

March 18: Engineering and society

September 11 The day meant a lot of things to a lot of people. On its anniversaries, the occasion is commemorated in a number of ways, here in Boston, in my hometown of New York City, and around the country and the world. I can't hope to be as profound as some of the speakers at those services, but can talk about a few things it meant to me personally, in particular as I have reflected on my decision to become an engineer, and my purpose in the profession. Perhaps some of it will resonate with one or two of you; I invite your comments or questions, and we'll take as long for this as we have to. The timing may seem odd, coming in late March instead of mid-September, but its reasons will become apparent presently.

I'd like to start nine days before the tragedy, when I was in New York for my sister-in-law's wedding. My wife's parents live in Brooklyn, which is where the ceremony was held, but we were staying with her aunt and uncle in Long Island. At least twice a day in the few days beforehand, we drove the Belt Parkway and Brooklyn-Queens Expressway, wrapping around Brooklyn, passing under the Verazzano bridge and entering New York Harbor, with the view of the Statue of Liberty and the majestic buildings rising ahead, the skyline dominated, of course, by the World Trade Center.

During those drives, I recalled the experience of my High School French teacher Mr. Schwartzbart, an Austrian Jew who survived World War II in a rural Belgian boys' camp which, unknown to him at the time, was made up entirely of Jewish boys, and in fact, was set up to keep them safe throughout the Nazi occupation. He described the terror he felt under the occupation, and then the arrival of the American soldiers, "All of them giants," he said, then pointed to me, "like Adam," they had come to set the continent free.

And he described the journey to America as a young teenager, a transforming experience. Most amazing was the entry of his ship carrying scores of poor immigrants like himself into New York Harbor, this impossibly enormous bridge which just got bigger and bigger as they approached (the Verazzano was the longest span in the world for about 50 years), the tranquility of the harbor within, with the great buildings visible ahead including the Empire State, and the Statue of Liberty to his left as they steamed toward Ellis Island (the World Trade Center's construction was still 20 years away). There was an awe-inspiring sense of the magnitude of this great nation of impossible size which had overwhelmed some of the greatest evil the world had ever known, and his heart swelled with joy at the thought that there was such power on the side of liberty.

These days it is fashionable to reflexively cringe at the identification of this country with freedom, and this teacher in particular very frequently commented cynically on the deficiencies in American culture and education. Having come to know this side of him, when we asked why he came to this country, Mr. Schwartzbart's reply surprised us: "The land of the free and the home of the brave." Then after a pause, "It really is true." His personal experience of this gave great weight to these words.

During these drives along the Belt Parkway, my thoughts also turned toward the fragility of the grand edifices, and in particular to the 1993 bombing of the underground parking lot of one of the Twin Towers. Fortunately the towers withstood that attempt to destroy them, but there would surely be more attempts, and no amount of devastation was too horrible for the perpetrators to dream up. Should anything happen, I was grateful for the opportunity to see this beauty, and even to feel a small piece of what Paul Schwartzbart had felt some fifty years earlier. I thought of how fortunate is his generation which came through the Depression, fought that terrible war, and lived to see the nation preside over such a long and prosperous peacetime as the world had perhaps never before known.

So you can imagine my shock when just nine days later, as I sat in my office, my wife called from home to say that while watching CNN, they announced that a plane had crashed into the World Trade Center. Well, I thought, about 60 years ago a small plane hit the Empire State building, I'm sure there was a lot of damage and many people killed, but the rest of the building should be fine. Just a few minutes later she called again to tell me about the second plane, and suddenly I was afraid. Then the Pentagon, and the missing plane in Pennsylvania. My thoughts turned to the Mid-East, and this administration's policy of deliberate neglect in the Israeli-Palestinian peace process. Then the last call, one tower had collapsed. With her voice choking from the tears, she described its fall as "like a house of cards," and could say little more. Immediately, I logged out, got on my bike, and pedaled home as fast as I could.

I'm sure each of us can tell a story about where we were when it happened. Being from New York, I was immediately concerned for friends and family. My wife's grandmother went to the roof of her building in Queens, from where she saw the second plane hit the south tower, and that tower's collapse. I had shared this view every day growing up as I rode the Roosevelt Island tramway to school and saw these buildings which seemed as permanent as mountains. My wife's best friend in College, who lives in the Prospect Heights section of Brooklyn and works in the southern tip of Manhattan, noticed people in his neighborhood looking up and saw some smoke, but rushed into the subway as he was late for work; the packed subway stopped after it left Brooklyn and waited in the tunnel for about 20 minutes before it turned back and he got out and learned what had happened. My Elementary School best friend worked in the 17th floor of Tower 1, and had a bad back which would have made it painful and difficult to get out—if he hadn't been home sick that day.

Then there was my father's friend whom I know well and whose business had just finished moving into the 89th floor of Tower 1. His staff had been told not to come in that morning until 10 AM, because their carpets, freshly washed during the 1-7 AM shift, would need to finish drying. As he drove north on the New Jersey Turnpike, he saw the first plane crash right through the windows of his new office, then took the next exit and went right back to his daughter's kindergarten class.

The previous Spring and Summer I had a course 6 UROP student in my group. His brother worked above the 90th floor of Tower 2, and on the first and second day afterward without a word to anyone in his family, my student grew panicked, then desparate, then increasingly hopeless. His brother finally called to say that a friend had literally dragged him from the office after the first plane hit, and they ran out of the building together just as the second plane smashed into it. He described bits of the hell that was the area around him, but at the time had no other thought than to get away, go home and lie down in shock, not even thinking about his relatives who were trying to reach him. My student described the moment when they connected as one of the happiest of his life.

Another friend was not so fortunate. Her father worked in an upper floor of Tower 2, and was one of just two in his company who didn't make it out. To make matters worse, she was trapped in L.A. because of grounded planes, unable to get back and try to locate him, so day upon day she was not only uncertain and hurting but frustrated at being far from anyone who could help her. She is still grieving, as it's hard to accept that she lost the closest person to her in the world because a handful of maniacs decided to crash a plane into his building.

There are of course tens of thousands more stories like these, so many people were affected directly or knew someone who was. But even if you were not so directly involved, if you're like me, the tragedy didn't end on that day, but played out over and over again in your mind. I can't count how many mornings in the ensuing months I woke up at 3 AM thinking about the towers' collapse, feeling hurt, afraid, angry, and much as I hate to admit it, somewhat vindictive as we learned of the total destruction of the Al Queda camps and cave complexes in Afghanistan.

Then thoughts turned to my own life. What can I do, what's my role in the world, how can I help?

I turned to the motivations I had for entering science and engineering, and materials science in particular, which I came up with in High School. Motivations for studying these things vary greatly, from interest in the subject matter, elegance of the equations, beauty of nature etc., to being able to earn a stable income and support a household, or perhaps a large income, to serving society in some way. My own motivations fell somewhat in the first category, but if I had followed that alone I would have been Course 6-3 (computer science); it was the last of these categories, serving society, which steered me into Materials Science.

As a high school student, I verbalized this service as follows. As a scientist or engineer, I would be helping to solve the world's little problems, which I listed as:

- Agriculture, to feed a growing planet.
- Medicine, allowing people to lead longer, healthier lives.
- Transportation and communications, to bring people together and lessen the chances of conflict. For example, much of the reason war between France and Germany today is unthinkable is because there

are so many more personal cross-border relationships now than in 1940 or 1914, it's very difficult for a propagandist to castigate an entire people as "the enemy" and it's becoming more difficult every year.

- Human interactions with the environment, for sustainable living.
- A recent addition, information access, with implications for democracy, as the biggest enemy of an authoritarian state is the truth.

All of these are important in themselves, but even more important, if we do our jobs well and make a difference in these areas, we help the artists, politicians, economists, philosophers and theologians to solve the big problems, which I would list as:

- World peace.
- Averting famines, and their relief. Almost all famines can be avoided without resort to international aid, and are the result of poor resource management and the vicious cycle of price increases and hoarding by the few who can afford it.
- Real public health, made available to those who need it around the world.
- Justice, including somewhat equitable economic distribution.
- Truth in journalism and history.
- Human happiness and fulfillment.
- Purpose and meaning for our lives.
- Artistic expression of emotions, of values, of that purpose and meaning.
- Last year Ross Benson added: Tolerance of differences.

An important consequence of this understanding of "little problems" and "big problems" is that being a scientist or engineer requires a lot of *faith*, faith that our knowledge and our inventions will be used wisely, for good and not for evil. The more "sciencey" our contributions, the more faith is necessary, with the ultimate example perhaps being nuclear science, which can be used to produce lots of cheap power or cure diseases, or destroy entire cities in an instant. If we work on weapons, they can of course be used for defense or for aggression.

But even if we're not working on nuclear science or weaponry, one of the lessons of September 11 for me is that no matter how careful we are to focus on purely non-military technologies, this tragedy showed that even a civilian jetliner—built to bring people together—can be abused by people with sufficient hatred as a weapon of mass destruction. This is truly frightening for us, and requires us to have that much more faith in the people, institutions and systems surrounding the technology in whose development we participate.

So what should we do? Shall we abandon technology altogether and go back to rubbing sticks together? Perhaps we should join the peace corps? For some of us that will be the answer, but I think there's a lot more that can be done with the little problems that can help to make a real impact on the big ones. So how can we put ourselves in positions to do as much good as possible?

I can think of a few ways, but at your age and even at mine, perhaps the most important is to take a step back and examine what we're doing and why. I have an advisee taking this class now who took off all of last Spring for that very purpose, and ended up returning to MIT (and in fact to Materials Science) that much more focused than the previous December for the experience. Of course, you don't have to take off a semester to do this, there are very good ways to do some of this right here.

First, the HASS and HASS-D subjects present outstanding opportunities for this kind of exploration. MIT is no longer just about training technology leaders, but also about training world leaders who know about technology, and this school has put enormous resources into building world class departments in the Humanities, Arts and Social Sciences. For example, I've heard tremendous things about our Anthropology

department from a variety of external sources, and even within our department we offer a HASS subject called Materials in the Human Experience (3.094) every Spring.

Second, I've made a point of suggesting to all of my advisees that they get to know the MISTI programs (MIT International Science and Technology Initiatives), which do an outstanding job not just of sending students to companies, universities and government labs in foreign countries, but also preparing them for the trip, even culturally and psychologically.

Third, develop a habit of using your wealth to support organizations and causes which effectively promote what you view as positive values. You may not have much now, but you will later, and getting into this habit is not hard; furthermore, membership in many of these organizations requires a contribution of as little as \$30. If you like I can discuss offline some of the organizations I've given to since my undergraduate years, one even since high school.

Fourth, look for opportunities to participate in the process of improving lives yourselves. Whether tutoring or mentoring, or working in a social justice organization, or writing to Congress, participating in society in a meaningful way is important to making it all work, and I believe important to improving ourselves too. Believe it or not, time is actually one resource which you will *not* have more of later in life than you have now, particularly if children become part of your life.

Fifth and perhaps most importantly, get to know your fellow students. This buzzword is repeated over and over again, but it's worth repeating yet again: because MIT attracts the best and brightest from all over the world, the *diversity* of the students on this campus is truly extraordinary, it's almost certainly broader and deeper than anything you've experienced before college, and almost certainly broader and deeper than anything you will ever experience later in life. That goes for many other universities as well, though somewhat less so on the graduate level and beyond. And by getting to know your colleagues, I don't just mean hanging out and eating pizza, nor even getting to know what spices they use to cook lamb, though food is of course an important part of intercultural social interaction. I'd encourage you to learn something about your friends' lives, their families, their values—and be willing to discuss these aspects of yourselves too.

And given its importance, I'd encourage you to learn something about your friends' faith. Human institutions, organizations, systems and even nations are terrific, but never perfect, as we learned in a powerful way on September 11. Participating in and strengthening them is an important and honorable activity, but I believe that placing all of our hope on them is not viable in the long term. At some point they're going to let us down, as this country has in some ways let down my French teacher Mr. Schwartzbart. Furthermore, evidence abounds for forces at work in the universe beyond those of physics, and even grows with the increase of human knowledge about this universe; perhaps the most significant example is the Anthropic Principle in Cosmology, which some of you may have heard of and I'd be happy to discuss offline.

That concludes what I said last year: the tragedy reminds us that our work here is very important, but must be viewed in context, and done with faith that it will be used for the broad purposes for which we intend it. Since writing this for the Fall of 2002, time has passed and some of the emotions have subsided just a bit, also several important things have happened, or have not happened, causing my own feelings about this to be somewhat more complicated.

For one thing, the message from Washington continues to urge us to live out lives as if nothing had happened, because if we changed anything, we'd be giving the terrorists what they want. But what sense does this make, when important things have changed, and as citizens there are things we can do on a daily basis to improve our country's security, and the silence from Washington has been deafening.

A while ago I saw a book provocatively titled, "When you ride alone, you ride with bin Laden." The cover art was derived from a World War II poster, "When you ride alone, you ride with Hitler," whose point was that the practices of avoiding driving, carpooling, and using public transportation save gasoline needed for the war effort. In that vein, an important thing which has *not* happened is that there has been no effort whatsoever on a national level to reduce our dependence on imported oil, which has been a huge factor in our problems in the Middle East. In fact, we've seen the opposite in this administration's rollback in fuel economy standards, and heard talk about the costs to the auto manufacturers and consumers of requiring increases in efficiency, with no mention whatsoever of the multitude of costs of continuing to burn fossil fuels as extravagantly as we like.

Another thing which has changed my view of the world is the war in Iraq. For months, the administration hyped any evidence at all for Iraqi connections to Al Qaeda and possession or development of weapons of mass destruction (WMD). Then inspections were allowed (to be fair, largely due to U.S. pressure, and no thanks to the posturing of certain countries like France), and one-by-one the inspections eliminated every piece of purported WMD evidence save the rumor about uranium purchase from Niger. And so with that one rumor as justification, we sent an invasion force to Kuwait, and two years ago this Sunday, some two hundred thousand U.S. soldiers—including my brother—crossed the border and destroyed the Iraqi army in about four weeks.

I personally disagree with the war pretty strongly, but today would like to present a somewhat more balanced view than I did in the Fall of 2003, and talk about some lessons we can draw from the experience.

First, unconditional and stubborn opposition (particularly from France) was of no help in encouraging Saddam Hussein to accept inspections. The credible threat of invasion was necessary for him to let inspectors in with open access, and we all learned a lot from those inspections which informed the debate on the eventual start of the war.

As evidence lined up between September 2002 and March 2003, it was overwhelmingly against connections between Iraq and terrorism, and against the presence of WMD or an active WMD program.

The proverb talks about following a “multitude of wise counsel” which in this case was solidly against the war, including three of the five Security Council permanent members, some of our most important allies, and both of our neighbors. The three most prominent foreign policy advisors of the previous Republican administration of Bush Sr. came out strongly against the war during the Fall of 2002 via *New York Times* op-ed pieces. And of course there’s Colin Powell, whose opposition in private stood in strong contrast to his public stance.

Never brag about the lethality of weaponry. Today with over 1000 Americans and some 100,000 Iraqis dead, who is the better for all of that “Shock and Awe”? Those lives lost lives very nearly included that of my own brother, a Captain in the U.S. Army third infantry division’s second brigade, whose unit was hit by an Iraqi missile just after their capture of downtown Baghdad. Like my Course 6 UROP student more than three years ago, the days between learning of the attack and confirming my brother’s safety were some of the longest of my life. I cannot imagine the terror and grief of hundreds of thousands of loved ones of Iraqi soldiers who did not know for weeks or months whether their sons, brothers, husbands or fathers were dead or alive, nor the pain of those whose worst fears were in the end confirmed.

A great disappointment was the childishness with which the administration spoke of “punishing” the opponents to the war—particularly the French—and then turned around to ask them to contribute money and troops to the occupation and reconstruction to reduce the resource burden on us.

Turning to the other side, that August as my brother’s convoy rolled through southern Iraq on his way to Kuwait and back home, he passed through what had been the home of the Marsh Arabs, victims of Saddam Hussein’s ethnic cleansing which in this case took the form of diverting water away from these areas so they starved. That tyrant is gone, and can we put a price on the ensuing freedom?

In the long term, the most diplomatically problematic aspect of the war is the precedent it sets for accusing a nation of violations of one sort or another, brushing aside international outcry for restraint, and using military superiority to crush the weaker victim. This precedent can easily be abused by, say, Turkey, Syria, Egypt, Jordan and Saudi Arabia against Israel, North Korea against the South, Russia against the former Soviet Republics, China against Taiwan—any nation with a fight to pick can say, “But of course it’s been done before, by the Land of the Free and Home of the Brave!”

And so we are reminded of our duty as citizens to speak out about matters of importance to our country. And in particular, as scientists and engineers we have the duty to speak out with authority on certain issues such as the small cost of reducing energy consumption, and the enormous costs of not doing so. Most of all, in the changed world our need for faith is greater than ever, in our work as well as our outlook for the future. I welcome any comments, contributions, or questions.