NASA KC-135A Reduced Gravity Undergraduate Program

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Abstract

The Johnson Space Center of the National Aeronautics and Space Administration (NASA) sponsors the Reduced Gravity Student Flight Opportunities Program. The highly competitive program affords undergraduate students the opportunity to propose, design, fabricate, execute, and evaluate reduced gravity experiments. NASA's KC-135A research aircraft flies multiple parabolic loops that simulate zero gravity for periods up to 25 seconds. Students and their reduced gravity experiments fly in the aircraft's cargo area.

In December 2002, a team of seven students from two North Carolina universities was selected to conduct reduced gravity aqueous diffusion experiments aboard the KC-135A. The students, from The University of North Carolina at Charlotte and the University of North Carolina at Pembroke, worked together on the project, collaborating via videoconferencing, email, and occasional face-to-face meetings. They successfully overcame the obstacle of the 120 mile distance between the institutions, and executed their experiments during multiple flights in April 2003.

As part of the project, the team performed numerous outreach activities. A highlight was bringing their test apparatus to local classrooms and having students perform some of the normal-gravity portions of their experiments. They later returned to the same classrooms with video of the same experiments performed in zero-gravity.

The team experienced some difficulties with their experiments, as might be expected in a first-year project, and submitted a proposal to continue for a second year. The proposal was accepted by NASA and work on design changes has already begun. This year's flights will take place April 15-24, 2004.

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Reduced Gravity

NASA's Reduced Gravity Program was initiated in 1959 to investigate the behavior of humans and equipment in a weightless environment. NASA adapted Boeing Aircraft's model 367-80 for the program, calling it KC-135A Stratotanker. The aircraft was based on the same basic design as Boeing's commercial 707 passenger plane. The Air force purchased the first 29 aircraft of its future fleet of 732 in 1954. The first aircraft flew in August 1956 and the initial production Stratotanker was delivered to Castle Air Force Base, California, in June 1957. The last KC-135A was delivered to the Air Force in 1965. The KC-135A continues flying today in support of the Reduced Gravity Student Flight Opportunities Program (Figure 1).

Figure 1 – KC-135A Aircraft

To generate the reduced gravity environment, the KC-135A flies parabolic curves that produce altered gravity for periods of 20 to 25 seconds (Figure 2). The parabolas can be varied to produce zero gravity, lunar (1/6) gravity, Martian (1/3) gravity, or nearly any other desired gravitational force. Approximately 80,000 parabolas have been flown in support of the Mercury, Gemini, Apollo, Skylab, Space Shuttle, and Space Station programs.

Student Flight Opportunities Program

Houston's Johnson Space Center sponsors the Reduced Gravity Student Flight Opportunities Program. Universities throughout the United States apply for the very competitive program where only 20% of proposals are typically accepted. Students submit proposals for reduced gravity experiments to be flown aboard the KC-135A research aircraft, which carries the nickname the "Weightless Wonder."

The competitive nature of the program results from the limited number of flights available. An obvious reason for the limited flight schedule is the direct cost involved, as well as the costs in administering the program. Another reason is that the aging

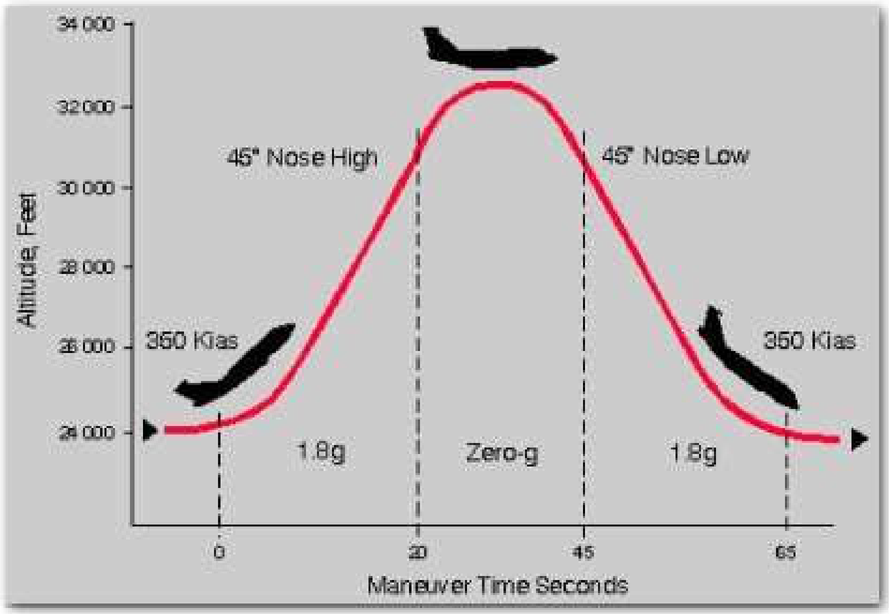

Figure 2 – Typical Reduced Gravity Flight Maneuver

KC-135A has a finite number of flights available before it will be retired by the Johnson Space Center.

The Johnson Space Center provides scheduling, test coordination, human psychological tests, and extensive in-flight instructions for the program. A typical mission lasts 2 to 3 hours and consists of 30 to 40 parabolas. The loops can be flown in succession or with short breaks between maneuvers to allow time for reconfiguring test equipment.

<u>The Two-University Student Team</u>

In the fall of 2002, seven undergraduate students from two North Carolina universities collaborated on a proposal to conduct reduced gravity aqueous diffusion experiments aboard the KC-135A. The students, from The University of North Carolina at Charlotte and the University of North Carolina at Pembroke, had varying backgrounds in chemistry, engineering technology (civil and mechanical), communications, biology, and business. The team, pictured in Figure 3, learned in December 2002 that their proposal had been accepted by NASA, with flights that would take place in May 2003. This was the first opportunity for either university to participate in the program, and all team members were proud to accept this honor.

With the two institutions separated by 120 miles, the team faced numerous logistical challenges to the project. The schools held numerous meetings by video teleconference, and members had constant email exchange during the proposal, design, and build phases of the project. Occasional face to face meetings were required to successfully complete the experiment procedures and apparatus before the scheduled flight date.

Figure 3 – Team Photo
From left: Mary Beth Brayboy, Ginger Moody, Kiel Locklear, Joe Oxendine, Toni Chagolla, April Oxendine, Robie Goins

The Pembroke students had expertise chemistry, biology, communications, and business, while the Charlotte students had expertise in civil and mechanical engineering technology. The Charlotte students did most of the design and build work, but had to consult regularly with the Pembroke students to ensure that the design met the required specifications, and would successfully complete the experiment as required. Difficulties often arose, with budgetary limitations being one of the hardest to overcome.

<u>Aqueous Diffusion Rates</u>

The team's primary experiment, titled Aqueous Diffusion Rates, examined the effects of a reduced gravity environment on the rate of diffusion in liquids. The main test apparatus was a modified Polson diffusion cell. Though a typical Polson cell is made from stainless steel, the team opted to build theirs from a transparent acrylic material so that the diffusion process could be viewed during flight. The apparatus contains mating cells filled with different liquids (Figure 4). The cells are isolated from each other until one disk is rotated, opening a fluid path between them. The cells were only aligned during the zero-gravity portion of the flight and were returned to the unaligned position before gravity was restored.

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Figure 4 – Modified Polson Cell

The apparatus worked well during testing in the lab, where normal atmospheric pressure exists. But the team was unaware that the cargo bay of the KC-135A would not be maintained at a constant pressure while ascending to test altitudes. When the apparatus was exposed to a reduced external pressure during flight, the pressure differential caused the fluids to leak from the cells. The leaks contaminated the fluids in the cells and resulted in insufficient data from the experiment.

Going Aboard The Equipment

A major goal of NASA's reduced gravity undergraduate program deals not just with the science involved, but with associated outreach activities. Prior to the flight, the team began an experiment they titled Going Aboard The Experiment (GATE). Their goal was to show a comparison between the mixing of liquids in a normal-gravity environment (a classroom setting in this case) and the same mixing process in a zero-gravity environment. The first part of the experiment was conducted in local classrooms with school children in grades ranging from 4^{th} to 12^{th} as co-participants (Figure 5). Team members visited local schools and conducted an interactive instructional period with the students. A portion of each period was used for an introduction to space science, micro gravity research, and the distribution of related educational materials.

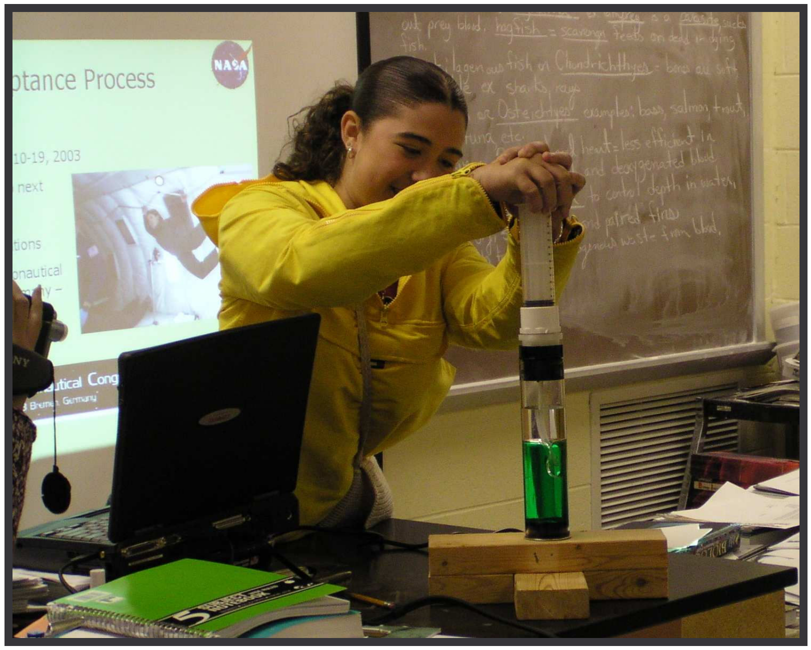

Figure 5 – Outreach Activities

The majority of these pre-flight outreach sessions were dedicated to supervising the students in data acquisition for the normal-gravity fluid mixing portion of the experiment. The children mixed the solutions while the process was documented on videotape. Several different fluid combinations were utilized. They were:

- Cytochrome-C mixed into a buffered water solution
- Blue Dextran mixed into a glycerol/water solution
- Colored water mixed into clear water
- Colored water with into water of a different color (e.g. red and blue making purple)

The mixing apparatus consisted of clear polycarbonate cylinders equipped with a syringe mounted in a sealed cap. One fluid was placed in the cylinder and the other in the syringe. The syringe fluid was injected into the cylinder fluid causing a mixture between the two. The students also introduced a low density solid into a high density liquid demonstrating the properties of buoyancy.

The experiments were reproduced by the project team in zero-gravity aboard the KC-135A aircraft (Figure 6). Mixing processes identical to those performed by the school children were accomplished during the zero-gravity portion of the flight parabolas. The experiments were video taped, which facilitated analysis once the flights had concluded.

After conducting the flight experiments, a presentation was developed that included video footage from the KC-135A flight. The team returned to the same classrooms with video footage from the zero-gravity experiments. The zero-gravity results were compared to the normal-gravity results that were previously conducted by the students. The team members led discussions of the results to help stimulate and answer student questions. This proved to be very beneficial for the college students as well as the young students. Some of the questions helped generate new experiments and ideas for future projects.

Figure 6 – Experiments in Zero Gravity

Plans For 2004

Based on the group's experiences from the first flight, the team submitted a proposal to continue the project for a second year. The proposal has been accepted by NASA and work on design changes has already begun. This year's flights will take place April 15-24, 2004.

Once again the team is testing aqueous diffusion rates in a weightless environment. However, with a year's experience behind them and with an idea of what to expect, many changes are underway for this year's project. The Polson Cell (Figure 4) is being completely redesigned in an effort to stop the leakage problems encountered due to pressure differential during the 2003 flight. The transparent acrylic design will remain for observation purposes. In addition, the mixing process will be automated, eliminating the need for manual activation during flight. The outreach to local schools is an ongoing program and will continue with the 2004 flight year.

Summary of Benefits

This unique project brought students from two universities together to work in concert on a scientific project supported by NASA. It covered multiple disciplines, including biology, chemistry, business, communication, and engineering technology. It offered a real world, team building experience that is simply not available in regular classroom environments.

During the course of the project, the students had the opportunity to work directly with NASA engineers, who reviewed their project documentation to ensure that it satisfied the specifications set forth by NASA. Having a team of practicing engineers review the student's work, evaluate their assumptions, and check their calculations, was a great learning experience. Although the students didn't receive any academic credit for the 2003 project, the engineering technology students are using the design and construction of this year's test equipment as their senior design project.

In addition to the scientific work, the project also involved outreach activities whose purpose was to inspire younger students in the fields of science and engineering. These visits to area high schools, youth centers, service organizations, etc. proved to be as rewarding as the project itself.

NASA, along with the North Carolina Space Grant Consortium, provided a terrific opportunity for these students, and also extended this invitation to help promote interest in the fields of science, mathematics and engineering.

Biography

GREGORY K. WATKINS
Gregory Watkins received a B.S. in Mechanical Engineering from North Carolina State University, a Master of Engineering Management from Old Dominion University, and a Ph.D. in Mechanical Engineering from UNC Charlotte. He has taught in the Engineering Technology department at UNC Charlotte for the past 1.5 years. He joined the KC-135A program as faculty advisor for the 2003/2004 year.

KEIL L. LOCKLEAR
Keil Locklear is a Mechanical Engineering Technology student at UNC Charlotte. He will receive his bachelors degree in May 2004.

R.J. GOINS
Robbie Goins is a Civil Engineering Technology student at UNC Charlotte. He will receive his bachelors degree in May 2004.

C.W. Spivey
Chad Spivey is a Mechanical Engineering Technology student at UNC Charlotte. He will receive his bachelors degree in May 2004.