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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 to nine month period. The overall experience includes scientific research, hands-on experimental design, test operations, and educational/public outreach activities.

Objectives

➤ To provide students and educators with a NASA unique educational opportunity to explore microgravity.
➤ To attract outstanding young scholars to careers in science, technology, engineering and math (STEM).
➤ To introduce young scholars to careers with NASA and in the space program.
➤ 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

➤ To date, student teams from all 50 states have flown. These include 3,646 undergraduate students from 206 universities.
➤ More than 100 college undergraduates from 18 states (representing 22 different institutions) participated in the Undergraduate Student Program. Fourteen proposals were selected for the 2013 flight year. Seven projects focused on engineering concepts, four on physical science experiments, and three on life science (including biology) experiments.
➤ Just over 50 college undergraduates and faculty participated in the System Engineering Educational Discovery (SEED) program from 6 states (representing 6 different institutions) in 2013. The projects in this flight week were all system engineering based.
➤ Sixty-four students and teachers participated as part of the High Schools United with NASA to Create Hardware (HUNCH) flight teams that flew with the NES teachers during the April flight week.
➤ Over thirty K-12 educators from 12 states (representing 14 institutions) participated in NASA’s Microgravity eXperience (Teaching From Space) Flight Week. Twenty applications were submitted for the 2013 flight year.
➤ Eighteen K-12 educators from NASA Explorer Schools (NES) participated in the 2013 program.
➤ Each selected flight team was also required to complete a 3-5 minute video of their Reduced Gravity Education Flight Program experience (including how the experiment was selected, hardware build-up, activities in Houston and results). Students have posted several of these videos on YouTube and other various video sites.
➤ Several flight teams have submitted papers to present at various STEM-related conferences during the Fall 2013 semester, including the American Institute of Aeronautics and Astronautics (AIAA) and National Science Teacher Association (NSTA) Conferences.
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 2013 flights came from all over the United States, with participants from 18 states representing 22 different institutions. Fourteen proposals were selected for the 2013 flight year. Seven projects focused on engineering concepts, four on physical science experiments, and three on life science (including biology) experiment.

Overall, all 14 selected teams were able to complete their projects for flight. This year saw the introduction of three new institutions to the program in Baldwin Wallace University, John Carroll University and Robeson Community College. This year’s participants in the NASA Reduced Gravity Education Flight Program Student Program reported to Ellington Field in May, June and July. The following pages contain abstracts about each project. Full final reports are available upon request.

Systems Engineering Education Discovery (SEED)

The Education Office offered a nationwide solicitation of student applications aimed at addressing systems engineering challenges within a microgravity environment. 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.

The 2013 flights came from across the United States, with participants from 6 states representing 6 different institutions. Thirty two projects were submitted from NASA Glenn Research Center, Goddard Space Flight Center, Jet Propulsion Laboratory, Johnson Space Center, Langley Research Center and Marshall Space Flight Center. Six proposals were selected for the 2013 flight year. Overall, the six selected teams were able to complete their projects for flight. This year’s participants in the SEED Program reported to Ellington Field in July. The following pages contain abstracts about each project. Full final reports are available upon request.

ISS NASA Education Projects

The ISS NASA Education Projects Office is working to increase the education research portfolio on the International Space Station. In those efforts, the Office has formed a partnership with the Reduced Gravity Education Flight Program to support a reduced gravity project team. This pilot project will work to take an experiment from reduced gravity and graduate it to flight on the Space Station. The team selected for this inaugural opportunity was from Gadsden State Community College in Gadsden, Alabama. The following pages contain this team’s abstract for their project, a full final report is available upon request.
**University Student Launch Initiative**

The Reduced Gravity Education Flight Program has partnered with the NASA Student Launch Projects out of NASA’s Marshall Space Flight Center in Huntsville, Alabama to support one team to participate in the 2013 flight campaign. NASA Student Launch Projects challenges middle, high school and college students to design, build and launch a reusable rocket to one mile above ground level while carrying a scientific or engineering payload. The Academic Affairs Office at NASA’s Marshall Space Flight Center in Huntsville, Ala., manages SLP. It comprises two project elements: NASA Student Launch Initiative, or SLI, for middle and high school teams; and NASA University Student Launch Initiative, or USLI, for community college and university teams. University teams submitted reduced gravity proposals in addition to their USLI proposals and the team from Georgian Institute of Technology was selected as the initial participant in the program.

**HUNCH Participants**

The High Schools United with NASA to Create Hardware, or HUNCH, project is an instructional partnership between NASA and high schools and intermediate/middle schools throughout the nation. The HUNCH project provides work experiences to inspire these students to pursue careers in science and engineering fields. This partnership benefits both NASA and students. NASA receives cost-effective hardware, soft goods and educational videos that are produced by the students. The students receive hands-on experiences and in some cases, NASA certification in the development of training hardware for the International Space Station Astronaut crew members or ground support personnel. A spin-off of this teaming is the inspiration of the next generation.

Eight teams were selected for this opportunity, representing 6 states from across the United States. The HUNCH students reported to Ellington Field in April to complete their flight week activities. The following pages contain abstracts about each project. Full final reports are available upon request.

**Microgravity eXperience (Teaching From Space) Flight Program**

Teaching From Space (TFS), located at Johnson Space Center, manages Education Flight Projects, a NASA Office of Education Elementary and Secondary project. TFS activities are national in scope and involve formal and informal education communities and other NASA Education projects.

TFS facilitates education activities that primarily involve K-12 educators and students. These educational opportunities are designed to inspire, engage, and educate educators and students in science, technology, engineering, and mathematics (STEM) disciplines using NASA unique content and resources. TFS provides K-12 educators and students with instructional and learning experiences that utilize NASA missions, content, people, and facilities. These experiences include educator professional development opportunities and hands on student activities that connect them real time to the Agency’s mission and future space exploration.

This flight week is being offered through a partnership between Teaching From Space and the Reduced Gravity Education Flight Program. This flight opportunity will allow teachers and students to propose, design, fabricate, fly and evaluate an experiment in a reduced gravity environment. Teachers and students will share their experiences and research in a series of interactive Web Seminars after the flight week.

Seven teams were selected for this opportunity, representing 6 states from across the United States, and reported to report to Ellington Field in July. The following pages contain abstracts about each project. Full final reports are available upon request.
**NASA Explorer Schools**

NASA Explorer Schools provides access to high-quality STEM classroom resources and professional development to educators across the country. In the 2011-2012 school year, the project reached teachers in over 1,500 schools. NES recognizes teachers, schools and students who become highly engaged, demonstrate innovative use of STEM content in the classroom, and use research-based best practice in implementation.

Schools who demonstrated exemplary participation in the project and engaged a broad school population can become eligible for school recognition. Schools must have a minimum of three NES teachers at the school, one of whom demonstrated in-depth use of NES classroom resources. Schools then submit an application describing their efforts to engage the school wide population in NES activities.

In September 2012, six schools were recognized by NASA Explorer Schools for broadening the impact of NES beyond one classroom during the 2010-2011 school year. Three teachers from each of these schools had the opportunity to participate in a reduced-gravity flight experience at NASA’s Johnson Space Center in Houston, Texas.

The 2013 Reduced Gravity Education Flight Program opportunity provided to the NES teachers was created last year in support of these recognized schools. The schools built and evaluated three reduced gravity experiments that teachers later performed during flight in April of this year. The sixth month process included live video conference connections with RGEFP staff to discuss experiment production and analyze collected data. The following pages contain brief school profiles of each of the recognized schools. Full final reports are available upon request.
Abstracts

Top, left: Georgia Tech students observe their experiment in microgravity. Middle, left: HUNCH students and their teacher prepare for flight. Bottom, left: Students from West Virginia University experience microgravity with Astronaut Mike Fossum. Top, right: University of Nebraska-Lincoln students test their free flyer during microgravity. Middle, right: MIT student evaluates their experiment as it maneuvers in the reduced gravity environment. Bottom, right: Teachers from Prior Lake Savage schools evaluate their experiment.
**Undergraduate Participant Program**

Undergraduate Student Program
Participating Universities – By State
* First Time Participant (institution), ISS Education Partnership**, USLI Partnership***

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**Undergraduate Participants**

The Reduced Gravity Student Flight Opportunities Program provides a unique academic experience for undergraduate students to successfully propose, design, fabricate, fly and evaluate a reduced gravity experiment of their choice.

**Baldwin Wallace University and John Carroll University:** Berea and University Heights, Ohio

**The Stability of Liquid Bridges**
Proposal ID: 2013-25432

Liquid bridges are thin, cylindrical strands of fluid held between two supports. The literature lacks experimental data on the dynamics of liquid bridges under varying total body acceleration because of the difficulty in maintaining such an environment on the earth and the inability to exert large forces in spaceborne experiments. Therefore, in a previous experiment, liquid bridges of glycerol were subjected to periods of microgravity by flying them on NASA’s C9 parabolic aircraft. During the descent portion of each arc \( g_{eff} \), the effective total body acceleration due to external forces, became negligibly small so that bridges could be suspended across two co-axial support posts. At the bottom of each arc, \( g_{eff} \) increased to 1.84g, causing the bridges to deform and in some cases collapse. In this proposal, modifications in hardware and procedures will allow us to investigate two follow-up questions suggested by the original experiment:

1. Previously, glycerol bridges were formed only up to limited maximum slenderness values. Literature suggests that such bridges in zero-g should be stable up to a maximum slenderness of \( \pi \). Though our prior work was successful, a wide range of slenderness values remain untested. Therefore, the first part of our experiment will be to determine the stability of glycerol liquid bridges up to a maximum slenderness of \( \pi \). These measurements will complete the experimental knowledge-base on glycerol, giving us an expanded picture of bridge stability over the entire range of theoretically possible slenderness values, for both radial and axial total body accelerations.
2. Prior results suggest that the surface tension-to-density ratio of a fluid is a new, important variable in understanding bridge stability. Therefore, the second part of our experiment will be to measure bridge stability for a set of liquids other than glycerol, chosen for their disparate surface tension forces.

**Boise State University: Boise, Idaho**

**Effects of Teriparatide in Bone Cells**
Proposal ID: 2013-25464

Astronauts in prolonged space flight and bedridden patients experience bone density loss due to a lack of mechanical stimuli. The mechanisms by which cells transduce physical stimuli to chemical signals are poorly understood. The goal of this experiment is to investigate the molecular mechanisms of calcium flux in response to hyper- and microgravity. Thus, the “Weightless Wonder” is an ideal environment in which to conduct the experiment.

The primary focus of this experiment is to determine if the pharmaceutical teriparatide will alter calcium fluctuation in response to hyper- and microgravity. The FDA approved pharmaceutical teriparatide is known to induce bone formation in bedridden and osteoporotic patients. During the team’s research, no references to the testing of teriparatide in hyper- or microgravity conditions were found. Research proposed by the 2012-2013 Boise State Microgravity Team will be the initial real-time exploration of teriparatide at the cellular level in hyper- and microgravity.

The team hypothesizes that changes in cytosolic calcium concentrations in response to hyper- and microgravity will be enhanced by the presence of teriparatide. An original apparatus designed, built, and successfully flown by the 2011-2012 Boise State University team will be utilized to measure calcium fluctuations. Modifications will be made to the apparatus to more accurately monitor rapid calcium fluctuations. The modified version will include: (1) better image capture devices, (2) increased sample size, and (3) streamlined data analysis. To optimize cell culture conditions and data acquisition, specific ground experiments will be performed prior to the flight experiment. This unique experimental design will improve understanding of molecular mechanisms of calcium signaling in bone cell response to gravitational changes.

“This entire experience from writing the proposal to after the flight had been a learning process that has changed me forever. Before joining the team, I had very little direction and did not know what I wanted to do. By participating I have come to learn my strengths and weaknesses form an educators point of view (major in biology and education) this is how every subject should be taught”. Junior, Boise State University

**Missouri University of Science and Technology: Rolla, Missouri**

**Microgravity Testing of ACD-CPR Device**
Proposal ID: 2013-25450

Potential methods of cardiopulmonary resuscitation (CPR) in microgravity environments will be illustrated in this experiment. We aim to achieve this with an Active-Compression-Decompression (ACD-CPR) device in two separate experiments. The first involves assessing the feasibility of this technique in microgravity by performing compressions with the ACD-CPR device, to determine if the average person is able to perform CPR in this way. The second experiment involves a more complicated model of the human chest designed
to test the flow rates of fluid in the heart during CPR in microgravity, and to compare those flow rates to traditional CPR methods in the same environment. In both experiments we hope to show that our method for CPR in microgravity is more effective than traditional methods.

**Oklahoma State University: Stillwater, Oklahoma**

**Investigation of Artificial Gravity Habitat Dynamics**

Proposal ID: 2013-25448

Future envisioned missions to deep space bring problems and challenges not currently fully investigated by the world’s spaceflight organizations. One of the most glaring issues is prolonged exposure to weightlessness (Clement et al.). Astronauts that return from ISS missions spend weeks, sometimes months rehabilitating. Most cannot walk straight, if at all, upon returning to Earth. The human body functions day to day with the resistance and force of gravity; remove this phenomena and bone/muscle atrophy is swift. Still, even with extensive exercise equipment currently on orbit on station, astronauts return with measurable losses in both muscle mass and bone density, about 1-2% per month in orbit. The European Space Agency has reported bone loss of up to 20% for a six month mission on the ISS. Another alarming effect that has been brought to light in recent years is the loss of vision due to prolonged spaceflight. Out of a sample group of 300 astronauts, 60% returning from long duration missions reported substantial vision loss (e.g., see Mader et al.). Researchers hypothesize that the lack of gravity increases pressure on the optic nerve, thus causing vision loss. As spaceflight becomes more ambitious and longer duration deep space missions become possible, spacecraft designs must provide crew with an Earth like gravity environment. Currently, it is acceptable for ISS astronauts to return to Earth in a weakened, disoriented state because it is effectively the end of their mission. However, deep space missions may require operations on a planetary body that has a gravitational force, so astronauts need to be acclimated to such gravity environments to perform the mission effectively. There is no month long rehabilitation period available in space. Currently, the only practical way to generate a force similar to gravity is to rotate a body producing a centrifugal force. For a small-scale investigation of this concept, the OSU team has designed an inflatable beam rotating experiment. The effects of various internal pressures on the beam’s stiffness and rotational stability will be examined.

Inflatable structures are a light-weight, low-mass option useful for many space-related applications. When inflated, they provide strength needed to resist tensile force and retain structural stability. Inflatable structures, when not deployed, can stow into a lightweight and compact volume. This is especially advantageous when the cost of launching payloads out of Earth’s atmosphere continues to be a limiting factor. However, the inflation volume of gas required could be a significant issue on a large-scale structure as would the amount of tension force the actual inflatable material could withstand as it is being pulled by the masses at the end of each arm. Other concepts include a payload on a tether, which would remain stable during rotation under ideal conditions, yet these conditions do not exist on Earth or in space. Tether strength and rotational stability also raise safety concerns. Inflatable structures are lightweight, have a high ratio of deployed to packed volume, and could provide sufficient support for a rotating spacecraft that produces an artificial gravity force.

The concept developed by the Oklahoma State University Space Cowboys team consists of rotating air beams within an aluminum frame. The end-caps on each inflatable beam simulate crew quarters or a similar structure where a continuous gravity force is desirable. The experiment is designed to allow the deployment pressure to be altered between test runs (parabolas). This will allow the team to examine the effect of varied pressure, hence beam stiffness, on the stability of the structure under various rotation rates in a reduced gravity environment. The flight test results will be dynamically scaled to provide systems requirements for full-scale design and maturation of the concept. Demonstrating the feasibility of this concept will provide an additional solution path for long duration space missions, providing NASA with data and design concepts to help justify further development.
**Purdue University:** West Lafayette, Indiana  
**Water Removal in Proton Exchange Membrane Fuel Cells**  
Proposal ID: 2013-25459

The performance of a proton exchange membrane (PEM) fuel cell relies heavily on proper water management within the fuel cell channels. Excess liquid water leads to flooding of catalyst layers as well as channel clogging - which decreases the reaction rate and thus the power output of the cell. The traditional solution to this problem involves the use of a pressure drop to push air through the fuel cell channels and pull out excess liquid water. The goal of such a design is to identify the optimum pressure drop between channel endpoints and flow channel geometry to improve fuel cell performance while keeping parasitic power loss associated with the vacuum pump low. Unfortunately, most fuel cells operate with very small channel sizes, rendering experimentation difficult and prone to error associated with measurement uncertainties. This problem is to be mitigated with the help of NASA's reduced gravity flight program. Experimenting in a low gravity environment allows the physical dimensions of the channels to be scaled upwards while a constant Bond number is maintained (the Bond number describes the ratio of gravitational forces to capillary forces on water in the fuel cell). Larger channel size allows the measurement of gas flow velocity in the channels as a function of the applied pressure drop with low error. These observations will aid in advancing water management designs of PEM fuel cells for both ground based and space based applications.

"The level of enthusiasm was as high as ever and program management create a comfortable environment conducive to learning and developing were passion for engineering (all STEM) as well as for NASA. Migration from the KC-125 to C-9 to ZeroG appears seamless and the experimental envelope remains constant, so this is very good. I hope the federal government continues to fund this terrific program for tomorrow's stars." – Purdue Journalist.

**Rice University:** Houston, Texas  
**Electromagnetic Position Sensing in Microgravity**  
Proposal ID: 2013-25438

The Rice – Pending Gravitation (RPG) team of Rice University proposes the development of an electromagnetic sensor that will provide read outs of voltage potentials over time that will enable the identification of a space vehicle’s position along an axis. To achieve this resolve, the team plans to utilize a suspended strong magnet to induce a current upon a high-density wire coil. Three identical electromagnetic sensors will be assembled, each pointing in a different axial direction. The small shifts in acceleration of the space vehicle will cause a shift in position of the centered magnet, altering the magnetic flux around the coil. This change in flux will induce a voltage potential proportional to the space vehicle’s velocity away from its non-accelerating trajectory for each orthogonal axis (Jiles 13). Following integration, the instruments will calculate the displacement of a space vehicle from its non-accelerating trajectory. Current position sensing technology, such as accelerometers, provide an energy cost to both run and communicate position back to Earth while also decreasing in accuracy over long periods of time. The proposed electromagnetic sensors would provide a method for locating space vehicles in microgravity that not only provides power during operation but would also not be encumbered to short-time space expeditions. Prior ground-based experimentation have already been conducted by RPG involving a similar circuit consisting of a wire coil, magnet, and simple DMM (Digital Multimeter) provided a voltage potential large enough to be analyzed without the use of operational amplifiers. This prior work, coupled with Faraday's Law and Fleming’s
postulate (the right-hand rule, a mnemonic used when considering three-dimensional vector analysis) offer the tools required after data acquisition analysis to utilize microgravity to determine an object’s position.

**State University of New York at Buffalo:** Buffalo, New York

**Microgravity Characterization of Zirconia Monolithic Electrokinetic Micropumps**

Proposal ID: 2013-25466

Fluid transport in space exploration missions is an important aspect to consider because of the no gravity conditions. Technology developed for terrestrial fluid flow may not behave in the same manner in outer space due to the absence of gravity. Traditional fluid pumping devices also have weight and dimensional demands in a spacecraft that can be costly. Electrokinetic (EK) fluid pumping has been identified as an emerging viable alternative for solvent delivery, which are cost-effective and lightweight devices. These are among other attractive features for potential use in space exploration. However, the literature lacks information on electrokinetic fluid transport under microgravity conditions. Herein, it is proposed to study the effect of reduced gravity on EK pumping. Zirconia based monolithic structures will be used for EK pumping since under normal gravity conditions, their EK pumping capabilities have generated higher flow rates than the traditional silica type EK pumps. A battery operated, self-contained experimental setup will be constructed similar to an existing system in the laboratory, which will have all the requirements for the microgravity experiments. EK pumping of two fluids will be studied: water and methanol. The flow rate of these fluids will be measured as a function of voltage. The results of the microgravity experiments will be compared to similar experiments under normal gravity conditions. The findings will provide fundamental knowledge that would set the basis for future studies.

**University of Arizona:** Tucson, Arizona

**Gravitational Effect on Fault Formation (GEOFF)**

Proposal ID: 2013-25463

The earth is governed by geological processes that occur from regional to global scales. New insights to physical events have been discovered at a rapid rate over the last several decades, but many require further investigation. Thrust faults are both terrestrial and extraterrestrial geological features that signify crustal compression. Thrust faults can be quantified by critical shear stress, cohesive strength, internal friction and normal stresses. They are intrinsically related to one another in Coulomb’s Law of Failure. However, in researching the topics, University of Arizona students found no studies taking gravity into account in this subject. It is unknown if gravity is a governing factor when computing the angle of failure for thrust faults. This experiment will test the influence of varying gravitational forces on thrust fault analogues. Motorized squeezeboxes will compress uniformly distributed sands until propagation of a fault occurs. Measurements and observations will be taken to record the angle of failure in thrust faults. If gravity is indeed an influential factor, it can be expected that the angle of failure will differ from terrestrial models where gravity is assumed to be a constant value. This research could have far-reaching implications in the study of faults in planetary geology. Refined equations accounting for gravity could be utilized to better predict the angles of thrust faults on any planetary body. These equations could allow for thrust faults to be positively identified even though the angle of failure of those faults would differ from what would be expected on Earth.

**University of California San Diego:** La Jolla, California

**Fiber Supported Droplet Combustion of Biofuels**

Proposal ID: 2013-25454

The combustion of fuel droplets is a key method for researchers to gain a fundamental understanding of burning rates and droplet combustion processes. However, burning rate data obtained from fuel droplet
Students from the University of Illinois at Urbana/Champaign during a parabolic maneuver. Combustion performed under normal gravity conditions is hindered by buoyancy, which causes droplets to lose spherical symmetry and produces convective flows. In order to reduce the hindering effects of gravity on droplet combustion, a microgravity environment is required. Further, a taut fiber, with a knot or cross-fiber, is used to maintain droplet position while in microgravity. Although significant research involving heptane and fossil fuel fiber supported droplet combustion has been performed in the past, little research has been performed using biofuels, or renewable plant-based fuels. Specifically, our research focuses on acquiring visual data of droplet diameter and flame diameter versus time in order to form a burning rate model of bioethanol and biobutanol. Specified droplet sizes from 2-5 mm in diameter of bioethanol and biobutanol will be accurately ejected onto a taut silicon carbide wire using an automated syringe ejection system. Once each droplet has viscously damped on the fiber and has obtained approximate spherical symmetry, a manually activated igniter will ignite each droplet. Visual data of droplet diameter and flame diameter versus time will be recorded using two separate digital cameras. This data will be used to determine the burning rates for bioethanol and biobutanol through image distance processing by pixel count. The droplet diameter data will be compared against the “d-square” law, which states that the square of the droplet diameter decreases linearly with time. Further, we may compare our burning rate data to that of past Fiber Supported Droplet Combustion experiments in order to determine any differences between biofuel burning rates and non-plant based fuel burning rates. Burning rate data such as this may be used to improve ground-based transportation and fire safety aboard spacecraft by enabling accurate predictions of the burning rates for biofuel droplets.

“Flying in ZeroG is like learning to walk again with astronauts by your side. I danced with Cady Coleman, a former astronaut in moon gravity today….it was awesome”. – Junior, University of California, San Diego.

University of Illinois at Urbana/Champaign: Urbana-Champaign, Illinois
Autonomous and Adaptive Docking Under Variable Gravity
Proposal ID: 2013-25452

This experiment is a test for a new docking system for spacecraft. The new system can be broken up into two subsystems: an adaptive control algorithm which navigates the craft to the dock, and a passive braking system which brings the craft to a halt. This proposal outlines the details of the control algorithm, from how it acquires data about its surroundings to how it adjusts the control of the drone to changes in gravity by choosing different parameters arrived at by a genetic algorithm. This proposal also outlines the details of the eddy-current braking system, including the necessary geometries of the dock and of the magnets as well as the computer simulations and physical experimental results of the braking forces. Along with the details of the experiment, this group has also put together a thorough outreach program that works with existing programs to reach a very broad range of unrepresented youth.

“Wonderfully run, inspirational in addition to being educational!” - Senior, UIUC
University of North Carolina - Pembroke and Robeson Community College:
Pembroke & Lumberton, North Carolina
Effects of Gravity on the Cori Cycle
Proposal ID: 2013-25445

With the increased duration of space flights and the continual habitation of the International Space Station, the human body is put under new and unexplored stresses. Although there has been significant research conducted to investigate the effects of microgravity on human biological mechanisms (Stein, 2005 and references within), there has been very little research conducted to better understand the effects of microgravity on the Cori cycle (Woodman, 2009; Inobe, 2002). The Cori cycle is important because it is responsible for producing the energy needed to allow muscular activity. Muscle activity requires energy, which means that glycogen is broken down to glucose via glycogenolysis (Wickman). After glycogenolysis, the resulting glucose is fed into glycolysis, which is the process that actually makes energy, or Adenosine Triphosphate (ATP), for your skeletal muscles to use. During muscular activity, glycolysis occurs constantly and ATP is constantly replenished (Elmhurst, 2003). Glycolysis can occur aerobically or anaerobically. When oxygen is not present, such as during intense muscular activity, ATP is formed through the conversion of pyruvate to lactate. The lactate produced by anaerobic glycolysis is taken to the liver where it is converted back to glucose and the process starts again (Romano, 1996). This process is shown schematically in figure 1a. Part of this critical process is lactic fermentation, figure 1.b. In lactic fermentation pyruvate is converted to lactate, which consumes Nicotinamide Adenine Dinucleotide (NADH) and NAD+ is released. It should be noted that the NAD+ is essential for glycolysis to continue to occur, thereby to obtain energy through the consumption of sugars. To summarize, the process serves to regenerate NAD+ so that glycolysis can continue to occur in the absence of O2, as glycolysis is the process that will produce ATP (Nelson, 2004). The majority of a human’s life is lived in a gravitational pull of 1-g whereas an astronaut, in orbit around the Earth, can experience extended periods of reduced gravitational pull. Does the change in gravity experienced by the human body affect some of its most basic functions, such as the Cori cycle? The main focus of our research is to understand the effects that a reduced gravitational field (0-g) has on the reaction rate of pyruvate to lactate during anaerobic glycolysis. We believe that in a reduced gravitational field the conversion rate of pyruvate to lactate will be lowered in comparison to the rate measured in 1-g. In the human body, a reduction in this reaction rate results in a decrease in the energy available for skeletal muscular activity and could adversely affect an astronaut’s productivity.

University of Texas at El Paso: El Paso, Texas
Combustion of Regolith with Magnesium
Proposal ID: 2013-25462

It is generally agreed that future missions to the Moon and Mars will involve in-situ resource utilization (ISRU). Usually, ISRU researchers focus on the production of rocket propellants from lunar regolith and Martian CO2. However, lunar and Martian regolith could also be used for the production of construction materials that are needed to build radiation shielding, landing/launching pads, and other structures. Specifically, mixing regolith with magnesium creates thermit-type mixtures that, upon ignition, exhibit self-sustained combustion leading to the formation of ceramic composites. This process may be affected by gravity due to the presence of liquid...
materials in the combustion front and natural convection in gas phase around the sample. The project investigates the effect of gravity on the combustion wave propagation and the product microstructure for the mixtures of lunar and Martian regolith simulants with magnesium. The proposed experiment is a follow-up to the reduced-gravity tests conducted with JSC-1A lunar regolith simulant / magnesium mixtures in June 2011 and June 2012. The experimental setup will be modified to exclude technical problems that occurred during the 2012 flights. Also, combustion of mixtures based on a Martian regolith simulant and magnesium will be studied for the first time. The enhanced experiments will generate results that allow for better understanding of the combustion mechanisms in mixtures based on both lunar and Martian regolith.

**Virginia Polytechnic Institute and State University:** Blacksburg, Virginia

**Moving Mass Deconing Controller for Spacecraft**

Proposal ID: 2013-25460

Nutation of satellites, re-entry vehicles, and missiles is an area of major concern in ongoing research. Traditional methods of deconing such bodies with a certain amount of "wobble" consist of using thrusters, momentum exchange devices, magnetic torque rods, or other methods of attitude control. It is our goal to validate experimentally that moving masses are capable of reshaping the inertia of the aforementioned aerospace vehicles allowing for de-nutation. We plan to use linearly translating masses to change the spin axis of a 6U CubeSat (10cm x 20cm x 30cm). The nonlinear equations of motion have been derived for this system, and a feedback control law has been developed. Numerical simulations suggest that a linear quadratic regulator control is capable of deconing a spinning satellite in roll, pitch, and yaw. This is a novel means of orienting exo-atmospheric bodies for re-entry. The ability to perform quick discrete mass maneuvers also has applications in the control of agile low earth orbit (LEO) spacecraft. Moving masses have advantages over many control systems. Noncontinuous operation reduces mechanical wear and will therefore contribute to a lengthened mission lifetime. Because no mass is being dumped, as in the case of thruster control, ow disturbances (such as on atmospheric re-entry) will be eliminated. A demonstration of moving masses to decone a small satellite platform will be the first of its kind and provide insight into numerous applications.

**West Virginia University:** Morgantown, West Virginia

**Variable-Gravity Liquid Spray Cooling Optimization**

Proposal ID:2013-25440

An investigation is outlined to analyze spray cooling effectiveness in a variable gravity environment aboard NASA’s Reduced Gravity Aircraft. After conducting and documenting background research, the team has designed an experiment to optimize spray cooling flow rates for specific cooling effectiveness, and to determine a relationship between the spray cooling flow rate and the associated heat flux rate. The proposed experiment focuses on using an atomizing nozzle to spray water droplets at various mass flow rates onto an instrumented heat source. By varying the mass flow rate and pressure of the spray liquid, the heat flux rates at the cooled surface of the heat source can be altered and then measured. The goal of this experiment is to determine an optimized relationship among several variables to increase the efficiency of the cooling method in microgravity environments such as those found in many NASA applications. The proposed experimental apparatus consists of a spray nozzle, a liquid capture system, a liquid coolant pump system, a well-insulated heated copper cylinder with integrated thermocouples, an infrared camera, a high speed camera, and a protective aluminum frame. A community outreach program involving, but not limited to, local school visitations, collegiate functions, and collaboration with several professional societies was also developed as a means to promote engineering, science, and technology education.

“My students are all extremely excited about their experience here. The team certainly has learned an immense amount about problem-solving and teamwork, as they worked together to solve several technical problems with their experiment. Thanks to all for a great experience!” – Faculty, West Virginia University.
ISS NASA Education Projects

Gadsden State Community College: Gadsden, Alabama
Behavior of Organic Solvents in Water Under Zero-G

As humans travel beyond Earth orbit, there will be a need for very light, compact and robust instruments for monitoring the crew cabin environment. For the past decade, our group at JPL has been producing miniature gas- and liquid-based sensors for environmental monitoring for including a volatile organic compound (VOC) monitor for the International Space Station. We have been awarded NASA funds to work on sensors for both robotic (ASTID program) and human (Advanced Exploration Systems) exploration applications. The detection of trace quantities of organics inside potable water is of primary importance for both ISS and future long-duration manned missions. Under normal earth gravity trace hydrophobic organics inside water will separate, forming either layers on top or bottom of the water, depending upon their density. Under microgravity the behavior of these hydrophobic organics (e.g. aldehydes, alkanes) is poorly understood. This has dramatic implications for the design of future miniature sample handling and delivery systems for water quality monitors. Therefore, we would like to test the physical behavior of these organics in microgravity. A simple video monitor of aliquots containing trace quantities of dyed organics and water could satisfy the requirements. The results will give us valuable insight into how to design the sample handling and delivery systems for spaceflight.

Principal Investigator: Murray Darrach (Jet Propulsion Laboratory)

Georgia Institute of Technology: Atlanta, Georgia
Liquid Stabilization in Microgravity

The experimental simulation of low-G environments is a notoriously difficult problem in the development of space and launch vehicle systems. Whether in the case of satellite deployables or the LSIM goal of damping slosh, a low-gravity environment analogous to the free fall environment found on orbit is difficult to simulate and to maintain. Ground testing at 1-G is currently planned for LSIM; this testing may give insights into the general performance of the MR fluid and as well as provide more insight into various active slosh damping techniques. However, ground testing alone is insufficient; in order to provide a simulated environment and gain more understanding of the behavior of slosh and various active slosh damping techniques, the LSIM experiment will also be flown as the flight experiment aboard the Ramblin’ Rocketeers’ Student Launch Project (SLP) launch vehicle. While high launch accelerations and perturbations from aerodynamic forces make the flight experiment less-than-ideal for simulating a microgravity environment, RGEFP promises to offer at least several 30 second periods of high precision low-G environment for the testing of microgravity experiments. For sustained durations of microgravity, the true performance of an MR fluid baffle can be measured, as well as the whole-architecture (simulated) propellant cleaning system.
California Polytechnic University: San Luis Obispo, California

Real Time Object Targeting in Microgravity

Develop and demonstrate technology to allow a floating experimental rig to continually determine range/bearing to a target. The target could be a special color/shape (i.e. have a “fiducial marker”), but preference would be given to a target point that can be selected at the start of each parabola airplane, and then tracked from that time forward. In addition to finding and tracking the relative location of the target point, the experiment must visually verify the accuracy of the solution by continually controlling a “laser pointer” to point at the target during the entire parabola. This would be accomplished by having a motors move the laser pointer, or by thrusters that could re-orient the vehicle, or a combination of both. The pointing accuracy desired would be better than 1 degree of angular. Since it must be demonstrated inside an airplane, assuming a target range of about 3 meters, this would mean the laser pointer would need to stay within 5cm of the designated target as the experiment “floats” during an entire 20 seconds of a 0-g parabola. Of course, obtaining even smaller errors in pointing accuracy is better.

Principal Investigator: Robert Hirsh (Johnson Space Center)

Carthage College: Kenosha, Wisconsin

Degassing of FC-72

Non condensable gases in a fluid affect the heat transfer characteristics in a flow boiling or flow condensation process. The heat transfer coefficient is compromised with the presence of non-condensable gases in a refrigerant. Thereby, it is rather important to degass the FC-72 fluid, or a fluid in the n-perfluorohexane family, before using the fluid in a two phase flow unit like a condenser or a boiler. The Flow Boiling and Condensation Experiment (FBCE) is an International Space Station (ISS) flight experiment planned for flight to the ISS in 2017. The data obtained from this experiment and from ground testing will culminate in a methodology or design guidelines that will enable a designer to design a two-phase flow component and eventually proof test the whole system. The team will be responsible for designing and constructing a small scale system that enables the FC-72 degassing. The system will involve the acquisition of the fluid from a reservoir, the degassing of the fluid and the measurement of the concentration of the non-condensable gases in the fluid via the total pressure and temperature measurements. The system must be compatible with the short duration microgravity and partial gravity environment (~20 seconds). It is envisioned that the students will generate various collection concepts, which with assistance of the PI will be down-selected to one or two designs to be tested in flight. These concepts include degassing by heating and by interfacial effects.

Principal Investigator: Nancy Hall (Glenn Research Center)
Massachusetts Institute of Technology: Cambridge, Massachusetts
Model and Test an Artificial Gravity Vehicle

Design and build a small model of a rotating Artificial Gravity Transit Vehicle for evaluation during 0-g flights. It should be based on the conservation of angular momentum -spin part of the spacecraft by spinning another part in the opposite direction, thus avoiding the need for propellant for spin-up and spin-down. Design into the model the ability to vary rotation rate and radius. Include a second rotating mass to allow rotation axis to slue in other 2 directions. Allow for design mods to quickly change the orientation of the habitat along each of 3 axes to determine stability of rotation. Also allow for adjusting mass in the two major rotating parts of the vehicle to evaluate the range of probable designs. Stretch goal - simulate low-thrust propulsion of rotating vehicle, which need not be along center of rotation or through the center of mass.

Principal Investigators: Dr. Jennifer Rochlis-Zumbado and Dr. Thomas Sullivan (Johnson Space Center)

University of Nebraska-Lincoln: Lincoln, Nebraska
ARGOS and Microgravity Free Flyer Evaluation

This project's purpose is to evaluate the ability of the Active Response Gravity Offload System (ARGOS) to provide a microgravity environment for a free flying vehicle. To evaluate the ARGOS performance it could be compared to the known microgravity environment generated by the parabolic flight of an airplane. The other option for comparison would be an experiment on the International Space Station. ARGOS is a robotic system that provides reduced gravity environments through a large motion based platform. It is a facility at the Johnson Space Center (JSC) that has been used for human and robotic testing over the past three years. However, ARGOS has not been used for testing free flyers and the evaluation of the ARGOS control system to maintain a microgravity environment for a free flyer is a unique area of research. The student design team will need to develop a free flyer (probably a quad or hexa-copter) that will fly a specific set of motion patterns in both ARGOS and plane induced microgravity environments. A method of collecting data for comparison is required. The data should be a combination of collection methods that may include motion capture camera system and inertial guidance units. Parabolic flight provides an ideal environment to collect a data set for comparison to the data collected on ARGOS. Ultimately, this data will allow the ARGOS system to be evaluated and the control system to be tuned for optimal free flyer performance.

Principal Investigator: Larry Dungan (Johnson Space Center)

“Flight was fantastic. The crew did an amazing job. 10 out of 10, would fly again.” – Senior, UNL.

University of Wisconsin @ Madison: Madison, Wisconsin
Hands Free Controller for an EVA Jetpack

A new EVA jetpack is in development at the Johnson Space Center. This technology takes the currently used SAFER astronaut rescue device, and re-imagines it as a mobility device for exploring Near Earth Asteroids and deep space missions. To make a jetpack truly functional for such missions, a hands-free control method is desired. One novel method proposed that is currently being developed for Earth-based testing is foot-based control. This concept was inspired from undersea diving and submarine devices that use foot pedals controls for piloting. However, since real estate is at a premium within the spacesuit, and with nothing to counteract forces in microgravity, pedals cannot be used. As a result we have designed a concept that allows the operator to merely press their foot within their boot and activate force sensors, which send commands to fly the jetpack. We currently off-load the weight of operators and give them a footplate to rest upon for 1-G testing. However to determine if this concept would indeed be functional in microgravity,
we would like to test it within the proper dynamic environment of free-floating, unrestricted movement. We propose an engineering evaluation of the hands-free control hardware and software to accurately test an operator's ability to fly a jetpack simulation using this foot sensor method.

Principal Investigator: Pedro Curiel (Johnson Space Center)

“I thought the flight week was an awesome experience. The staff did a good job at preparing you for the flight and how to reduce motion sickness. The flight seemed to go by really fast but was still well worth it and I would recommend it to everyone.” – Senior, University of Wisconsin Madison.

Yale University: New Haven, Connecticut
Effects of Screen Curvature in Spacecraft Propellant Management Devices

All spacecraft, whether they are in orbit around Earth or visiting distant locations, have the requirement to understand and mitigate propellant slosh as well as deliver gas free propellant to the systems engines – the Juno spacecraft and Multi Purpose Crew Vehicle are no exception. The engineering solution to both of these problems is the application of a surface tension based propellant management device (PMD). Propellant management devices range in complexity and are unique to every propulsion system. However, a large subset of PMDs use surface tensions screens to directly control the location of gas, and indirectly the location of the liquid, in the tank. The limiting capability of any surface tension screen is defined by its “bubble point”. It is known by the propellant management community that curving a surface tension screen alters its bubble point; in the direction of degradation for a concave screen and goodness for a convex screen. However, the effect of curvature isn't easily quantified and the problem is typically overcome by overdesigning the system to ensure its proper function. This overdesign can cost the system in terms of weight, money, and general uncertainty. In this project the students will attempt to quantify the effects of curvature on the bubble point of several typical types of surface tension screen. Since the surfaces will be curved, a zero gravity environment is required to ensure that the pressure across the screens is uniform. The presence of gravity makes it very challenging to get an accurate quantification of this small effect. The researchers will design test cells that are capable of testing various screen types for various radii of curvature in a zero-g environment. The results will show how sensitive the bubble point is to screen curvature and if screen type also plays a role. The team will get to witness fluid behavior in zero gravity and will also be faced with unique challenges. Students will be working closely with the project principal investigator as well as industry experts from Lockheed Martin on the topic. Ultimately the results of this project will help to close the gap in understanding about this important on-orbit

Principal Investigator: Christine Edwards (Jet Propulsion Laboratory)

“The RGEFP has been truly incredible. Here in Houston I really feel like the two priorities are to do whatever necessary to facilitate our research and to make sure we have an inspirational and educational experience. I wanted to major in Economics two years ago and now, after doing two flight weeks with Frank, Jamie and the rest of RGO, I am taking next semester off from school to intern at SpaceX and I hope to work for NASA in the near future. Microgravity University has single-handedly made me decide to spend my life advancing technologies for human space flight.” - Junior, Yale University.
**Billings Central Catholic High School:** Billings, Montana  
**Drosophila Experiment and Chlorella Growth Chamber**

**HUNCH Algae Group**  
Algae have several potential beneficial uses for space environments. Most importantly, algae can be used for the remediation of CO₂ and production of oxygen. Algae are also super foods that contain high amounts of proteins and carbohydrates, and may also offer some protection from radiation exposure. The goal of this study is to optimize growth conditions for the algae *Chlorella pyrenoidosa* in microgravity. Chlorella cultures are normally maintained in liquid media. However, this is a problem in microgravity due to the unusual behavior of liquids. Our goal is to optimize the growth of Chlorella in a solid agar growth media. Chlorella stocks are commonly maintained on agar slants and we have demonstrated growth of Chlorella on the surface of agar in Petri dishes. We are attempting to grow Chlorella embedded in small blocks of agar to provide a growing area comparable to that of a liquid culture, but easier to handle. Molds for the agar blocks will be sealable to minimize evaporation, but will allow for digital probes. Probes will measure either oxygen production or carbon dioxide utilization as an indicator of photosynthesis efficiency. Algae growth will be estimated by measurement of chlorophyll fluorescence. Growth of Chlorella in agar could enhance its practical uses in space, providing essential life support services at a reduced cost.

**HUNCH Drosophila Group**  
Enzyme activity is an essential part of all biological processes, and is dependent on complex three dimensional shapes that are held together through weak intramolecular interactions. Microgravity could potentially disrupt these weak bonds, resulting in deleterious changes in enzyme function that affect normal physiological functions. Our experiments will utilize fruit flies, *Drosophila melanogaster*, as a model system to test for altered activity of the alcohol dehydrogenase enzyme responsible for ethanol metabolism in altered gravity. Fruit flies will be exposed to ethanol via vapor in a sealed chamber for a fixed time. Preflight and post-flight ethanol levels of flies will be compared to that of control flies not subjected to the flight to detect any changes in ethanol metabolism. Changes in sensitivity to ethanol due to altered gravity will also be assessed by exposing flies to ethanol vapor in-flight for a fixed time. Ethanol sensitivity will be quantified by the determination of a ST50, the standard time it takes for 50% of flies to become immobilized due to intoxication. ST50s will be compared to a control group of similarly exposed flies that remain on the ground. Flies with a mutation in the alcohol dehydrogenase gene (adh) will be used as a negative control for all studies. Alterations in enzyme activity or sensitivity to ethanol may provide insights into astronaut health challenges and could have important implications for treatment of individuals with pharmaceuticals in a microgravity environment.
**Clear Springs High School**: League City, Texas  
**Plant Viability for a NanoRack Food Growth Chamber**

Clear Springs High School is developing a food growth chamber that can function in a microgravity environment. The chamber will be Nanolab size and will incorporate a nutrient system to provide seedlings opportunity for growth once activated onboard the International Space Station. Additionally, we will be using moisture, pH and temperature sensors to access the health of the food growth chamber. The knowledge used from this experiment will be applied to the final development of a food growth chamber that is proposed to supply the ISS crew with fresh food. The experiment is contained inside a box constructed through the inventor Autocad Program and is printed on the 3D Printer. The chamber that houses the plants will contain rock wool as the growth media and will be fed from a nutrient filled 50 ml IV bag and IV tubing with luer lock connections. The IV Bag will be compressed with mechanical springs to create a constant pressure head for the nutrient filled water, but the water delivery will be controlled by a solenoid valve that is controlled by the microcontroller. The moisture sensors will tell the microcontroller when the plants need to be watered. The simulation of night and day will come from the LED (Red and Blue) lighting that will also be controlled by the microcontroller. The microcontroller will also house a camera that will take many stills during the Zero G portion of the experiment. The objective of this experiment is to provide an initial phase (second phase harvesting) of food growth and to have a system that is completely automated for the crew. The plants will be of the legume family. We will collect and record data from the readings received from the sensors and the visual data from the camera during the zero G Flight.

**Jackson Hole High School**: Jackson, Wyoming  
**Three Dimensional Magnetic Modeling with Ferrofluids**

Our team decided to do an experiment involving ferrofluids (a magnetic liquid) in order to create thin 3D parts in microgravity. We will use ferrofluids that are made of various types of carrier materials (possibly waxes, plastics, alloys, or resins) so that the resulting substance is a solid at room temperature but can be melted to a liquid in order to shape the part. When using the resins, we will need to mix the carrier material and ferrofluid on the microgravity plane. The ferrofluid will be sealed between two slides and each slide will contain one of the different types of carrier materials. A magnet will be attached to the outside of one of the slides. We will heat the slides to melt the carrier material. Once the substance has become a liquid, it will shape itself to the magnetic field. After the ferrofluid is completely shaped, we will cool the carrier material so it hardens back to a solid and then examine the different types of carrier materials to see which one made the most stable 3D part in microgravity.

**Lakewood High School**: Lakewood, Colorado  
**Hydrofuge Alpha and Bravo Plant Growth Chambers**

*HydroFuge Alpha Abstract*

The experiment is designed to be an efficient method of growing plants in microgravity in a 4 in. x 4in. x 5in. area using an ebb and flow growing method. The methodology of growing plants in said system is described as follows. Water will be stored in a fish tank, where the fish provide nutrients for the plant, or a water bag with nutrients. Using tubes, the colored water (colored to enable the flyers to better see where the water is within the system) is delivered to a reversible micro pump, which delivers the water to the plant root chamber. In the plant root chamber the roots soak up the water and then the water will be pumped back through the tube, through the micro pump and back down into the fish tank. After the water has evacuated the plant root chamber, the centrifuge system spins the plant and expels the water off of the roots to prevent root rot. The experiment is to be controlled by an Aubdiuno Uno board activated by an accelerometer that will sense a loss of gravity.
HydroFuge Bravo Abstract
The experiment is designed to be an efficient way to grow a plant in microgravity, in a 4 in.x 4 in.x 6 in. area using the minimum amount of electronics. It will be constructed of ABS plastic and Lexan. The plant chamber is tear shaped because in zero gravity the water naturally flows to the smallest angle in a container. In the plant chamber there will be hydroton, clay rocks, to bring the water up to the plant roots and absorb extra water on the plant roots to prevent root rot. Nutrients will be provided through another cube containing shrimp and snails, or through an IV bag. To prevent root rot, small vents made of semi-permeable Gore-Tex will be glued over holes in the plant chamber to allow airflow but still contain the water in the chamber. Recessed lights will be anchored to the lid and point up to the plant and give it the full LED spectrum a plant needs to grow. However, for the microgravity flight white lights will be used for better visibility. The experiment is to be controlled by an Arduino Uno board activated by an accelerometer that will sense a loss of gravity.

HydroFuge Fish tank Abstract
The experiment is designed to provide water with nutrients to the plant chambers. It will be 4inx 4inx 6in and made out of ABS plastic and Lexan. The fish tank will provide water to both the Bravo and Alpha cubes. In the fish tank there will be small snails and shrimp, these fish will use oxygen from that the plant produces and the waste produced by the fish will be used by the plants. There will be an IV bag to fill the fish tank with new water as the water empties into the fish tank and the water will go back into the IV bag as the water is emptied from the plant chamber into the fish tank. There will be motors in the plant chambers to pump the water in and out of the fish tank.

North Carolina School of Science and Mathematics: Durham, North Carolina
Spinal Expansion and Shape Memory Alloy Peristaltic Pump

Spinal Elongation
As astronauts continue to explore the final frontier that is space, pain in the lower back has become an increasingly problematic issue. Not much is known about the cause of these astronauts’ back pain, so our mission is to better understand the differences between the forces on a spine in space and a spine on Earth. We do know that the problem is related to a phenomenon known as spinal elongation, which causes an average adult to be one to two inches taller in space. This spinal elongation is related to the relief of the lumbar curve (in the lower back), which typically supports most of the body’s weight, compressing the lumbar curve. In microgravity, there is no such compression, as the gravitational force (9.81 * mass) is reduced to a negligible value. Spinal elongation creates space between vertebrae and intervertebral discs, causing pain. Astronauts can sleep or hug their knees to somewhat mitigate the pain, but there are no significant data at the moment investigating this problem.

In order to gain the necessary data and specifications for a solution, the forces and interactions in the spine and attached muscle tissue must be understood, and that is what this experiment hopes to accomplish. In 2012, this investigation was flown in the microgravity aircraft as a part of the HUNCH
program; however the results of experimentation were inconclusive. Therefore, in 2013, we hope to address these problems in order to better understand forces affecting intervertebral discs.

Peristaltic Pump
In any spacecraft, the plumbing system is vitally important. Pump mechanisms used today in spacecraft such as the International Space Station are prone to frequent malfunction due to a large number of moving parts. We propose a new pump mechanism for use in microgravity containing no moving parts. We seek to do this by employing peristalsis, a biomimetic type of movement imitating that of the human digestive tract, which functions by sequential contraction. This peristaltic pump is actuated using Nitinol, a shape memory alloy that can be activated by applying electrical current. This mechanism could entirely eliminate the need for moving parts and therefore increase the reliability of the system.

Overland High School: Aurora, Colorado
Container Shape Effects on Crystal Growth

Understanding crystal growth is important because the microgravity environment is known to affect both the size and quality of the crystal formed. Better crystals mean a more precise structure of the molecule can be determined. This is critical to understanding the biological binding sites of drug targets and the development of new pharmaceutical products. As a result, the ISS has been used extensively to grow some of the best bio-molecular crystals ever. It is well known that surface tension is a dominant force acting upon liquids in microgravity and containers shape therefore plays a large role on the position of the liquid inside a container. However, to the best of our knowledge, no one has yet studied the effects of container shape and surface tension on the crystallization process in microgravity. Using solid works software and a 3-D printer we will design and create a number of containers with a variety of internal shapes but identical volumes. Each container will be filled with an identical volume of a saturated sodium acetate solution which will be nucleated and allowed to crystalize during the microgravity portion of the flight. The crystals will then be preserved and their average size and purity compared to the control group grown in a 1-G environment.

Tri-County Regional Vocational Technical High School: Franklin, Massachusetts
Z-Gravity Scale

The experiment that we designed was based off of the problem of measuring mass in zero gravity. The fact that measuring mass is in of itself more of a comparative process than anything makes it difficult to do in a zero-gravity environment because gravity is usually the constant force that we use to compare the object of question to the reference object. In our experiment we decided that since gravity is now non-existent that we must replace this constant force with centripetal force. The way that we are to achieve this is we are creating a machine that spins a fishing scale with an object attached to the end. As the device spins centripetal force will pull the object out allowing the fishing scale to measure its mass. Obviously we can't take this reading because replicating gravity perfectly would be a long, arduous and unnecessary process. Instead, we will measure an object of which we already know the mass of and compute the ratio in order to find the mass of objects which are unknown to us. If we are successful in this this technology can be used to analyze substances in space without the need to send them back to earth. This can be extremely helpful when testing new planets for colonization.
Warren Tech Career and Technical High School: Lakewood, Colorado

Egg Cooker and Eggrifuge

Our group is investigating shipping, cracking, and cooking eggs on the International Space Station (ISS) so that astronauts can fry their very own eggs in space. Astronauts’ ability to “Cook Their Own Meal” on the ISS would boost their nutritional and psychological wellbeing, especially as astronauts spend longer times in space.

The first step to successfully cooking eggs in space is to develop egg carriers that will protect eggs from the extreme vibrations and hypergravity forces as they travel to the ISS. Our group is currently working on using foam to accomplish this task. The next step is to develop an extractor that not only cracks the egg, but also propels the egg toward the cooker. Our egg extractor functions by spinning and cracking the egg followed by “flying” the egg on to the cooker. It works like salad spinners where you push down on the top to make it spin. As you push down on the spinner a spring uncoils pushing a rod forward that cracks the egg. Finally, we are developing an egg cooker that uses Peltier Thermoelectric plates and induction cooking. With thermoelectric plates we can cook the egg in under a minute. Induction cooking uses conduction to directly heat a ferromagnetic cooker, as opposed to more traditional cookers. In the end, we hope to provide astronauts with home cooking on the ISS.
**Microgravity eXperience (Teaching From Space) Flight Program – By State**

* First Time Participant (institution)

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**Einstein Fellows:** Arlington, Virginia

**Gravity’s Impact on Coacervate Formation**

Team member Denise Thompson came up with the idea based on a laboratory investigation that she uses in her AP Biology and Astronomy classes. We liked the subject matter of coacervates as it relates to foundational science concepts that are applicable to physics, chemistry, biology, environmental and earth science classes. In addition, we felt that analysis of our data would provide students with opportunities for practicing a wide range of skills such as measurement and random sampling as well as mathematical, graphical, statistical, and digital imagery analysis. Lastly, we were looking for a topic that was unusual and that could be facilitated in the temporal and spatial limitations of the Micro GX program.

Specifically, this investigation tests the fluid dynamics of lipid membrane self-assembly under changing gravitational conditions. In addition, there are a variety of tangential concepts that are related such as diffusion, convection, surface tension, molecular attraction, and energy transfer and transformation. Depending on the context of the class, practical application of this research could apply to fuel or other fluid storage in space, micro-g manufacturing, and optimal conditions for the origins of life. This investigation complements NASA studies and applications regarding fluid dynamics such as interfacial tension using coacervates as a model, origins of life from cosmic and planetary precursors, such as characterization of system properties (viz., our investigation under micro-g and hyper-g conditions).

Before allowing students to analyze the data, they will be required to formulate their own hypotheses and explain their reasoning. As a flight team, we have two predictions. First, for each parabolic cycle, the average volume of the coacervates will increase proportional to the increase in gravitational acceleration. Secondly, over the course of many parabolic cycles, the average volume of the coacervates will increase as time increases. Students may come up with novel questions that are equally testable such as how gravity affects the homogeneousness of coacervate formation or if there is a limit to coacervate volume.

**Evansville Day School:** Evansville, Indiana

**Tornado Fluid Flow in Microgravity**

Our team came up with this investigation because it is developmentally appropriate and engaging for a wide range of students at our school, which serves JKPK -12th grades. Our students are fascinated by and fearful of tornados since we live in Tornado Alley. Recent events such as Hurricane Katrina and Hurricane Sandy have also raised students’ interests. The hands-on and visual components of this activity are particularly engaging for the younger students. Whenever we have a tornado tube set up with the bottles, the students all want to do their own investigations and discoveries.
The experimental set-up demonstrates an extreme atmospheric event – the vortex caused by the heavy water in the top soda bottle needing to flow to the lower bottle (and thus displacing the lighter air) in the fastest way is an analogy for a tornado or hurricane. This experiment tests weather and physical science concepts such as how warm air is less dense and “heavy” as cold air, so the war air will rise, pushing the cold air down.

Based on what we know of microgravity, the water in the top bottle may just stay up in the bottle, or drip down or gush into the lower bottle with or without a vortex. When the plane is in hyper-gravity, we expect a vortex of great intensity and speed of flow, or possibly just one intense gush.

**Poinciana Elementary and Atlantic High School:** Boynton Beach, Florida

**How Does Gravity Affect Convection?**

The teachers met as a team to generate ideas for investigations that would be appropriate for our 3-5th grade students. We want all of our students to be able to take an active role in the investigation, from setting the parameters, to building the instruments, and finally collecting and analyzing the data generated by the control runs at school and from the runs at 0g/2g.

We expect the convection cell to become unstable at 0g, but are unsure about how quickly (if at all) it will be able to restabilize at 2g. How convection changes at the boundaries between 0g and 2g seem to be interesting areas to investigate. Will convection speed up at higher g’s, or change in some other way?

**Prior Lake-Savage Middle Schools:** Prior Lake, Minnesota

**Behavior of Acoustic Energy in Microgravity**

Choosing our investigation was a collaborative endeavor between students and teachers at the two middle schools in our school district; Hidden Oaks Middle School and Twin Oaks Middle School. Students were involved in developing and offering the original proposals, evaluating the proposals and determining which proposals would have the greatest chances of success.

Using the Google.doc platform students had the opportunity to submit entry ideas through their teacher’s websites. Students were asked to give a summary of the experiment they would like to see done as well as an explanation of why their particular proposal would be a good experiment to do in microgravity. Over the course of several weeks, over 130 experimental ideas were submitted by students in our district.

After ideas had been submitted, 8th grade science students then worked in collaborative groups to perform a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis on the submissions to determine which submissions would offer the best opportunity for the Micro GX flight. Students took into consideration both the strengths and weaknesses of each experiment to determine the advantages of one experiment over other experiments. This included performing internet research to determine whether other groups had performed similar experiments on microgravity flights. They also engaged in research to determine the potential for what could be learned through the investigation to be useful to future space missions in micro and hyper-gravity.
Students also analyzed the threats and opportunities created by external elements that could either be exploited to the advantage of the experiment or could be potential hurdles to its success. This included looking at what resources we had available with regards to expertise in designing the experiment, potential cost as well as the plausibility of designing a reliable and controlled experiment to test the proposed investigation. The SWOT analysis proved to be particularly important in choosing our investigation as students tended to initially choose experiments that would be “cool” despite the fact that it did little to advance knowledge, was potentially dangerous or that the exact same experiment had been done in the past.

After the completion of the SWOT analysis, student teams each chose one proposal that they believed would be the most successful based on their analysis. These submissions were then evaluated by the teacher team and it was determined that we should investigate sound in micro and hyper gravity.

We will be investigating principles related to sound and acoustic energy. With the use of acoustic location technology in geosciences and ultra sound technology in a variety of fields including medicine, students felt that testing how sound reacts to gravitational changes holds the potential to be useful in real-world micro-gravity and hyper-gravity applications.

One of the aspects determined by students to be most favorable about this particular experiment is that they truly do not know what the results will be. Students felt that many of the experiments that had been proposed had predictable results based on experiments that they found in their research. After multiple discussions our final hypothesis is as follows:

Air has mass and mass is impacted by the force of gravity; sound waves traveling through air will also be influenced by the force of gravity.

**Riversink Elementary School:** Crawfordville, Florida  
**Wakulla Waters: A Liquid Investigation**

We first talked to our students about what makes our community unique. We felt that involving our community in this opportunity would be beneficial for everyone. We live in a small rural community that is home to many wonderful natural resources. In addition, our students showed a significant interest in the way they saw liquids behaving on NASA videos of the International Space Station. We also considered the standards that unify the grade levels for all of our team members (K-4). Each grade level of our team contains standards that address properties of liquids. Further, we elected to conduct an investigation that involves the essential skills of observation and classification, as we feel these are extremely important foundational scientific skills for our students to learn.
The scientific concepts being tested are the properties of liquids on Earth compared to the properties of liquids in microgravity, including miscibility. We expect the food coloring to behave differently in the microgravity environment because the force of gravity will not be a factor in the motion of the food coloring in the water. We believe that gravity has an effect on the way the food coloring mixes with water on Earth. We also expect that the lack of gravity will affect reaction of oil and water. On Earth the oil rises to the top of the mixture. We believe gravity may play a role in this. Therefore, we believe that there will be a difference in the way the oil and water react to one another.

**St. Joan of Arc School:** Lisle, Illinois  
**Gravity’s Effect on Magnets**

Our team wanted to investigate a topic that could be discussed and used throughout all the grade levels of our school. Magnets and magnetic properties are studied Kindergarten through 8th grade at our school. Our team will be testing gravity’s effect on the repulsion of like magnetic poles. If weight affects the distance like magnetic poles can repel then in a microgravity environment like magnetic poles should have a higher measurement of repulsion and in a hyper-gravity environment like magnetic poles should have a smaller measurement of repulsion.

**Team Kennedy:** Hillsboro, Missouri  
**Absorbency of Liquids in Space**

Our team is made up of teachers from across the country that met this past summer at Honeywell’s Advanced Space Academy for Educators. We currently collaborate nationally and internationally with projects in our classroom. We were able to use NASA video clips from the shuttle and ISS to show students how objects react to a microgravity environment. After viewing the clips, our students brainstormed on their own and in combination with each other. Students asked a variety of questions, such as “What happens to liquids that spill? Can liquids pose a danger to equipment on the space station? Are liquids vacuumed up on the station?” Our classes even sent a message through Twitter to Astronaut Clay Anderson to ask him about the cleanup of liquids during his time living on the Space Station. Anderson responded that a towel is typically used, but that the liquids behave differently than on Earth. From there, the students inquired how different liquids behaved. What is the towel made of? Is the material the best for the job? Even though our team members teach a variety of grade levels and live in various parts of the country, our classrooms were able to communicate and collaborate to come together with one question for our investigation: What happens when liquids spill in space? Our students collaborated and met with each other via video conferencing to share ideas and discuss their predictions for an experiment. Students were thrilled to be meeting new students across grade levels and across the country and to be sharing in a connected experience.

We wanted an experiment that was unique, interesting, could reach a variety of ages, and would inspire kids to inquire more about the true challenges of life in space. After conducting mini-experiments, debating, and voting, the students finalized their experiment. How do different absorbent materials react to various liquids in a microgravity environment? Shooting liquids at a target in an attempt to absorb as much liquid as possible is naturally engaging to kids. However, it also opens up our classrooms to concepts surrounding absorption, density, capillary action, porous versus non-porous materials, engineering processes, and even nanotechnology.

We expect that the most porous materials will have the highest absorption rate, because of the increased surface area that can absorb the liquids. We also think that the water will be more easily absorbed than the blood because it is less dense than the blood.
The Experience
The Reduced Gravity Education Flight Program has teamed with the NASA Explorer School Program (NES) to provide a one of a kind flight experience. The flight opportunity is a unique academic experience for teachers to successfully fly and evaluate three reduced gravity investigations. 2013 marks the second year of this program where teams of three educators, from 6 different NES schools, will conduct these STEM investigations in their classrooms and repeat them in the reduced gravity environment.

Descriptions of the STEM investigations are:

*Experiment One: Mass vs. Weight*
Students and educators will build an inertial balance to determine the mass vs. weight of unknown objects. Students will compare the data from their 1g experiments to the flight experiments and determine what the unknown masses weigh.

*Experiment Two: Projectile Design Challenge*
Students and educators will build a projectile launcher and data table to analyze the effects that gravity would have on a projectile launched in reduced and hyper gravity. They will measure the distance of the various ball bearings launched at different forces and launch angles. (Not included in 2013 flight)

*Experiment Three: Fluids in Microgravity*
Student and educators will observe what happens in a microgravity environment when a cork is placed in a closed container filled with a fluid and if water and oil will mix. We will test common masses in different fluids with different viscosities and time how long it takes the mass to reach the bottom of the container in 0g and hyper g. Students will need to figure out the unknown masses from the data collected in the classroom.

**Corpus Christi Catholic School:** Chambersburg, Pennsylvania

Corpus Christi Catholic School is a private Catholic school located in south central Pennsylvania. Our current enrollment is 267 students. CCS strives to be on the cutting edge when it comes to advanced educational opportunities. Team members include Amy Fetterhoff, Amanda Blough, and Kelly Hockensmith.

Amy Fetterhoff has been teaching for fourteen years. She has a Bachelor of Science in Elementary Education and a Master of Education in Educational Leadership. She has been with NASA Explorer Schools for three years, and has participated in the NES National Student Symposium and two NES Teacher Recognition Opportunities. Amanda Blough has been teaching for thirteen years and has a Bachelor of Science in Exercise and Sport Science from Penn State University and an Elementary Education certification from Wilson College. She has been with NASA Explorer Schools for three years and is also completing her NASA Endeavor Fellowship. She has attended two NES Teacher Recognition
Opportunities. Kelly Hockensmith has been teaching for three years and has a Bachelor of Science in Elementary Education from Shippensburg University. She has been with NASA Explorer Schools for one year.

We are hoping to expose our students to NASA technology and innovations through this experience. We also encourage our students to pursue careers in Science, Technology, Engineering, and Math through exposure to different STEM professionals. The team members, students, school, and community are ecstatic to be involved in this once-in-a-lifetime experience.

**Fairport High School:** Fairport, New York

Fairport High School is located in a southeastern suburb of Rochester, NY and houses grades 10-12 with an overall enrollment of 1800 students. Our school offers 15 AP courses and six SUPA (Syracuse University Project Advance) courses as well as a variety of electives in all disciplines, including business, art, drama, music, science, and technology. Central to our teaching efforts is a commitment to the ideals fostered in Brotherhood-Sisterhood week, in which our school community gathers to honor the unique strengths of each person. In nurturing well-rounded students, our school also focuses on developing a genuine sense of self. Accordingly, 34 clubs provide a variety of co-curricular experiences for our students in the arts, music, service, and intellectual pursuits. Some of these offerings include Robotics team, student ambassadors program, Model UN, Outreach, Youth to Youth, Leo Club, Drama, or Downstage Improvisation. FHS is a school community committed to team, support, leadership, and success. The Fairport Family works to maintain a learning atmosphere that challenges all students to excel at high expectations, respects the diverse talents of all people, and asks all students to lead and collaborate.

The Fairport team consists of Elizabeth (Beth) Burns, Eugene (Gene) Gordon, and Donna Himmelberg. Beth Burns has taught a combination of AP Chemistry, Chemistry, and SUPA Forensic Science in the past 12 years at Fairport High School. She has been active with NES for over a year and is a member of STANYS and NSTA. She is also active in the Local Section of the American Chemical Society, where she serves as the Local Section Secretary and chairs several committees. Gene Gordon is a National Board Certified Physics teacher who has taught Regents Physics and astronomy for 26 years. He is the Director-At-Large for Physics for the Science Teachers Association of New York State as well as a member of NSTA and AAPT. Donna Himmelberg has been teaching chemistry, biology, anatomy & physiology, and/or physical science courses for 15 years. She has been active with NES for over a year and is a member of STANYS and NSTA. All three team members are looking forward to riding the Weightless Wonder a second time and sharing this experience with their current students.

Our team is fortunate to be making our second flight aboard the Weightless Wonder. Using our experience in physics, chemistry, and biology, we look forward to using this interdisciplinary knowledge to involve students with a wide variety of interests in this current opportunity. Students will be utilizing class time as well as after-school sessions throughout the year to construct and run the experiments. As we did with our first flight, we plan to share our work and experience with others in our school and larger Fairport community through class work, presentations, and professional development.
**Forest Lake Elementary Technology Magnet School:** Columbia, South Carolina

Forest Lake Elementary Technology Magnet School is located in Columbia, SC. The school services 646 students in Pre-K through 5th grade. The school provides a technology infused integrated curriculum that demands academic excellence, encourages positive self-esteem, and promotes responsible citizenship and respect for others.

Tammy Lundy teaches 5th grade Math and Science. She has a Bachelor of Science Degree in Biology, a Bachelor of Arts Degree in Elementary Education, and a Master’s Degree in Technology in Education. She has been teaching for 16 years. Denise Duke teaches the NASA Explorer Lab for kindergarten through fifth grade students. Denise has her Bachelor of Art Degree in Education from the University of South Carolina and her Master of Education from Columbia College. She has been teaching for 21 years and enjoys providing engaging STEM-G lessons for her students. Kevin Durden joined the Forest Lake Elementary Technology Magnet NASA Explorer School staff in 2007 as a 4th grade teacher after ten years in the United States Air Force, six years as a parent volunteer and mentor, and a Masters in Elementary Education from the University of South Carolina. He specializes in Science and Social Studies project-based learning in a one-to-one technology classroom (one computer per student). His wife and three children (a high school senior, junior, and 4th grader) as well as his students look forward to following his adventure on the RGO flight digitally.

The Forest Lake Team is excited about the RGO experience and the impact it will have on our students and community. Our team is constantly seeking out new opportunities to enrich our already challenging curriculum. We are excited and know the Reduced Gravity experience will show the students how everyone should continue their quest for knowledge. This collaboration with our school and NASA will heighten the students’ interest to pursue STEM-G related careers and/or opportunities.

**Franke Park Elementary:** Fort Wayne, Indiana

Franke Park Elementary School is located in Fort Wayne, Indiana. The school has an enrollment of 550 Kindergarten -5th grade students. We have been involved with the NASA Exploratory program since 2004. Team members include: Jarod Leasure, Donna Ashcroft, and Mary Roush.

Jarod Leasure has taught for six years, with five of those in the NASA Exploratory program at Franke Park. He has had the opportunity of being involved in the student symposium the last two years. Donna Ashcroft has a MS in Elementary Education. She has been teaching for 24 years, seven years have been at Franke Park Elementary School in Fort Wayne, IN. Mary Roush has a MS in Elementary Education. She has been teaching for fourteen years, three of them at Franke Park.

The Franke Park Elementary team has been extremely excited about the opportunity to be a part of the Reduced Gravity Education Flight Program. The team connected the three experiments with the Common Core Standards and the Indiana Academic Standards in the Kindergarten and Fifth grade classrooms. In the future, the team hopes to transfer their excitement of the experience to the students and their interests in Math and Science careers.
Mountview Road School: Morris Plains, New Jersey

Mountview Road School is a K-5 public elementary school in Hanover Township, New Jersey. We service over three hundred children in our suburban, northern, New Jersey community. This is our second year as a NASA Explorer School. Five of our teachers were honored to have been chosen in 2011 to be part of the Reduced Gravity Education Flight Program at Johnson Space Center in Houston Texas. This experience inspired our students and teachers to make STEM a focus at Mountview. Our team members include Kerry Brennan, Drew Burns and Michelle Marks.

Kerry Brennan has been an educator for 14 years and currently teaches 4th grade at Mountview Road School. She has previous experience teaching grades three through six. A Pennsylvania native, Kerry is a University of Pittsburgh graduate. She has a Bachelor’s Degree in history and a Master’s in education.

Drew Burns is also a 4th grade teacher at Mountview. He has been an educator for 11 years and is a graduate of Ramapo College. Mr. Burns holds a Bachelor’s degree in psychology and education. Michelle Marks is a gifted and talented and basic skills teacher for students K – 5 at Mountview Road School. She has been teaching for 14 years and also has experience as a classroom teacher in grades K – 2. Michelle holds Bachelor’s Degrees in English and communication from The University of Delaware as well as a Master’s Degree in educational technology from Montclair State University.

Our Microgravity Team is thrilled to be going back to Houston! Our students are very excited about the STEM activities we have pursued through NES. Last year our fourth graders used their skills to conduct the NASA designed thrust structure experiment as an introduction to our annual rocket building and launching unit. Our fourth and fifth grade gifted and talented class did a wonderful job with the Spaced Out Sports project. Our entire school has become tuned in to the happenings at NASA and even the little ones are showing excitement when it comes to STEM activities. Our hope is to continue and expand this love of learning by involving our students in these exciting new microgravity experiments and opportunities.

Woodrow Wilson Middle School: Glendale, California

Woodrow Wilson is a California Distinguished school and is one of four middle schools in the Glendale Unified School District in Glendale, California. Wilson recently celebrated its 100th anniversary in 2011 and has a culturally diverse population of almost 1500 sixth through eighth grade students. Team members include Mary Inglish, Paula Jackson, and Anita Lalaian.

Mary Inglish is currently teaching her thirteenth year of middle school Science. She truly enjoys utilizing the NASA Explorer School lessons, hands-on activities and real world STEM connections in her classroom and with her robotics and MESA (Math Engineering Science Achievement) students. Prior to becoming a teacher, Mary majored in Biological Sciences and minored in Psychology for UC Irvine, California. Polly Jackson has been a middle school math teacher for nine years. She has enjoyed doing many STEM activities with her students over the years such as; robotics club, MESA (Math Engineering Science Achievement) and incorporating hands on learning in the class. Before teaching, Polly majored in math and later got her Masters in Math Education. Polly loves teaching and spending time with her family. Anita Lalaian has been a middle school science teacher since 1983 and has taught in Pennsylvania, Maryland,
New York and California. She has included STEM activities throughout the years in Science Fair projects and has incorporated hands-on learning in science class lab activities. Anita majored in Psychology and Biology and received her Master in Biological Education. Anita loves teaching and spending time with her family.

Our team and students are very excited about performing these NASA experiments into our 8th grade Math and Physical Science classes and reporting our data via web conferences to JSC. The NASA Explorer School program provides a great deal of valuable lessons and hands-on activities that our teachers have enjoyed using at our school. We are excited to be working with the HUNCH program high school students this year that will hopefully inspire our middle school students to continue on in STEM related careers.

“The experience has been life changing. Although I have always appreciated the work that NASA has done, this week has opened my eyes to the work the organization does for students and teachers. I will use the NASA sources and experiences to enhance my lessons. I am very grateful for the experience NES has provided for us. Thank you for all that you do.” – Wilson Middle School, 7th grade teacher
Appendixes

Top, left: Students from MIT work with their mentor just prior to the first parabola. Middle, left: Microgravity eXperience experiment in between test runs. Bottom, left: University of Nebraska students and faculty with Astronaut Clay Anderson. Top, right: UNC – Pembroke students experience microgravity. Middle, right: Overland High School students and their mentor prepare their computer prior to flight. Right, bottom: Students from Baldwin Wallace University experience microgravity with Astronaut Cady Coleman.
## Appendix 1 – Proposals at a Glance

### Undergraduate Student Program
#### Selected Engineering Proposals

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### Selected Physical Science Proposals

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# SEED Program
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# HUNCH Program
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# Microgravity eXperience (Teaching From Space) Program
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Appendix 2 – Demographic Data
Combined Undergraduate Students Demographic Information (UG & SEED)

Program Participants by Gender

- Female: 22%
- Male: 78%

Program Participants by Ethnicity

- African American: 2%
- Asian: 11%
- Hispanic/Latino(a): 10%
- Native American: 2%
- Caucasian: 58%
- Other/No Answer: 17%

Academic Disciplines for Participants

- Aerospace Engineering: 37%
- Mechanical Engineering: 26%
- Aerospace & Mechanical: 13%
- Biology: 13%
- Chemistry: 13%
- Computer Engineering: 13%
- Computer Science: 13%
- Other Disciplines: 3%
- Electrical Engineering: 44%
- Physics: 27%
- Education: 4%

Academic Level of Participants

- Freshman: 3%
- Sophomore: 13%
- Junior: 13%
- Senior: 44%
- Graduate/Faculty (Ground Crew Only): 27%

Program Experience of Participants

- New Participants: 74%
- Returning Participants: 26%
Undergraduate Student Program Demographic Information (UG)

Program Participants by Gender

- Female: 19%
- Male: 81%

Program Participants by Ethnicity

- African American: 2%
- Asian: 10%
- Hispanic/Latino(a): 12%
- Native American: 3%
- Caucasian: 55%
- Other/No Answer: 0%

Academic Disciplines for Participants

- Aerospace Engineering: 44%
- Mechanical Engineering: 27%
- Aerospace &...: 13%
- Biology: 13%
- Chemistry: 3%
- Computer Engineering: 78%
- Computer Science: 22%
- Other Disciplines: 13%
- Electrical Engineering: 10%
- Physics: 12%
- Education: 10%

Academic Level of Participants

- Freshman: 44%
- Sophomore: 27%
- Junior: 13%
- Senior: 13%
- Graduate/Faculty (Ground Crew Only): 3%

Program Experience of Participants

- New Participants: 78%
- Returning Participants: 22%
Program Participants by Gender

- Female: 30%
- Male: 70%

Program Participants by Ethnicity

- African American: 11%
- Asian: 16%
- Hispanic/Latino(a): 2%
- Caucasian: 5%
- Other/No Answer: 66%

Academic Disciplines for Participants

- Aerospace Engineering: 14%
- Mechanical Engineering: 25%
- Computer Science: 59%
- Biology: 2%
- Astronautics: 2%
- Other Disciplines: 39%
- Electrical Engineering: 61%
- Physics: 61%

Academic Level of Participants

- Sophomore: 59%
- Junior: 14%
- Senior: 25%

Program Experience of Participants

- New Participants: 2%
- Returning Participants: 61%
High Schools United with NASA to Create Hardware (HUNCH) Demographic Information

Participants by Gender
- Female: 37%
- Male: 63%

Participants by Ethnicity
- Asian: 5%
- Hispanic/Latino(a): 11%
- Caucasian: 25%
- Other/No Answer: 59%

Academic Level of Participants (High School)
- Sophomore: 2%
- Junior: 17%
- Senior: 6%
- College: 2%
- Faculty: 2%

Program Experience of Participants
- New Participants: 91%
- Returning Participants: 9%

HUNCH participants pose for a picture after their flight.
Microgravity eXperience (Teaching From Space) Educators Demographic Information

Participants by Gender
- Female: 45%
- Male: 55%

Participants by Ethnicity
- African American: 3%
- Hispanic/Latino(a): 6%
- Caucasian: 42%
- Asian: 3%
- No Answer: 46%

Grade Level Taught by Participants
- Elementary: 30%
- Middle School: 15%
- High School: 15%

Academic Level of Participants
- Master's: 30%
- PhD: 6%
- Bachelor's: 64%

Position of Participants
- Classroom Teacher: 100%
NES Demographic Information

Program Participants by Gender

- Female: 78%
- Male: 22%

Participants by Ethnicity

- Caucasian: 33%
- No Answer: 67%

Grade Level Taught by Participants

- Elementary: 14
- Middle School: 2
- High School: 2

Academic Level of Participants

- Bachelor's: 72%
- Master's: 28%

Position of Participants

- Classroom Teacher: 100%
Appendix 3 – Participant Comments

Program evaluations were collected post-flight. Educators, students, and faculty overwhelmingly praised the program for providing a once in a lifetime experience and a real world hands-on engineering experience for K-12 and undergraduate students. A few of the educator and student responses are listed here.

- The microgravity flight program experience was one of the best things I have ever done in my life. Preparing for the experiment in the months leading up to the flight increased my confidence as a scientist. I feel the program is vital to help more students get involved in science.-Senior, Boise State University.
- As always, the education staff and RGO staff was amazing. This is my third time down here and every year is better. Communication between the team and staff was great. After the first day (flight) the staff, both education and RGO worked with us to make sure we were set. The experience was amazing; we always take away a ton. We love flying with RGEFP! - Senior, Oklahoma State University.
- I found the flight program as an exhilarating experience. I worked on portions of the experiment that I would not have with my college course work including TCP networking, threading, video streaming, and building test hardware. Zero-gravity is a once in a life time experience and I feel privilege to have participated in the program.-Senior, University of Illinois at Urbana Champaign.
- The program provides an incredible opportunity for all students. Not only do the participants benefit, but their community as a whole benefits from the outreach activities. NASA and the Microgravity University provide outstanding education and outreach opportunities and promote STEM learning with a unique and exiting experience. I have never learned so much about teamwork and research at NASA than I have since offered the opportunity to work with the Microgravity University.-Senior, Boise State University.
- I cannot think of a single thing that could improve the program. Everything was absolutely wonderful. This program does a great job of inspiring students and allowing people like me to gain not only experience in engineering, but experience in experiencing zero g. – Senior, Purdue University.
- This is a great program for undergraduate students. The tours of the NASA centers were a great learning experience. Having NASA astronauts around to speak with them and fly with them is great motivation to look forward to and the possibility of being an astronaut. I look forward to taking advantage of for when I become a professor and motivate the undergraduate students to apply. – Faculty, SUNY Buffalo.
- The overall coordination and set up was great. It was truly spectacular to see that this much stuff was crammed into one week. The JSC and RGO staff were very helpful and enlightening in terms of my future career goals. – Junior, West Virginia University.
- The experience as a whole helped me to see what a research project was all about (especially in the field of engineering). We thought of questions, made a hypothesis, designed an experiment, conquered challenges and obstacles, tested the experiment, and wrote about it after wards. This was a great overview of what the scientific method is all about. It made me have a greater interest and appreciation for my coursework. Thank you for such a great experience and for letting me see what it is like to work in such a great work environment. - Sophomore, Yale University.
• This was a very useful learning experience for me. I was able to work with a team, design and test an experiment. I've enjoyed every minute of flight week so far and I think you guys have done a great job of putting everything together and making it an enjoyable experience for everybody who participates in the program. Thanks. – Sophomore, University of Wisconsin Madison.

• Everyone was extremely accommodating and helpful. The RGO staff has always been on top of their work and we had a smooth and productive flight week. Because of this experience we are now exploring the possibility of senior design projects and master's thesis in the area of our research. This trip has improved everyone on the team and will make a positive impact on the engineering college at UNL. – Senior, University of Nebraska-Lincoln.

• Participating in the SEED program was definitely a worthwhile and educational experience for me. Unlike my lab experiences from university this program was much more collaborative and encourage student inspired innovation and creativity. The demands of the experiment provided an opportunity to learn new skills with tools and design; using these skills to create systems and parts of the experiment forged a sense of ownership and involvement, much more so than undergraduates find in other types of science projects. - Junior, Yale University.

• This is my third year in the SEED program. Every year that I return I am introduced to new experiences and make very valuable connections with other people interested in the same fields as me. This program has changed my career path since Day 1 of my first year of the program. – Senior, Carthage College.

• Thank you so much! Everyone was incredibly supportive of our research as well as being extremely patient and kind. I was inspired by the RGO staff both personally and professionally and could not imagine a better group of people to work with students as they explore the possibilities offered by parabolic flight, by NASA, and by STEM fields as a whole. - Senior, Yale University.

• The SEED program made me become a better engineer. Working on a team project over 6 months is an incredible learning experience. As an engineering student, I got wrapped up in the technical details and forgot the big picture but the microgravity experience made me see the big picture and made me infinitely more times excited about being an engineer! - Senior, MIT.

• The RGO experience was a fantastic way to get my students involved with hands on science and real world applications. The experiments covered topics that my students understood easily, while also providing a chance for additional research. The RGO program was well organized. – Forest Lake Elementary, 5th grade teacher.

• This NES experience was amazing! Our students and ourselves both are taking so much from this. Our kids can't get enough NASA and STEM activities and we love teaching it. We've learned so much this week about new activities and challenges we can bring back to our kids. Thank you!!- Mountview Road School, K-5th grade teacher.

• It was amazing!! Loved doing the research that Jamie build and loved observing the outreach items. It was a nice touch to have HUNCH students involved this year. We loved connecting with them. Thanks for giving me this once in a life time experience and changing not only me, but the students I teach! – Forest Lake Elementary, K-5th grade teacher.
### Appendix 4 - 1995-2013 Participating College and University Status

3,646 Student Flyers (does not include ground crew)
206 Institutions / 743 Teams / 50 States (plus DC & Puerto Rico)

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*2013 participants are highlighted in blue
*First Time Participant (institution)
## Appendix 5 – 1998-2013 K12 Participating Institutions

1,315 Educator Flyers (does not include ground crew)
241 Institutions / 229 Teams / 40 States (plus Puerto Rico & Ecuador)

### Institution Participation:

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Oklahoma State University student operates the team's experiment during microgravity.

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West Oso High School
West Ward Elementary School

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Mack Benn Jr. Elementary School
Oakcrest School for Girls
Oceanair Elementary School
Key Peninsula Middle School
Roosevelt High School

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Greendale High School
Menomonie High School
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Jefferson High School
Einstein Fellows*
K.W. Barrett Elementary
Mack Benn Jr. Elementary School
Oakcrest School for Girls
Oceanair Elementary School
Key Peninsula Middle School
Roosevelt High School

2013 participants are highlighted in blue
* First Time Participant (institution)

Appendix 6 – 2004-2006 Museum and Informal Education Participating Institutions
97 Flyers (does not include ground crew)
10 Institutions / 18 Teams / 9 States

Institution Participation:

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Appendix 7 – Summary Participation

Since its inception in 1985, the Reduced Gravity Program has hosted teams from all 50 states plus Washington, D.C. and Puerto Rico. The map represents the cities of all participating teams throughout the 18 years of the Program. The blue points indicate higher education participants and the red points indicate high schools, teachers, and other organizations and groups.
Appendix 8 – About the Microgravity Aircraft

The NASA-JSC Reduced Gravity Education Flight Program flies on a modified Boeing 727 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 two photographers 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 18-25 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”).

![Diagram of parabolic flight pattern](image)

![Image of students operating equipment](image)
Appendix 9 – 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 RGSFOP 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 The program changed its name to the Reduced Gravity Education Flight Program (RGEFP) to reflect the teacher components. 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).

2009 The program moved to a contractor Boeing 727 aircraft. Through the special opportunities flight week, internal partnerships were explored as well as revisiting the policies of human-testing and the high school program.

2010 Four additional partnerships were added: The NASA Explorer Schools (NES) Opportunity flight week brought additional teams representing NASA Science, Engineering, Mathematics and Aerospace Academy (SEMAA) and Motivating Undergraduates in Science and Technology (MUST). An additional flight week was developed in conjunction with NASA Teaching from Space (TFS) Office and National Science Teachers Association (NSTA). Also added were two flight teams from the U.S. Department of Energy (DOE) in conjunction with the Princeton Plasma Physics Laboratory (PPPL).

2011 The total number of participants exceeded 500 individuals during the flight season, which is a record for the program. Also, three additional partnerships were added: The NASA Headquarters Office of Education provided funding for a flight week that focused on minority-serving institutions and community colleges. The National Space Grant Consortium funded a flight week for first-time participants. An official collaboration between the Reduced Gravity Education Flight Program and Princeton Plasma Physics Laboratory was established.

2012 The Reduced Gravity Education Flight Program officially has had at least one team from all fifty states (plus Washington DC and Puerto Rico). This milestone was achieved with the flight team from Delaware Technical and Community College. Twitter and a Facebook fan page (and social media plan) were implemented. NES Reduced Gravity program was redesigned to provide teams of educators with pre-designed experiments that were able to be tested by their students in the classroom (shared with NASA via videoconferences) and then tested in the aircraft.

2013 The Reduced Gravity Education Flight Program has now flown over 5,000 participants. The current total is 5,058 students and educators. This year marked the beginning of two new partnerships with the University Student Launch Initiative (USLI) and NASA ISS Education Projects; both of which flew an undergraduate student team this year. The program has also started a long term partnership with The Office of Chief Technologist and the Flight Opportunities Program (FOP). The Flight Opportunities Program logistic and flight week operations will be conducted by the RGEFP in the coming year.
Program Support

To successfully complete the flight season, it takes the effort and generous support of numerous groups and the Reduced Gravity Education Flight Program would like to take this opportunity to thank the following organizations and individuals.

**NASA Funding Sources:**
- Human Exploration and Operations Mission Directorate
- NASA Explorer Schools Program
- JSC Teaching from Space Office
- High Schools United with NASA to Create Hardware (HUNCH)
- ISS Education
- University Student Launch Initiative
- NASA Flight Opportunities Program (FOP)

**Other Sources:**
- State Space Grant Consortium for supporting their flight teams

**Proposal Evaluation Support:**
- Undergraduate Technical Review Manager – John McQuillen (Glenn Research Center)
- Undergraduate Technical Review Manager – Edward Jeffries (Marshall Space Flight Center)
- Technical Reviewers from Glenn Research Center, Johnson Space Center and Marshall Space Flight Center
- Safety Reviewers from Johnson Space Center – Dominic Del Rosso, Fernando Zumbado and Robert Roe.
- Education Outreach Reviewers from Johnson Space Center

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<td><strong>Engineers:</strong></td>
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**Flight Medicine Clinic**
- **Lead** Dr. James Locke
- Flight Surgeons
- Staff Members

**Human Test Support Group**

**Imagery Acquisition Group**