The Float'n Illini
University of Illinois, Urbana-Champaign

Free Body Control in Microgravity

A Controls Theory Experiment

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Adviser Signature:

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Flight Week Preference:

Primary:	Group 2 (March 17-26)
Secondary:	Group 3 (March 30- April 9)
Tertiary:	Group 1 (March 3-12)

Mentor Request: Not Applicable

Acknowledgments

The Float'n Illini would like to thank several people who have made our research possible. First, we would like to express our appreciation to our main advisers, Professor Austin and Professor Loth, for their help this year and in years past. Also, we thank Professor Errede who is working with us on this experiment this year as our technical adviser. Rohan, Ashwin, and Yew Yin have been integral members of the team as well ... a special thank you to the three of you! We also thank all the companies and University of Illinois organizations who have assisted in funding our research. Finally, this would not be possible without the Reduced Gravity Student Opportunities Program, sponsored by JSC, NASA. Thank you all! We couldn't do this without you!

Technical

I. Synopsis

Modern satellites traditionally incorporate rotational flywheels as a method of attitude control. As a flywheel accelerates, its changing angular momentum will impart an equal and opposite change in angular momentum to the satellite. As a flywheel rotates, its rotational inertia will tend to keep the satellite's orientation constant despite small disturbances. We will expand upon this system by proposing an experiment which tests varying flywheel orientations and relative placements as well as varying control algorithms. The goal will be to determine the combination of flywheel placement and algorithm selection which most effectively provides three-axis control of the satellite. Effectiveness of any method will be measured by the accuracy, speed, efficiency, and stability by which the satellite obtains a given orientation.

In order to achieve this, we will construct a cube with internal flywheels to model a satellite. Two cameras mounted in the cabin will monitor the satellite's orientation and position. In real time, a computer will analyze the image data, along with acceleration sensor data from the cube. A control algorithm will then be applied, and commands will be wirelessly transmitted to the satellite. These commands will instruct the flywheels to spin at certain rates. Different control algorithms (proportional, proportional derivative, proportional integral derivative, etc.) as well as flywheel configurations will be tested. After the flight, the recorded data will be analyzed and the effectiveness of each method will be evaluated.

II. Test Objectives

Any type of spacecraft, be it a docking vessel or an orbiting communications satellite, needs a method of controlling and monitoring it's attitude. Because of this, satellite orientation is an ongoing field of interest and research. Due to the limitations of spaceflight, it is necessary to do this with as little energy and mass as possible. Although methods exist to control a satellite passively, these methods are not capable of very precise, quick, or stable attitude control. Therefore, active control methods which use more energy and mass are typically used. Our experiment is designed to find the most effective strategy involving flywheels which minimizes the above constraints.

Active control methods are characterized by three components: a sensor array, a control algorithm, and actuators. The most common sensor system incorporates accelerometers sensors to monitor linear and angular acceleration along with sensors to directly measure the current orientation of the spacecraft. The latter is typically accomplished using Sun imagers or star trackers ("Attitude Control"). A similar system is used in our experiment.

The control algorithm then takes the sensor input and sends commands to the actuators. Ideally, it would calculate a single direct movement necessary to get the spacecraft to the desired orientation. This can be accomplished by taking a generic movement, and then applying the correct parameters to fit it to the movement that needs to be done. This is done by one of several different controller algorithms. The control algorithms we will study are combinations of three components: proportional control, derivative control, and integral control. These are the building blocks to which more robust control systems can be devised (Emami-Naeini, 179).

There are many methods of actuators. In this experiment, we will study flywheel methods (also known as momentum wheels or reaction wheels). Because the flywheel itself holds angular momentum when in operation, it becomes non-trivial to use torques on the system to achieve the aforementioned ideal movement. For example, consider attempting to rotate a spinning gyroscope in the direction perpendicular to it's axis of rotation. Because of this fact, the system becomes complicated quickly and flywheel placement and configuration can affect overall control effectiveness greatly.

Flywheels are typically oriented on orthogonal axes to allow three-axis control. We plan to experiment with varying flywheel configuration to seek out the most effective method. In addition to this, we will also vary the control algorithm to determine what is the most effective control algorithm. Our objective is to find the algorithm and flywheel configuration which together maximize the effectiveness of our control system. Effectiveness in this case will be measured by the speed, efficiency, accuracy, and stability of acquiring the desired satellite orientation.

Factors such as mass(number of flywheels used) and energy used will also weigh into the analysis.

Our hypothesis is that proportional integral derivative control will provide the most robust control algorithm. Furthermore, it is hypothesized that using many flywheels, including off-axis ones, will provide the best control but will use the most mass in flywheels.

III. Test Description

In order to determine the best method of control for a free-floating body in microgravity, several parameters will be varied. The two parameter groups that will be studied are the control algorithm and the actuator placement and orientation. The experiment will have four motors, three orientated on-axis in the cube and a forth oriented off-axis in the cube as shown in Figure 1. It will also have three fans, used for translation, located on-axis and passing as closely through the center of mass as not to cause any unwanted torques. The purpose of these fans, or thrusters, is to allow the satellite to stay within the field of view of the cameras to ensure good data. We will also analyze which control algorithm controls the thrusters the most effectively. Different controllers will be implemented on the motors and fans to control the satellites orientation and stability.

Cameras will track the cube's orientation by making use of distinct color coding on the sides and edges of the cube. Encoders will be used to track and record the motor velocity and acceleration during each test. Accelerometers will also be used to obtain fine resolution data on the satellite's position and orientation.

Initially the satellite will be simulated using an off the shelf software package such as Simulink to determine the control algorithms that will be run while on the DC-9. This simulation will also help to calibrate the system. From there a test plan will be developed around a design of experiment (DOE) in order to reveal the most significant parameters in the post flight analysis.

The projected results of this experiment include the feasibility and effectiveness of varying parameters to orientate the cube. Post flight the control effectiveness of each test run will be studied from the flight video and the encoder data collected. The control effectiveness will be judged based on the accuracy, speed, efficiency, and stability of each test. Once the data has been reduced, a Pareto chart of effect will be compiled to show the most significant factors effecting the general accuracy, speed, efficiency, and stability of the cube.

The need for a reduced gravity environment is high due to the complexity of the system. It can not be reduced to a 2D system that may be tested on a frictionless turntable, for example. Furthermore, microgravity is an ideal medium for random translation and rotation of the body. This will effectively test the multiple flywheels' ability to orient the body, as well as the thrusters' ability to maintain a constant position.

IV. Justification for Follow-up

This project is a new endeavor for the Float'n Illini and therefore, a follow-up does not apply.

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Experiment Safety Evaluation

I: Flight Manifest

Flight Crew:

Alternate Flight Crew Member:

Journalist:
We are currently in the process of selecting a journalist.

II: Experiment Description/Background

In order to evaluate the properties of using flywheels for rotational control in the absence of gravity, a student designed mock satellite will be studied. This satellite will consist of a number of flywheels attached to separate motors, and an electronics package to control the motors. Also contained within the satellite will be three bidirectional fans used as a propulsion system. These components will be secured inside a protective aluminum frame covered with lexan. This casing will allow the crew to see inside the satellite and still protect them from its internal components. Two cameras will be mounted to the cabin of the airplane and aimed at the satellite. A computer will look at the camera data and in real time, will determine the orientation of the satellite and wirelessly transmit commands to control the motors. Each side of the satellite will display a different pattern of colors to aid in computer processing. During each parabola, the satellite will attempt to orient itself using varying controls algorithms. The satellites response, along with the speed and stability in orienting itself according to different algorithms, will be recorded.

III: Equipment Description

The experiment consists of two main parts: Main Structure (free floating) and Orientation System (bolted to C-9).

1. *Main Structure*

The Main Structure of the satellite is constructed of a cube frame with dimensions of 10” X 10” X 10”. Two solid aluminum square frames with dimensions 10” X 10” will be used as the top and the base of the cube. Aluminum bars will be bolted to the remaining four edges to form a cube. Additional aluminum bars are then connected to the top and bottom squares of the cube to provide support for the motor, flywheel, and electronics mountings. To complete the support structure, ¼” thick lexan will be fixed on each of the six surfaces of the cube frame.

2. *Orientation System*

A range of equipment will be used to determine the orientation of the structure in microgravity. Unique colors will be assigned to each of the six surfaces of the satellite. Data capture will then be performed using two cameras. The cameras will be secured with quick connect devices and cargo straps. The colors images will be analyzed in real time by the laptop computer. Wireless control signals will then be transmitted to the electrical system of the satellite.

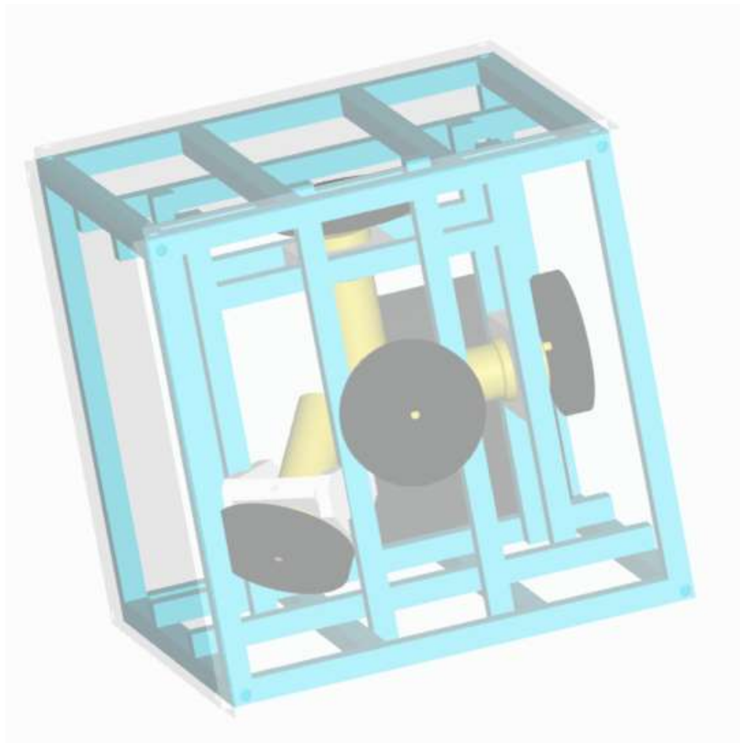


Figure1: Free Floating Satellite Rendering (shown without thruster fans)

IV: Structural Design

The free-floating satellite will be comprised of two solid pieces of aluminum connected by four aluminum beams. The two solid pieces will be made of 1/2" thick aluminum, 10" wide and 10" long. A square hole 9" x 9" will be cut in each aluminum plate. These can be thought of as the "top" and "bottom" of the satellite. Connecting these two solid pieces will be four aluminum beams. These beams will be 9" long, ½" thick, and ½" wide giving a cross sectional area of ¼" in^2. When connected, these will give the satellite a cubic structure.

Several additional components will be screwed to this supporting structure. Covering each face of the cube will be a 10"x10" sheet of ¼" thick sheet of Lexan. These will be screwed directly into the structural beams at each corner of the Lexan. Within the cube, there will be additional beams of aluminum ½" wide and ½" thick to support the motor mounts and electronic systems. A grounded electronics box will be mounted directly to the supporting structure using bolts.

The other component of the experiment is not free-floating. A ¼” thick, 24” x 24” base plate will be secured to the main deck of the aircraft. Bolted to this will be one of our two cameras. It will be secured to the base plate with cargo straps and a quick connect device. A second camera will be mounted either on a camera post from the DC-9 or on a preassembled camera mount secured to the base plate using bolts and cargo straps.

V: Electrical System

There will be two independent electrical systems used for this experiment, one in the satellite and one attached to the DC-9. The external electrical system will consist of two cameras, an RF transmitter, and a laptop computer. The cameras will be powered with an AC/DC transformer and will draw power from the 120 V DC-9 power supply. One camera will be mounted on a horizontal plate and the other on a vertical plate or camera mount. There will also be a laptop computer powered by another AC/DC transformer drawing power from the DC-9’s 120 V power supply. Each of the cameras and the laptop will also include their commercial supplied internal batteries in case of power failure. The RF transmitter and receiver will draw its power from the laptop’s 5V USB port. All power cables will be connected to one power strip connected to the DC-9. All wires will be insulated

The electrical equipment on the satellite will consist of 4 motors, 3 fans, acceleration sensors, LED lights, and electronic circuitry. The electronic circuitry will be a custom designed circuit board which will retrieve information from the sensors, control the motors and LED lights, and communicate with the laptop via RF transmitters. All this circuitry will be contained in an insulated metal box. All of these components will draw power from an internal battery. All wires will be insulated to avoid shorts.

External Parts	Quantity	Current per component (A)	Total (A)
Laptop Comuter	1	2	2
Camera	2	0.5	1
RF Transmitter	1	0.8	0.8
Total:	4		3.8

Table1. Current draw of external electrical system. This indicates that 3.8 total Amps will be drawn from the DC-9's 120V electrical system for our external electrical system.

Internal Parts	Quantity	Current per component (A)	Total (A)
Motor	4	1.5	6
Electronics	1	1	1
LED Lights	30	0.002	0.06
Sensors	5	0.2	1
Air Thruster	3	2	6
Total:	43		14.06

Table2. Current draw of external electrical system. This indicates that a total of 14.06 A will be drawn from the satellite batteries.

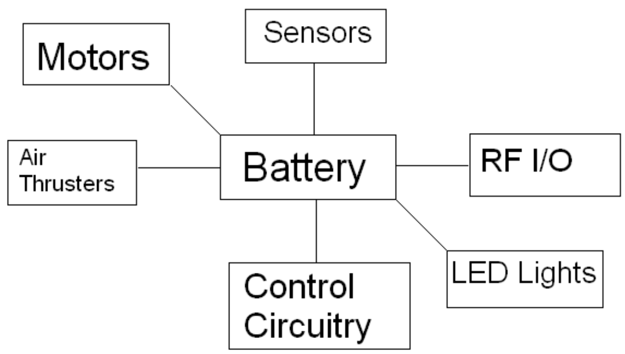


Figure 2: Internal electrical schematic

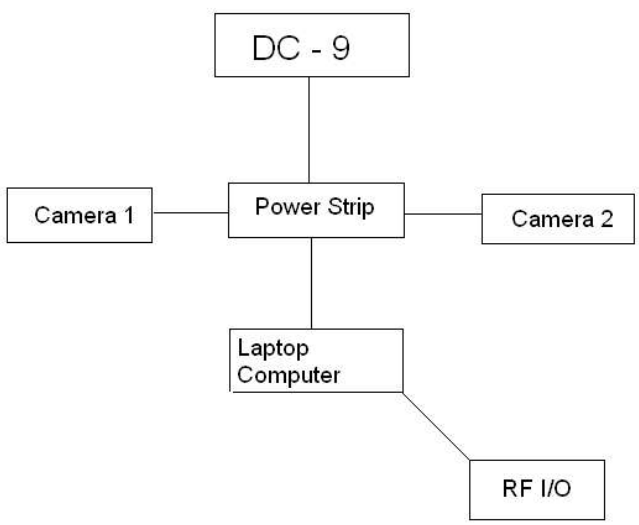


Figure 3. External electrical schematic

VI: Pressure Vacuum System

No component of the experiment is pressurized.

VII: Laser System

No lasers contained in this experiment.

VIII: Crew Assistance Requirements

Because the satellite will be in free-float, it will be apt to translate though the cabin during the various phases of the flight. For this purpose, we have opted to install small thrusters to maintain the satellite's position within the cabin. However, in case this method proves inadequate, we may require assistance with keeping the satellite within our designated area.

No assistance will be required while on the ground.

IX: Institutional Review Board (IRB)

No review by IRB board will be required. No biological specimens will be used.

X: Hazard Analysis

HAZARD SOURCE CHECKLIST
(Enumerate or mark N/A)

N/A Flammable/combustible material, fluid (liquid, vapor, or gas)
N/A Toxic/noxious/corrosive/hot/cold material, fluid (liquid, vapor, or gas)
N/A High pressure system (static or dynamic)
N/A Evacuated container (implosion)
6 Frangible material
N/A Stress corrosion susceptible material
N/A Inadequate structural design (i.e., low safety factor)
N/A High intensity light source (including laser)
N/A Ionizing/electromagnetic radiation
7 Rotating device
N/A Extendible/deployable/articulating experiment element (collision)
4 Stowage restraint failure
N/A Stored energy device (i.e., mechanical spring under compression)
N/A Vacuum vent failure (i.e., loss of pressure/atmosphere)
N/A Heat transfer (habitable area over-temperature)
4 Over-temperature explosive rupture (including electrical battery)
N/A High/Low touch temperature
N/A Hardware cooling/heating loss (i.e., loss of thermal control)
N/A Pyrotechnic/explosive device
3 Propulsion system (pressurized gas or liquid/solid propellant)

N/A High acoustic noise level
N/A Toxic off-gassing material
N/A Mercury/mercury compound
N/A Other JSC 11123, Section 3.8 hazardous material
N/A Organic/microbiological (pathogenic) contamination source
8+ Sharp corner/edge/protrusion/protuberance
N/A High voltage (electrical shock)
N/A High static electrical discharge producer
1 Software error
N/A Carcinogenic material

Flammable/combustible material or fluids

N/A- No flammable materials is used in the experiment or experimental setup.

Toxic/noxious/corrosive/hot/cold material or fluids

N/A- No such materials are used.

High pressure system

N/A- No high pressure systems are used.

Evacuated container

N/A- None of the containers are evacuated.

Frangible material

6- The only breakable materials used in this experiment are the Plexiglass sides of the device, but breakage is not probable. The Plexiglass used will be of sufficient strength to withstand small impacts within the cabin.

Stress corrosion susceptible material

N/A- No part of the experiment will be susceptible to stress corrosion.

Inadequate structural design

N/A- The experiment has been designed such that there are no safety factors that are inadequate.

High intensity light source

N/A- No high intensity light sources are used in this experiment.

Ionizing/electromagnetic radiation

N/A- No radiation is involved.

Rotating device

7- Fans and flywheels will be inside the satellite. They will be completely contained so no risk of contact is present.

Extendible/deployable/articulating experiment element

N/A*- No extendable/deployable/articulating parts are used, however, the whole experiment is free floating.

Stowage restraint failure

1 - Possible restraint failure may involve the two cameras that are used for data capture and other electrical devices (i.e. circuit, computer). These devices potentially could become dislodged from the apparatus and be thrown outside the experiment.

To ensure that this will not be a problem, the devices will be secured with several cargo straps and locking devices. These precautions will ensure that the devices do not become disconnected.

Toys used for educational outreach will also pose a stowage restraint failure threat. These devices will not be dangerous and care will be taken when they are used.

Stored energy device

N/A - The only stored energy device will be the flywheels. The energy stored in them will be minimal, and they will be contained within the satellite enclosure

Vacuum vent failure

N/A- No vacuum is used.

Heat transfer

N/A- No large sources of heat are used.

Over-temperature explosive rupture

4 - Both cameras and the laptop will use their standard batteries as a back-up in case of electric disruption aboard the DC-9.

The free-floating satellite will be powered using an array of 12V batteries. They will be wired in parallel for maximum current draw and will be selected to ensure that their maximum rated current draw is never exceeded.

All batteries are UL certified and are not expected to pose any problems.

High/Low touch temperature

N/A- No high/low touch temperature systems will be used.

Hardware cooling/heating loss

N/A- Change in temperature is not used in this experiment.

Pyrotechnic/explosive device

N/A- No such devices are part of the experiment.

Propulsion system

3- Three fans will be situated on the satellite body with the purpose of maintaining a constant position of the satellite with respect to the cabin. At full power, these fans will produce only the minimum amount of thust necessary to keep the satellite stationary withn the cabin.

The satellite will have only around 10 kilograms of mass. The thust required to provide small accelerations to this mass will be minimal. Such a thrust would not be capable of overpowering a human.

High acoustic noise level

N/A- Noise level will be at a minimum. No electric devices that may cause loud noises are used.

Toxic off-gassing material

N/A- No such materials are used.

Mercury/mercury compound

N/A- No such materials are used.

Other JSC 11123, Section 3.8 hazardous material

N/A- No hazardous materials are used in the experiment whatsoever.

Organic/microbiological (pathogenic) contamination source

N/A- No microbiological organic materials are used. A pathogenic contamination is not a problem.

Sharp corner/edge/protrusion/protuberance

8+ - Edges and corners of the experiment may be sharp or rough. During microgravity, experimenters may accidentally bump into the side of the apparatus.

To prevent any collisions with the sharp edges, padding will be attached to all every side of the experiment. Padding will be secured with tape after the experiment is finalized and about to be loaded onto the aircraft.

High voltage

N/A- No appliances that would produce high voltage are used.

High static electrical discharge producer

N/A- No device that would create such a charge is used.

Software error

1 - There is a small risk of software error that may render the flywheels or fans uncontrollable. In this case, remember that the force of the flywheel motors as well as the thrust from the fans will not be large enough that the satellite would pose a threat in such a condition. As discussed in propulsion systems above, the fans will only be delivering a minimal amount of thrust.

In case of partial software malfunction, a command can be issued to the satellite to cease and desist all motor activities. However, if this also fails, a master kill switch will be placed prominantly on the outer satellite body. This switch will ensure that power is cut off to all circuitry and actuators within the satellite. A similar master kill switch will be provided to shut down the external electronics.

Carcinogenic material

N/A- No carcinogenic materials we be used.

XI: Tool Requirements

An inventory of tools to be brought to the Reduced Gravity Facility will be limited to the following list:

1 set of 8 Standard English hex wrenches
1 Philips screwdriver
1 Standard screwdriver
3 Crescent Wrenches
2 ½" Ratchet
Duct Tape

The remainder of the tools inventory will consist of a small variety of accessories that will include set screws, bolts, nuts, and washers. All tools and accessories will be stored in a toolbox.

No tools will be necessary for in-flight use.

XII: Ground Support Requirements

We will require 120V power connections to test our experiment. No other ground support is required.

XIII: Hazardous Materials

No hazardous materials contained in this experiment.

XIV: Procedures

i. Ground Operations

The experiment will be shipped to Houston in its completed state. All parts of the experiment will be previously constructed and ready to go out of the box. Parts will be tested and determined to be ready for flight. There will be little to no operation on the ground aside from testing.

ii. Pre-Flight

This experiment should not require any pre-flight preparation.

iii. In-Flight

During the flight, the computer will be turned on and the appropriate software will be loaded and run. Using this software, we will run the experiment, manipulating the satellite to our liking. The satellite will be autonomous, so the crew will only have to interact with the computer. Even so, such interaction will be minimal. The computer will make all necessary adjustments to the control method being used.

During flight will be our first full test of the thruster implementation. If this method proves inadequate, then our main task during the flight will be manually adjusting the satellite's position as it leaves the view of the cameras.

iv. Post-Flight

After the first flight, data from the cameras will be collected and stored. The cameras will be prepared for a second flight. Once all the data has been collected, it will be analyzed on the ground. Quantitative results will be collected from analysis of speed, accuracy, and efficiency of the satellite's movements using the different control methods. A final report will be submitted containing the results of the experiment and all Educational Outreach activities.

Educational Outreach Plan

I. Objective

Educational Outreach is a high priority of Float'n Illini. Our two main focuses are promoting interest in space exploration as well as NASA sponsored events and activities.

With the landing of the Mars rovers and the recent Xprize competition, interest in space exploration and NASA has intensified. As such, it is important that these interests continue to thrive. In order to accomplish this, Float'n Illini has created several programs designed to meet the needs of specific audiences. The K-8 program focuses on sparking interest in space exploration and science. On the high school level, the team teaches more abstract physical concepts (in a classroom setting), presents research done by the team, promotes NASA sponsored events to teachers, and encourages students to be actively involved in science related fields. The final program focuses on adults and provides Float'n Illini with a way to promote experiments and also with opportunities NASA provides. Each of these programs will be discussed in detail in Section III.

With any outreach program comes a great opportunity for Float'n Illini to educate our audience about NASA and its numerous programs. By fueling the dreams of younger students, we hope to actively engage the next generation in space exploration. Through our dedication and hard work, we are able to fulfill our own dreams of working and researching with NASA.

II. Website (http://www.ae.uiuc.edu/floatn/)

The Float'n Illini Educational Outreach programs are accessible to the general public through our team website. It is a way for us to highlight past and present events as well as our team's involvement in RGSFOP. Our website provides teachers and other educators with detailed information about our organization as well as our extensive educational outreach programs. It also provides teachers with a means to request presentations by filling out an online request form (this portion of our website is currently under construction). The website is just one way that Float'n Illini is able to aid students, teachers, and community members in finding information about the team, the experiments, and NASA.

a. *Educational Outreach* - The Educational Outreach page specifically details our mission statement, framework, awards, and presentations. It also provides contact information, along with a page for teachers, and a page for the press. The mission statement and the framework state the objectives of the program and how those objectives will be accomplished. The presentations section outlines upcoming outreach activities. The link page also allows people to access several exceptional sites on space exploration and other science related material.

b. *Acknowledgements* - It is only through the generosity and support of University Departments, local business, industry, and individuals that Float'n Illini is able to achieve all of our goals. The acknowledgement page recognizes those who have assisted Float'n Illini.

III. Specific Audiences

As mentioned earlier, Float'n Illini has designed three programs dedicated to meeting the needs of three specific types of audiences. The goal of each of these programs is to present material on space exploration and microgravity research in an exciting and educational manner. Each program is outlined in more detail below.

A. Grades K-8 at Local Schools

On the K-8 level, visually stimulating and interactive demonstrations are used to convey information. Some of the lesson plans used by the Float'n Illini are based off of NASA and the National Air and Space Museum education materials. One of the presentations involves a drop tower which is used to demonstrate concepts of gravity. Film canister rockets (“Pop Rockets”) using antacid tablets and water demonstrate Newton’s Three Laws of Motion along with rate of reaction principles. Finally, paper airplanes workshops relate basic concepts in aerodynamics. The basic goal of the outreach programs at this level is to help younger students experience the excitement and fascination of space exploration and scientific fields in general.

B. High School Students

At this stage, most young adults begin to seriously consider their future education and career options. This presents Float'n Illini with a great opportunity to encourage those students to pursue careers in math, science, and engineering. In presenting our research, students have the opportunity to learn about the research process and also find out the results of each of our experiments. To ensure that all relevant topics are covered NASA’s publication, “*Micro-gravity - A Teacher’s Guide with Activities in Science, Mathematics, and Technologies”* is often used.

C. Adults such as Professors, Community Members, and University Students

Adults in the community play a big role in the research of Float'n Illini. They have a positive impact on NASA through their support of space exploration and microgravity research. The presentations for this audience focus on the current research in microgravity and also future research. Another main focus is the achievements made by NASA in space exploration. These presentations also provide the Float'n Illini with an opportunity to learn about other research opportunities.

IV. Educational Outreach Activities

As shown through each of the programs provided, a versatile array of media and demonstrations are used to convey concepts related to space exploration. Each of the presentations attempt to stimulate interest in space and introduce students to challenging scientific problems. These presentations, used to engage students, are described in detail below.

Drop Tower

Float'n Illini's primary purpose is to conduct microgravity research. It is important, therefore, that outreach presentations highlight concepts of gravity, using demonstration tools that simulate microgravity in a way that is "physically real." The Float'n Illini Drop Tower is one way this is accomplished. The drop tower is approximately eleven feet, six inches tall, yielding up to 0.86 seconds of micro-gravity in the payload's reference frame. A video camera, mounted inside the payload box with the video feed set to a frame advance VCR, provides viewers with a chance to see the brief .86 seconds of micro-gravity. These payloads include magnets, postage scales, and capillary tubes. Fully portable, the drop tower can be taken anywhere and assembled in minutes. This makes the drop tower a popular and very effective resource helping students to understand the concept of micro-gravity.

Newton's Rockets

One of the most exciting presentations conducted involves rockets. For students in elementary school, antacid tablets and water are used to create small paper rockets which we refer to as “Pop Rockets“. This demonstrates concepts such as Newton’s Three Law’s. Older students are able to go more in depth, learning about rocket motion, rates of reaction, and conservation of momentum. On the high school level, small model rockets are used to demonstrate concepts. Students are encouraged to apply their knowledge of kinematics in order to calculate rocket trajectories.

Paper Airplanes

Paper airplanes are one way that Float'n Illini explains the four principles of flight. Many of the Float'n Illini team members are Aerospace Engineering majors, and have been very enthusiastic about sharing knowledge about flight mechanics with younger students. Each student designs their own paper airplane after Float'n Illini members explain the concepts of lift, weight, thrust, and drag. This gives the students practice in using these concepts as well as following instructions. Later on, students also experiment by adding a paper clip to their plane, teaching them the concept of center of mass.

Lunar Colony

This activity combines a variety of fields including social studies and science. The entire class discusses what would be necessary for a community (food production, housing, waste management, etc.) to survive on the moon or Mars. The class is then divided into small groups. Each group designs one component of a lunar colony out of recycled materials such as Styrofoam balls, Popsicle sticks, pipe cleaners, and clay. As the students combine the modules to create the lunar colony, they talk about the needs their module fulfills and their design process.

In-Flight experiments

During the 2004 RGSFOP, the Float'n Illini conducted several educational outreach experiments onboard the KC-135. "Newton's Laws: That's the way the Apple Falls" is designed to help students understand concepts relating to gravity. By filming an object on a scale students are able to understand the difference between mass and weight. For more advanced students, an experiment was conducted involving a spring chamber and a billiard ball. The billiard ball was "launched" along a wire with the help of the spring. By knowing the spring constant, students are able to study conservation of energy. Through the study of kinetic energy, the mass of the ball can be determined. Also demonstrated was the concept of conservation of angular momentum through a system of gyroscopes. The experiments were all video taped. One of our main Educational Outreach goals this year is to edit the tapes and create videos that will be used in high school presentations. Each of the demonstrations from our experiment will be used in creating interactive lessons plans that will be presented to area schools.

V. Recent Educational Outreach Efforts

Float'n Illini is very proud of the strong tradition of excellence in the educational outreach program. Not only does Float'n Illini visit schools, members also visit scouting groups and participate in Space Day and the University of Illinois' Engineering Open House.

Outreach Programs

Robeson Elementary School
October 7, 2003
Champaign, IL

The first educational outreach event of the school year was at Robeson Elementary. Float'n Illini was welcomed by third and fourth grade students. The students were separated into groups. One group discussed the difficulties of going to Mars, while the other group moved outside to learn about rockets. The students thoroughly enjoyed the experience of seeing the model rockets fly.

Bottenfield Elementary School
November 4, 2003
Champaign, IL

The teacher's at Bottenfield asked the Float'n Illini to come and instruct their third and fourth grade classes about Mars. At the time, the classes were learning about the solar system. The students then played a game where they had to decide what supplies should be taken on a trip to Mars. After their decision, they were to build a fully functional Mars Colony. The colony had to have power generating abilities, life support, and research facilities.

Leal Elementary School
November 12, 2003
Urbana, IL

Float’n Illini members went to Leal Elementary to teach the concepts of rocket propulsion. However, since they were English as a Second Language students, we decided to do Pop Rockets as a more “hands-on” project approach. For the first half of the presentation, the students built pop rockets. While the students were building pop rockets, Newton’s Three Laws were discussed. This way, the students would have a better understanding of how a rocket works. The second half of the presentation was spent launching them. The lesson taught the students the very basics of propulsion and Newton’s Laws.

King Elementary School
December 10, 2003
Urbana, IL
The teacher in Leal that contacted us also taught ESL at King. She enjoyed the presentation so much, she invited Float'n Illini to come to King Elementary. The presentation given was the same presentation given at Leal Elementary.

Thomas Paine Elementary School
February 27, 2004
Urbana, IL
Winter conditions limited our number of presentations for a few months. However, when a break finally came in the cold weather we started up again with presentations. At Thomas Paine, we taught the students to make pop rockets while teaching them the concepts behind rockets.

Franklin Middle School
March 5, 2004
Urbana, IL
At Franklin Middle School the Float'n Illini got a chance to show off the drop-tower. Newly improved, the drop-tower was a great success. From this experience we gained valuable information on creating more effective lesson plans. The students were a joy to work with.

Boy Scout Merit Badge Seminar
Holy Cross School
March 6, 2004
Float'n Illini was invited to give a presentation at a Boy Scout Merit Badge Seminar. The Float’n Illini teamed up with the Illinois Space Society and gave a very successful presentation. Our two societies covered a variety of subjects throughout the presentation including facts about the solar system, Mars, rockets, Newton’s Three Laws, and discussed what one might need to develop a Lunar Colony. This event was a huge success.

University of Illinois
Engineering Open House
March 12 and 13, 2004
The University of Illinois’ Engineering Open House attracts over 30,000 visitors each year. It is an opportunity for the Float'n Illini to showcase our research.

Visitors to the Float'n Illini booth learn about the organization, and have the opportunity to attend research talks about the educational outreach and astrobiology experiments. Visitors also see the drop tower in action. The 100th anniversary of flight was celebrated by designing and flying paper airplanes. Everyone also had the opportunity to become a rocket scientist by building antacid film canister rockets. The film canister rockets were especially exciting. Some reached the ceiling of the 40 foot high lecture hall. All told, Float'n Illini probably attracted more than 1000 visitors. Over 300 film canister rockets were launched and over 150 paper airplanes made. People of all ages enjoyed the presentations and hopefully learned some interesting and fun facts. This year, Float'n Illini received three Engineering Open House awards at the Knights of St. Patrick Ball. The paper airplane presentation won second place in the "Hands on Learning: Just for Fun," category. The pop rocket presentation won third place in that same category. Finally the Astrobiology presentation received third place in the category "Non-Technical Presentation."

VI. Educational Outreach Contacts

Each of the following schools has been contacted by the Float'n Illini and has expressed interest in having the Float'n Illini come and give a presentation.

Vernon Barkstall
Elementary Bottenfield
Elementary Carrie Busey
Elementary Dr. Howard
Elementary Garden Hills
Accelerated School Kenwood
Elementary Marquette School
Robeson Elementary
South Side Elementary
Kenneth Stratton Elementary
Martin Luther King Elementary
Leal Elementary
Prairie Elementary
Thomas Paine Elementary
Booker T. Washington Elementary
Westview Elementary
Wiley Elementary
Yankee Ridge Elementary
Edison Middle
Franklin Middle
Jefferson Middle
Urbana Middle
Centennial High
Central High
Urbana High
University Lab High
Unity High

Oakwood High

VII. Media

Our Educational Outreach program has received publicity from several media outlets. The campus newspaper The *Daily Illini* wrote two articles on the Float'n Illini last year. We are also currently in close contact with *The News Gazette* of Champaign. We intend on contacting several media outlets in the community to publicize our educational outreach program.

Administrative

The Float'n Illini are willing and able to comply with all of the program requirements. This team will pay close attention to the program timeline and deadlines and will comply with all requests to provide information to any of the Program Coordinators.

III. Institution Letter of Endorsement

Please see next page (original copy only)

IV. Statement of Supervising Faculty

Please see page following next (original copy only)

Funding Budget Statement

IV. Institutional Review Board (IRB)

Not Applicable

V. NASA/JSC Human Research Subject Consent Form

Not Applicable

VI. JSC Institutional Animal Care and Use Committee (IACUC)

Not Applicable

VII. Parental Consent Forms

N.A. All team members are age 18 or over.

Appendix

I. Material Safety Data Sheets

N.A. No hazardous materials are being used

II. Sample Education Outreach Presentation

This handout gives instructions and plans for kids to build pop rockets at home, explain some underlying scientific principles, suggests ideas for further experimentation, and lists educational, space-related websites for kids.

Build a Pop Rocket at Home

Here are instructions so that you can build another pop rocket and try to launch it even higher.

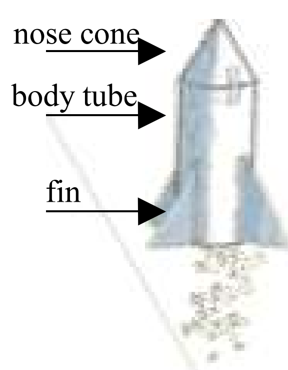
First, gather the materials you will need

4- Fugi film canister[1]
5- Rocket pattern
6- Scissors
7- Cellophane tape (scotch tape)
8- Colors (markers, crayons, or colored pencils)
9- Effervescing antacid tablets[2]
10- Water

1) The film canister must have a lid that snaps to the inside of the rim of the canister. If you need a Fugi film canister, try asking photo shops for empty canisters. If they have any, they will usually give them to you for free.
2) Only the fizzing antacid tablets, like Alka-Seltzer work. The chewable calcium antacid tablets don't release the gas needed to propel the rocket.

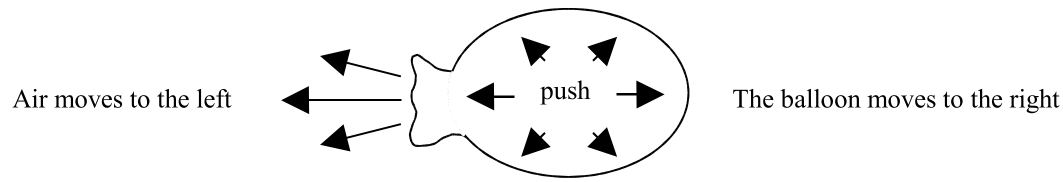
Second, learn the parts of a rocket

The pointed tip of the rocket is the nose cone. The streamlined shape of the nose cone helps reduce drag. Drag is air resistance, which slows down the rocket. The nose cone attaches to the cylindrical tube called the body tube. The engine is inside the body tube. The fins attach to the outside of the body tube and help stabilize the rocket. The engine in your pop rocket is the film canister and the fuel is antacid and water.



Third, understand how a rocket flies

The rockets that launched astronauts to the moon work the same as the pop rocket you will build. An un-tied balloon can be a very simple rocket. When you untie the end of the balloon and let it go, the balloon will fly until all of its fuel (the air inside) is used up. The air inside pushes out on the sides of the balloon in all directions, but can only escape through the open end.

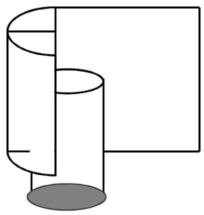


The law of action and reaction describes the movement of the balloon and other rockets. For the balloon, the action is the air escaping and the reaction is the balloon moving to the right. For pop rockets and real rockets, the action is the gas being pushed out of the engine and the reaction is the rocket launching into the air. When the fuel (antacid and water) in your rocket reacts, a lot of gas is produced. The gas presses out on the canister on all sides until it pushes the lid off of the canister and the rocket into the air. The rocket continues to be pushed upwards until the all the fuel is used up or falls out.

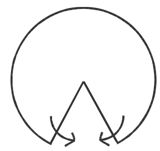
Fourth, assemble the pop rocket

Now that you know the parts of a rocket and how it flies, you are ready to build your own:

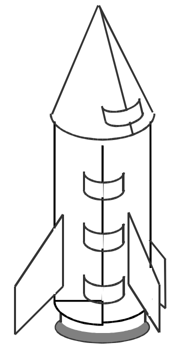
- Cut out and color all the pieces of the rocket pattern.
- Wrap the rectangular piece for the rocket body around the film canister. Tape the paper to itself, not to the film canister. Make sure that the lid of the film canister is showing.
- Form the circular nose cone piece into a cone and tape it together. Bring the two ends together and overlap them.
- Tape the nose cone to the top of the rocket.
- Choose how many fins you want and tape them to the rocket body.



Wrap the rocket body around the film canister.



Form the nose cone.



Your rocket should look similar to this design.

Fifth, launch the pop rocket

Be safe, have an adult help you launch your pop rocket. Wear safety goggles or sunglasses when launching the pop rockets to protect your eyes. The pop rockets can fly up to 15 feet high and are a little messy, so launch them outside on a flat, hard surface like a sidewalk. You will need two people to launch a pop rocket.

4- Put the film canister engine inside the rocket body with the lid end sticking out.

5- Test to make sure that you can quickly put the lid on tight. An adult might have to help you with this step.

6- Crush one antacid tablet into a fine powder.

7- Turn your rocket upside down, take off the lid, and pour the antacid into the film canister.

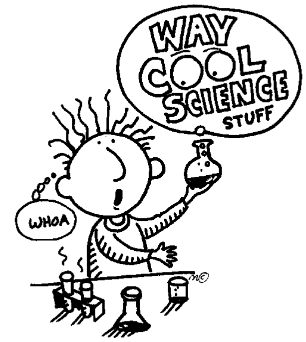
8- Have your partner fill the film canister 1/4th of the way with water.

9- Quickly, snap on the lid. Make sure it fits on securely.

10- Stand your rocket up on the ground and step back. Begin the countdown sequence. 10, 9, 8, . . . The rocket will take between 10 seconds and 1 minute to launch.

11- Watch and see how high your rocket flies and how long it stays in the air.

Sixth, Further experimentation ideas



If you want to be a real rocket scientist, experiment with your rocket design to see how many different rockets you can build. Here are a few ideas to get you started.

- Try a different number of fins or different shaped fins
- Vary the amounts of water and antacid
- Change the water temperature
- Try using a whole antacid tablet instead of a crushed one
- Use a different container for your rocket body. Try one of the miniature m&m containers. Use your imagination

Seventh, more resources

- http://www.aae.uiuc.edu/floatn - the Float'n Illini website.
- http://www.spaceplace.nasa.gov - make and do spacey things
- http://www.lpi.usra.edu/education/EPO/fun_w_sci.html - more project ideas
- http://www.howstuffworks.com/rocket.htm - learn more about rockets.