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## Paper Session I-D Leveraging Space for Improved Science Programs

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# **Leveraging Space For Improved Science Programs**

## **An Example of How Industry May Contribute to Improving Science Education**

Robert B. Friend

### Abstract

This paper provides an overview of a program at Boeing's Reusable Space Systems unit which was created and designed to show educators and students how science and engineering classes, lessons, and education can be made "fun" while teaching not only basic scientific principles, but how the principles may be applied in the real world. This program, called DiscoverE, for Discover Engineering, is an offshoot of the national program administered by the National Engineers Week organization which is comprised of several corporate affiliates, of which Boeing is one. The Discover Engineering program at Boeing-RSS consists of three basic segments and is a year-round activity. The three segments are an Educator Enrichment Day (EED), classroom visitations by Boeing engineers, and a Summer Science Camp. EED is normally scheduled to coincide with Engineers Week in February, and provides over 500 elementary and middle school educators with lessons, lesson plans, and access to resources with which they may not have been familiar. Science Camp is scheduled annually over three consecutive Fridays and Saturdays in July and August and typically has over 200 participants. Classroom visitations by engineers occur on an as requested basis year-round. The program leverages the expertise of the engineers, the corporate presence of Boeing, access to space related resources, and volunteerism to create a showcase program that, judging by reviews of the educators and students touched, is very successful. The program is described, workshop outlines and sample lessons are provided, and a student project which flew on the Space Shuttle is described.

### **Introduction**

One of the pioneers of the space industry, Dr. Robert H. Goddard once said, "It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow." We, both government and industry, need creative and inventive people to develop the new technologies and innovations to improve our future.

A significant downturn in graduates with technical degrees, and a downturn in interest in the technical fields in general was experienced in the late 1980's and early 1990's. The results of research performed by several organizations led to the conclusion that there were multiple reasons for this downturn, with a major one being lack of interest in math and science subjects. It was found that students typically begin to lose interest in these subjects at an early age, many prior to 5th grade. By the time these students graduate from high school, they have taken so many fewer math and science courses, that they are prevented from pursuing science and engineering majors in college. This loss of interest is directly traceable to lack of resources, both material and financial, on the part of the schools, and to the lack of specialized education on the part of the classroom instructors<sup>1</sup>.

In 1992, in recognition of this fact, and that qualified technical graduates are critical to the survival of any high technology corporation or organization, the Engineering organization at Boeing's (at the time Rockwell's) Reusable Space Systems (RSS) business segment began to participate in the national Discover Engineering program. This national program promotes science and engineering careers, primarily during Engineer's Week in February, and involves classroom visits by engineers and distribution of lesson plans and activities to educators.

### **Discover Engineering at Boeing RSS**

The mission of the RSS Discover Engineering program at Boeing RSS is to arouse and foster the inquisitiveness of elementary and middle school students and their instructors in the areas of math, science, and engineering through hands-on activities so that the instructors will

feel comfortable with the concepts they are teaching, and so that the students will actively pursue careers in the mathematical, scientific and engineering fields.

Given this mission, it was felt that the Discover Engineering annual program was not comprehensive enough. Rather than relying on classroom visitations during Engineers Week, a program, called DiscoverE, now in its seventh year, was designed with the mission as its goal, supported by three legs. These legs consist of an Educator Enrichment Day for instructors, classroom visitations by engineers and scientists from Boeing, and a Summer Science Camp for students. It was felt this approach would result in a program with a more significant and longer lasting impact.

Educator Enrichment Day is aimed at providing hands-on exposure to mathematics and science for elementary and middle school teachers. The Discover Engineering team felt that the best way to “turn on” the maximum number of students was through their teachers. At the annual Educator Enrichment Day, teachers learn innovative methods of presenting math and science concepts. The teachers attend workshops that range in topics from flight to team building. Everything from “What Makes a Doorbell Work” to “Living and Working in Space” is explored. Participants are each given “how to” kits and lessons to take back to their own classrooms to share with their students and fellow teachers. From an original 21 workshops presented to 250 teachers representing 147 schools in 1992, this portion of the DiscoverE program has grown to 28 workshops presented to 520 teachers from 240 schools.

The second part of the Discover Engineering commitment to education involves sending engineers, scientists, and other professionals into the local schools to present motivational programs, share activities for gifted students, act as science teachers for a day, perform one-on-one counseling, participate in science fairs, and perform numerous other support activities. It is the aim of the Discover Engineering program that these visits inspire and motivate students to excel in all their academic pursuits. In 1992 there were a total of 48 classroom visitations performed by Boeing employees and, since 1992, Discover Engineering volunteers have made over 300 school and classroom visitations.

The third part of the overall Discover Engineering Program involves sponsoring a Summer Science Camp program, during which the students learn difficult science concepts through fun hands-on experiments. From an original 6 workshops presented to 84 students in the 3<sup>rd</sup>-9<sup>th</sup> grades the program has evolved to 12 workshops and 270 students in the 3<sup>rd</sup> -12<sup>th</sup> grade levels.

Response to this approach to the Discover Engineering program has been overwhelming, from both educators and students. Evidence of this are the many testimonials from excited parents, teachers, and children stating that, on their own initiative, the students have used these activities as stepping stones to investigate the fascinating worlds of math and science.

The DiscoverE program, would not be possible without extensive contributions by Boeing and community volunteers of their time, expertise, and materials. A virtual army of volunteers is required to ensure that the program is successful. Between 180 and 300 SSD employees volunteer up to 10,000 hours annually, supporting and participating in one or more of the three programs. For some events, such as the Summer Science Camp, over 130 community volunteers give of their time and service. Contributions in various forms are also made by over 30 other corporate entities, including The Von's Company, ITT Canon, Frito Lay, Lego/Dacta and HobbyShack Enterprises.

## **Foundations**

The basic foundation of the DiscoverE program is the workshops developed by volunteers interested in participating in the program. Most workshops are designed to apply to multiple levels of difficulty, making them applicable to a wide age range of students. For example, where a fourth grade class may be presented with a simple explanation or demonstra-

tion of Bernoulli's principle, higher grades may be presented with root fluid dynamics concepts and Bernoulli's equations, as well as equations to determine lift and drag.

This wide applicability of the workshop serves two primary purposes- to satisfy the demands of teachers across multiple grade levels who participate in the Educator Enrichment Day activities, and to support presentation at the Summer Science Camp where students in a single class may range from 5th to 9th grade levels. In these classes, older students often assist some of the younger students in completing projects or problems, helping to develop team building and cooperative skills and incidentally showing the younger students that there are reasons to learn some of the more difficult math and science concepts in their classes. Normally, it is left to the individual instructor to tailor the lessons contained in the workshop to their student audience.

When a workshop is developed, it must meet several criteria, some imposed by the DiscoverE program administrators, and others imposed due to requests from educators. Each workshop is developed using the National Science Education Matrix, the mathematics portion of which is excerpted in Table 1. The applicable blocks are checked by the workshop developer. This matrix, along with a workshop outline provided by the workshop developer such as that following Table 1, is used by program administrators to guide student participants into workshops that will most apply to their grade level, and by teachers when they are selecting which workshops that they would like to attend on Educator Enrichment Day.

Other requirements specified by the program are that each workshop should be designed to contain one hands-on activity for every ten minutes of lecture, and experiments and demonstrations in each workshop must have clear, concise explanations of what the experiment is showing, what scientific principles are being demonstrated, and step-by-step instructions. Additionally, as a budgetary consideration, the materials required to perform the activities in the workshop should be inexpensive and readily available. A example lesson from the FUNdamentals of Flight workshop is shown following the workshop outline.

*Insert Science\_Ed.xls here, reduced to 2.5" width*

### **Table 1- National Science Education Matrix**

#### **Sample Outline: FUNdamentals of Flight**

In this workshop, over the course of six days, students will learn the history of flight, beginning with lighter-than-air craft, and continuing with airplanes, helicopters, and rockets. Workshop activities include constructing and racing an airship, various lessons demonstrating Bernoulli's principles, making smoke tunnel test articles, building wing sections for testing in a home built wind tunnel, and building hand launched and rocket powered gliders. Complete instructions are provided for teachers to perform all of the activities in the classroom, including instructions for making simple smoke and wind tunnels. For Educator Enrichment Day, a highly compressed two hour version of the workshop is presented and activities include building and racing airships, wind and smoke tunnel demonstrations, activities demonstrating buoyancy and lift, and how aircraft control surfaces work.

#### **Sample Lesson: Buoyancy Demonstration/Activity**

Buoyancy is the property of an item that relates its density to the density of what surrounds it. *Density* is how much something weighs compared to the *volume* it displaces (space it takes up). For example, 1 cubic centimeter of water weighs 1 gram, so its density is 1 gram per cubic centimeter (1 gm/cm<sup>3</sup>). The density of steel is about 5 gm/cm<sup>3</sup>, so steel is five times more dense than water.

Buoyancy can be changed by changing how much an object weighs without changing the volume or space it takes up (like a submarine), or by changing the volume of the object without changing its weight (like a blimp). This experiment demonstrates these two concepts. Using the submarine analogy, by adding alcohol to the water you are increasing the density of the oil in relation to the “ocean” around it (water/alcohol mixture). Using the blimp analogy, you are decreasing the density of the “atmosphere” by adding alcohol to the water.

**Terms to learn:**

Positive buoyancy  
Negative buoyancy  
Neutral Buoyancy  
Density  
Equilibrium  
Volume  
Miscible

**Materials Required**

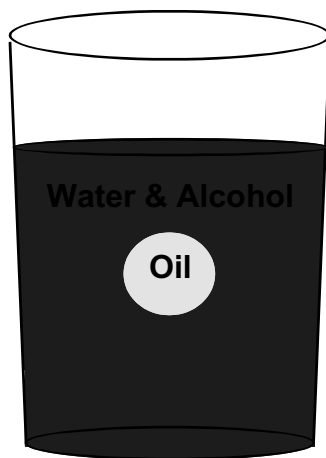
Vegetable Oil  
Isopropyl Alcohol (Rubbing alcohol)  
Water  
500 ml Beaker or clear glass jar  
Tablespoon  
Eyedropper

**Step 1**

Pour 1 Tablespoon of cooking oil into the jar with the water. Now, slowly pour about 150ml of water into the clear class beaker or jar.

**Results**

The oil floats on the water.



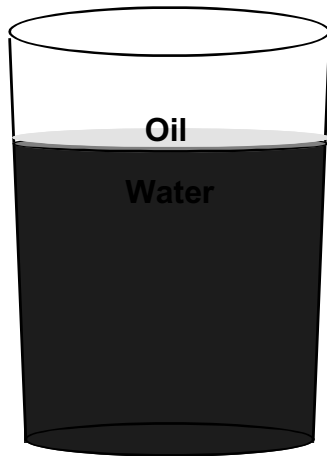
**Figure 1 Oil and Water in the beaker**

**Why?**

The oil has a lower density than the water so it floats on top. This is what happens with a helium balloon and the air. The balloon weighs less than the air it displaces so the forces acting on it make it go up. When the balloon rises, it is exhibiting *positive buoyancy*.

**Step 2**

We will now try to make a solution in which the oil is neutrally buoyant. Using the eyedropper or a teaspoon, slowly add alcohol to the water/oil solution.



**Figure 2 Neutrally Buoyant Oil**

## Results

After adding quite a bit of alcohol, the oil will begin to form a ball and slowly begin to sink. When the oil begins sinking, stop adding alcohol, and *gently* stir the solution with a mixing rod or toothpick. If the oil sinks to the bottom, add a little more water. Eventually the oil ball should float suspended in the middle of the jar or beaker.

## Why?

Alcohol and water have densities that are very close, and their molecules have little surface tension. This makes them *miscible*, meaning they mix very well together. Alcohol is less dense than the oil. By adding alcohol to the water you decreased the density of the water by making a solution composed of both water and alcohol, and the oil started to sink. The surface tension properties of the oil molecules made it form a ball. By adding water or alcohol you can make the ball go up and down. When the ball is floating suspended in the middle of the water/alcohol mixture, it has *neutral buoyancy*. If it sinks it has *negative buoyancy*. This can be explained by relating it back to the balloon. The balloon will rise in the air until it reaches a state of *equilibrium* which means balance. This is when the force of gravity is equal to the force of buoyancy (*neutral buoyancy*).

Submarines adjust their buoyancy by pumping water in and out of their ballast tanks. This changes their weight without changing the space they take up (volume). Blimps adjust their buoyancy by pumping helium from their gas bags into small reservoirs. This changes their volume without changing their weight. By pumping helium out of the gas bags they sink because their volume decreased. If helium is pumped in, the blimp rises because the volume has increased but weight has not.

## The DiscoverE Space Experiment Module- “Fanning Falcons, Flying High”

In October, 1996, at a Cargo Integration Review for STS-85, it was learned that one of the GAS canister payloads would not be able to meet the mission integration milestones for installation. In place of that experiment, the SEM-02 payload was manifested. Since the manifesting of SEM-02 was unexpected, there were several open experiment modules available.

Boeing engineers at the Cargo Integration Review realized that this was an excellent opportunity to cooperate with students in the classroom as part of the DiscoverE Classroom Visitation program, and show them how lessons learned in school apply both to everyday life and to a typical Space Shuttle mission. These engineers, in cooperation with the sponsoring school, William E. Fanning Elementary, submitted a proposal to the SEM Project for evaluation. William E. Fanning Elementary School is in the Brea-Olinda Unified School District, and is a public K-6 school with approximately 620 students.

The Space Experiment Module (SEM) program is run from NASA's Goddard Space Flight Center, in Greenbelt Maryland, and has its roots in NASA's Shuttle Get Away Special (GAS) program. A SEM experiment consists of one or more passive or active experiments contained in a half-moon shaped module. These experiments are designed, built, and tested by students of all ages from kindergarten through university level, with teacher and/or mentor guidance. Once the experiments have been built and tested by the experimenters, the complete article is shipped to GSFC for integration by NASA technicians into the Shuttle SEM payload carrier system. This integrated assembly forms the SEM Payload for the shuttle mission for which it is manifested. A total of ten experiment modules are integrated into the SEM carrier for each shuttle mission for which SEM is manifested.

Following the shuttle mission, the SEM experiment hardware is returned to the experimenters accompanied by a "Certificate of Space Flight" and a copy of the measurement data collected during the mission from any active experiments that were in the module. Experimenters are requested to provide a copy of their postflight data analysis and reports to the NASA SEM Project. The experiment results and reports are then archived so that they may be available for future experimenters to reference.

Upon acceptance of the "Fanning Falcons-Flying High" proposal, the experiment design team, which consisted of 1 teacher, 2 Boeing North American mentors, and 19 first grade students, began flight and classroom experiment design.

The teachers responsibility was to teach the students the scientific principles involved in the experiment, as well as giving students exposure to the scientific method: hypothesizing, observing, and drawing conclusions. When constructing the ground-based testing apparatus, the role of the teacher and mentors was that of facilitators. The students were highly involved in a hands-on approach to this experiment. Students were responsible for constructing accelerometers (from kits) and conducting experiments themselves in the "real world" (i.e. in amusement park rides, the family car, and running races against each other).

The primary responsibility of the mentors was to provide technical support in the design, construction, and integration of the flight experiment, and support in design of the ground based accelerometer kits.

Two distinct experiments had been proposed, each complementing science unit curricula in the California FOSS (Full Option Science System). Each experiment had two components, a ground based segment, and a flight segment. The flight experiment is shown in Figure 3.

The primary experiment was an acceleration experiment, and supplemented the first grade Balance and Motion science unit by demonstrating to the students the principles of acceleration and gravity in a manner such that they could associate these principles with common events in their lives. In the Balance and Motion unit students discover many ways to balance objects, gaining an understanding of balance and stability. Students study rotational and translational motion through the construction of tops, flying spinners, and investigation of rolling objects. Students work together in teams to create ramps and runways to explore what they can do to affect the speed and longevity of rolling objects. The experiment gave students the opportunity to observe the effects of acceleration in several real-world settings, culminating with the experiment aboard the Space Shuttle. To accomplish the experimental purpose, it was

proposed that the individual students experience accelerations in various familiar situations and record measurements from equipment they themselves have constructed.

In the ground based portion of the acceleration experiment, the individual students performed measurements outside of the classroom using experimental apparatus they constructed in the classroom. This ground experiment apparatus was designed to be similar to the flight experiment apparatus in order to allow students to associate the phenomena they measured with the data to be recorded during flight. They measured and recorded accelerations experienced in a car during slow and rapid starts as well as gradual and rapid stops. The class also traveled to the Knott's Berry Farm amusement park where, with the park's cooperation, they took their accelerometers on various roller coasters, and recorded the accelerations they measured on these rides in order to compare them to the accelerations to be measured on the STS-85 mission. Measured data consisted of translational accelerations sensed by accelerometers constructed by the students. Using these measurements the student were able to directly compare accelerations in a space environment to those experienced here on earth. This was done in an effort to give significance to the flight experiment data, so that they could associate the flight results to the physical phenomena they have personally experienced in preparation for the flight experiment.

*Figure 3 not available*

### **Figure 3- Fanning Falcons Flight Experiment, SEM-02**

The Flight Experiment segment consisted of three separate hardware experiments designed to illustrate the effects of acceleration and gravity. These experiments had the following objectives:

- 1) Measure the maximum acceleration experienced by the apparatus (In theory, acceleration during the ascent flight phase).
- 2) Show the absence of apparent gravity in space through comparison of pre-recorded ground data with flight data from quiescent periods (No RCS firings) during the On-orbit flight phase.
- 3) Measure accelerations in the Orbiter X-axis during primary Reaction Control System translations.

The secondary experiment was a biology experiment designed to enhance a seed growing science unit by involving the students in a comparison between plants grown from seeds flown on the shuttle in SEM-02, on the NASA LDEF satellite (Long Duration Exposure Facility), and control seeds. In the ground based segment of the seed experiment, experiments are performed to compare the effects on tomato plants, grown from seeds of the variety "Rutgers", to exposure to a weightless space environment which has higher radiation levels than the normal Earth surface environment. These exposed seeds will be grown and compared at various stages of development with control seeds kept on the Earth. In addition, several hundred "Rutgers" tomato seeds flown on the Long Duration Exposure Facility (LDEF) payload were obtained. These will also be grown by the students and compared with the SEM-02 seeds flown on STS-85. The students use the Scientific Method to set up and carry out the experiment, following orderly procedures as much as their age and experience level allows. At the same time, upper level elementary, middle school and high school classes were invited to devise experiments to test for effects of various parameter variations from amongst the many samples of seeds collected, in order to widen the student experience, and benefit a greater number of students in the district. The flight apparatus consisted of two NASA supplied Space Capsules, each containing one-half ounce of Rutgers variety tomato seeds, an open pollinated, non-segregated variety of tomato selected on the advice of Dr. Jim Austin of the Park Seed



Company because it allows direct comparison between generation of plants, unlike hybrid varieties which will revert in later generations. The seeds were carried in the Space Capsules mounted to the SEM experiment baseplate, and are visible at the top of the baseplate shown in Figure 3. The Flight experiment segment was passive during the mission, the objective being only to expose the seeds to the weightlessness and space environmental radiation in the Shuttle cargo bay.

As an ongoing project, coordination efforts with Dr. Austin and Mr. Park regarding participation in future experiments already planned are being pursued. These experiments involve growing tomato seeds to be flown in an unpressurized GAS can several months following SEM-02 and comparing them to control seeds and seeds which have been exposed to the pressurized environment in an undersea habitat (Pressure>1 atmosphere). If coordination efforts are successful, samples of these seeds will be obtained by the experiment group for use in their comparison studies. The involvement of the entire school district will greatly increase the benefits from this experiment and, hopefully, enhance the learning experience for all involved.

### **Concluding Remarks**

In order to ensure a continuing supply of graduates in scientific and technical fields, and support society's current knowledge and technology base, it is necessary to keep the students enthusiasm for these subjects engaged until they make college and career choices. The Boeing approach to the Discover Engineering program is one that attempts to accomplish this. The three parts of our Discover Engineering commitment are designed to help students gain confidence in their abilities, cultivate a joy of the sciences, and develop self-respect. The program has directly touched over 2,600 teachers and 8,400 students directly through Educator Enrichment Day, classroom visitations, and Summer Science Camp. It is estimated to have potentially affected over 10,000 teachers and 200,000 students through distribution of the workshop lessons by teachers returning to their schools and classrooms, and teacher inservice presentations. It has been shown through this program that corporations like Boeing, with their access to talented volunteers and space and technology related resources can have both positive and powerful effects on educators and their students when these talents and resources are properly leveraged.

The dedication and commitment of the many volunteers of Discover Engineering cannot be underestimated. They make Discover Engineering a win-win for everyone — the students, teachers, community, and our customers. An important element of the Boeing's Vision 2016 is to be recognized as engaged, enthusiastic supporters of our communities. Scores of Boeing RSS employees and volunteers have certainly made a lasting contribution to the well-being of our communities through the Discover Engineering program. By relentlessly pursuing their own mission and expanding Discover Engineering's activities each year, they have helped RSS come that much closer to making its Vision the reality of tomorrow.

### **Acknowledgements**

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<sup>1</sup> A recent study released by the U.S. Department of Education reported that nearly 40% of teachers have neither a major or a minor in the subjects that they teach.