NICE TO KNOW

Tony Starfield Shares His Thoughts on Modeling

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What I'm going to try and do in just talking about modeling and my interactions with modeling is give you some idea of how my thinking has evolved over the past 50 or more years, and what I'm really trying to achieve in this particular course. I was born and educated in a world before computers. That meant that if you wanted to solve a problem, if you wanted to build a model, the only way to get an answer without spending your life doing arithmetic was to use mathematics.

If you think about it, Newton had to develop calculus in order to develop his theories and his physical laws, because there was no way to put them into practice without calculus. Mathematics was the mechanism from going from a perception of a model to an answer. So right through my undergraduate education--and I was educated as an applied mathematician, somebody who was going to use mathematics to solve problems--the emphasis was on illustrating the mathematics rather than how you solved the problem.

Let me explain that a little differently. All the examples I saw in class were examples that were designed to show the power of the mathematics. So it was, "Ha. Here are partial differential equations, and look at the problems we can solve with partial differential equations." It was never the other way around, of, "Here is a real problem. Now, how do you design the problem, how do you develop the problem, and then how do you solve it?"

And so when I was faced with actually dealing with real problems as a graduate student, I discovered that there were a lot of problems out there where the mathematics was undeveloped or the mathematics was unable to solve the problem. So the difference between an applied mathematician and a mathematician was that an applied mathematician had to take a problem, look at it, and say, "You know, there isn't a mathematical solution to this problem. But if we make these assumptions, or if we twist the problem in this way, then I can get you an answer."

So the **art of modeling** was in finding a similar problem, getting a precise answer to a similar problem, and then saying, "Okay, maybe or maybe not this is going to be helpful to you in your real-world problem." And now, for the first time, I started thinking about the difference between **"real world"** and **"model world."** Because the real world was the problem you were trying to solve; the model world was the problem you could solve. And so the model world wasn't designed so much by your objective, it was designed by what mathematics could do for you. And so the emphasis was more on the interpretation back to the real world, than on the design of the model world.

So that was modeling, and people probably didn't even use those words. Nobody taught modeling, nobody thought about modeling; they thought about applied mathematics. That is what it was like before computers came along. And then, suddenly, along came computers, and there was a huge sigh of relief. "With a computer, I can solve the real problem. I don't have to worry about the fact that I can't get an answer to this problem; I can figure out with a computer." And as computers became more and more powerful, I could say that with more confidence, "I can solve your exact problem."

Two things happened with this. The one was that there was a huge sigh of relief in the real world. People like engineers and physicists and so on, who were trying to deal with difficult problems. And they said, "Gee." - they didn't say it in so many words, but it was - "We don't need to have this distinction between the real world and the model world anymore. We can solve the exact problem." There was the one end of the spectrum.

The other end of the spectrum was from the mathematicians, who said, "You know, if you solve a problem with a computer, that's got no value at all. It's got no intellectual value. If you want to get a real answer to a problem, you better use mathematics." Mathematics can give you generalizations, which is true, and mathematics gives you a deeper understanding of the problem, which is sometimes true, and sometimes false.

And that persistence of that kind of thinking still exists to a certain extent in academia. There's the kind of snobbery, that if you give me a problem and I get you a mathematical answer, that is somehow or other more intellectually valuable than if you get an answer on a computer. If I'm dealing with a population model and I talk about Leslie matrices, I'm going to give you a better answer than if I just go to a spreadsheet and I don't talk about Leslie matrices. And that is patently false. But at the same time, the people who said, "Ah, we can solve any problem we like now, we've got a computer. And we can solve it exactly," were it also wrong.

Because in one sense, the mathematicians were right. And that is that the value of using mathematics to solve a problem gets you thinking hard about what it is you are trying to do. And so it seemed to me that as people in ecology and elsewhere started trying to solve problems in more and more detail, they began to realize that in going to the computer and trying to put everything into the model, they were, in a certain sense, throwing the baby out with the bath water. Because by putting in everything, they understood nothing.

And so, to me, the first big realization was that this dichotomy between the real world and the model world was thought absolutely essential. Maybe even more so, once one was using computers to solve problems. Because it forced you to go through the discipline of thinking through your problem and dealing with just sufficient information and a sufficient degree of complexity to make a contribution.

The difference now is that the model world is not determined by what you can and can't do mathematically. The model world is defined by the objective of the problem. So that's the sort of argument along the lines of, historically, how one goes from mathematical modeling to computational modeling. And when the mathematician says, "There's no discipline in modeling without mathematics," they're missing the point that the discipline now is in figuring out what to put into the model world and how to use your model. And that that is every bit as intellectually demanding as in being able to solve partial differential equations, for example.

Okay. Another theme is that in terms of my own career, I ended up being the chair of an applied mathematics department in South Africa at a time when computers were just beginning to take off. And this gave me a wonderful opportunity to think about how does one teach and where can one use applied mathematics? I wasn't thinking in terms of modeling then, I wouldn't have used the word "modeling," but when I talked about applied mathematics, I was really talking about modeling.

And up to that time, modeling had been concerned very largely with the physical sciences. And I suddenly realized that the computer opened up possibilities across disciplines. That there was a value in learning how to model in medicine, in psychology, in architecture, in biology, and in ecology. And I'm now talking about the early 1970s. And it was a time when probably from all of those disciplines, there was actually a lot of resistance to using mathematics and modeling. The resistance to mathematics was people were basically mathaphobes. Very often, they went into a discipline because they weren't good at "mathematics." What computers changed was that you didn’t have to be good at mathematics anymore, in order to model. But nobody realized that at the time.

And the second resistance they had to it was that their disciplines, what they’d been taught, the way they thought about problems, the way they acted as professionals, was an integral part of them as human beings, and somehow or another they thought that computers and modeling were trespassing on that “special knowledge” they had as human beings.

So through all of the ‘70s, and a large part of the 1980s, I sort of felt that I was a missionary going out to these disciplines saying, “Look, models can be useful. Expert systems can be useful. Structured decision making can be useful. These are disciplines that you, as a professional or academic, in a discipline that hasn’t used them before, need to latch onto.” And I got a lot of kickback.

I can remember in the 1970s talking to professors and students at a university in South Africa about what I was trying to do with ecological modeling, and I would have pompous professors saying to me--and I thought they were pompous and they probably thought I was a young upstart--saying to me, “You might be able to play around with models, and you might be able to play around with computers, but we understand our subjects, and what you do has got nothing to do with all the things that we know about our subject. In other words, you might be having fun, but that’s no use whatsoever to us. In fact, you’re kind of wasting our time.”

I can also remember talking to professionals. I can remember, for example, teaching rangers, the people on the ground, the people who did the hard work in the Krueger National Park, something about modeling. And showing them how to develop an elephant model. And I can remember this class of maybe 15 or 16 tough, sunburnt men, people who had grappled with leopards, who had been gored by rhinos, who had done all sorts of fantastic feats out in the wild, sitting, and I’m busy showing them how to put an elephant model on a spreadsheet. And I can remember one person coming up proudly at the end of it and saying, “Here’s my model,” and it turned out this person had a skill at drawing cartoons. And his model was starting with a sketch of me, and then working really hard on my ears, and morphing me into an elephant. And he said, “There’s the elephant model.” He was proud of that. But I was proud of the fact that I managed to get them to realize that the model enabled them to take information they were being given by scientists and put them together and see whether or not it made sense.

So one of the things that came out of that particular exercise was the realization that if they put the numbers together of what they thought was the growth rate of the elephant populations in the Krueger Park, and what they believed were the fecundity and survival rates, these things just didn't match together in any way. So they began to get an interest in modeling. But still, I was playing the role of missionary. It wasn't saying, "Look, here's a model to do this." It was, "Look, modeling can be useful to you."

So the first change in my development was from going to mathematics to a world with computing, and then having people resist that world in disciplines that weren't used to modeling. And then the second change was much more gradual. And it started coming in with the use of personal computers and the development of spreadsheets and people all over becoming much more familiar with computers. And somewhere towards the end of the '80s, I realized I was still practicing as a missionary, saying, "This is what you need to do." I suddenly began to realize I was preaching to the converted. That a phase change had occurred in the way in which people thought about computers and models, and people were suddenly very receptive to this.

And instead of me heaving a sigh of relief and saying, "Okay, my career is over," I suddenly discovered, to my horror, that everybody was beginning to think about and use and talk about models, and I was horrified at what they were doing with models. And I began to realize that the methodology of modeling, talking about what is a good model, talking about what is a bad model, talking about how to present a model, talking about how to interpret model results, was more important than ever. If you live in a world where everybody is producing models and they say to you, "Gee, look. Do you have a problem? Let me give you a long description of my model, and let me show you my results, and there you are. I've solved your problem," and you accept that without understanding exactly what that whole process was, then you're in trouble.

And slowly I started thinking a lot more about the methodology of modeling. That when you present a paper or a talk or a report on modeling, it isn't as much what you did that matters, it is how you defined your model world. How you did your assumption analysis. How you understood your assumptions. What assumptions you made. How you did your sensitivity analysis, and how prototyping would help you think through what you were doing. And so it is those things that, to me, are the essence of modeling.

One of the moments of insight that I had was in teaching an undergraduate modeling class to a very mixed group of students at Oberlin College in Ohio. Oberlin College has been doing some interesting experiments. It is trying to develop modeling as a theme across the curriculum. So the idea is that you might be taking a course in economics, and you will learn something about economic modeling. You might be taking a course in sociology and you'd learn something about sociological modeling, and so on, right across the discipline. And I've been involved in, A, developing an introductory modeling class for students, so they get the essence of modeling. And then, B, in helping faculty develop ways of bringing those ideas into their curriculum.

And as always, when I teach, I had the students come in with insights. And in this case, it was a class where they came in with an insight once a week. And the insight that really got through to me was a student saying, "You know, in this past week, I've been looking out for where the word "model" has been used. In newspapers, on TV, on the radio, and in classes. And you know, it came up all over the place. It came up in my economics class, it come up in my political studies class, it came up in people talking about the healthcare program, it came up everywhere. And the question I asked myself," this was his insight, "is if modeling is so ubiquitous and is such an important part of the world around us, why aren't colleges teaching modeling as an academic subject?"

And that seems to me to be the challenge in these times. It seems to me that if you are to be an educated person in the 21st century, you need to understand enough about modeling to be able to ask some hard questions when a politician tells you that their model shows this. Or when, as a professional, you are dealing with a problem and a consultant tells you that they have solved your problem with this model. And the ideas behind modeling, there, are not so much what you do on the computer, are not so much the techniques that you get in this particular class, for example.

I mean, the techniques are interesting and it's nice to know them. It's good to be able to know how to do things on a spreadsheet. But the real skills that I'm trying to get across in the Principles of Modeling class are the skills of how to think about modeling. And those skills are recognizing that a model is an experiment. It's a thought experiment, and it takes place in the model world. But while you're doing the experiment, and the way in which you do the experiment, is dictated by objectives that you have in the real world. And so it's this experimental exercise of doing something with a model and then interpreting it back and recognizing and exploiting the difference between the real world and the model world that, to me, is the essence of what, one day, I hope will become a college subject called "Modeling." That's part of the intellectual apparatus.

And along with that goes the understanding of, “Is this a good model?” Is it a bad model?” “How am I dealing with my assumptions?” “Have I done an assumption analysis?” “How do I deal with data that I might not have? Or data that are imprecise?” “How do I do a sensitivity analysis?” And as I’m trying to explore whatever the problem is that I’m dealing with, how can prototyping help me to do that? And out of that thinking, you develop the approach of, “How do I interpret, or read and critique, a modeling paper or a modeling report? And even if I don’t know how to develop a model on a spreadsheet, how can I work with a modeler, or a modeling consultant, to get what I want out of it?”

And when I say this, I’m very much aware of the fact that modeling consultants, people who make money out of developing models, have got different pressures on them that actually compete with my view of what modeling is all about. So a modeling consultant wants to dazzle you with beautiful pictures of output without necessarily thinking hard about whether that’s the output you really need, and a modeling consultant has a vested interest in making the model more complicated than in keeping it simple. And so, along with the methodology of modeling, if you are working in conservation, one has to start developing a modus operandi, whereby you impose the ideas of rapid prototyping and certain ways of developing models on people who work for you.

So the course here is pretty much about how to think about modeling effectively, and how to interact with modeling, more so than how to build your own little models. Along the way, with a bit of luck, you’ll realize that there are places where you can build your own little models, and that simple models, first prototypes, can be remarkably powerful.

So my history goes from calculus through to sensitivity analysis, assumption analysis, model world, real world.

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