MATH, SCIENCE AND ADVENTURES IN SPACE

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When asked to speak to you at this 1997 Summer Colloquium, it was with a great deal of reluctance and a bit of arm-twisting that I agreed – not because I don't appreciate the goals and purpose for this institute, but because it is my personal policy not to talk at great length on a subject about which I know very little. For some people that is not at all inhibiting, but it makes me uncomfortable so I try to avoid doing it. So I won't talk to you about years of experience in classrooms, about research in teaching methods, or about innovative new ways to teach math and science. What I can tell you from first-hand experience is the profound effect you, as teachers, can have on your students.

Along with three other scientists, I spent about a year and a half training for my last Space Shuttle mission. We worked closely with the principal investigators to learn all the procedures we would use to conduct more than 30 experiments during our 16-day stay in the Spacelab module onboard the Space Shuttle Columbia. After one particularly long day of training, over Chinese food and a couple of bottles of wine if I remember correctly, we began to reminisce about how we got where we were; how we got interested in math and science and ultimately got a ride in space. Remarkably, for each of us it was the same: a teacher in middle or high school who made all the difference in us and on our careers.

For me it was my high school physics teacher who helped me realize that science was interesting and exciting and what I wanted to do with my life. I don't recall any particular encouragement for me as the only girl in my physics class. It was just a statement of fact that anyone who was willing to try could learn physics. For that I thank him.

I also have to thank another teacher in another country for the exciting experiences I have had. Wernher von Braun admitted to a strong dislike for math as a student, even failing in the subject, until someone introduced him to the field of rocketry. He quickly realized that he could not follow his passion for space flight unless he understood mathematics. So he learned

The Journal of Mathematics and Science: Collaborative Explorations Volume 1 No 1 (1997) 1-7

math. He learned it so well that he became a tutor for fellow students in math and physics. As an engineering student and a member of an amateur rocket society who used an abandoned Army ammunition dump as a launch site for their experiments, von Braun's talent and energy were recognized by the military. Where von Braun and his colleagues saw a vehicle for space travel, the German Army saw an instrument of war. In 1932, when the Army offered von Braun the opportunity to pursue his education and rocket research with funding, he accepted and became their top civilian rocket specialist at the age of twenty. Only a few years later, von Braun became technical director of a secret rocket development center at Peenemunde, as Germany began gearing up for another war. Von Braun never gave up the dream of space flight and, in fact, was once arrested by the SS and imprisoned for spending too much time working on a rocket for space rather than a weapon for the war effort. In the final months of World War II, as the Russian Army was about to take over Peenemunde, von Braun and his team hid hundreds of secret documents about the dreaded V-2 rocket in an abandoned mine shaft, and traveled hundreds of kilometers south using forged orders to pass checkpoints in order to surrender to the American Army. He believed that his best chance to continue his dream of space flight would be in America. He and more than a hundred German rocket specialists came to the United States to become the nucleus of the American Space Program. His Redstone rocket put Alan Shepard into space. His Saturn V rocket took twelve men to the moon.

To Wernher von Braun's teacher: Thanks for igniting that spark in him which ultimately allowed me to travel in space and orbit the earth 650 times. And thanks to all the other teachers who lit those sparks in all the other scientists and engineers who were and still are sending men and women to Earth orbit and robots to explore Mars, Venus, Jupiter and beyond our solar system. I am personally indebted to them all.

In part to repay that debt and also to help keep the dream of space exploration alive for the next generation, I believe that those of us who are privileged to live that dream have an obligation to bring back as much as we can to those who have not, or not yet, had that grand adventure. As you may know, astronauts are selected for their technical abilities, not because they are particularly articulate. So we take a lot of pictures. I'm sure you have seen some of those remarkable photographs of the Earth from an astronaut's vantage point. If you have not seen the IMAX films shot in space, you should definitely not miss any opportunity to see them. What you will see in IMAX is very close to what I saw from space—the Earth passing by at five miles per second; the blue of the oceans, the distinctive colors of the continents. What you cannot get from films or photographs is what it feels like to launch, to float, or to watch the Earth "go by."

I'll do my best to describe to you an indescribable experience. T-0, the moment of launch, does not feel as violent as you might expect watching all that fire come out of the rear end of the rockets. It felt to me like a firm push on my back, not unlike the firm but unrelenting push it takes to get your kids out the door in the morning to catch their school bus. That firm push is followed by a bumpy ride during first stage, when the solid rocket boosters are burning. If you can imagine lying on your back in a hard chair, riding in the back of a pickup truck on railroad tracks with a bowling ball on your chest, that would be close to what I felt during first stage. That lasts for about two minutes until the solid rocket boosters have done their job. They separate from the rest of the stack with a boom and a lot of fire as separation rockets push them away. The boosters parachute into the Atlantic Ocean to be recovered and reused on another flight. You continue "uphill" with the three main engines on the Orbiter, which is a smooth, almost electric motor-feeling ride. Toward the end of the ascent, you experience 3 G's, or three times the acceleration of gravity. That can become a little uncomfortable, feeling like a weight is pressing down on your chest as you try to breathe. But it only lasts for a couple of minutes.

The single most magical moment of the whole flight is main engine cutoff, or MECO, when you go from feeling like you have a gorilla sitting on your chest to having your feet float up in front of you. The first time I experienced MECO, I had to check to see that those were my feet because I didn't put them there. The sensation of floating is one of complete freedom. You can move effortlessly in any direction. World-class gymnastics moves are easy even for those of us over the age of 18, provided the rules can be amended so that after a spectacular 3½ rotation maneuver it is permissible to land on the ceiling instead of the floor. It is also a sense of frustration because you can't stay where you want without using your hands for positioning. Simple tasks take twice or three times as long because nothing, including your own body, stays where you want it to. Imagine trying to work in an office or a lab with a strong wind blowing through. You can't simply put down a pencil or a screwdriver or a piece of paper because it will not be there when you want it. Imagine having to hold yourself in place with at least one hand while trying to work with the other. It takes a lot of thought, planning, velcro and bungees to set up a work site when you are floating.

There are three impressions of space flight that I hope to remember all of my life. The first is about our place in the Universe. I came to understand how ancient peoples believed that the Earth was the center of the Universe. I could float in the middle of a spaceship traveling at 17,500 miles per hour and yet feel none of the usual cues of motion: no vibrations, no wind noise, no centrifugal force pressing me against the wall as I traveled in a circle.[1] It appeared to me as if I were fixed in the Universe while the Earth turned in front of me just to give me a show, and the sun did a dance around both of us. I felt like the Universe was centered on me and my spaceship. Fortunately, someone more clever than I developed a heliocentric model of the Universe, which we know to be correct.

The second lasting impression I have is about the Earth. I expected to and tried to see the Earth as a fragile, blue marble in the blackness of space. That is an image from Apollo astronauts who went to the moon. Sadly, human space flight is now limited to low Earth orbit, so the view of Earth we get is dramatically different. If you were able to shrink the Earth to the size of a basketball (12 inch diameter), the Shuttle would fly only about ½ inch above the surface. The moon would be about 30 feet away.[2] Flying on the Space Shuttle, I

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[1]Most of us have experienced the sensation of flying in an airplane on a clear day. Looking out the window, we feel like we are moving very slowly relative to the earth below. Even though we do not hear wind noises or feel vibrations, all our experience tells us that we are moving and the earth is not. We might imagine that we are flying in a straight line over a map, every minute bring us closer to our destination.
Orbiting two or three hundred miles above the earth, we can see that the earth is indeed round. If we were traveling in a straight line, we would go whizzing past this planet and on to the next. We don't *feel* like we are traveling in a circle (no centrifugal force). We don't *feel* like we are moving at all (no wind or vibration). Therefore, in spite of all our experiences and common sense, we may *feel* like we are fixed in space and the earth is turning in front of us just to show off its splendor.

[2]For these calculations I used round figures and English units because those are the facts I remember from my pre-metric childhood. The radius of the earth is about 8,000 miles; the diameter of a basketball about 12 inches; the highest Space Shuttle orbit has been about 360 miles; and the distance to the moon about 250,000 miles. We can set up the following ratios:

$$\frac{12\ inches}{8000\ miles} = \frac{X\ inches}{360\ miles} = \frac{Y\ inches}{250{,}000\ miles}$$

Solving for our scaled-down shuttle orbit (X), we get 0.5 inches. The distance to the moon (Y) is 375 inches, or 31 feet. The distance from the earth to the sun in the real universe is about 93 million miles. In our scaled down solar system it is just a little over 2 miles.

never felt separated from the Earth but I did get a new perspective. The Earth I saw was a living, breathing, powerful thing. I could look out the windows during any night pass and within seconds see lightning somewhere. Frequently there would be sympathetic discharges where one lightning bolt would trigger several more nearby. There is a tremendous amount of energy evident in the electrical activity of our atmosphere. I would look for and photograph volcanoes for scientists to study and compare changes over the years. As powerful as they are to us, volcanoes like Soufriere Hills in Montserrat or Kilauea in Hawaii appear as only the tiniest pimples on the face of the Earth. Looking at the sun's reflection on the oceans, I could see eddy currents churning in the water all the time -- not major currents like the Gulf Stream, but random motions. If you have even been to the beach after a storm and been tumbled by the waves, you know how powerful the ocean is. Imagine the energy it takes to keep all the water of all the oceans in constant motion. If I had not been a believer in plate tectonics before I flew in space, I would certainly be a convert now. I could see cracks in the surface of the Earth, like the Great Rift Valley which extends 4000 miles from Jordan in southwestern Asia southward through eastern Africa to Mozambique. I could see the effect of India crashing into Asia at geologic speed and, in the process, forming the Himalayas, which are the highest mountains on Earth and still growing. Compared to all the energy involved in these natural processes in the Earth, we humans seem very small and powerless.

My feeling after seeing the Earth from an astronaut's vantage point is that the Earth has been here for several billions years before us and will be here a long time after we are gone. We will not hurt the Earth. What we should worry about is ourselves, our children, and our grandchildren. We are the ones who are fragile. We can live in a very limited chemical environment and a very narrow temperature range. We are capable of making ourselves extinct by our own actions, but we will not hurt the Earth.

The third impression I always want to remember is about neighbors. We think of neighbors as the people who live close to us. If we travel across the state and meet someone from our hometown, we immediately feel that we have a relationship with them; we are neighbors. If we travel to California and meet someone from Virginia, again we have a neighborly feeling even though their home may be hundreds of miles from ours. Still we are neighbors. If we travel to California and meet someone who even knows someone in Virginia, he is sure that we know them too because we are neighbors. It occurred to me that I could circle the whole Earth in about the same time it took to drive around the City of Houston, my home at the time. If I felt that if all Houstonians were, in a way, my neighbors, then perhaps all the people within the globe I had just circled were my neighbors, too. Maybe if we all had the opportunity to see our world from that point of view, we would learn to get along better as neighbors.

How did I get so lucky to experience the thrill of space flight? There are a number of factors including good health, having the educational credentials NASA was looking for, and a lot of luck. Certainly my life's choices had something to do with being prepared to answer NASA's call for volunteers, but I also credit my parents for good health genes, fate for the stroke of luck, and dedicated teachers who ignited that spark in me.

I don't believe you can light a spark in every one of your students. I know I can't. I try to keep them all awake, some of them interested and a few excited about the possibilities that lay before them. There is a group of engineering students at the University of Virginia who called themselves the Space Advancement Society, reminiscent of the amateur rocket societies who kept the science of rocketry alive during the 1930's. The UVa Space Advancement Society members have drafted me as their faculty advisor this year. My job, as it was explained it to me, was to sign papers when they need evidence of adult supervision and otherwise stay out of their way. Actually, they were very polite; they invited me to tag along on their rocket launching adventures but they are clearly a self-motivated and self-directed group of students. Sometimes I wonder if there is young Wernher von Braun, Robert Goddard, Alan Shepard, Neil Armstrong, Sally Ride, or Shannon Lucid among them, and if have I done my part to ignite that spark in them.

I was very fortunate to be a crew member on four missions on the Space Shuttle. I gave that up last summer to accept a new mission: to do what I can to improve math and science teaching and learning in Virginia. It wasn't so long ago, at least in some states, that citizens had to pass a literacy test in order to vote. It was believed that if a person could not read, he could not be informed on the issues and, therefore, could not cast an informed vote. Those literacy requirements were forbidden by an act of Congress in 1965 because they disenfranchised groups of people and because, by that time, a citizen could become informed without reading by listening to radio or television. Today mathematical and scientific knowledge is increasing in importance as our society becomes more technology based. The decisions we as citizens must make require us to be technologically literate. Our students must acquire thinking, reasoning and problem solving skills in order to become informed adults and participate in a knowledgeable way in the democratic process in this country. As director of the University of Virginia Center for Science, Mathematics, and Engineering Education, I join with you in your goals to support and promote math and science in K-12 classrooms across the Commonwealth. And as a parent of three children in the public schools, I deeply and personally appreciate what you and this Collaborative are doing for all our children and for the future of Virginia. ■

An earlier version of this paper was presented to the Summer Conference of the Virginia Collaborative for Excellence in Teacher Preparation, supported by the Division of Undergraduate Education of the National Science Foundation.