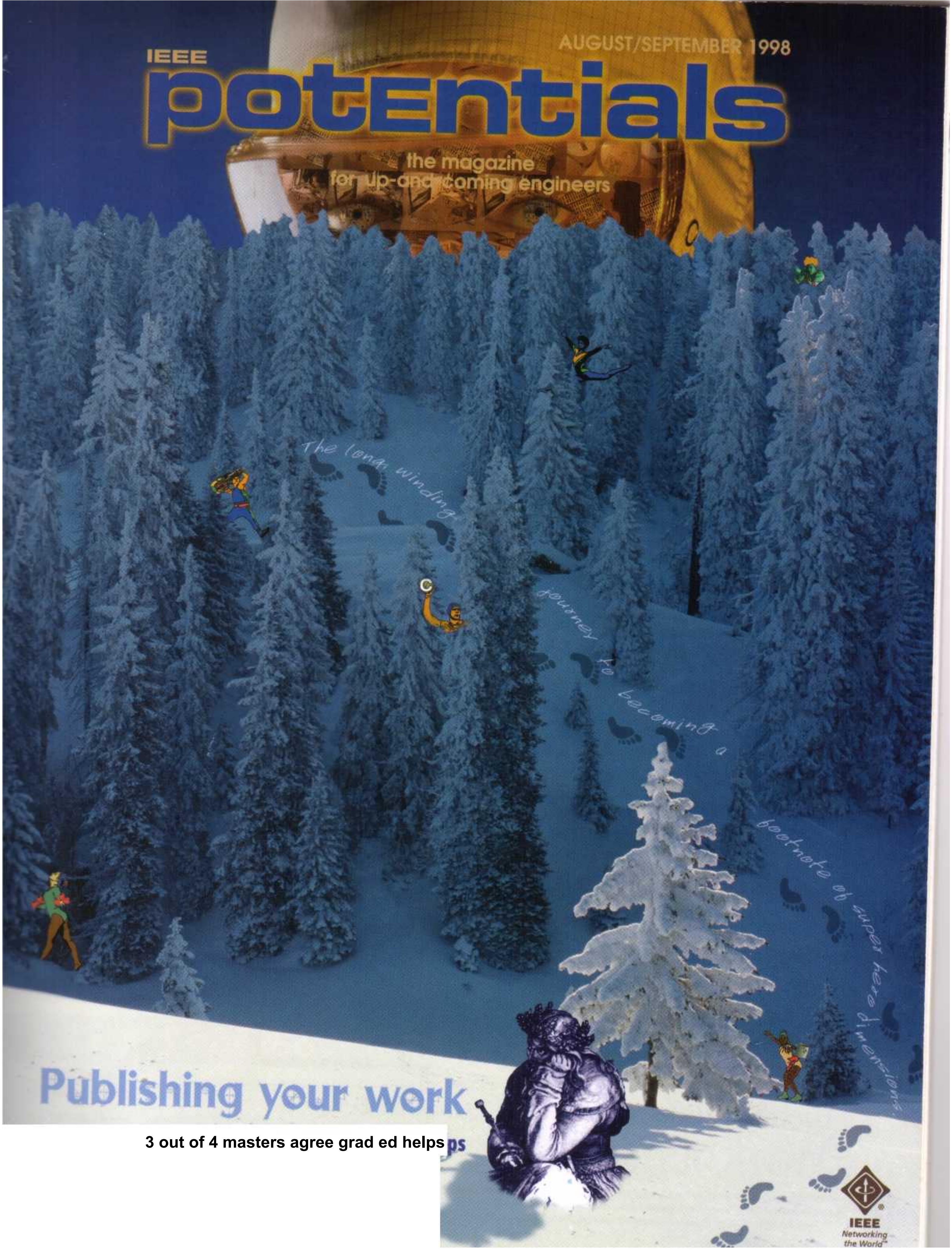
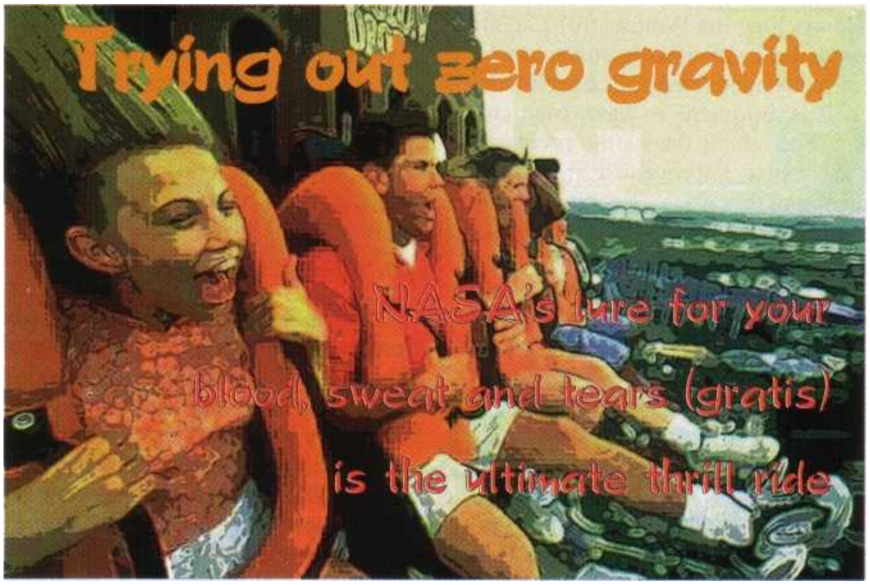


AUGUST/SEPTEMBER 1998
IEEE
potentials
the magazine
for up-and-coming engineers
The long winding journey to becoming a footnote of super hero dimensions.
Publishing your work
3 out of 4 masters agree grad ed helps
IEEE
Networking the World



arrow power is an age-old mechanism for making otherwise mundane tasks palatable. Take, for example, bunches of students who *volunteer* to construct, conduct and convey the outcomes of a scientific experiment. On their own time. Missing Spring Break. The carrot is a ride on the infamous "Vomit Comet."

For those uninitiated, the pilot in a military Boeing 707 (it has four instead of two engines) creates the sensation of weightlessness for its passengers by flying "parabolics." The pilot angles the plane up while gunning the engines until it reaches the peak of the parabola. The pilot then thrusts the plane's nose down while keeping the wings even (see "Why a parabola," pg 40). For passengers, zero gravity (0 G) lasts about 25 seconds before the next climb pulls them down at twice the rate of gravity. The overall result: Serious science conducted during a BIG roller coaster ride.

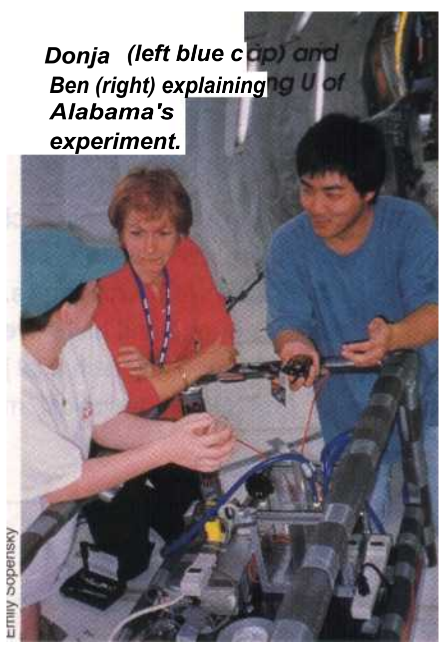
About the program,

An endeavor administered by the Texas Space Grant Consortium, the NASA Reduced Gravity Student Opportunities Program (see <www.wsgc.uwexas.edu/wsgc/floawn.hwml>) will be three years old in 1999. Forty-eight university teams from thirty-nine schools flew in the Spring of 1998.

The program is the brainchild of Burke Fort, a former environmental litigation attorney, who is crazy about planes. Fort worked hand-in-hand with NASA's Johnson Space Center (JSC) in Clear Lake, Texas to create it. His goal was a program that attracts students with initiative and ability, and provides a great educational opportunity.

In addition, both NASA and the Consortium use this program as a link between NASA and schools across the United States. NASA co-ops-who are assigned to JSC-astronauts and scientists are quite active in supporting the program.

Modeled after the Land Grant and Sea Grant programs, the National Space Grant Program began in the 1980s. The aim was to provide outreach and a means of linking academia, government and the public sector. But, whereas the Land Grant program has outreach in US Department of Agriculture co-ops, this is not a funded grant program. Instead, the lure is the opportunity to ride the Vomit Comet; to spend two weeks in Houston with other students, co-ops, NASA officials and astronauts, and to ready an experiment for flight and conduct it on board.



Donja (left blue cap) and Ben (right) explaining U of Alabama's experiment.

A key component to any real-world research and development is communicating the results. With that in mind, the students also get invaluable opportunities to work with the media. The program requires a professional journalist on the team and an outreach plan. In return, NASA sets up live feeds back to the universities' local stations. NASA also provides high-resolution, in-flight digital photos and video shots to each team.

But for Fort, the payback is the reaction each student has when first experiencing 0 G. Fort states, "The first time, spontaneous laughter inevitably erupts as each student experiences the abrupt change of going from 2 Gs to 0 G."

The application *process*

NASA and the Texas Space Grant Consortium diligently distribute information on the program to most universities. However, the details are always available at the web site cited previously.

The deadline for a letter of intent is in early October, followed one month later by the actual proposal. Proposals are reviewed by scientists in NASA facilities across the country. The acceptance rate is slightly below 50 percent. Selected teams are announced in December. To fly, each team member must pass a physical-a Federal Aviation Administration (FAA) requirement. Training and flights are usually mid-March, when most schools schedule their spring breaks.

To give you an idea of the range of project topics, here are a few from 1998's class of flying teams:

- University of Colorado studied performance testing of rachetless Extra Vehicular Activity (EVA) hand tools.
- Georgia Institute of Technology proposed Acoustic Shaping in Microgravity: Phase 2 (they did Phase 1 in 1997).
- The San Francisco Institute of Art, in a unique endeavor, investigated creativity in a microgravity environment.
- University of Alabama used video to capture data on a droplet of fuel ignited in an electric field.

While proposals tend towards cutting edge topics, they need not be. Fort maintains the most important aspects are the proposal, the plan and the ability to execute. Some other hurdles include: engaging a faculty advisor, designing and building the experiment, getting the university to buy-in and finding fund-

0278-6648/98/$10.00 © 1998 IEEE

Outsmarting the urge

There are all sorts of theories, rumors, discussions and personal anecdotes about how to defy the Vomit Comet moniker. In our physiological training at NASA, I overhead someone official say that only 18 percent of those riding the parabolas get sick. And just who was counting, I want to know. We had a higher than 18 percent rate on our flight (based on my highly scientific, personal experience and observations). There's no doubt that your flight will be less afflicted if it lives up to the laws of averages. Nevertheless, if you do get a chance to ride the Vomit Comet, here are some possible remedies.

1. Peppermint is reputed to be a natural way of settling upset stomachs.
2. Ginger capsules can be used for motion sickness.
3. Somewhere about the 32nd parabola, offer enviously watching the San Francisco Art Institute students frolic midair for the umpteenth time with no side effects, Matheus "swam" over to me to tell me they had a secret pill that *really* works. It turned out to be your average over-the-counter *Tums* tablet. Well, if it works, it works.
4. Something must be said for stomachs used to diets of Frito-Lay chips and colas.
5. Donn Sickorez, NASA's PR gun in charge of University Relations, took his first flight along with our ride. Donn has his own test to run. Says he, "I'd like to test the theory that repeated exposures can lower the threshold. If it works out, I'm going to go a few more times. If I still experience some gastrointestinal disturbances due to spatial disorientation, I'll quit."

Then there are the stories like the one about the Colorado School of Mines students who are on their seventh flight. Like clockwork, they all turn to one of theirs as he upchucks on cue-the same parabola each flight.

Finally, there is NASA's Test Director Bob Williams who has never, ever, in 72,000 parabolas felt even slightly ill. In short, the urge to purge may be genetic.-ES

ing. The logistics of getting team members, equipment and journalist to Houston, and setting up housekeeping for two weeks also can be challenging. Then there is the fun of negotiating with equipment makers and/or finding out how to rent a car when under twenty-five. What's more, this is being done while carrying a full course load.

But real-world experience is what this program is designed to provide. Add lectures from NASA scientists and astronauts, along with guidance on readying the experiment for flight, and the educational experience is unparalleled. Most students find they can get course credit.

Each project has its own merits

For instance, the University of Alabama (UA) project showed me how complex combustion science and theory are. Studying, for example, just the shape, color and burn rate during any part of the combustion process involves an incredible amount of data and computation. In fact, methodologies for evaluating combustion for high-performance jet engines are dependent on high-end computing power and recently developed modeling programs.

Flames are shaped by two forces-gravity and any tension on the surface, for example, inside an engine. Studying the flame is also important in determining how fires spread in a microgravity environment, such as on a spacestation.

Companies such as Boeing, Rolls Royce and other aircraft engine manufacturers are hard at work trying to understand the dynamics of combustion. This is so they can reduce emissions and pollutants, reduce fuel costs and make engines more efficient to carry heavier loads farther. To put it bluntly, studying combustion and the characteristics of a droplet of fuel being ignited not only adds to the growing body of valuable data. but is also a hot field of interest (pun intended).

Details, firsthand, on how it works

I, a journalist, was delirious to fly but had no assignment. Discovering that the UA team had not yet found a journalist to fly with them, I pleaded my case.

Dr. Gerald Micklow, the team's advisor and combustion theory expert, acknowledged that the team needed a journalist. However, Micklow still treated the issue as a real commercial project with a corporate chain of command. "It's up to the project manager, Matheus Neves de Medeiros," he stated, adding, "He's a freshman." I mentally groaned. What does an eighteen-year-old know about coordinating a team and making it happen?, I asked myself. Lucky for me, Matheus is bright, energetic and quite reasonable. He readily agreed to bringing me on board as the journalist.

Over the next few months, Matheus, his teammates Donja Parr and Ben Lu, and I exchanged e-mails that gave me a running commentary on their progress. When I finally met them, students from other schools and other journalists, the degree of exhilaration was flying higher than the stratosphere. I spent a few days with them during our physical training. Then I returned to my office and moni-

Emily **Sopensky**

Why a parabola?

Why does the plane fly in parabolas? Sounds like a simple enough question. But, often, the simpler the question, the more difficult it is to answer.

I asked a student from the University of Washington on our flight. He said, "Every falling object is on a squared function. $y = x^2$ is a 'parabola.'" Okay. That was one way to answer the question. But it didn't tell me why.

I went back to NASA and expanded on the question. I asked, "Is there an official explanation for why the KC-135A (the military Boeing 707) must do parabolas? What are the laws of science that make it so? Or is it a combination of science and practicality?"

After a few days, I surmised that there was no stock answer. Finally, I received an e-mail from Julia Kramer of the JSC Engineering Directorate's management staff. She wrote the following response after compiling various engineers' and scientists' answers.

The short answer

The parabolic flight path is a combination of vertical and horizontal velocity. It's the up-and-down motion of the aircraft that gives you your feeling of weightlessness. The forward motion (which produces the parabolic shaped flight path) is really extraneous. (Well, it's important for making the plane fly, but unrelated to the "0 G" effect.)

Any "nose-over" maneuver, like that seen at the top of the parabolic trajectory, will give you a 0 G feeling. However, the parabolic flight path optimizes the amount of 0 G time against the performance capabilities of the aircraft.

The

The objective is to produce the longest period of simulated 0 G, while keeping test subjects safe and isolated from external environments (weather, temperature, etc.). Inside the KC- 1 35A, these needs can be met. The trajectory can be explained by two independent aspects:

1. Physics

If you take any object (airplane, tennis ball, whatever) and throw it up in the air with a given velocity, it will rise until that initial vertical velocity is overcome by gravitational effects. At the peak of that trajectory the object has, instantaneously, zero velocity-it appears "weightless." On the trip back down, the object is in free-fall.

While not being truly "weightless," meaning **zero** gravitational forces, the object falling has the perception that it is weightless. It is the **same** as the *Dungeon Drop* ride at *Astroworld* **in Texas,** where they take you up ten stories **and atop** you. You are "weightless" there, too.

VM **dropped** (do *not try* this, you could kill someone**). you** would see it suspend itself in **front of you,**" weightless." Well, we all know it is **" weightless";** it is just falling at the **and** acceleration as you. So, relative to you it

important principle is one of **The one** that says a body in **In motion** unless acted on by

trot, at the top of the **of your** seat. While the **ID go back** down, you continue on your path. There is a more subtle aspect as well. Take the *Dungeon Drop* example again; if you release a feather instead of a penny, what happens? Remember what Galileo proposed would happen if you dropped a feather and a rock in an evacuated tube? They would fall at the same rate. The physics behind this says two objects with an initial velocity of zero in the same gravitational field will accelerate at the same rate (32 ft./sec./sec. for Earth). It has nothing to do with the mass of the object.

Well, that doesn't happen when you have two different-shaped objects. The idea is now understood as aerodynamic drag-a fundamental principle of flight.

2. Aerodynamics and the capabilities of the aircraft

In the simplest sense:

thrust = drag,

lift = weight of airplane and contents.

These are some of the parameters that you are trying to optimize. They are governed by the two previous statements.

a) Velocity-The plane must keep its forward motion or it will fall out of the sky.

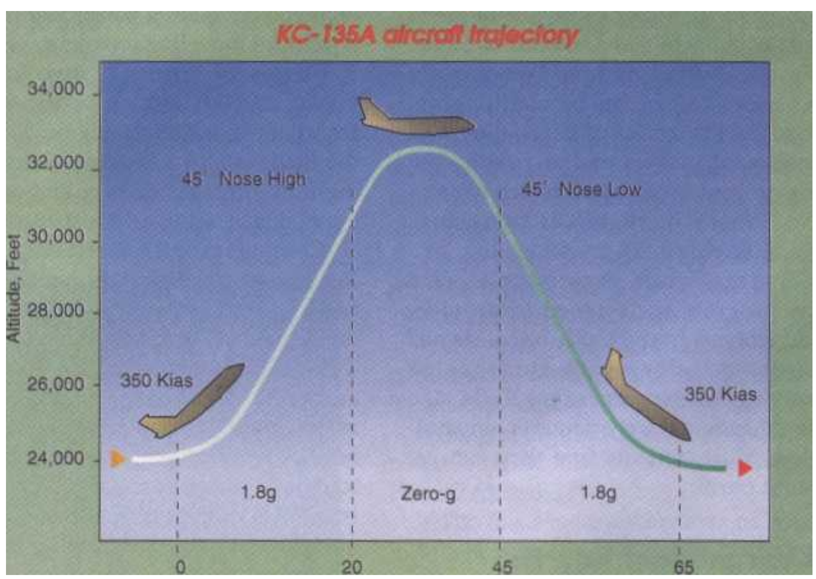
b) Fuel-The length of time it can stay up is limited by fuel.

c) Altitude-The altitude at which it can fly these maneuvers is limited by safety and aerodynamic performance considerations as well as structural capability,

d) Time-The speed at which it can go up and down (and forward, for that matter) is limited by the structural capability of the aircraft and the performance of the engines.

You want as much weightlessness as you can possibly get in one day. The pilot knows that he must get up to some safe altitude prior to doing a "nose-over" to give you the "weightless" effect. How fast he can do this is limited by his engine's capability.

As the pilot reaches the proper altitude, he cuts engine power and pitches the nose over. This is important for two reasons. First,



Maneuver Time Seconds

The above diagram shows a typical zero-G maneuver. However, the maneuver can be modified to provide any level of G-force less than one G. Some typical G-levels used on different tests and the corresponding time for each maneuver are as follows:

Negative-G (-0.1 G)	**Approximately 15 seconds**
Lunar-G (one-sixth G)	**Approximately 30 seconds**
Zero-G	**Approximately 25 seconds**
Martian-G (one-third G)	**Approximately 40 seconds**

he is reducing his upward velocity (remember Newton's law, stated earlier?). The pilot doesn't want you to go flying out of your seat into the ceiling. The closer he gets to zero, the less upward force there will be on you as he crosses the top of the parabola.

Second, he is keeping his forward velocity constant. If he were to change his forward velocity as he went over the top, you would have an acceleration in that direction as you came out of your seat. That could be a bad thing if a bulkhead is right in front of you.

So, you come over the top, out of your seat and you are now free falling inside the aircraft. The pilot wants to give you the longest period of apparent weightlessness possible. He pitches the plane over and actually starts to accelerate (powering up the engines), so that even with the large amount of drag that he is experiencing, he matches your free-fall for a brief period. (You are not experiencing any drag because you are safely tucked inside the fuselage of the aircraft.)

But, now, the pilot knows he is going downward very rapidly. He must be able to level out the plane. How rapidly he can do this is limited by the capability of his plane (and you) to take the forces, and by how low he can fly safely. The parabola is also conducive to gradually increasing and decreasing G-forces. This is important for the safety of the aircraft's occupants.

All these aspects combine to make the parabola the only trajectory for repeated cycles of 0 G. The amplitude and frequency of the parabola are dictated by the capability of the aircraft and its occupants.

Our pilot, Steve Feaster, states, "Because of physics, it's an arc. If we continued on down (after peaking), the plane would go into the Earth and back up. Actually an orbit is a parabola without the Earth in between."

It's not a loop-de-loop because "we don't have enough Gs available. It takes 4 Gs to get over the top before running out of airspace. Fighter planes such as the T38 can do 7 Gs." Explaining the characteristics of the parabola the KC-135A makes, Feaster adds, "The plane redlines at 350 nautical knots at the bottom of the trough. We pull up the nose to 55 degrees and at the top of the parabola we are doing 240 knots and throttling down during the first half of the 0 G on the backside of the parabola."

To sum it up. Flying a parabola is the best use of the equipment, time and space to create a sense of weightlessness within the practical limitations of the laws of physics.-ES

monitored their trials and errors there until returning for flight day. As a journalist, I was pleased to be among reporters from *Good Morning America, Life, People* and even *The Wall St. Journal.*

Being able to work in real-time-retrofitting the experiment to fit existing conditions-is a key element to what makes one engineer more valuable than another. That ability to problem-solve on the fly is just another reason why this program is so dynamic. In the UA's combustion experiment, the filament chosen proved too difficult to ignite during the flight. So out came the backup plan-a barbecue lighter.

This NASA program is a gold mine for those with initiative and zeal for testing themselves scholastically and physically. I asked Ben and Donja what they were getting out of the program . Donja, a math and physics major. said simply, "I'm getting life experience: nothing is handed to you." Ben's response was reflective: "I've come to appreciate physics and math more. In a way it's easier to work with math and physics problems. Working in a team engineering environment takes a lot more work and time. But the best reason is to go on the ultimate roller coaster-with no brakes!"

About the author

Emily Sopensky is a professional writer as well as Secretary/Treasurer of the IEEE Intelligent Transportation Systems Ad Hoc Committee, a cross-society committee which will become a permanent IEEE Council in 1999. She is eager to test the Sickorez Theory of Non-Purge-that "repeated exposures" can make you immune to gastronomical disorder. Sopensky has already received her physiological training from NASA (good for five years), knows the ropes and is ready to go again. In short, if you and your colleagues are making a proposal to the Reduced Gravity Student Opportunities Program and you need a professional journalist, e-mail her at <emily@iriscompany.com> or <e.sopensky@ieee.org>.

Built decades ago, this Boeing plane is an old workhorse. Used for decades to train astronauts in weightlessness before they headed off into the skies above, the plane is also used for midair refueling and countless missions requiring a reduced-gravity environment. This KC- 135A also: is the behind-the-scenes star h the movie, around

o

I