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HOST: We are very fortunate today to begin with the first speaker, Professor Richard Bellman. I first met Dick at RAND corporation, many years ago. He received his doctorate from Princeton University. In 1970 he was awarded the first Norbert Wiener prize in Applied Mathematics. He has a number of honorary degrees: University of Aberdeen, University of Notre Dame; Doctor of Law degrees from University of Southern California; and he has been one of the most prolific and creative researchers in this field. Used his books on game theory, …control theory, those are just two out of thirty, and something like over 500 research papers he has produced. We are indeed very fortunate to have Professor Bellman.

One thing I should point out, before I give him the microphone, is that, like almost all of our speakers, he is interdisciplinary, and this is reflected in his triple appointment at the University of Southern California, which is in mathematics, electrical engineering, and medicine. So it gives me great pleasure, and it is a very great honor to have Professor Bellman.

[applause]

RICHARD BELLMAN: I am glad to be here in Portland. leave you, so there's no time to waste. I'd like to begin with a poetic story. Gertrude Stein was dying, and Gertrude Stein, as you may recall, was a hippie of the 1920s. She said, "A rose is a rose is a rose." And actually, acquired quite a reputation for herself. As she lay dying, some of her acolytes said that she would […] truth. So, one of them, probably Alice B. Toklas, her […] said, "Gertrude, Gertrude, what is the

answer?" And Gertrude Stein, opened her eyes one last time and said "What is the question?" And I think that too many people have given answers without asking "What are the questions?" Today, I want to pose some questions. I wish I knew the answers, but it is not important. It is much more important to ask good questions. Let the younger people supply the answers. One must always leave […] for the bartender, as a friend of mine says.
Now, the questions are many, but some questions are obvious. They are that society cannot run itself. In other words, we must guide society, we must understand the systems of society. And that is why this week is so important, because it will focus attention on systems, and the systems of society. What systems do I have in mind? Well, I have the economic system, the city, which is the prime machine of civilization. It is a good way of thinking of the city, and we must make that machine work. Right now it is not working well. I am thinking of energy, environment, health, education, welfare… we are surrounded by systems. I am sure that you will think of many others. Every business is a system. I wonder, what can a mathematician do? He must not become an anthropologist or a sociologist; he has neither the training nor the inclination. He must remain a mathematician, but he must work with others, he must be interdisciplinary.

So, the first problem is that of communication. That communication is very difficult. After all, we must remember that in ten thousand years, we have not made a good teapot or coffee pot. In other words, we don't know yet how to convey water from one place to another. So it is not to be expected that in 25 years, we will have learned how to use a computer. In other words, the communication of ideas is difficult. Communication between people and communication between people and their computer. What we don't realize until we try to use a computer is that we communicate with a person with a great deal of ambiguity, and it is very important. We depend upon the person understanding the culture in which we are all immersed. But a computer has no culture, so it is very difficult to communicate with a computer. We have to break things down into simple, logical units, and sometimes these logical units do not exist.

I could spend a great deal of time on communication. But I want to mention that it is a significant mathematical problem. How does a mathematician communicate with a non-mathematician, and conversely, how does a sociologist communicate with a mathematician? How does a sociologist tell a mathematician what problems he has in mind? It is not easy. And I think that is a great deal of the power: to realize that these problems are not easy. At first, it is simply also a surprise, to realize how difficult these problems are, but after a while we get accustomed to the difficulties. So, the first problem is that of communication. This is a big problem with many parts.

The second problem is that of structure. What is the structure of our system? We use the term, what do we mean? And it should be remembered that one of the functions of a mathematician is to make terms as precise as possible. Sometimes, that cannot be done, but they can be known. The social sciences spend a great deal of time trying to define things precisely. Maybe impossible, maybe it's not, we should note. And the mathematician can tell. It is a new question, and a difficult question. I cannot over-emphasize how difficult these investigations are. They are not easy, nor are they direct. They require a great deal of thought and a great deal of effort. Now, in dealing with structure, that is where the algebraics, the topologists, and the logicians can be of great help. We have left far too long these problems to the analyst. He can do a great deal, but the algebraic and the topologist must help, especially with such concepts as structure.

Then there is mathematical models. The mathematician should be regarded as a keeper of our structure. It is up to him to make various mathematical models corresponding to different ideas that a non-mathematician has. One of the functions of mathematics is to make assumptions explicit. There are people who pride themselves, they say "I am very practical, I never use a theory." Absurd, everybody uses theory. Some people use explicit theories, some people use implicit theories. We must know what theories are implicit, what are explicit. I always remember what Kurt Lewin said: "There is nothing as practical as a good theory." So it must be remembered: everybody operates according to theories, even the people who think of themselves as most practical. It is often surprising to find that our theories were given to us by our parents, and occasionally, we have to think something out, we say, "Where did I ever get that idea?" and the answer is, we got the idea at the age of 5, from our father or our mother, who got it from some parent and so on. So the idea may be hundreds of years old, and may have no relevance at all to current problems.

Then, what mathematical theories should a mathematician have? Well, he has to deal with two basic problems. He has to deal with uncertainty, and he has to deal with decision-making. Now, for uncertainty, obviously he should have classical probability. But it should be remembered that classical probability is basically a frequency theory. So it works well in cases where there are long runs over time, or a large number of people. In other words, it works well for card games and […] It does not work so well in the stock market. That is another story. But obviously, we must deal with uncertainty with other tools besides classical probability. Many people have recognized the limitations of classical probability. But I want to recommend, very strongly, the new theory of Lotfi Zadeh: fuzzy systems. This is another way of dealing with uncertainty, and with different axioms. It must be remembered that classical probability is an axiomatic system, just like geometry. Sometimes it applies, sometimes it doesn't. I always remember what […] said. He said, "The physicist thinks the mathematicians have proven, and the mathematicians think it is the law of nature." It is not so. It is a mathematical theory and it must be checked. Let the axioms hold, which they do, but it is the only […] We use it because until now we had no other. But now we have.

Now, for decision-making, which is very important, I think that dynamic programming will play an important role. Not so much the analysis as the ideas, the concepts. It should be remembered that very often it is sufficient to describe a system. It is not necessary to determine the optimal policies. It is sufficient just to describe what the system is, and what policies are available.

But, what is that problem? It should be remembered that every theory answers some questions, and raises some questions. As I said before, that is quite fortunate. No theory answers all the problems, and then most probably, every theory creates more problems than it solves, which is good. It is good for the mathematician. After all, we must make a living, too. We don't want to solve all the problems of society, but there is no danger, there is enough for everybody. But we are very fortunate people, society needs us. While we don't want a society run by mathematicians and computers, we don't want a society without mathematicians and computers. The problem is, how do we mix? How do we use experts? We all face that problem, we face the problem with doctors, we ultimately connect with TV because… etc. How do we use experts? I don't think we know.

What I am talking about the difficulty, the difficulty especially today, is not so much too little data as too much. We find that […] is too large, even for a computer, and these are days when computers are getting faster and memories are getting bigger and cheaper. Still, […] in classical terms is too much. So, it should be remembered that we cannot expect a solution from conventional mathematics. This is very difficult; we wish it were true. After all, two thousand five hundred years ago, the Greeks thought they had a perfect system; then they finally […]. Well, we have found many other difficulties. As somebody said, the universe is strange, it may be stranger than we think, it may be stranger than we can think. And it may well be that there is no good solution to the problem of systems. This is very heretical; we never say this publicly, at least not often. One of the fortunate things is that when we say that, nobody believes us anyway, so it's all right. We can be honest at no cost.

And what, then, is a solution? A solution lies in the use of simulation. What is simulation? Simulation means that we construct a model of a process, and check various policies. To begin with, simulation is hard. Everything is hard. Everything worthwhile is hard. It must constantly be remembered. We always expect easy solutions from the […]. We think doctors, and we think lawyers, we think businessmen know what is going on. Not true. Everybody is in the same sea of difficulty. But, we pretend that in our field, we know, accept to experts. But, one of the advantages of simulation is we can use computers. That means, we can check in […] time, we can try five years, or ten years, and see, without disturbing the actual system. It is an old idea; it is the feasibility which is new. It is now feasible to do this, but I must emphasize: it is difficult. If we make the model too large, we learn nothing. If we make it too small, we probably learn the wrong thing. I don't want to mention names, but those of you who know […], some of the cases […] modeled have been made too small, and it is easy to draw deductions which are probably wrong.

So, what I want to emphasize is that there is a great deal of opportunity for the young mathematician. Very often, the young person thinks that the major problems have been solved. Not so. The major problems remain. Some problems, which were important in the 18th century and in the 19th century have been solved, but the 20th century and the 21st century problems remain. It is up to us; it is very easy to avoid these problems. These problems are difficult, as I said before. They are new. But, we must contribute some of our time. After all, we are run by society, and we can be ruined by society. So, it is a question, how can we run society better? It would be nice if we run it well, but that is too much to unpack. But the people of higher intelligence must devote some time to the problems of society. They cannot repeat, they cannot leave our problem to others. You know the joke that Roosevelt showed that a man can be president for four years, Truman showed anybody could be president, and Eisenhower showed we didn't need a president. It's not true, we do need a president. Somebody has to make major decisions, that we know now, and what we have now is not good enough. We must do better. Thank you.

[applause]

HOST: Thank you very much, Professor Bellman. We have some time for questions from the floor, so… we'd be delighted if you want to ask them. Yeah, use the microphone.

AUDIENCE 1: Well, I'm addressing the first question you posed, here. How does a sociologist communicate with a mathematician, for example…

BELLMAN: […] to hear that… [laughs]

AUDIENCE 1: Okay. Don't you think that systems programs, like the one we have here, for example, would help bridge the gap between different people from different disciplines? And if so, I would have a question, then, about the structure of these programs. Do you think that it's better to have different courses from different disciplines, like, for example, studying engineering courses together with sociology courses and the like; or creating new kinds of courses which address problems in a generalized way, where a force for example, can be either a Newtonian force or a driving force in society or whatever? And… do you think it would be advantageous if these programs started in the undergraduate level, with generalized concepts, something like the generalized […] mechanics, for example, just as an example, and go on, proceed to a graduate level?

BELLMAN: Why not have both… why not a course in the engineering department and the […] department. As a […] you know I used to say: "Different strokes for different folks." So, I would offer you two […]. I think that the more we have, the better, and the more ideas, the better. The more different ways we think of these problems, the better, from inside and outside.

HOST: Well, we will have a coffee break now, and there will be a small discussion opportunity in room 329. We will be shifting over to the grand—not grand—[laughter] pseudo-grand ballroom, where we were yesterday for the 11:00 talk by Professor Duncan. I should also mention that tomorrow, those of you who are not aware of it, the […] is conducting an all-day workshop. If you want details, just check with one of our lovely and charming secretaries, or one of our faculty will be glad to get those to you. So, we'll have a coffee break now, and again I want to thank Professor Bellman very, very much, on behalf of all of us.

[applause]