INTERVIEW WITH
JAY FORRESTER
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Sloan Oral History Series

J: Jay Forrester
A: Alan White
B: Bob McKersie

B: We're here with Alan White and Jay Forrester and Robert McKersie, to start this interview.

The first question we will ask Jay is to say a little bit about his connection to MIT before he was hired into the Sloan School. Just give us that early leg of the journey.

J: I originally grew up on a cattle ranch in Nebraska, but not being all that interested in taking care of cattle in a winter blizzard, I chose electrical engineering at the University of Nebraska where I graduated in 1939. Then I was advised by faculty that rather than going to work for GE I should consider graduate school. I applied several places; I was turned down by Cornell. I was offered a free tuition and $100/month from MIT, so I came here; originally in electrical engineering. That included the Servo-Mechanisms Lab during WWII under Gordon Brown, who was my mentor, responsible for a lot of my career at MIT. That background in feedback control systems later became rather important in my work at the Sloan School.

After WWII, I had assumed I would either go out and start a company in engineering feedback control devices or work for such a company, when Gordon Brown called me in and said he had a list of several possible projects, would one of them interest me? I chose one that ended up designing the first digital computer at MIT, the Whirlwind I computer, which by using the computer to run aircraft interceptions, controlling fighter planes to intercept a bomber, led to the creation of Lincoln Laboratory where I was head of the biggest division in charge of the design of the North American Air Defense system along with George Valley who was doing the radar part of the system.

One day, Jim Killian, President of MIT was bringing a group of dignitaries to tour the Lab, and just walking down the hall, he turned to me and said MIT was starting a new management school and maybe it would be something that would be of interest to me. That led to conversations over most of a year with Eli Shapiro and Edward Bowles who was a consulting faculty member, leading to my coming to the School in July 1956.

At that time, Alfred Sloan had given $10 million to launch a management school. My understanding is that he felt that management school in a technical environment would develop differently from one in a liberal arts environment, like Harvard or Columbia, or Chicago. Maybe better, maybe worse, but it was worth $10 million to run the experiment and see what would happen.

Up until my coming, the School did not have any significant ties to the technical or scientific side of MIT.

A: That is true.

J: So in a sense, I was the first link between what was then called the School of Industrial Management and the technical side of MIT.

I had my first year here free of any other duties other than to try to figure out why I was here. And I think I, and probably other people, thought that this would be to push forward the field of operations research or how business would use computers. In thinking of those, it seemed to me that neither qualified for my kinds of interests. I'd always been very much active in the outside world rather than the academic world. Operations research was a well-defined field, it was doing interesting work, probably well worthwhile, but it certainly was not dealing with the big issues of why corporations succeed and fail. And on the side of studying how business should use computers, this already had momentum. We had pretty much launched the computer age with reliable high-speed computers, and banks and insurance companies were already beginning to use computers, and it seemed like 1, or 2, or 3 of us here wouldn't have much effect on what was already gaining considerable momentum.

Then—I don't remember the reasons or the first contacts—I began to have some conversations with people at GE who were puzzled by why their household appliance factories were working three shifts a day, seven days a week, and have half the people laid off three years later. It was conventional to say, "Well, that's because of the business cycle," but nobody was quite sure that was the explanation.

Then I tried my background in feedback systems, I suppose—I wasn't aware of doing it—but I just laid out a notebook page of columns for inventories, labor force, production rates, backlogs of unfilled orders – each line being a week; I had talked to the GE people enough to get a good impression of how they were making their decisions about expanding and contracting production. I discovered that using their policies that they said they were using, that I would get internally within the system this huge fluctuation they had been experiencing even if the consumer demand were constant. And that really was the launching of the field of what's now called System Dynamics, but initially it was called Industrial Dynamics because we thought of it as applying to corporate policy and how corporate policy produces the stability, instability, successes, and failures of companies.

Within about the first year after the industrial dynamics ideas began to take shape, we put on a summer session program, a two-week program for people from industry. I was very hard-pressed to have material for two weeks. We turned the supply-line instability that we'd been looking at into a game. We lined up people along a table, maybe 4-5 stations – a retailer at one end, the distributor, the wholesaler, the factory warehouse, and the factory manager. There was a deck of cards at the end of the table which the retailer would turn over, one every week, to see what he was selling to the outside. Everything was on the table, you could see all the movements of goods; the orders were physical pieces of paper moving through the system; the refrigerators were chips moving; the whole structure going on was visible to everybody. And it was all set up in equilibrium to start with, and then the person at the retailer end would turn over his card and he would get an order that was 5% higher than what they had been. And it continued at that new amount permanently thereafter. Yet the actual increase would set up a wave through this chain of people that would lead to huge fluctuation up at the factory, such as had been encountered in real systems. That did two things: it showed that the system matters. If the system is driving things, you can put any group of people on this table and they will do the same thing. This game is still available; it's now sold as "The Beer Game." It's been sold all over the world; it's been played in

every society, at every age. Anybody who has grown up in an industrial society ends up producing this instability.

B: You mentioned that in being brought to the Sloan School, you were seen as an important connection between the science/engineering side of MIT and this new Sloan School. The thing that intrigues me is that even before the establishment of the Sloan School, there were undergraduates who were majoring in industrial management. And my guess is that some of them were people who decided that engineering was maybe not their cup of tea. I can remember this from my days of studying engineering, that people who shifted out of engineering and went over to The Wharton School were seen as the "dropouts." I'm wondering whether there has always been, at MIT, a feeling that people who were studying industrial management were ones who couldn't "cut it" as engineers.

J: I think that's true. It had been part of the atmosphere, at least then. Those who went into liberal arts or management were looked on as not quite making it in engineering. Course 15 was in existence for a very long time. The Sloan Fellows program I think started in the 1930s.

A: 1931, yes.

J: So all those things were already underway. The creation of the Sloan School somewhat authenticated what was already going on and became the basis for expanding it.

My own role in it was really starting the field of System Dynamics and fighting the battles with skeptics about it.

But there was a very important actor in this, who needs to be mentioned, although he was never connected to the Sloan School, and that's Perry Crawford. He was an electrical engineer from MIT; he had graduated probably a year or so ahead of me. He was working as a technical staff member for Captain Louis de Florez in the Navy in the Special Devices Center in Port Washington, Long Island. And it was de Florez who had the vision of the project that Gordon Brown had, which I had chosen to work on. That was to design a very advanced Link pilot trainer. In other words, there had been trainers for pilots that had been designed to match the characteristics of known airplanes. But de Florez wanted one that would match the characteristics of an airplane that had not yet been built, based on wind tunnel data from a model.

Initially in those days computers were analog computers and it was natural for someone to build an analog computer for that project. We spent about a year coming to the conclusion that an analog computer of that complexity and of its limited dynamic range would probably only create its own internal instabilities and never solve the problem.

This was under the guidance, or financed through, Adm. de Florez' office, and Perry Crawford worked there. And Perry, standing on the steps of 77 Mass. Avenue one day discussing the project and its prospects, asked me if I was in touch with what was going on in digital computers, which I had not been at that stage. At that point, the Harvard Mark One was just being announced, and the ENIAC already existed, and there was a little bit of activity on EDVAC at the University of Illinois. So he put us in touch with all of those, and we went to them and learned what they were doing. We concluded that the serial computer like EDVAC couldn't possibly have the speed that we would need for this project, this analyzer. So we began to turn our attention to the idea of a parallel computer, which is the modern nature of such machines.

About that time, Perry came in again with the idea that the analyzer wasn't all that important; what we really wanted to do was have a computer information center for the Navy

that would gather together in one machine the air picture, the surface picture, and some kind of picture of an air battle. So now we had shifted to what became the Combat Information Center. In 1948 we wrote a couple of papers on how you would program a computer to do that sort of thing. And in 1948 Carl Compton who was President of MIT and Chairman of the Military Research and Development Board, had begun to hear enough rumors about computers that he asked us to prepare a report for him on what we thought about computers for military purposes. It took a couple months to do this, and we delivered a report that ended up with a big sheet at the end – you can have a copy if you want it – that listed 15 years across the top and 12 areas of military applications down the side, and every box filled in as to what we thought the story would be in terms of the stage of development, the research money spent, the development money, the production money, for 15 years in the future when no general-purpose, reliable computer had yet worked.

We went into a meeting with the Navy with this, where they thought the agenda was whether or not we could have another $100,000, and we said they would be spending $2 billion. There was a BIG communication gap in that meeting! [Laughs]

One of those lines was an air defense system. I would say the North American Air Defense System created at the MIT Lincoln Laboratory, came in about two years ahead of that schedule.

A: What year was that?

J: We wrote it in 1948, the first SAGE (Semi Automatic Ground Environment) was installed in the late 1950s.

B: Moving forward to 1956 when you came to the Sloan School, who were some of the other additions? I guess it was Eli Shapiro who became your colleagues in those early days?

J: Well, Elting Morison in Industrial History was very good, very influential. I'm not sure whether Douglas McGregor was there. My recollection is he was there but I'm not sure whether he came the same time I did, or a little before or after. He was somebody I admired.

Warren Bennis I guess came in a little later.

Holder Hudgins was a member of the faculty and an interesting case. He was formerly a vice president of Montgomery Ward. I know he was looked down upon by faculty and students as being somebody who was just a business man, and he didn't have any real academic credentials. And yet, when you talked to students 10 years out, he's the one they remembered as having been relevant because he was discussing politics and the organizational challenges.

B: So his "war stories" had some value…

J: That's right.

A: Jay, there's always been this, I guess you would call it "tension", between the economists and your System Dynamics.

J: "Tension" is perhaps an understatement, but go ahead…

A: So to what extent—Eli was an economist by training, right? Eli is the one who had a lot to do with your coming here. Was any of this known at this time? Did they see bringing you here, with the kind of work you'd been doing, as something that was going to bring diversity in approaches to the school?

J: I think only in the sense that I was from the engineering and scientific side of MIT, but without any detail as to what that meant. And the field that is now called System Dynamics, and for a long time was Industrial Dynamics, simply did not exist.

A: So it really had to do with an approach to integrating the school more deeply with the other parts of MIT.

J: In some ways it was probably a daring appointment, although the rigidity of appointments probably was not as great then as it is now. But I would probably have no chance of getting an appointment here now with no earned doctorate, with one published paper in a second-level physics journal, and experience in running a $2 billion operation.

A: I'm going to say this – Bill Pounds once said to me: "You know, we've had a lot of first-rate minds pass through these halls through the years. Probably the best was Jay Forrester." I don't know if you knew Bill said that, but he told me that once.

J: Well, that one paper in the second-level business journal was a paper about the random-access magnetic-core memory, which really launched the modern computer field. Up to that point there had not been anything that was fast and reliable. "Fast" is a relevant term; it's nowhere near as fast as today's computers.

A: Well, it's a lot of other things, too, Jay.

B: In terms of these colleagues, and what you called "Industrial Dynamics," — was that the term, before System Dynamics? What was the reception from people like McGregor and others?

J: Well, I would say very warm, because we started a series of weekly seminars with Carroll Wilson and others using system dynamics to analyze the future of African countries. With McGregor, we started discussions of how system dynamics might help understand "T Groups" and organizations. That was starting the spring when McGregor died. But he'd been very active in delving into the system dynamics approach to look at the structure and behavior of organizations.

So at that stage, there were no controversies of the sort that you are talking about. It's only after the published documents came out, my *Industrial Dynamics* book and more seriously, my *World Dynamics* and *Urban Dynamics* book came out, basically pointing out that the most influential policy in the decay of cities was the building of low-cost housing, and one should take it out, not put it in. One full professor of social science here in our fine institution walked up to me, looked right at me, and said, "I don't care if you are right or wrong. The results are unacceptable." So much for academic objectivity! [Laughter]

So at that time, you see, the economists especially, when *World Dynamics*, and then *Limits to Growth* came out, that was the place where the divide really showed up.

B: Let's get a timeframe for this.

J: *Industrial* Dynamics was published in 1961; Urban *Dynamics* in 1969; *World Dynamics* in 1971; *Limits to Growth* in 1972. All these are still in print, and *Industrial Dynamics* is still a good text, although John Sterman's book is probably used more now.

But *Urban Dynamics* was the place where industrial dynamics moved beyond management because that occurred with the arrival of John Collins.

A: Yes, I worked with him.

J: John Collins had been mayor of Boston for 8 years, decided not to run again. MIT offered him a one-year appointment as Visiting Professor of Urban Affairs. Through a series of happenstances, he ended up in the office next to mine where Douglas Brown was on leave.

B: That was at Chicago. Brown was at Chicago 1959 to 1960.

J: Well, this would have been 1968.

B: Oh, well later then.

J: Anyway, just in visiting with him and his experiences with cities and battling the riots and the fires and everything that was going on in cities at that stage, I began to get the feeling that I'd come to recognize in corporations, and that is, there's a big problem; people know what it is; they know what they're doing to solve it. But if one looks under the surface, one will find that what they are doing to solve the problem is in fact the cause of it. If you think you are solving the problem and matters are getting worse, you do more and more of the very thing that makes it worse because you think you know the solution. And in something as complicated as a high-order, non-linear dynamic system, you should not expect people to be able to solve it in their heads.

So I got that feeling about the city from what John was saying. Everything he said was sensible, but it didn't hang together. So I said, "Well, maybe we can take your background in cities and mine in systems and see if we can make some sense of it."

He said, "What do we have to do?"

I said, "Well, we'll never get the information we want from the Urban Studies Dept., we'll not find it in the Urban Studies library, we're going to have a group of people who have battled these problems, who know the real world, and we might want them for a half-day a week for we don't know how long, for discussions."

And John said, "They'll be here Wednesday afternoon." Just like that. And his position in Boston was such that he could ask almost anything in business or politics for Wednesday afternoons and get them.

A: People really respected him.

J: So he delivered the people, and we started talking about the problems of cities. Absolutely rambling, unconnected, disorganized conversation, as you might expect, and it went

on for about 6 weeks. And for maybe 30 hours a week, I was trying to make some sense out of this. It's the only dynamic system I've ever gone into where I had no clue whatsoever as to what to do about it or where we'd come out. Every other one I've gone into – like the national economy or anything else, I know I can do it. That one, I had no idea. About six weeks later emerged what became the core diagram of the *Urban Dynamics* book. The model showed a city just beginning, going through a healthy growth period, ending up in stagnation, the whole dynamic range over 200 years of a city, and we showed policies that would keep it from stagnating.

A: Yeah, I know we had that program for Urban Executives.

J: That was very interesting.

A: Very interesting. I was program director…

J: I was asked to come in on Monday afternoon and Wednesday morning to discuss the *Urban Dynamics* book. I'd never lectured on it before. I never have had a talk go so badly anywhere as on that Monday afternoon. Because in the group was Gene Callendar from Harlem. Black, intelligent, articulate, not buying a thing I was saying, and carrying the whole group with him. He said, "This is just another way to trample on the rights of the poor people and it's immoral." Another time he said, "You're not dealing with the black vs. white problem, so you're not dealing with the urban problem."

When I said Roxbury and Harlem had too much low-cost housing, rather than too little, he replied that he came from Harlem, and that there wasn't too much housing in Harlem. That was just a sample of the afternoon.

There was a dinner for the group on the intervening Tuesday evening at Endicott House and neither Collins nor I were there. But some of our students were. One called me up at home that evening and said the group was very hostile. And on that basis, I started Wednesday morning.

About an hour into Wednesday morning, Gene Callendar's comments began to change in character. They began to be questions for information rather than tearing down what was being said. Two hours into the morning, he said, "We can't leave it here. We have to have another session."

He made an appointment to come to my office, and he asked me to come to New York and discuss this with his colleagues. And he sat there just as relaxed as could be and said, "It's not a race problem in New York at all. It's an economic problem," as if he hadn't said exactly the opposite 4 days before! He took a report out of his briefcase reporting the amount of empty housing and the rate of abandonment in every borough of New York, including Harlem, demonstrating that the economy couldn't support what they already had, never mind wanting to build more.

A: You be having fun thinking about the housing problem in the US lately!

B: Tell me the name again of this gentleman from Harlem?

J: Gene Callendar. And two years later, a journalist called me wanting to write an article on the aftermath of the *Urban Dynamics* book, who could he talk to? So I gave him some names, including Callendar's. I had no idea what he would say two years after the MIT meeting. The journalist called me after his interview with Callendar and said Callendar had said to him that not only do they have the solution to the urban problem up there at MIT, they had the ONLY solution.

Now, I've seen that reaction several times. People get much more uptight and emotional about cities than they do about corporations. I've never seen a corporate official react in any deep emotional way to saying his policies were backwards. You get that from people connected to cities.

With Urban Dynamics, it takes about 4 to 5 hours for people to see the point, and they will get so upset that if they are not a captive audience, they will walk out in the middle. If I have a captive audience I can see the instant they understand. Everything they knew is still true, and the meaning is turned inside out.

A: Jay, you said you were working on this model of the national economy. You've completed that work?

J: No, I'm still working on it.

A: I thought so, I thought you were still working on it, because I have never seen the completion of it. And I thought you had pretty much concluded that in order to create such a model, there were so many variables involved, and the project was of such magnitude that it would be forever to pull it together.

J: No, it has been scaled back because we put in more sectors of the economy than we found there was any need for. But now it's a model that has a capital good sector, a consumer goods sector, the Federal Reserve, a banking system, and a household sector.

A: Who are you working on with that, Jay?

J: Well, we had a major project at one time, you know, there were 10 or 12 people working on it. Now I'm the only one. And it's had a long and checkered history. We had good support from people on the outside. There were times when we had very negative support inside. We had one dean of the School tell sponsors to cut off sponsorship to us and turn the money over to the School instead. We've had that kind of "help". [Laughs]

See, I've never had academia as my constituency. It's always been the outside world, and that has created ripples of various sorts.

A: You would like our current dean. Our current dean is oriented to the outside world in ways that put an emphasis on that.

J: Well, a school should be oriented to the outside. The things that tend to get appointments are published papers and not anything to do with being useful.

A: One of the other problems is being a part of MIT. There's a certain expectation of publications.

J: Well, the field of system dynamics is falling victim to internal academic orientation. Go back to Operations Research; OR was a very practical, WWII activity, and as far as I know it was very successful. It began as an academic program, again focused on outside problems, but more and more it became academic. Then people thought there ought to be something focused on business, so the field of Operations Management was started to fill that gap. But it also declined into academic papers.

A: No they are both there together. They've been trying to – there's been a move to try to merge those groups in the school, but they haven't succeeded.

J: Well, if they really maintain their outside focus it would be good, but I think again, they've been pulled into the academics rather than focus on the outside world.

B: But Jay, on this point about being focused on the outside world, we should ask you for your reaction to something. When we interviewed Bill Pounds, he was comparing how salary is positioned for folks in the engineering school versus here in the Sloan School. His conclusion was that people in engineering, and to some extent science, they have to support their salary with grants and contracts, they have to understand what are the issues out there that are of interest to the government and to foundations, etc. It keeps the faculty tuned into the real world. Here in the Sloan School, we guarantee salaries, so it enables people to study what they want to study, but it may not be very relevant. Do you have a reaction to that? It's quite a radical suggestion, saying that Sloan faculty ought to be more like engineering faculty and have to generate part of their own salary support through grants and contracts.

J: Well, are you aware of the Olin School of Engineering? No tenure and they get something like 150 applications for every faculty opening. I think tenure has it advantages, but there are serious disadvantages.

But you asked about the clash between economics and system dynamics and that still goes on. It's because the two bases for modeling are so different. An examples lies in where does information come from? I would say the information in people's heads is probably a million times greater than what has ever been written down in the books or newspapers. Which, from the standpoint of dynamics, is a million times more useful than anything that's ever been measured in numbers? And yet, social sciences and economics tend to use that one-millionth of one-millionth of data as the basis for their analysis. And that is absolutely insufficient to run the world. If you took all the managers out of a company and told their replacements that they will find everything they need to know in the written policies and the numbers in the office, so carry on. You would have disaster, because the world runs on the mental models. And if you're not willing to tap those in formal modeling, you're not going to come to grips with how the world works.

Now, that's a big break from what's going on in the social sciences. They say, "But it's not scientific." OK. Neither is science. They think they're following science but Einstein's laws did not come from data; Ohm's Law in electricity did not come from time series. They come

from hypotheses about how the world might work, and THEN you look at information to see if the proposition, the theory, matches the world.

So the system dynamics models are models in the sense of those physical models. And no model of that sort can be proved. The social scientists think they are proving the validity of models when they run various regression analyses, but it's a closed set of data. They are using the same kind of data, even if it's not the same time series, the same KIND of data to validate models. It is a closed system that is out of touch with the real world. Now, that's a clash of philosophy.

Also, in social sciences, economics in particular, the gold standard of modeling is often stated as the ability to forecast. One can demonstrate within a system dynamics model the inability to forecast usefully. Nobody has ever succeeded in doing much better than just extrapolating the past. What one can do is forecast how changing policies will change the KIND of behavior of a system. There is little basis for communication between economics and system dynamics. People ask me what I'm going to do about it, and I say, "We'll outlive them." [Laughs]

A: Well, I have to go. We have to have another session with Jay.

J: We haven't really done what you wanted.

A: No, but it's absolutely, totally fascinating. So a question: What should I say to this report that you haven't read so far, about what was Eli's big contribution to the school?

B: As you look at the other major business schools that we always take reference from – that one across the river, and the Wharton School, University of Chicago, etc. – and the subject you were just discussing in terms of trying to understand complex phenomenon, are the other schools doing anything at all that makes them more relevant?

J: That leads into a discussion as to what the future might be. If you look at the history of management, I think one of the big breakthroughs was the case study method pioneered by Harvard around 1920; that may still be dominant. But it has a fundamental flaw. Case studies describe and talk about a complex system with the high probability that the wrong conclusions will be drawn because one's mental ability cannot handle dynamic complexity. On the other hand, it has been a lot better than nothing.

Then we had the movement toward more mathematical things, at Carnegie and MIT and other places. But those approaches have, for the most part, been out of touch with reality because the mathematical methods can't cope.

Now we come to system dynamics, which in my view is a link that has yet to be fully appreciated because it's basically a big step beyond the case study. But it's connected much more to the case study than it is to the mathematical threads that have been going on. The system dynamics model might start with essentially the same process that you would use for a case study, but you would take those observations and translate them to the language of system dynamics modeling. That's simply a translation, nothing very elegant. You're translating those assumptions into a different language, a language that is absolutely unambiguous, absolutely clear about what its saying (the English language is never that way), and you lay out the assumptions you're making. People can argue about those assumptions because they're

absolutely tangible, exclusive, they're right there in front of you, and anybody who wants to differ has something to differ with. What you find is that you rapidly get a convergence of views about the assumptions when they are stated with that clarity. Then you put them together and you get a dynamic scenario based on those assertions.

One thing you should be sure to start with is that you have a model that shows why you're in the trouble you're in. Most people only start with where we are, and how we get out. But you are ill-advised to do that until you are quite clear on how we got in. So the model should lead INTO the problem as well as dealing with policies that lead you OUT.

System dynamics is a very radical change from what's going on in business schools, and I personally believe it is the next big step forward. But it's apt to be picked up by the second- or third-level schools rather than the first-level schools. The first-level schools are quite satisfied with what brought them to their present status.

We used to have more system dynamics activity here in the Sloan School, but it has been allowed to decline. It's unclear to me whether the Sloan School can build onto what we've done, or whether we should look to other places. There is a lot of activity at the University of Texas, and various other places. There are in North American about 100 universities that claim they are teaching system dynamics. I think some of them may have only a lecture or two in some other course. But there are about 100 that allege that they are doing something about system dynamics.

The future is to use system dynamics as an integrating approach to interconnect everything else that's being taught. We have a faculty that teaches finance, and one that teaches production, and one that teaches labor relations, and we assume that the students can pull all this together into one whole, whereas no faculty member has ever done it. One solution would be to have a faculty member spend not more than 3 to 4 years in a field and then he would HAVE to change to some totally different field and teach that one. By the time you've made the whole round, you'd have a faculty that knows something about the whole picture. But better than that is to teach them from the beginning, in a tied-together way, and I think the only way known to do that is through system dynamics modeling. I don't think there is any competition for it at this stage. You can't teach integration as a capstone term at the end of a program. It must be built into the emotional responses and the inner feelings of people, and it will take a few years to do that.

System dynamics is a profession with the depth of medicine or engineering, and eventually it will have to be taught like those: 4 undergraduate years; 2 or 3 or 4 graduate years for the most expert. But like engineering, you can learn to be an electrician in much less time, and you can lead a useful life. So there's a whole gradation, from relatively little to full depth. But the full depth is a profession every bit as comprehensive and difficult to learn as the other major professions. And I think management will become that sort of thing.

You see, at present, many people in the sciences look upon management schools as trade schools, and that's basically right. Take the analogy to an airplane. If you ask, "Who are the two most important people in the successful flight of an airplane?" I think you would have to say the designer that made it flyable, and the pilot who runs it. And then you say, which of these two is more like the output of a management school, and you have to say the pilot, the person who's running it. But if you ask, who designed the corporation that he's running, there is no answer, its happenstance. It's those policies that are happenstance that really make how it's going to turn out.

So we need to have a school of social system design, which could be the future of management schools. Very different from what's going on. But more and more, the present

management schools are going to be just competing with each other doing essentially the same thing, no great distinction between them. That's already pretty much true. And they worry about how they get rated by some magazine, and who is No. 1 and who's No. 17, but it's immaterial because they are all pretty much alike. The question is: who is going to do that breakthrough that is as great as Harvard did when they did the case-study method? That next BIG change?

B: This is a bit of a tangent, Jay, but were you around when some people tried to improve on the case method here, and they called it the "incident method"? It was a kind of an "in basket" exercise where the presumption was that you were not going to be handed all the facts like you get in a case; you're going to have to ask for the information that you want. You're given a problem…. But it never went very far. And yet conceptually, it seemed to be something that was an improvement on the case method.

J: It wouldn't go very far because as far as I know it has no framework into which to put what you observe. A system dynamics model is the repository of your interviews, and the gaps in it are the things that say, "I have to go get something else." So I would say that the "incident method" would be an interesting start for a system dynamics model. And we don't have many people who are top-notch system dynamics modelers. System dynamics takes a lot of experience, a lot of work to understand existing models, and lot of experience in going out and learning how to fit new information into a useful model.

Something like 20 of what we call generic models, 20 fundamental models, would cover 95% of what a manager needs to know. If a manager really understood those 20 models and understood how to recognize whether or not they apply, he/she would be way ahead of the game. Now, each of those models is itself the subject of a small book and each of them is probably the subject of an academic term. They have tremendous subtlety; they have a variety of possible outcomes depending on the policies that are attributed to various parts of that system; and they're not very complicated models. They have 4, 5, 6, 8 levels. I would nominate my "Market Growth and Capital Investment" paper as being one of those, and the Production-Distribution model is another one. They are that level of complexity.

If you take the production-distribution system in my *Industrial Dynamics* book, that's now the subject of a whole professional society devoted to the dynamics of distribution chains. It's of that importance and that depth. And there are 20 or so fundamental structures—20 is just my estimate, we do not have them identified. One of them is the aging chain: as people age and get promoted, organizations get top-heavy, which is going on at MIT and most companies. There are various fundamental models that come up repeatedly. Generic in a sense that they apply in present time, they apply in history, and they apply in the future.

That would be the basis of a kind of management education that trains managers. But those don't exist, and the full scope of them hasn't really been developed. If you take my "Market Growth and Capital Investment" paper, I thought I would dispose of it in two sessions of a class, but when I found the extent to which the class did not understand it, and the elaborations that I myself hadn't worked on, it went on for six weeks, discussing just that one very simple model, because of the subtleties.

So there is a huge untapped possibility for a kind of management school that would be a breakthrough of the future, get out of the competitive, all-alike pattern that we now have.

B: Earlier you mentioned the Olin School, and you mentioned it in conjunction with not having tenure. Have you visited the Olin School? My understanding is that they establish learning contracts with the students so that people focus on what are the outcomes that the faculty are currently committed to. But I haven't been out there to visit. I was just curious if you had been?

J: I have not been, no. I don't know the internal details. I have a grandson who applied there and got turned down, so he came to MIT. [Laughs]

B: Got turned down because they probably have so many people applying.

J: Yes, they do. And tuition is very low. I thought it was free, but I guess it's not free. But I think its low by comparison to other schools.

B: Well, someone I know has been evaluating it, and he has a book coming out in a couple of months, and he's looked at a couple other educational innovations. He's on the faculty at Carnegie-Mellon. So it will be interesting to get this book. It's on what we're talking about, how to break from the status quo that so many schools find themselves in.

J: Well, I'm very much involved in that because one of my major current interests is system dynamics as a foundation for a new kind of K-12 education. That's been pioneered at the grass roots for 25 years, and it's making quite dramatic progress. But it's almost out of sight as far as most people are concerned.

B: A large part of it's in Texas, is it?

J: It's widely scattered. I think the greatest concentration at the moment is in Portland, Oregon, but it has major activities in Tucson, Arizona, and then scattered other places around the world. There is activity in the Netherlands, and probably in China, and other places.

But the results are dramatic. I had one teacher say that the number of students in detention hall for misbehavior had dropped from an average of 50 to an average of 5 because the students are so involved in what they are doing. I've had teachers come up to me and say, "I had no idea these students could do so much." The students are doing things the teachers didn't dream they were capable of. Some students in Portland, Oregon, decided they would look at the 50- or 100-year future of China's population policies. They found they could strike up an email correspondence with a fairly high official of the Chinese government; that was exciting for high school students to find you could engage the government of China in your project. All was going very well; they were sent a stack of data to work with, until they began to get the computer simulations of what was going to happen. At which point, I'm told, the Chinese colleague in effect said, "Go away, I don't dare know that!" because they will run headlong into what US and Europe have, and that is the aging population without enough underlying support for it, except it could be more extreme in China. But the point is that high school students are willing to undertake projects that universities are afraid to try. Very exciting.

B: And you say, K through 12? So you can start at a very early age?

J: You can start in kindergarten. One of the fundamental characteristics of systems, which most people don't realize, is that there are two kinds of variables, and only two. Anybody in business should know that because you look at the annual report of a corporation and you find the balance sheet and a profit-and-loss statement, and you do not find a third comparable page. The balance sheet is stocks, and the profit-and-loss statement is flows. Every system that changes through time under any circumstance has those two variables, and only those two. And a kindergartner can understand that distinction. The water in the bathtub is a stock, the water flows in and flows out. But your reputation is a stock, and the good and bad things you do are the flows. Anywhere you look, its true—social, physical, environmental, internal medicine, anywhere. By fifth grade, it's been demonstrated that fifth-graders can do what is being taught in the graduate school here.

B: So what materials do people draw on to guide them? What do the teachers use as references?

J: That's the big weakness at the moment. I am trying to raise $100 million for the next phase. Six years ago, we had an intensive, one-week conference with about eight active teachers, and four or five of the most able system dynamics professionals to plan the future of system dynamics in K-12 education. We laid out a program for 25 years. Year by year, activity by activity, as to what could be done. We figured in 25 years we might bring a third of the US schools into this orbit for a cost of about $2 billion, which is not much compared to what's spent on education. That 25-year program hasn't really been launched. The first ten years would take about $100 million and I am hoping that I can make contact with some wealthy person who would see that as his goal in life. It's had probably $10 million put into it already by individuals.

B: I would think on this idea, Jay, that some combination of the experimentation that charter schools are engaged in, and support from foundations like the Gates Foundation, where they are really behind a lot of innovation. But the innovation isn't as basic as what you're outlining.

J: The Gates Foundation has a statement on his website that "unsolicited proposals will not be accepted." They absolutely shut the door for new ideas. Bill Gates himself is different, and I have yet to contact him personally, but that's my next step. But this kind of major K-12 change does not have much chance in government because government is not able to take a 25-year view of change. The big foundations don't work either because they are run by relatively timid people who don't want to get in the middle of a big controversy. So I think it has to be the principal, the person who is supplying the money, who would have the long-term view and the courage to try. And it's not easy to make contact with those people. Very often they have staffs for the purpose of saying "thank you" to suggestions, so breaking through is not easy. The money so far has come from meeting people in cocktail parties.

B: But given the success in places like Portland or Tucson, some of them may have entrée into the Department of Education. The guy who is there now, Arnie Duncan, is showing interest in – they are putting out quite a bit of money in this "Race to the Top", etc.

J: Which is a disaster. They are in the category of the organizations that are doing what is creating the problem. The academic scores are going down as they work harder and harder to

bring them up. They don't stop for a moment to think that maybe what they are doing is causing the problem. This whole "No Child Left Behind" is potentially a disaster. First of all, it's not clear why you want everybody to excel in science and mathematics. That's not true. You don't want everybody alike. Also, it's very uninspiring for a student to be learning under the pressure of "You've got to do it because the teacher will be promoted and the school will get more money." That's not a motivation for learning. A student should be learning because it's exciting and something the student wants to do. One person behind the push on science and math in the National Academy of Engineering said we've spent $600 billion to get better grades, and grades have been going down. I think he needs to face up to the fact that maybe what he's doing is the reason for the decline.

B: Well, we're getting close to 2:00, so we'll quit. Thanks, this has been terrific. And as Alan said, we will have to schedule another session.