-135.

2005 The program moved to the C-9 aircraft. Modifications and issues with the aircraft caused delays and cancellations. In all, only ten teams and thirty-two students flew. Teams were rolled over to the 2006 program.

2006 Flights returned to normal, as sixty-five teams are selected from 2005 and 2006 proposals. The first teams from Kansas, Pittsburg State and University of Kansas, fly their experiments. In addition, the first full group of museums and science centers are flown.

2007 In addition to the typical zero gravity parabolas, the student program's first lunar gravity experiments are flown. Lamar University, Michigan Technological University, and University of Missouri-Rolla flew experiments for 30 parabolas at 1/6G. Experiments ranged from lunar dust removal to welding.

2008 Two additional programs were added: Network of Educator Astronaut Teachers (NEAT) and the Systems Engineering Educational Discovery Program (SEED). Three states were also added to the participating states (Nebraska, Alaska, and Maine).