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CSU College of Engineering Commencement Address
John Brophy

Dean Woods, faculty, family members and friends, and especially members of the Class of 2006, good afternoon and congratulations. It is a truly great honor for me to be here with you today. However, soon after I accepted this honor I realized that I had no idea how to prepare for this address. So I did what everyone does these days when they need information, I Googled "college engineering commencement addresses," and in 80 milliseconds out popped 990,000 speeches, which I will read to you now.

There are two recurring themes in these commencement addresses: First be passionate about what you do; and second expect that the future will be full of surprising changes and new opportunities. And I can tell you that this is exactly right.

I know the significant effort it has taken for you to get here today. The good news is that this has prepared you well for the future – I have pulled many all-nighters since leaving CSU.

I received my Masters degree in Mechanical Engineering from CSU in 1980. I also met my wife here, so CSU is near and dear to my heart. I liked it here so much, in fact, that I came back and completed by PhD in 1984. The world is a different place now than when I graduated. My PhD thesis was the last thing I wrote by hand, just before the widespread availability of PCs and word processors. There were no iPods then, no cell phones, or web search engines.

But there were ion thrusters – at least in the laboratory – which were intended for the propulsion of deep-space robotic spacecraft. I did my research here at CSU on understanding how ion thrusters work, and then went to NASA's Jet Propulsion Laboratory as a newly minted PhD egger to see this advanced technology used to explore the solar system. Ion propulsion or ion drive as Scotty from Star Trek called it; it sounds futuristic and high-tech. But, the first ion thruster was actually tested in a NASA laboratory in 1959 – when I was 3 years old. Part of my self-assigned job at JPL was to make this really old technology sound new and exciting.

Now, since ion propulsion technology had already been under development for 25 years by the time I left CSU for JPL, and given the enormous performance advantages that it offers, I figured that it wouldn't be long before it was used on a deep-space mission. Twenty-two years later that's finally going to happen.

A young engineer at JPL recently asked me, "wasn't it a risky thing to base your career on this very narrow field?" But I never looked at it that way. I believed that by I could make a difference. I was passionate about developing and getting this technology used. And it took a lot of passion over many years to change the system and make this happen.

But it did happen, and it happened in December 2001 when NASA selected Dawn as the first use of ion propulsion on a deep-space science mission – in this case to rendezvous with the two largest main-belt asteroids located between Mars and Jupiter. Then in December 2003 NASA cancelled the mission. Four days later NASA uncancelled the mission. In October 2005 NASA cancelled the mission again. Five months later NASA uncancelled the mission. The aerospace business is not for the feint of heart. But we persevered and are now just 7 months from launch. So keep your fingers crossed.

The Dawn ion propulsion system will be the most advanced propulsion system ever flown. It will enable the Dawn spacecraft to go into orbit around the asteroid Vesta, which is roughly the size of the state of Iowa. After doing its science thing there it will do something no other spacecraft has ever done. It will leave that body and travel to another target, another asteroid – well actually a dwarf planet now –called Ceres and it will go into orbit about it. Ceres is about the size of Texas – so it's a fairly substantial body. Dawn will be the first spacecraft to orbit two different extraterrestrial bodies.

In an ion propulsion system xenon atoms are ionized by stripping off electrons and then accelerating the positive ions out the back of the rocket at a very high speed. To understand how ion thrusters work, a knowledge of plasma physics is required. Now plasma physics encompasses an extraordinarily rich set of physical phenomena, but it is not a rich source for jokes. Nevertheless, I happen to have one here… Two xenon atoms bump into each other in a bar. The first one says, "I think I lost an electron." The second one says, "Are you sure?" The first one replies, "I'm positive."

As I said earlier, lots of things have changed since I graduated from CSU. The coming changes, however, will be much bigger and more dramatic than before and engineering solutions will be required. Engineers will literally be needed to save the world.

If you doubt that large-scale changes are possible, consider this example. Two billion years ago lowly photosynthesizing bacteria that produce oxygen as a waste product created a buildup of oxygen in the atmosphere. This increase of oxygen resulted in a severe change in the environment and many organisms could not live in the new "poisonous" oxygenated atmosphere. Bacteria had changed the world. Fortunately many organisms managed to adapt and survive [1].

So what are the changes that lay ahead? It is, of course, difficult to know. But one change seems certain. The current sources of cheap energy that are responsible for our high standard of living are limited, and a change to other energy sources will be required. Real wealth represents useable energy, and real cost reflects the energy cost of doing something [4]. In this context, space-travel is expensive in large part because of the tremendous amount of energy required to get into space and to move around the solar system once you're there. Ion propulsion reduces that cost because it provides a substantial improvement in efficiency.

Back on Earth, it has been estimated that in the U.S. our use of this cheap energy is, on average, the equivalent of everyone having 17 of their own personal servants working for them, and who wants to give this up?

The news media made a big deal recently over the fact that there are now over 300,000,000 people in the U.S. More importantly, however, there are now more than 6.6 billion people in the world. When I first came to CSU in 1978 there were only 4.3 billion people in the world. The result of such population growth is that the global per capita oil production actually peaked in 1979. Since 1979 the world has been producing people faster than it has been producing oil. New sources of energy are required along with ways to control the growth of the world's population.

Methods for controlling human population, of course, are enormously controversial. From an engineering perspective, however, there is one method that seems to be relatively humane and acceptable. People who are taught calculus tend to have fewer children [1]. Calculus is evidently an effective method of birth control.

On a more serious note, the key challenge will be to engineer solutions to the coming energy crisis. The good news is that we are awash in energy, but it will take new engineering, innovation, and passion to get it, make it widely available, and change the world. Perhaps CSU's innovative algae-to-oil research will be successful. Perhaps it will be something else. Most likely it will be a combination of things. The challenges are enormous; the opportunities endless.

Truthiness was recently named the word of the year by Merriam-Webster. It is defined by Stephen Colbert as, "truth that comes from the gut, not from books." This is a great word, and I know what you're thinking, why couldn't our final exams have been based on truthiness? The answer, of course, is that this is the exact opposite of engineering excellence. Nature is ruthless to those that don't deal in reality. Engineering is a demanding discipline. Engineering is hard. As Tom Hank's character said in the movie *A League of Their Own*, "it is the hard that makes it great." Engineers do everything they can to understand how nature really works, and then they add lots of margin. When it absolutely has to work, you'll really learn to appreciate engineering margins. You don't want your bridges or spacecraft designs to be based on truthiness. While the word is new, the concept is not. I found one of the most useful books in the library here when I was a student. It was a small book written in the 1950's titled, *How to Lie with Statistics* by Darrel Huff [5]. It showed how to spot truthiness dressed up with a veneer of statistics. And it is as true today as it was more than 50 years ago as evidenced by the fact that the book is still in print.

What a great time to be alive and starting your careers. New discoveries are being made at an incredible rate. It now appears that liquid water may still exist on Mars; there may also be liquid water on Europa – a moon of Jupiter, and on Enceladus – a moon of Saturn. Since life as we know it requires liquid water, you may be involved in the first discovery of life outside the Earth. You could be involved in the first discovery of Earth-like planets in other solar systems, or in the use of gravity waves to open a new window

through which to observe the universe. You may develop engineering applications based on new ideas such as that presented in the book, *Programming the Universe*, by Seth Lloyd. In this book he describes the universe as a giant quantum computer in which there are only two fundamental quantities, energy and information. These quantities interact to compute the future and create complexity in the process. It is a fascinating idea.

One parting bit of advice, there is often a tendency to guard hard-won information and knowledge. But this is a mistake. One of the commencement addresses I read in preparing for this speech said, "If knowledge is power, then knowledge shared is power multiplied [6]." And this is true. By sharing what you know you'll make yourself more valuable not less. So share information, be confident, and be the best. The world needs you.

Congratulations and good luck.

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1. Kenneth Deffeyes, *Beyond Oil*, Hill and Wang, 2005, IPSN 0809029561.
2. Paul Ormerod, Why Most Things Fail, Pantheon Books, 2005, ISPN 0375424059.
3. Seth Lloyd, *Programming the Universe: A Quantum Computer Scientist Takes On the Cosmos*, Knopf (March 14, 2006), ISBN: 1400040922.
4. http://www.lifeaftertheoilcrash.net/
5. Darrell Huff, *How to Lie with Statistics*, W. W. Norton & Company, 1954, ISPN 0393310728.
6. Carol Hart, The 2006 College of Engineering Commencement Address, Wichita State University.