"BEYOND THE BORDERS OF IMAGINATION"
DANIEL YERGIN'S COMMENCEMENT ADDRESS

(as prepared for delivery)

It is a great honor to address today's degree recipients of this great institution Caltech, both undergraduates and graduate students, as you take those final steps in your long educational journey at Caltech. I might note that the few steps you walk today to pick up your diplomas are by far the easiest steps compared to everything you have done over the last few years to do to get to this point.

I have to tell you—recognizing the extraordinary education here at Caltech, its dedication to teaching and research—and the strength of this community—it is a little daunting to be asked to speak at the commencement.

I found some guidance in the history of the ancient Greek historian Herodotus. People talk today about the "clash of civilizations." But that clash has been going on for a long time. Back in 480 B.C. the clash pitted Asia against Europe. The Persian king Xerxes, bent on conquest, invaded the Greece of city-states.

At one point, the beleaguered island of Samos, threatened with defeat, dispatched a delegation to Sparta to beg for help. The delegation made one of the greatest errors you can make—delivering a really long speech.

At the end, the Spartans, their patience sorely tried, explained that they had lost concentration and didn't pay attention to the second half of the speech and that, the speech had gone on so long, they had actually forgotten the first half.

So I will try not to make the mistake of those good citizens of Samos and overstay my welcome on this platform.

The impact of Caltech is so manifold. You owe many things to Caltech as graduates and some of which you are not even aware – such as this beautiful late spring day. Yes, Caltech plays a role in the climate you and your families enjoy.

Arie Haagen-Smit was a brilliant chemist who taught on this faculty from 1937 to 1971. His great interest was the chemistry of plants. He figured out from what derived the taste of onions, garlic, and wine. He also identified the active agent in marijuana. For which, legend has it, there is a statue somewhere to him in the state of California. But his great subject was the chemistry of the taste of pineapples.

One afternoon in 1948, he was working in his laboratory on his beloved pineapples when he walked out of his lab for a breath of fresh air – or if you look at that extraordinary dashing photo of science-researcher, in my book *The Quest,* puffing a cigarette midst his test tubes, you might suspect it was for a smoke. Anyway, instead of this brilliant sunshine, he found himself engulfed in the dark noxious cloud of smog. It really was awful.

Everybody was against smog. But no one knew what the source of the smog was. Anyway, Haagen-Smit said to himself I'm a chemist, I'm a Caltech professor, I can solve this. And he did, as he said, "hit the jackpot on the first nickel." It was the incomplete burning of gasoline in auto engines.

That started the regulation of auto exhausts, problem-solving technological innovation, the establishment of the California Air Resources Board by Governor Ronald Reagan – first chairman, one Professor Arie Haagen-Smit, and eventually to the mandate for the development of the electric car, which is now beginning to appear on the roads.

Congrats to Professor Haagen-Smit and to Caltech's spirit of inquiry.

I encountered Professor Haagen-Smit in writing my most recent book *The Quest.* That book reflects the field for inquiry that I have carved out for my own work – energy – which is really the interaction of technology and innovation with markets and economics, geopolitics and history.

And I thought I might draw a few lessons from this field as you think about your own futures. At least the lessons that I take away.

The first, I'm tempted to say, is to follow your passions. But to be frank, I know that's a little over-used, and so let's just say – do what really interests you. You'll enjoy what you do more, and have a bigger impact.

When I look back, that's what I did, without quite realizing what I was doing. After I finished my Ph.D. I had a two-year post-doctoral fellowship.

The only problem was that the topic I was supposed to work on I found progressively less interesting, which is a scary thing for any researcher. At the same time, the subject of energy, once relegated to the business pages, had burst onto the front pages and increasingly engaged me.

And in those two years I had the great good luck that no one was supervising me. So I just began working and writing on it. And then unexpectedly I was offered an academic job where I could continue to pursue this new interest. It wasn't what I had expected to be doing – at all. But I said to myself, "I'd better take it as they'll never make that mistake again."

Second lesson, flows from the first, take your opportunities when they're there.

Let me tell you the story of a young man who graduated with a very good degree in science – though one of his professors had criticized him as a "lazy dog"—but could not get a job . He tried to earn money as a tutor. Got nowhere.

His prospects looked so bad that his father wrote to one his professors saying, Can you help my son. He grows more and more unhappy and fears that his career had been completely derailed.

That was Albert Einstein.

Then along came a job in the patent office in Bern. The workload was light and over the course of the summer Einstein wrote five papers that changed the world. Moral of the story: don't scoff when you're offered that job in the patent office in Bern– especially if it affords you the opportunity to do what really interests you.

Of course, this isn't a hundred percent deal. You all will have to find the opportunities and balance security versus risk that fit in your own lives and your own character.

Lesson three—be curious – ask questions. It's true whether you're a researcher or go into business. A few weeks ago Jeff Immelt, the CEO of GE, identified curiosity as one of the key requirements for running a company of the scale and complexity of G.E. Yes, ask the "why" and "how" and "what's new" – and the "what ifs" and "why nots."

The fourth lesson—so obvious, but need to be reminded—is that things really do change.

We're in a period of extraordinary economic change when proud companies that rode one wave of innovation are being undermined by the next.

This is a period that Marc Andreessen, the founder of Netscape and venture capitalist extraordinaire, describes as one in which "software eats everything."

Try to see the changes early. Try not to be too locked in. Ask the "what ifs?" Try to pick up the signals. Sometimes you don't see the future until it knocks you over.

In the energy business, seeing change is a big problem in the energy business. A great consensus forms in the industry about where things are going, everybody agrees, and people invest and make decisions with great confidence.

The only problem – the world changes – and dramatically. This is a huge problem for an industry that invests hundreds of billions of dollars with a 20- or 30-year time horizon.

Let me explain: In 2004—that's just ten years ago—the price of oil was going to be $20 a barrel. Yet, at the time, economic growth in the emerging markets of China and India and others was changing the balance in the global economy, setting oil prices on a trajectory that would them over $100 a barrel.

In 2008, peak oil and peak natural gas were said to be at hand. We were going to run out of the stuff. The US industry was – definitely—disappearing into a terminal sunset, and we were headed into an era of permanent shortage of oil and natural gas.

Yet that very year the unconventional revolution in oil and gas – shale gas and tight oil—began to make its impact felt. Today, the United States is gearing up to one of the world's three largest exporters of liquefied natural gas, U.S. oil production has risen 64 percent since 2008, and the International Energy Agency says that the United States will within a few years overtake Saudi Arabia and Russia as the world's largest oil producer.

So much for running out.

A fifth lesson that I take away from all the work I've done over the years is a simple one. The power of conviction and willpower to act on that conviction. These can be very important for achieving results as a researcher, for getting the job done in the private sector. Sometimes it can change the world.

Steve Jobs is example number one, as so superbly captured in Walter Isaacson's biography. You all know about him.

But I have another example that will be unknown to most of you. It's the son of a Greek shepherd who had immigrated to the United States and settled in Texas. His name is George P. Mitchell. And he believed in natural gas.

He became convinced that you could extract commercial natural gas from dense shale rock. The view throughout the industry was that this was not possible. The only thing you could get was "uneconomic gas."

Anyway, for a decade and a half, starting in the early 1980s, Mitchell had his company labor away on figuring out how to do it. The people working for him said, "George, you're wasting your time. You're wasting your money". His answer was "It's my time. And it's my money."

It was only in the late 1990s that the first breakthrough occurred in hydraulic fracturing – better known as fracking. The second breakthrough occurred in 2003 when fracking was linked up with another breakthrough – horizontal drilling. Yet even then the impact of this yoking together of technologies did not become apparent until 2008.

And then it took off. Really took off.

I have already cited how it has changed the energy picture in this country – dramatically.

The economic effects are very large. Over two million jobs supported by the unconventional revolution in oil and gas. And remember this was at the period when the economy was heading into the worst recession since the Great Depression. Without these economic impacts, the picture would have been even worse.

A couple of months ago, I had the opportunity to interview former Fed Chairman Ben Bernanke at our annual conference in Houston. I asked him about the economic impact of the unconventional revolution. His answer: "one of the most beneficial developments if not the most beneficial development since 2008."

In the wake of the unconventional revolution is an industrial renaissance in the United States – one that will offer opportunities for some of you. Because of its impact in lowering U.S. energy prices, it has suddenly made the United States a more competitive place in which to manufacture, at least for many companies. President Obama has cited $100 billion worth of new investment scheduled for the United States as a result of this development.

And now people – from Moscow to Beijing to the Arabian Gulf—are beginning to ask what this change in the U.S. energy position means for geopolitics and for providing a new dimension of American influence in the world.

Pretty amazing what the conviction of a single person can do.

We're in a much better energy position than it seemed half a dozen years ago. But, with that said, I don't want to leave you with the impression that everything is now fine – and safe. There's plenty of geopolitical risk and danger for the global energy system, as events in parts of the Middle East and North Africa are now demonstrating.

Sixth lesson. Try to be innovative. And what you have going for you, if you go down that route is that both the market and the culture are more enabling – and more forgiving – than in times past.

One of my favorite characters in The Quest is General Georges Doriot. Although he was a professor at Harvard Business School for 40 years, he became a general during World War II as really director of innovation – although they didn't call it that – during the war. He described modern warfare as really "applied science."

He's also, more than anyone else, the father of venture capital. Of course you could say venture capital had been around for a long time. After all, that's what J.P. Morgan was doing when he financed Thomas Edison's development of the electricity system. In the 1930s, there had been some efforts in this direction. But it was initially called "adventure capital." But that wasn't very reassuring name. Sounded more like going to Las Vegas than prudent investing. And so the name was shortened to venture capital.

When Doriot returned to teaching after World War II, he also set up a company to fund innovation in a disciplined way. Or as Doriot put it: to interface, on one side, between large companies with resources but an inability to nurture innovation and, on the other, academics and inventors with creative ideas but no funds who were "trying desperately to become poor businessman."

Today, venture capital is a critical infrastructure for our economy. It's also of course shifted massively from the Northeast to California, albeit a little north of here. And one of its main missions is to connect the laboratory with the marketplace and bridge the "valley of death" for new enterprises. We would not have the remarkable innovation that has transformed our culture without this industry. And by the way a number of academics have demonstrated that they can be pretty good business people too.

Innovation can be remarkably fast in the tech and digital world.

In energy, it can take much longer for innovations to make their way into the marketplace. As Steven Koonin, former provost of this institution and former undersecretary of energy for science, has observed, "Even accelerated energy transformation will take decades."

Combining many different technologies together in an industry where physical risk has to be managed very carefully is quite different and more difficult than coming up with new smart phone app.

Caltech is at the forefront of research, of applying science to the energy needs of today and tomorrow – as reflected in the Resnick Sustainability Institute, JCAP, the Center for Sustainable Energy Research, and other programs – and in the outstanding professors who lead these programs. A lot of progress has been made in renewables – solar and wind – since those modern industries were borne more than 4 decades ago. The research being today at Caltech may well prove critical for bringing their costs down, for the breakthroughs that we don't yet see, for defining what will be our energy systems a half century from now.

A number of graduating students will have had the opportunity to participate in the critical research being conducted at these centers and Institutes.

Of course, as Caltech graduates, you will have so many choices, so many different directions in which you can go. Whatever you do, look for big challenges and impact.

In that regard, I do want to suggest that the world of energy has a lot to offer people with a Caltech education. There is what I see as the "great bubbling" of innovation – never has there been such a focus on innovation in the energy business.

There is the great issue of climate – what we do know and what we don't know about this extraordinarily complex system – and about mitigation versus adaptation.

There are the sheer numbers and scale of what's ahead. Economic growth around the world means rising demand for energy. Just consider that in 2000, 17 million new cars were sold in the United States and 2 million in China. By 2035, according to IHS' projections, 17 million new cars will once again be sold in the United States – and that two million annual cars in China in 2000 will be 41 million cars in China in 2035.

We need the technologies to promote much greater energy efficiency. But we will also need supply. If the world economy doubles over the next two decades, which is altogether possible, the world will be using 35 to 40 percent more energy.

Today, 82 percent of world energy is oil, natural gas and coal. What will it be two decades from now – and what will be the remarkable innovations on both the supply and the demand side that will deliver the supplies that a world rising incomes and falling poverty requires?

And how secure will our energy systems be in a world which is moving, as one CEO described it, not into a brave new world but a bad new world of cyber vulnerability?

So, from my parochial point of view, I hope that some of you will find fulfillment in applying what you have learned here to the great energy challenges of tomorrow. You're needed.

But, of course, you're needed all across the economy – and all across the spectrum of innovation – and the multiple fields of science and engineering, and beyond.

On this day of celebration, as you look to the future, think for a moment upon what a great tradition you are part of here at Caltech—and what Caltech represents.

As you pick up your diploma, that parchment that is the symbol of what you have done here in your years at Caltech, you will apply what you have learned – and will continue to learn in your careers – to endeavors that will contribute in one way or the other to changing the world.

When I was finishing *The Quest,* I happened to pluck from a bookshelf a history of the internal combustion engine and saw a quote from Sadi Carnot.

The Carnot Cycle is well known. But do you know much about its author, Sadi Carnot? Not that much is actually known. He died in 1832, age 36, of cholera, and because it was cholera, they burned his notebooks. He was of course a French scientist and engineer who decided to explain how the steam engine worked.

But he was interested in it not only because he was a scientist and engineer but also because he was a soldier. Indeed, his father had been minister of war under Napoleon, and Sadi Carnot was convinced that one of the reasons that Britain had defeated France in the Napoleonic wars was because of the British mastery of technology – specifically this amazing new technology of the steam engine. He wanted the French to understand the technology in order to restore the glory and preeminence of their nation.

But what caught my eye was what he said—that the advent of the steam engine constituted a great revolution in human affairs. Humanity had for the first time harnessed energy beyond that provided by muscle of human and animals and wind and running water.

When we look at the sweep of energy developments since the 18th century, it can be seen as the unfolding acts of the great revolution – changing the world again and again.

Standing before all of you, I am conscious that in fact what I describe in energy is but a subset of the great revolution – of science and engineering and mathematics continuing to transform our entire world –providing the muscle power to stretch beyond the borders of imagination.

But now I run the risk of that unfortunate delegation from the island of Samos in their plea to the mighty power of Sparta – and speaking too long.

So let me conclude by congratulating the parents and siblings and families gathered here on the support you have provided to today's graduates on this day of celebration.

And to congratulate the teachers who have taught and prodded and mentored, and most critically, inspired these students here today.

And, most importantly, of course, congratulations to you graduates on what you have achieved and what you will achieve in the future.

The future is uncertain. But as I look out on all of you in your gowns, of one thing I am certain.

As you graduate and go forward in the world, equipped with what you have learned at this great institution—wherever you go after today – you will make your distinctive contributions to the Great Revolution through the rest of this century – and indeed help the world to stretch beyond the borders of imagination.

Congratulations.