Stanford eCorner

Risky Business: Analysis from an Engineering Perspective (Entire talk)

Elisabeth Paté-Cornell, *Stanford University*

January 27, 2010

Video URL: http://ecorner.stanford.edu/videos/2364/Risky-Business-Analysis-from-an-Engineering-Perspective-Entire-talk

Don't set sail without thinking first: this sage advice sums up risk analysis for Elisabeth Paté-Cornell, department chair of Management Science and Engineering at Stanford University. She explains that risk assessment involves the study of scenarios, probabilities, and consequences. A risk analyst uses logic and statistics to makes sense of uncertainties and provides possible solutions to derail disaster. While some events force quick thinking, most can be avoided with a little forethought. After all, she simplifies: risk analysis isn't just nuclear reactors, it's also real life.

Transcript

Today we have a very special guest. And I want to introduce Professor Elisabeth Pate-Cornell. Professor Cornell was born in Senegal and she attended schools in Senegal and then moved to France. She ended up receiving her Master's degree in Operations Research and then her PhD in Engineering and Economic Systems, both at Stanford University. Then she became the chair of the Management Science and Engineering Department, which is the position she has held for the last 10 years. Professor Pate-Cornell is a member of the National Academy of Engineering and on the boards of many public companies. She is an expert in the field of risk analysis and today, we're going to hear her insights on risk and risk management from an engineering perspective. These are topics that are very relevant to all those people in the room who are interested in entrepreneurship. Thank you, Tina. It's a great pleasure to be here.

And as you can hear, yes, I was not born in Brooklyn. So I'm glad that I'm bringing to you some of my slides so that you can follow, perhaps more easily. So I'm going to talk about risks, and I'm going to talk about risk from a different perspective. Yes, entrepreneurship. In fact, what I have done in that domain is I that I got unique entrepreneurship in the department of Management Science and Engineering. But what I am going to try to show you is how we think about risks in the world of engineering using systems analysis, probability, decomposing the problem, using all the information at our disposal, and trying to put all these together in a systematic manner. OK, so what I am going to talk about is sailing through life, business and service in a world that's larger than us. I mean, but I love sailing and I've sailed particularly in the military. And I'm not a particularly good sailor but I think that I've learned a few lessons from it. And so I will use that image occasionally.

And a world larger than us, I think it's important. You have heard maybe very often sail often and then sail early, but what I like to add to it, 'but not if you can avoid it. And especially if it is a life or the money of somebody else that's at stake. In other terms, you can do all kinds of things with your own resources but be careful when talking about other people. Now, this cartoon shows you two little characters that are at the bottom of a cliff and there are these very threatening rock on top of it. And then they look at it and it's risk perception. Then they talk about it and it's called here risk assessment. And then they run away from it when it falls, it's called risk management. I don't call that 'risk management.' I call it 'crisis management.' That means, the thing is falling on you, you run away. But in terms of risk management, they could have thought about other things like either letting it fall on you or perhaps tying it to the cliff.

Now, the problem, the problem is that there you are balancing over a sea of crocodiles. And be careful. And you have now here a little cartoon where the consultant in risk management is facing his client and the client says, "Be careful? All you can tell me is be careful?" And what I'm going to show you today is that we can do better than that. So how do we show people how to "be careful"? So what I've learned in real life is don't sail into a storm without first looking into it. Let me tell you, last summer, we were sailing between Corsica and Sardinia with friends of mine and we're on a 50-foot boat, not something huge. But the captain said, "We are leaving immediately and we are going to put the sails at half-mast. Just half." And I said, "Well, why is that?" He said, "Well, let's look at the weather forecast." And of course, sure enough, we saw what was coming and he was absolutely right. We left immediately with half the sail and we made it without any problem. We are the only sailboat in the area. OK, so you have to be confident about what the venture is and of what you can take.

The first thing that you want to do when you look at risks and you look at what's ahead of you - I am not that interested in what is behind you when looking at past failures, except of course, to the degree that we learn from them. But probability and logics is a good place to start when you look systematically on the chances of the outcomes and the consequences. And I'm going to start with a few jokes and mistakes. And I'm sure you have heard the old joke about the guy was carrying a bomb with him because the chances of two bombs in the same place was small. OK, that you can't do anymore anywhere but the problem if -- you will be caught before you get very far. But the problem here is the problem of dependent and independent events. And what you have to recognize very often is what are these dependencies that you are facing. Now, another one was the guy who wanted to eliminate all the pedestrian crossings because more accidents happen there than elsewhere. Sure enough, that was a stupid idea. But why is it that you have more accidents in pedestrian crossings? Because many more people cross at pedestrian crossings.

Now, given that they cross the road, it's safer to be at pedestrian crossings, nonetheless. So you see here, the problem is one of the prior probabilities on the street. Now there is a guy who wanted to go as fast as he could on the road because he argued that the risk was smaller since he spends less time going from A to B. Now, that was a friend of mine who told me that one. I did not stay for very long in his car. And in fact, another one friend of mine was driving and texting. He was playing with his... and he explained to me that he had done it all his life and yet not had an accident yet. And I say, "Well, that's too bad." You see, of course, that's the problem of rare events and that, too, I did not take it down. So now, here is the problem: in a world of uncertainties you very seldom have statistics.

And that is where you have to think straight. And when you do a risk assessment, you have to look at scenarios, what is it that you are going to face or that you can face, the probabilities and the consequences. Let me say that risk is not an expected value. It's not the probability multiplied by the consequences because very often, you have rare events with very high consequences. So what you need is a distribution on these outcomes. OK, then you can use the results to do several things. One is to track that you can live with the results. And if not, how you are going to allocate the resources that you are going to dedicate to the reinforcement of that system. And I'm going to show you that there are many ways of doing that. So first, I'm going to talk a little bit about myself.

So my own experience was between France, first, Africa and then France and then the US. And that was a risk, I mean think about coming here with 200 words of English, in a world where there are very few women in engineering, in science and engineering at that time. I remember about being slightly nervous about it and deciding to go ahead. I then studied math and physics. Again that was not in engineering. It was not a very common thing to do but perhaps the greater risks, the greater things I took at that point is while the tenure clock was ticking somewhere between MIT where I was a sitting prof, and here. I had two babies. And thinking about it, that was a risk that I took, that we took, obviously my husband and I. And we knew that we had a challenge which was to balance the elements of life. It was a personal life and the professional life, and make sure that you didn't shortchange anybody while doing what you are supposed to do.

OK, I'm talking about real risk, so real risks of real life. I'm going to start with a very simple example and a very real one to show you all the different sources of data in risk analysis. And risk analysis is not only for airplane, satellites and nuclear power plants, but consider the following real problem to me. I had a two-year-old little boy who really liked to tumble down the steps. And we were about to move in a house where on the landing of the stairs, there was a sharp post. And immediately, without writing anything, I thought about the risk that he could kill himself. So here are the data that I had. The frequency of falls, it was roughly once a week, so statistics. But of course I hoped he was going to stop doing that. I had an engineering model of a baby as a ball, one-third of which is the head.

How is that? Very subtle engineering. And there was a sharp corner on the landing of the stairs. And I had and I still have an excellent neighbor who happens to be a doctor of emergency rooms so I said. "What do you think?" And he said, "Well, one chance in 10 that he might really hit himself." So you see the result if you put all these together from very different sources of data, gave me a risk of accident of 130 per week which was enormous and I found a risk management solution that was an engineering solution. I put three baskets, soft baskets, one inside of the other, in front of the post, tested it with a basketball. And it's the equivalent, in fact, of springs in series. There you had it. And by the way, not a gate at the top of the stairs because someone would have left it open. OK, so the lesson in this that there are many kinds of different data that you can use, statistics, models, expert opinions. And when things when it's very important to me, that's the way I think about it.

OK, now, let's look at professional risk analysis at academia. I've never created a company, so I'm not going to pretend that. What I did though is to be the first chair of the department of MS&E Management Science and Engineering, and it was a merger of three very different departments with very different cultures and different personalities, different kinds of emphasis from operations research to social science. And I'm happy to say that 10 years later, it's still going strong. Now, all risks don't need to be qualified. But I would say that for many risk management decisions, it does help. And I'm going to show you particularly for complex systems and new situations. The most interesting risk problems are with risks that were never seen, systems that we have never seen and things that are completely new. The others, that's much easier. OK, so how do we think about risk analysis and how do I approach it? Well, when I want to explain what I do in life, I'm going to see experts and I'm going to say tell me how it works, whatever it is.

So let's talk about satellites for a minute. Let's figure out how it might fail, guidance system, propulsion system, electric system, optical systems. In other terms, any of the critical functions of that engineered systems that you need to have for the whole thing to work might be a source of failure. Then let's find ways to reinforce it. There are many different things that you can do. One of them is to make some of the components stronger. For example, you can have stronger pillars, or stronger beams in a building. Another one is to put redundancies behind the system. Another one is to manage it better and to make sure that you give the right incentives to the people who are the operators of your system. We are going to see in a minute why it really matters.

So then we are going to find the best way of doing the application and again, as you can see, experts matter enormously. Now, other risk analysts are not making the decision. I'm just providing information to a decision-maker who has his or her own preferences and I want to help that person to the degree that that person wants help to make a number of decisions. For example, adopt a new technology. As you know, nanotechnologies these days RE sometimes feared by some. What's the real risk? There's the system, cite a facility. For example a chemical plant, where do you want to put it? Manage inspection and maintenance; there for, example, the airlines. I've worked with airlines with a group of students from the 250D which is the project class, the project course of mine. It follows my class. And the question is really how do you do the maintenance on schedule, how often do you do it, for what parts.

There the Federal Aviation Administration is allowed to say, and how do you do the inspection on demand, how do you manage that? And then finally, adopt and implement government regulations. The Nuclear Regulatory Commission, for example, makes decisions regarding the safety of nuclear power plants even though the industry itself does a lot of policing. OK, so as you can see, I see risk analysis in this context as part of systems engineering. Let me give you examples of things we have looked at in my group, offshore platforms that was after the Titerall accidents in the North Sea on a perfectly clear day when in fact, there is a problem at the interface, essentially, between the riser and the platform and the whole thing exploded in a big ball of fire. But it had started because there was a failure somewhere and a leak. And the leak was because a young inexperienced worker fixed around six o'clock at night with a pump with a valve at night had failed to tag it, decided to call it a day, no one was behind him. And that thing failed when it was cold upon later during the night. Medical devices, we've done quite a lot of work. For example, one of my former students, particularly, heart, cardiac, devices. Another change is to know how to begin to test these things and the test that the FDA now wants on statistical basis would take a very, very long time.

So the question is can we begin to compute the probability of failure to start from and then do an adaptive testing that allows us to use Bayesian methods to update the information as we do that. Space shuttle, I'm going to show that in a moment. But also we have also looked at system that involved human beings. And I'm going to show you the model of patient risks in anesthesia. And then I found my self one day looking at intelligence and counter-terrorism. And that's because, much to my surprise, and in a very non-political way, I became a member of the president's Intelligence Advisory Board. And I looked at the way people were analyzing these intelligence information and I will show you in a minute a few things that I wanted to put or to inject in that system. So that took me into national security problems and nuclear counter-proliferation strategies which is the thesis of my student David Carson whom you know. And the question being how do you interact with a country that's trying to develop nuclear weapons? So no problem is too big or too small. As you can see in a wide variety of things, some things I knew something about a priori, some of which I had to rely on experts and learn and adapt.

So why do we do that? We do that because of the uncertainties, to make sure they said we can live with the results, and to allocate our resources, again, because we are not infinitely rich. So how do we do it? By decomposing the system. That's really the ideal, that's systems analysis and try to the classes of failure and scenarios. We are not getting into exquisite details in all the scenarios of how things can fail otherwise we'd cover the walls. So classes of scenarios and get our arms around that. We include a lot of things that are tricky, dependencies that are very important, when failures are dependent in a system. And for one reason, for example, external events, earthquakes. An earthquake will shake this whole building, so all different components in the building might fail for the same reason. And the earthquake or these external events introduce a common cause of failure. We also include human errors and believe it or not, people make the same mistakes for the same reasons in many different areas.

And what is most interesting to look at is what kind of information do they have, what kind of incentives do you give them, how do you reward them, and what kind of resource constraints do you put on them? To come back to the story of the offshore platform, there was old incentive at that time in England to push production and to somehow let's say, perhaps at the expense of safety, and you don't stop the system to fix it. And that was part of the problem. OK, so we tried to look at the way people cut corners, because when you ask people to meet very stringent constraints, they will try to satisfy you. And sometimes, they do things that you will not like. OK, so do we it that way generally because we don't have enough statistics at the nuclear level? See, when we started constructing civilian nuclear power plants in this country, we had some experience with nuclear reactors. When I say 'we,' I was not there. But there was some experience with nuclear reactors in the Navy. But there was never enough experience with nuclear power plants at large and that's where these methods came from in part. Now, the fact is that the systems evolved. So the statistics that you may have, that you may have accumulated in 15 years may or may not be the information that you need.

Think of financial crisis. That was exactly the problem. New situations have emerged, and you find yourself with a conjunction of events that you have never seen before and that's what some people call 'the perfect storms.' As I was saying, the only of particular interest to me are these accidents that have never happened. And let me just talk about a few of them. Concorde, the supersonic transport system, the airplane and it failed in 2000, but it's not as if we could not see it coming. There had been about 50 explosions of the tires at take off because that's an aircraft that has a very small surface of wings and therefore, needed a very long runway. And the technology of the tires at the time was the technology of the '50s. And so regularly, these tires were exploding with small lozenges of rubber that were hitting the plane up until the day when it hit the tank and the whole thing exploded, again, in a ball of fire. This is one that can be seen coming and no one had done anything about it in spite of the fact that the tire maker proposed to fix it. Columbia in 2003, that's the space shuttle that also had an accident.

And I am going to show you that years before, we have done a study after Challenger of the year the tiles of space shuttle were -- the trajectory of the debris that were going to hit the tiles coming from the external tank had been calculated and included in this study. And there was also now a success story, perhaps I don't know, another accident that never happened. The same students worked with an airline here, on the management of a very popular airplane. From there, there was something a bit strange about the flaps and slots of the leading edge and the problem was corrected before it caused any accident, which after all, is what we call success. OK, so now I'm going to get into stories and I'm going to present to you a few things relatively quickly. So let's start with the tiles of the space shuttle and this is a classic case of an accident that has not happened yet and so you have to think about it systematically. So we were looking at the first 33 flights. There have not been any accident but there were errors in maintenance. And we knew that for a fact. In fact, I spent half - I remember spending a week at Kennedy Space Center with the technicians under the Orbiters in my jeans and sneakers, somehow anonymously perhaps.

But what I wanted to figure out were the kinds of errors they were making when they were under time pressure. And I found out and I'm gong to show you how. So we were calculating the contribution of tiles to failure risk. We're trying to look at which ones were really the most risk-critical. And we were looking at the effects of management on the risk. This is what the tiles look like. Each of them was about 8 inches. And the interesting thing is that they are glued on the lattice of filament. So each of them has to be glued in the cavity. And in order to gain some time, some of the technicians I found out, one technician at least, that this glue would cure faster if you add water to it.

And what they were doing, in fact, was to spit in it. And so the glue was curing faster, alright. He was gaining time but of course that was a dangerous thing to do. So how did we think about it? Well, we look first at what happens, what's the accident mechanism? We have an initial loss of a bunch of them for two reasons: debris damage or debris hits, or deboning because there is weak bone. Then at re-entry, there is a cavity. Now, the flow of gases heats up that cavity, you can then lose additional tiles. You expose the aluminum of the Orbiter, you can have then hot gases inside, the sub-system malfunctions, and you lose the whole mission. So the way we looked at this was by decomposing the system into these different parts, getting all the data that we could. Some of them was statistics, for example, we could get he measurements of temperature on the shuttle skin. Some others, we needed to go to expert opinions.

That's what I put in there. So what did we find? We find that in fact, the tiles were not as bad as the astronauts feared, and we showed them a map on which we have identified the most risk-critical tiles so that if you had a bit more time to test something before launch, you could start there. We made all kinds of recommendations for improvement. Some of them were listened to, some of them were not. And unfortunately, the payload where the Columbia accident where again, one of the pieces of debris from the external tank hit the Orbiter and caused the failure. This is the thing of beauty that I presented to Kennedy Space Center and what I had put in darker tones were the most risk-critical zones. And we had computed the risks in each of the different zones. It's not symmetric because there are fuel lines running on the external tanks that weakens the attachment of the insulation. But these was used. It was put as a huge map on the floor and what they did was to test first and to show me they had done it, the places that were put in dark.

Second case, the patient risks in anesthesia. Now, again for something entirely different. This is a classic case of dynamics of accidents. So the question was how can we improve the management of anesthesia system to decrease the patient risk? So what we did is to look at the accident sequences that could occur in the operating room environment. And so first, we look, generally, at how accidents unfold, how the competence and the alertness of the anesthesiologist influences the factors of risk, and how the management could influence the competence and alertness of these guys? And I'm going to show you what we found. So we did a classic model, and there is only one equation in all my talk. I'm only to show you that to compute the probability of an accident over all the scenarios, we sum over all the probabilities of the initiating events. These events that start an accident sequence. For example, a tube disconnect, since the patient needs to receive oxygen in the lungs multiplied by the probability of an accident once this incident has occurred. And that's where we had to do dynamic model.

And by the way, this is really one of the problems that you have in general. Once things go bad, how fast is it going to go bad? So that, you can ask yourself how much time you have to react. Their sources here were really interesting, because we had statistics at both ends of the model and expert opinions at the middle, so that we were confident, pretty confident, in our results. Now, the way we look in general, as I said, at the effect of human and management factors on risk in our analysis, we start by the filaments on the events. We look at the way human performance affect these filaments and we look at the way management policies that affect human performance. And as I said, these are generally incentives and resources. So what kind of management measures did we find that affect anesthetists' performance? Exactly what happens everywhere. I think this is - it could happen in the airlines, it could be pilots instead, work schedule, selection predicting, experience, supervision of the residents which turned out to be a critical problem, and of course, maintenance of the equipment. Now, for example, we look at simulator training. And we said, "Well, by how much could we decrease the risk if we were asking people that were on the simulator, let's say, every year?" And we asked many experts on the different parts of the crime, what difference would it make? Let me tell you, my best experts were the operating room nurses.

They have seen it all and they knew exactly how people are messing up. And they helped us identify the accident sequences, what it was that the simulator could teach these guys? And it's exactly the same problem as for pilots. They prefer that they encounter these problems on a simulator before they encounter them in life. So it was about the risk reduction of 16% that I think was pretty good. OK, and by the way, the British told me that this I was a bit optimistic, also perhaps I'm a bit optimistic but that's what my experts thought. Then let's go to another problem which is seismic risk, the one that you face everyday if you live in this area. And there the problem is really loads and capacities. What does that mean? It means that any given place in the western US, you have a certain risk of having an earthquake that's ground-shaking of a particular intensity. For example, the peak ground acceleration. Why is it that buildings fail? Because the load exceeds the capacity which is precisely the capacity load the building fails.

So we have two parts in this problem. And you want to decompose it carefully into the two parts. First, the seismic loads and for that, you go to see the seismologists. And second, the structure's robustness, for which you talk to the seismic engineers. So in here, the key to this problem is to get the right data from the right people, and the use of probability allows you to again put your resources across the country in places where they are needed the most without bothering anybody and everything, with seismic standards that might be excessive in some parts of the US and insufficient in others. And why do we do it? For example, to support building codes and they're not going to get through this model. So how do we use the result, again, to support building codes, to tell you what to do with your house, if you really want to see that. And after the earthquake that we had in, I think it was '89, I remember reinforcing the house again, with a shear walls and some number of things because it was a good thing to do, but also to assess the robustness of critical facilities. And that means, for example, the bridges in the Bay Area, the nuclear power plants, et cetera. And the water system, that some of you, and the water distribution system that some of you in the class are going to look at.

Another example, testing of cars in the automotive industry. And that was in a German company, and the question was to test the whole car within two days. We have only 10 minutes. Someone has decided it was going to be 10 minutes. How do we use them? So we looked first, what were the prior probabilities of having a problem in different systems, then what was the probability that these would be caught by the tests and how do we allocate that time. And then I asked the most indiscreet question: why not 15 minutes or why not 17? So we had a lot of conversation with the engineers. The challenge is with the new electronic systems. So I learned a lot more than I wanted about what there is in the electronics of my car. And the problem was to track down the functions and the dependencies because you have a very large number of monitors and of computers in these cars. And then psychologically, the problem was to ask people to recognize uncertainties, to recognize weaknesses and to qualify them, to compare them.

Well, at the end it worked. Let me now give you the example of intelligence analysis. So there I arrived, knowing almost next to nothing about it. And the problem of the intelligence community in all countries is the collection and the analysis of the information from different sources. First, the issues are the uncertainty by the priors of the situation a priori; and the uncertainties about the information, and the dependencies of the sources. And so what I said as a hard joke is if you hear about the sighting of a very famous terrorist in a bar in Moscow, the priors are very low and so you will have to check very carefully, not only the source that you have but even if you have several sources. And we also applied this, and so did David Carson to the state of the nuclear development program. What are the challenges here? Well, first in that community, the analysts are being trained to think that they are the ones who should "make the call," that is say it is and it is not. And what I've tried to say, and I think with some success, which is do not pick the most likely hypothesis and present it to the boss, whoever the boss is, as if you are sure of it. So at this point, I think that there has been some difficulties to think about information dependencies and priors.

But the idea that the boss in question had many bosses, would much prefer to hear about the uncertainties than not, has begun to penetrate that community. Interest. And now again, for something entirely different. One day, I got a call from the Insurance Consortium and they asked me if I wanted to look with some students of mine at the probability of bankruptcy of property and casualty insurance companies as a function of their age and a function of their size. And I said, "Why me?" because I am not a specialist of finance and insurance. And they said, "Well, that's because we would like a systems engineering approach to the problem, as opposed to a classic statistics that are used in the financial world." Fine. So with one of my doctoral students, Leah Deleris, we looked at what are really the key factors. And of course, insurance companies, I'll be calling investment bankers into to a large extent. So first, we got some insights into the industry cycles. And that's because after a big event, the rates of insurance become higher, harder than when the memory declines.

Competition is such that the rates decline. And another one happens. Anyway, there are industry cycles in the rates of premiums and the payments. Second stochastic problem of uncertainty, the proponents of the investments which is of course, where do they put the money insurance companies once you have paid your premium when in the market? So there was there a risk to them. Now, we look at the probability of large events and claims and in this case, it was in large part, let's say, hurricanes, let's say, in Florida. So it may be that this is not stable enough, stable either. And then we also looked at court awards, and we found out that the court awards were growing and were very uncertain and random, particularly in the southern United States. So we pooled all these together and we use all the information we could, but in particular, we interviewed about 20 retired CEOs of insurance companies. And let me say that we learned a lot about that. And the challenges were that, they had relied on time series, statistical time series, and in particular in the financial world on second moments.

So the correlations between the market as a whole and let's say, various securities. And they had difficulties thinking about perfect storms, even though that's exactly what their problem was or something that's called in recent literature, the black swan, because we have seen very many white swans but not too many black swans. And my question to the author of the book is that now that we have seen black swans, what is the probability of a yellow swan? You see what I mean? So what does it take to have something that we have never seen, and that forces you to get down to the fundamental mechanisms of how things happen. OK, so now, let's see a few lessons that I've learned. First, never do a risk analysis for someone who doesn't want to know and use the results, who's trying to tell you what data to use, and who's trying to tell you what result to find. So this one has been one of the problems of NASA, at the beginning of the space shuttle program, and I think that was too bad. Look out also for the small storm, the big storms, the large storms, and the question is that there is a lot of information in small storms but the big ones. Because that's where you see a number of small events can begin to accumulate and their culminations may be very rare and take you where you don't want to be. The role of imagination in risk analysis, that's a wonderful phrase that I found in a 9/11 commission report. The director said and wrote in that book that was Philip Zelikow that the failure was, in a large part, the failure of imagination.

And it was called, of course, an unknown-unknown, but it was not that much, 9/11 that is. It was not that much an unknown-unknown. A similar incident had happened when a French airliner had taken off from Algiers was going to Paris, was taken over by terrorists, had to stop in Marseilles for refueling and was taken over by the French troops at that point. But it was going straight into, apparently, from what I've heard, into one building in Paris. So it's not as if it was totally unknown-unknown, but it's true that it was an unknown and it was going to be extremely rare. OK, so some things can be imaginable. So you often know a lot more than you do. And yes, you can use the seat of the pants, otherwise take the time to think. That is in a crisis, you are not going to begin to do a computation, but otherwise again, small envelope, big envelope, whatever it takes. I've seen the whole risk analysis for this area on the back of an envelope.

Someone wanted to show you, "I can do it." It is correct but I don't care, just whatever it takes. Warning systems, that's one of the most important parts of risk management. Watch for signals and precursors and remember that they may not be perfect. To test or not to test? There is a point where you have tested enough and you have to decide of that, whether it's an aircraft, whether it's an electronic component, or whether it's a medical risk. And I was once trying to explain this question of the value of imperfect information to a senator, who couldn't believe the example that I'm going to show you. Suppose you have one chance in a thousand of having a deadly disease. And you have a test that says it's not that bad, because there is only a 5%

rate that of false positive. Now, if you start doing the computation, you'll find out that after a positive result, you only have a 2% chance of having the disease. So don't jump yet out the window! Why is it? Imagine that you have these thousand people in front of you. Only one has the disease, one in a thousand.

You put all of them to a test, 5% are false positive. On average, you're going to get 50 positive results. And yet only one has the disease, one in 50%. So you see some of these results are counter-intuitive and so the prior matters and the quality of the test matters. Another challenge is to manage the balance between the technical failure risk and the management failure risk, exceeding the budget and schedule. I talked about the Challenger accident and the pressures of NASA to launch on that day, but also about managing people who are tempted to cut corners to meet the deadline. And the story that I told this morning in the course was that of people who were reinforce constructing houses in the Central Valley. And they were up against a deadline. They were supposed to put nails around shear walls. And you know, time was passing.

They put one nail out of two because it was going faster. And during the North Ridge earthquake, sure enough, some of these houses collapsed and they are probably in jail for it. But you see, they were given all incentives to meet the deadline and to hide what they are doing. OK, so many risks are the result of human organizational factors. So as a manager, be very careful of the constraints that you set and of what people are going to do to satisfy you. And, you know, I have heard many times that perception is reality. So my response to that is, "Perfect, let's inject some reality to perception." And that is exactly what you are trying to do by giving some risk analysis results that allow you to put things in perspective. And why is that? It's because you may be scared to death by the headlines you see in the newspapers and that you begin to lose the perspective of the priorities. And if you have a budget and the budget of a country that needs to be spent, it's important that we know what you are doing. And when the risk management here is well-done, no one hears about it.

So success is anonymity, and this is risk management's success. You're wrong about the crocodiles but if you fall, which we hope not to, you have hopefully a soft landing. And that's my story. Male Host: So Elisabeth, thank you. As most of you know, I'm Steve Blank. I teach MS&E278, the class that surrounds these ETL lectures, Spirit of Entrepreneurship. And we listen to the speakers and go back and actually talk about and analyze their discussions, and the class gets to ask the first couple of questions. So today, I'm going to kick it off with a question you almost answered as you were ending and that is, since you have been on the policy side and the government as well, how did you communicate to professional politicians the distinction between actual risk and the perception of risk? I mean as a parent, you know parents nowadays think that somebody is going to steal their child. And if everybody actually did the statistical analysis, they're more have been likely to choke to death when you're feeding them than they will be kidnapped. But no one worries about chopping their...

Does that make sense? Yeah, of course. If you ask me what scares me the most about myself, I would say drunk driving, OK? So let's stop there. How do you communicate the risk to politicians? By giving them first, if you have some kind of evaluation, numerical evaluation. You try to give them an idea of how the risks compare to each other. And in fact, I was surprised by how well they understand that. And I've seen an evolution in the last 10 years, perhaps, towards qualification of risks and toward wanting to hear not only one possible alternative but several. I would say the world of success in government has been with building codes. And why? It's because before the use of probabilistic methods, there was a pseudo-quasideterministic and there still is, to look at seismic hazard. Now, to complicate a measure that's a pseudo-upper bound of the earthquake damage or earthquake risk at given particular spot. The problem is that the probability of getting that kind of maximum credible earthquake, that's the name of it, was extremely different in different places.

So if you use a criterion, let's say, Louisiana and you use it in San Francisco, you would spend much too much money in one place, not too enough in another. And the politicians ended up understanding that. I think that Hurricane Katrina was also a wake-up call and there's now a lot more probabilistic studies being done about it because they realize that you're never going to have something that will be 100% safe. You have to decide at what height you are going to put these levees. The Dutch by the way, are the people who have, perhaps in the '50s, after they had a really nasty flooding, began to think in those terms. And that's the kind of the main thing that I've seen progress. Male Host: OK, next question is that did you believe even in your tenure in policy, that the American public has less taste for risk now or more, or are we more risk-averse? And that is, is your expertise actually more valued or less? Where are we going? I think that there is more information about all kinds of events happening around the world. It's not that they are more risk-averse. It's that they are bombarded by bad news and so what you can do is to help them sort them out. And yes, there's an enormous amount of demand for the kind of field in which I have.

In fact, one of my surprises when the current chairman of the Joint Chiefs of Staff, the head of the armed services of this country, wrote the first memo that he handed out to everybody. It was all about risk management. And I thought, "That's interesting." He probably doesn't hear it or doesn't understand it in the same way I do but I think there's more and more this idea that there is such thing a as risk management. There's no such thing as zero-risk, and that perhaps, resource allocation and setting priorities is important. Male Host: I'll just ask you the last question from me and my class and then, we'll open it up to the audience. Stanford has had a long history of advising the government, in various levels of presidential science advisory boards, intelligence community, et cetera. Were you aware of this long history and you were connected to a part of it. Or was this a point of entry? Or what was your biggest surprise about dealing with the government? Well first, let's focus on the call that I received when I was asked if I wanted to be on the president's, at that time, foreign intelligence advisory board. I said, "What in the world is that?" And it turns out that I had friends on both sides of the aisle and I had no idea. I was coming there as an outsider who could look with a cold eye at the information that they were getting, and so I did not know much.

So my answer to you is I was an innocent, yes, in that domain. Like you said, you learn quickly. You learn quickly by seeing the reasoning. And you listen to enough stories that you quickly figure out how you can help, how you would think about it in your world and how you could inject logic in all that. So I was not aware that time of the long history, although I knew Cid Well, of course. I knew all kinds of people who have been - John Schultz, all kinds of people in many domains and in engineering here who have been influential in advising the government. But that's when I discovered how it truly worked. And yes, I had surprises. And what was your biggest surprise, if I could make it... ? What was my biggest surprise? It was the naivete or the unwillingness of people to recognize uncertainties and to want to hear that things are or are not.

And what you're trying to say is I do not know but I can tell you are roughly the charters given the information that I have. Now, do you prefer me to tell you that they are or are not? No, of course not. But that was my biggest surprise, that they all saw the world in black and white, which is not the way I have seen it for many years, as you can imagine. OK, let's open it up to the class in the room. Just pick up the questions for Elisabeth. Yes. I'm just wondering if you can talk a little bit about the side from the side, some sort the engineering approach to risk analysis. Are there ways to work with policy makers, aside from what was discussed, and in other disciplines in order to deal with some of the current challenges we face in security? Oh, yes, the Department of Homeland Security, for example. So security, the question that was asked was: is there ways using these methods in other parts of the government, for example, in terms of security? The Department of Homeland Security has launched programs to do exactly that. And in fact, I have a grant from them just now.

And what we are trying to look at and this is a tiny part - what we are doing is a tiny part. But it's warning systems in crisis situations. So we are trying to figure out is all of a sudden, you get a piece of information that's a surprise. That's what I call a needle in the haystack. And you follow up what else is there out there? You have to decide quickly what it is that you would like to know and go look for it, or make a decision very quickly given the way things evolve. Homeland Security, of course, is also very interested in ranking the threats. Because it is always the same question, we cannot put our money. We are not immensely rich. And we're allocating all the money of Homeland Security across the different states in a uniform way. It's not very reasonable, even though there are many senators that would love that.

So you have to explain and you have to help them think through that question of prioritization. Another one that, I'm sure you're very sensitive to, although I have not studied it is the question of airport security. It is clear that some of the procedures in place have symbolic value so you feel protected. Some of them are really effective. And so I know that there are a lot of people who are working on these kinds of problems, et cetera. The food chain security, bioterrorism, there are lots of very good studies done by Larry Wine, for example. He had a business school in that area. So there are a lot going on at Homeland Security in that domain. So you're on the board of public companies. Well, on the board of yes, one.

I'm on the board of several companies of various status. I'm on the board of Aerospace Corporation, which as an FA founded. I'm on the board of InQTel, which is a venture capital of the CIA and other places. I'm also on the board of a small company that's publicly traded, that does desalination of seawater, et cetera. So these are the kinds of boards in which that I sit right now. The question is do you bring these processes and approaches to bear in that environment? Yes, so yes and yet even though these sound like companies and organizations that are very sensitive to it. It's not a natural way of thinking and let me give you the example of the aerospace industry, beyond Aerospace Corporation. They're in charge of the security of everything that's launched in this country. So you test and test and test, and you do all kinds of things. At what point do you decide that you have tested enough? But think about it in different context.

You go to the hospital and you get a test. They say, "I see something funny here." And you get a second test and then you third test, and then you keep testing. There is always that question of how much more information do we need and what is the value of that information. The value of that information is linked to the decision that it might support. If it might make you change your mind and change your practices, that is where you want to have more risk analysis. If you have reached the point where adding more money into more risk studies is not going to make you change anything, you don't think to invest anymore. So the challenge is to work between the risk analyst that can tell you what difference it could make and the decision-maker whose risk attitude is what is going to determine the decision based on that information, two different functions. Yes? You need - I'm sorry. I can't see you very well. OK, in the business perspective, we think that there is sometimes...

So how is risk management can be relevant to that? And who is responsible for studying that? Is that the risk analyst or the decision-maker? Yeah, let's - as a risk analyst, I'm generally asked to consider what can go wrong. But when I look at scenarios, I'm very careful - so the question was how do you introduce the benefits in that balance? As a risk analyst, when I look at the consequences of these different scenarios, I have both the risks and the benefits. And if I have the benefits, I am delighted to put them in here. For example, the risk reduction benefits of the raincoat are of course, you're going to have a benefit which is the risk-reduction. So this is a focus on benefits even though I'm talking about risks. There's another effect that in fact, I also put in the scenarios, and it is the redistribution effects. That is because in some cases, some people are going to incur the costs or the risks and other, the benefits. Think of a large dam, and you live on the path what would be the wave in case the dam breaks. You're going to take a lot of the risk and there's going to be a lot of benefits to the rest of the population but there is a redistribution here. And the risk analysis results have to, if they are well done, have to reflect that part also.

So the benefits, yes, also enter the consequences. And you have to be careful to make sure that you give a complete picture. Yes? I have more of a question about just your life and how you got to where you are? I'm just wondering you're a female in a very technical field and I'm wondering what sorts of challenges you face and how you cope with that? That's an interesting one, and on top of that, add my accent, OK? So imagine, there you are in Washington, talking to everyone in the Pentagon who would like really to hear your story. It is true, you're in a technical field, you're a woman, and you have a strange accent. I would say a German accent in a male is generally easy to carry around in the technical field. Well, that's all in there. So what happened? I really like math and physics. And so I was undeterred. My family, let's say, they thought it was not a very feminine thing to do. The medical area would have been more...

but I really liked math and physics then computer science and I really got into that. Then I came to Stanford and I got more and more involved in things that I found really interesting because they were very practical and they were really connected to life. And I think that's what I really liked about it. And then once you have done a few studies that people believe in, I believe that then it will snowball. You have more and more credibility. What's difficult is the beginning. And what you really need at that point is a very good support system and I'm happy to say that it's exactly what I had. And that's why on top of that, when you add two children, it becomes a bit more complicated. Then you don't sleep very much and you make sure that every thing gets done, that you say yes to things that you have to say yes to and you actually do it, and when you can't, you say no. But when you say yes, you actually do it.

So it's building credibility and making people trust you. I don't know apart from that. The rest, we can discuss later. Yes? So entrepreneurs tend to take more risk than non-entrepreneurs. So my question is it because they are more risk-averse or do they have more time for risk analysis? More risk prone. Or is it just better blind risk? You know the fact is that I do not know if entrepreneurs really take that many risks. What I have seen it's - let me start. Bank entrepreneurs is the banking system, the financing system. What is clear to me is that in this country, the venture capitalists take a lot of risks. And that I have seen and they generally have a pretty good idea of where they are going with this one.

In Europe, it's bankers, and they are not willing to take the same level of risks. It's an entirely different world. Now, but entrepreneurs themselves generally, very often, they start with an idea, a technical idea. And I think part of the success is to make sure that they have a great team with them and it's not only the technical part that dominates that small company, but also of course, the management part and to have good managers and good technicians together. And I think that's what the success of their risk-taking and their willingness to take risks, and the willingness of the venture capitalist to be behind them is to have teams. So perhaps it is that the first requirement for good entrepreneurs is to be team-builders, and teams often - builders with many talents, the management part, the technical part, and selling the thing, because after all, without the market, you are not going very far. Yes? I just want to know when you gather a failure for example, the Homeland Security and you said in Atlanta, do you scratch out everything and start out from the beginning? Or do you work with what you have? I'm not entirely sure where do I start. Do I start with what I know or do I start from scratch that -- I don't understand your question very well. When you get it, when you confront a very big favor after your planning. Do you know where to start again? Do you scratch off what you have or do you work on top of that? I start from scratch.

So when you realize that you're on the wrong track, start from scratch. That would be my recommendation. When you realize that you don't have the right formulation of problem, go to see other experts. Go see what it is that you are missing and do not get stuck in a rut. OK, if there's one more question, we'll take it. And if not... is there one more question? OK, going once, twice, three times. Elisabeth, thank you.