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High-Flying Success for Chemistry Students:

NASA's Reduced Gravity Student Flight Opportunities Program

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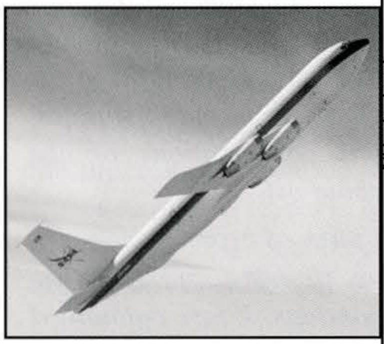
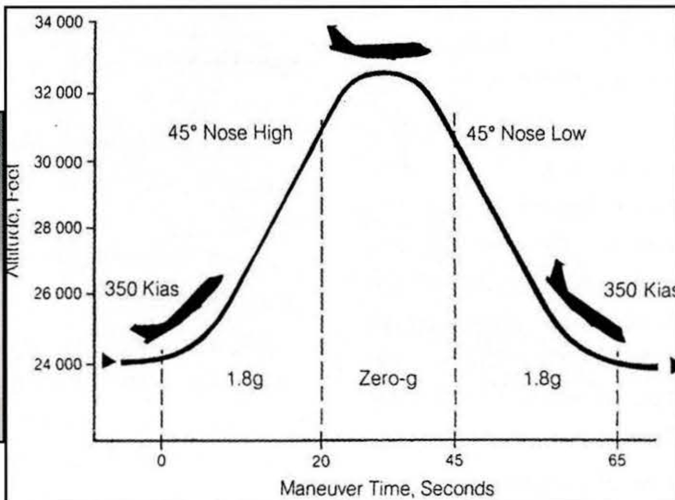
NASA's Reduced Gravity Student Flight Opportunities Program (RGSFOP) conducted at Johnson Space Center and Ellington Field in Houston, Texas, provides science and engineering undergraduates the opportunity to design and conduct experiments in a microgravity environment. The student program began roughly five years ago, although NASA developed a reduced gravity program in 1959. In the past five years, more than 100 different schools from around the country have participated. The KC-135 jet, which is similar to the Boeing 707, is used to produce a microgravity environment for training astronauts and testing equipment to use in space.





The KC-135's parabolic flight path.

To create the microgravity environment, the KC-135 is flown in a parabolic flight pattern. The flight pattern consists of 32 parabolas flown over the Gulf of Mexico. The parabolic arc consists of a climb and a dive at 45-degree angles with an altitude ranging from 26,000 to 34,000 feet. As the jet levels off after the climb, microgravity is simulated at the peak and lasts for approximately 20 seconds. The climbs and dives of the parabola simulate 1.8-g, which is almost twice the gravitational pull of Earth. Our experiment sought to test the effects of a reduced gravity environment on plasma movement in an inert gas discharge tube (IGDT). We hypothesized that the movement of the streamers were caused by buoyancy-driven convection, which would not occur under reduced gravity conditions.

A plasma globe is a form of an IGDT, which emits streamers of plasma. The streamers are formed by electrons emitted from a central electrode that ionize the gaseous surroundings, forming arcs of plasma. In the IGDT, heat builds up on the electrode due to internal resistance. The heat is then emitted to the surrounding gaseous molecules, decreasing the density of the gas close to the electrode. A difference in densities is created between the gas close to the electrode and the outer layers of gas. In the presence of gravity, the difference in densities will cause convection to occur, where the less dense gas near the electrode flows upwards to replace the denser gas in the outer region of the globe. The movement of these gases is analogous to the movement of the plasma beams. Thus, convection appears to play a principle role in the movement of the plasma beams.

If our hypothesis is correct, several observations should result. In the presence of gravity on the ground, the movement of the beams should follow a cyclical pattern emerging from the regions near

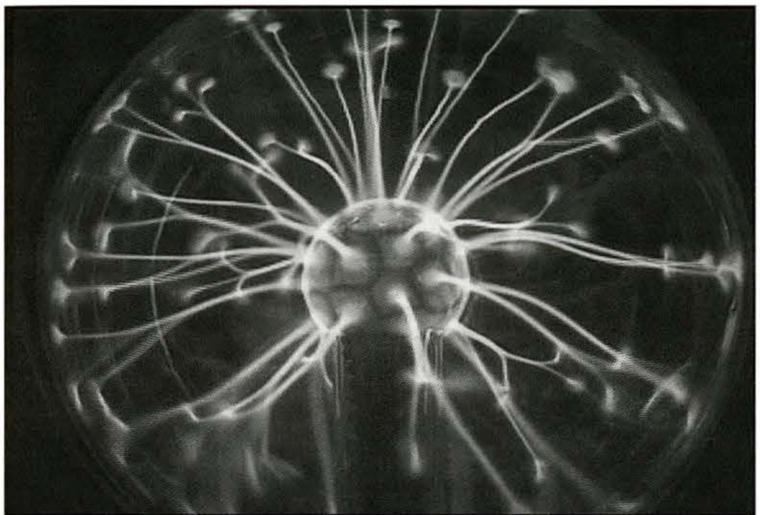


Image of a plasma globe at 1-g.

the electrode and rising to the top of the globe. If convection is the primary cause of the movement, then hot air around the electrode will rise to displace the cooler air at the top of the globe. The resulting displacement should carry the plasma beams in a cyclical upward movement.

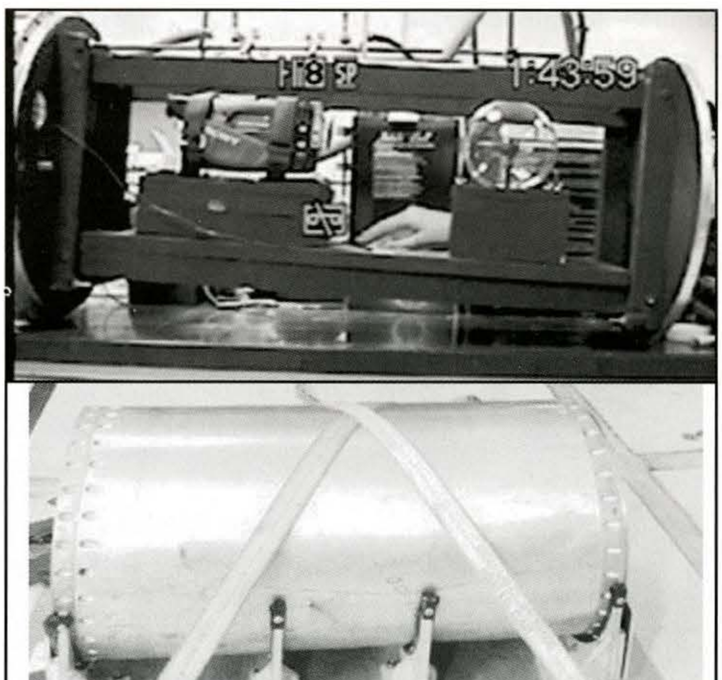
On the other hand, in weightlessness, the movement of the beams should nearly cease to occur, due to the absence of buoyancy-driven convection. The remaining pattern of movement should be consistent with the induced gravitational effects created by the rotational acceleration of the plane.

Thus, since some gravitational effects will remain, a minute amount of convection should continue to occur, and the overall pattern of the plasma movement should remain continuous but at a slower rate.

The effect of high gravitational force (g-force) on the system can also be studied. In 2-g the exact opposite of the predicted observations for convection should result. As the level of gravity is increased, the rate of the gas movement should increase. Thus a rapid displacement of the cooler air at the top of the globe by the warmer air at the base of the electrode should result. As this movement increases, the movement of the plasma beams should increase, and the beams should all migrate to the top of the globe.

The apparatus was designed to easily study the effect of convection on the plasma ball. The plasma ball was recorded in near darkness with a high-resolution video camera. The resulting streamer images were then studied after all of the flight data had been gathered. A system of vectors representing the motion of the beams was created once the displacement of the beams was measured.

The resulting patterns were then analyzed to determine whether they were consistent with the motion of convection within a closed system. This experiment is a model that can be used to study the movement of the plasma arcs on the ground, in reduced gravity, and in the presence of a high g-force.

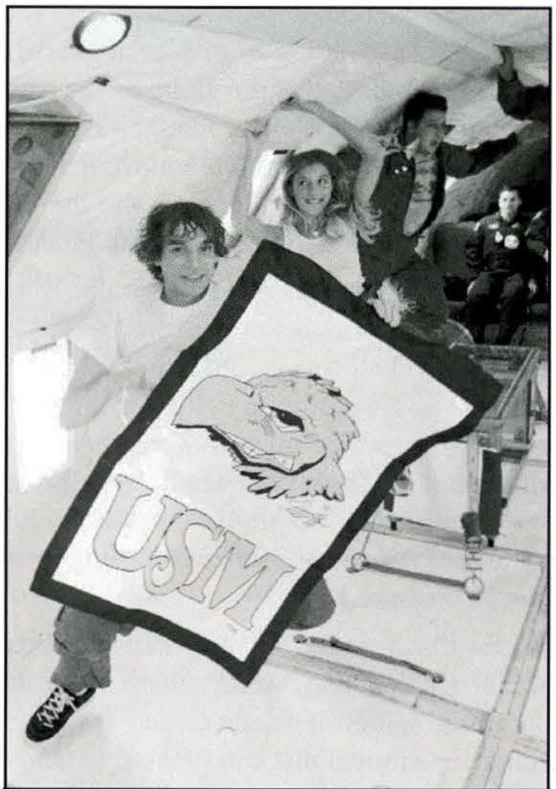


The apparatus used aboard the KC-135. (Top) Camera and plasma sphere located inside of the apparatus. (Bottom) The sealed container aboard the KC-135.

Photos by Bill Ainsworth, RGSFOP Graduate Adviser

The results from previous KC-135 flights indicated that convection does play a role in the motion of plasma arcs. It was determined that as the level of gravity decreased, there was a noticeable decrease in the velocity of the plasma arcs residing in the top hemisphere of the plasma globe, yet the motion did not stop completely as was predicted. This was due primarily to the plasma arcs being influenced by the magnetic field produced by the Tesla coil.

The arcs in the lower



Brian Zoltowski and Kayce Leard proudly display their USM banner in reduced gravity.

Photo by RGSFOP Photo Services

half of the sphere continued to move rapidly throughout all measured gravitational levels. We determined that this motion was a direct result of the magnetic field generated by the tesla coil in the base of the plasma ball. We believe that this magnetic field also caused the residual movement of the plasma arcs in the top half of the sphere. For this reason, we plan to repeat the experiment by separating the plasma ball from the tesla coil to remove the effects of the magnetic field. The undergraduate microgravity research team will return to Ellington Field to conduct the modified version of the experiment.

Acknowledgements

We wish to thank the University of Southern Mississippi, the College of Science and Technology, and the Department of Chemistry and Biochemistry for financial support for this program. We would also like to thank the NASA Reduced Gravity Student Flight Opportunities Program (NRGSFOP) for allowing us to participate in the 2001 competition.

About the Authors

Kristi Budzinski *is a senior biochemistry and mathematics major from Clinton, Miss. She says the NASA Reduced Gravity Student Flight Opportunity Program taught her a lot about writing a research proposal, and reminded her why she is majoring in chemistry. "During the semester, I become so bogged down in schoolwork that I forget how much I actually love chemistry."*

Christina Watters *is a senior from Mobile, Ala., majoring in environmental biology. She is a member of the Honors College, president of Beta Beta Beta Biology Honor Society, and participates in several other organizations. After graduation, she plans to attend graduate school and then work as a researcher in coastal ecology.*

Kayce Leard *is a senior chemistry major from Natchez, Miss. She is a member of the American Chemical Society Student Affiliates and was the recipient of a Chemistry Alumni Scholarship in 2000 and the Fred and Naydene Drews Endowed Scholarship in 2001. "Knowing that science and technology made an experience like this possible is real encouragement for those of us who are trying to make a career out of it."*

Nicholas Carter *is a senior chemistry major from Biloxi, Miss. He plans to attend medical school to become an anesthesiologist. "Weightlessness was just like being Superman for a short time," he says, "You could do just about anything imaginable that you can only dream about doing on Earth."*

Brian Zoltowski *is a senior chemistry major with a 4.0 GPA from Wausau, Wis. He plans to obtain a master's degree in chemistry and then pursue a doctorate in either theoretical chemistry or molecular biophysics. He is actively involved in undergraduate research and has been studying spinning drop tensiometric analysis of effective interfacial tensions in miscible polymeric systems.*

Glossary

Buoyancy

Buoyancy is a term used to describe the force associated with a difference in densities. A helium balloon rises because of a buoyant force. Human beings float in water because they are less dense than the surrounding water. We describe these occurrences as resulting from buoyancy.

Convection

Convection is a process of fluid flow that results in the displacement of one fluid by another. The fluid can be a gas or liquid. In the case of our experiment the fluid flow is caused by heat. When a gas is heated it becomes less dense. Since in an essence the heated gas weighs less it will rise, much like a helium balloon rises in the presence of air.

Inert Gas Discharge Tube

An inert gas discharge tube is similar to a light bulb. In an inert gas discharge tube, a glass casing contains a very low pressure of an inert gas, such as neon, argon, krypton, or xenon. A high-voltage electrode is in the center of the glass casing. When current is allowed to flow through the apparatus, an electric discharge occurs from the central electrode to the surrounding glass walls. The discharge creates plasma, which we intend to study.

Plasma

Plasma is a region of ionized gases. Lighting is a type of plasma. What we observe as lightning is actually a stream of air that has been ionized. Ionization can occur via a number of different pathways. Lighting, like the plasma in our experiment, is ionized because of a difference in electrical energy occurring between two regions.

Resistance

The voltage associated with an electric current is defined as, $V=IR$, where V=voltage, I=current, and R=resistance. Resistance in an electric current causes heat. This is why a wire becomes hot when an electric current is placed through it.

Tesla Coil

A tesla coil is a coil of wire that surrounds a magnet. It is often referred to as an electromagnet.

From left to right: Bill Ainsworth (graduate adviser for NRGSFOP), Christina Watters, Nicholas Carter, Kristi Budzinski, Brian Zoltowski, and Kayce Leard.

Photo by Kevin MacDermott of "Chemical and Engineering News Magazine"