SYSTEMS THINKING
in the
SYSTEMS AGE

By Dr. Russell L. Ackoff, 1978
Transcribed by Dag Forssell, 1991
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with the continuing segments:

VARIETIES of PLANNING

and

CONTENT of
INTERACTIVE PLANNING

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SYSTEMS THINKING in the SYSTEMS AGE

Summary: (Segment one: Systems Thinking in the Systems Age)

This segment provides an introduction to Systems Thinking. Dr. Ackoff begins with a discussion of the characteristics of the machine age, out of which we are coming, and the industrial revolution, one of its principal products. He describes the emergence and characteristics of the systems age, which we are entering, and the post-industrial revolution. This leads to a discussion of the systems paradigm and the three organizing problems of management in the systems age.

Contents:

A sampling of books By Dr. Ackoff:

Ackoff, R.L. *Redesigning the Future; A Systems Approach to Societal Problems.* New York. John Wiley & Sons. 1974.

Ackoff, R.L. and Emery, F. E. *On Purposeful Systems.* Intersystems Publications. Seaside, California. 1972, 1981.

Ackoff, R.L. *The Art of Problem Solving (Accompanied by Ackoff's Fables)* New York. John Wiley & Sons. 1978.

Ackoff, R.L. *Management in Small Doses* New York. John Wiley & Sons. 1986

Additional segments in this series:

VARIETIES OF PLANNING

CONTENT OF INTERACTIVE PLANNING

This overview of *1) systems thinking*, *2) conventional planning* and *3) purposeful, empowering planning* is from a one day seminar on Interactive Planning by Dr. Russell L. Ackoff, conducted in the spring of 1978. Dr. Russell L. Ackoff was Professor of Systems Science at the Wharton School at the time. In 1991, Dr. Ackoff heads the consulting firm Interact in Philadelphia. For more detail and supporting information, see "*Redesigning the Future*," listed above, pages 3-19. See also endnotes by Dag Forssell, providing a commentary on this seminar from a Perceptual Control Theory point of view[1].

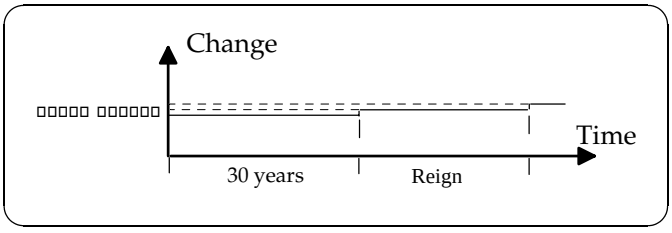
The Importance of Theory

I am going to start our day's discussion at a very general level and converge to specificity. I do that deliberately. I am a firm believer in an assertion that Bertrand Russell is attributed to have made, among others, when he once said that: "There is nothing as practical as a good theory."[2] As I have studied planning practices throughout the world, it has not been for lack of appropriate techniques or tools that most planning suffers. It is for lack of an adequate concept or theory of planning. So I am going to try to develop and sketch one for you and attempt to deal with it as practically as I can through illustrations. I am going to deal with principle and concepts and theory to a large extent, rather than with specific tools and techniques. There are no panaceas that I know of in planning, but the difference between good planning and bad planning, at least in my opinion, has to do with one's understanding of three things: An understanding of what is going on in the world, an understanding of organization, and an understanding of planning. We are going to try to deal with all three and we will start with the largest one.

The Rate of Change

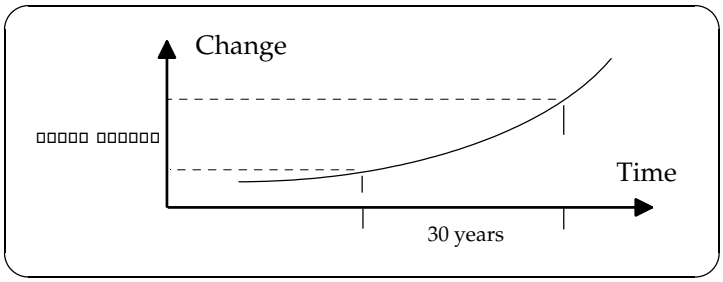
It is interesting to analyze the literature on management. One finds that in the last ten years the focus has changed tremendously and today we take it for granted that the principal topic under discussion is the rate of change. Management for change has become the central and most frequently referred to issue in the management literature. Like many things that have become commonplace, we have lost sight of its origins. There was an essay written in 1932 by Charles Snow, a famous British essayist, called: "Two Cultures", in which he took a fact that had been frequently observed by others, but extracted an inference from it that was new. The fact was that if we plot change against time it is exponential.

The rate of change is continuously increasing. But this is not unique to our time, because a characteristic of the exponential curve is that at any moment in time you can say that change is more rapid than it has been in the past. But he argued that a qualitative change had occurred, as a result of the increasing rate of change. And he argued essentially as follows: He said that the normal length of a rule, or a reign, is about 30 years. A normal manager will exercise control for about 30 years. He said if we go back to the last century, or any preceding century, and lay out a 30 year span, and project over to the vertical axis the amount of change which occurred, it is trivial.



Therefore it was possible to have two unconscious mechanisms. We are coping with them. The first was gradual, slow evolutionary adaptation. The second one was a change of reigns. That is why we study history by studying the reigns of kings. Nothing ever happens when the king is in power; it all happens with the change in power. So you study the change in dynasties.[3]

However, today (and he was talking in the 1930's) for the first time, we are a generation, which when we plot the 30 year period and come over to the axis, the amount of change has become sufficiently large that we can no longer deal with it in a slow, unconscious, evolutionary way.



It requires major qualitative adaptations by management. Since he was a philosopher and a novelist, not too much attention was paid to him by the managerial profession.

The principal philosopher of management in England, (much too little known in the United States), Jeffrey Knicker, picked up this notion and began to write about it in the management literature, but in this country we did not become aware of it until after WW II when Peter Drucker picked the concept up and made it the theme of his book: “The Age of Discontinuity”, in which Drucker argued that the central problem confronting management, was the management through these major qualitative changes that were called for.

We still did not pay too much attention until 1971 when Alvin Toffler dropped his bombshell, a little book called: “Future Shock”. In it he demonstrated, with incredible journalistic capability, that the principal deficiencies in our culture derived from our inability to cope with change. And this paralysis, this social paralysis, he calls Future Shock. The culmination of that chain of thinking came in the work that appeared very shortly after Toffler's, a book by Donald Schon called: “Beyond the Stable State”. It appeared in the early 70's. And Schon demonstrated an incredible property of the environment within which management must operate.

He showed that as the accelerating rate of change goes up, the complexity of problems does as well, because complexity is a function of the amount of change which occurs. As complexity increases, then the length of time required to solve the problem increases, so it takes us longer and longer to solve the problems we are confronted with. On the other hand, because changes occurring with increasing rate of rapidity, the solution to any problem that we apply, have shorter and shorter lives. And then he showed the incredible thing: That it now takes us longer to solve the problem, than the problem has to live!

Consequently, we are solving problems that no longer exist. He says the lag between the solutions that we come out with and the problems we confront is increasing. That really is a challenge! My students in the university are immersed in this literature of change and are impressed by the curious diagnostics that it has. Uniformly, it deals with the rate of change as the central problem. Toffler even says it doesn't matter what is changing. He says it is our inability to cope with the rate that is the critical problem. And the students accept that, but they go a step beyond what Toffler or Drucker or Vickers or the others have done. They say it may be true, that to identify the nature of the central problems we are confronted with, all we need to deal with is the rate of change. But how in the world can we deal with that change unless we understand its nature?

Therefore, the fundamental question they ask is one that is incredibly simple to formulate, but is probably the most difficult question in the world to answer. Their question is: What in the world is happening in the world? Now, that might seem like a very grandiose question at the beginning of a discussion of planning. What I hope to show you is that implicitly or explicitly, your answer to that question has more effect on what you do as a planner than any other question you ask. Therefore, professionally you have an obligation to face that issue and to answer as best you

can.

As a professor, I don't have an alternative. I am required to provide some kind of an answer, as pretentious as it is to try to answer such a question. And so I'd like to begin this morning, by putting before you a set of hypotheses about the nature of the changes which are occurring. And I do so as the basis for developing a concept of planning, to which we will direct the rest of the day.

The Machine Age

An ornamental argument that I am going to present before you, is that starting about the time of WW II, we began to go through a change of age, or era; that the era that began with the renaissance and began to end with WW II, gave way to a new one, which was appearing. Now the term era or age is a poetic one, and the meaning is not clear, so let me try first to make explicit what I mean by an era or an age. I mean a period of time, in which the peoples of various cultures share a common concept of what the nature of the universe is. The Germans had a marvelous word for this and curiously we have none that corresponds to it. The Germans talked about a "*weltanschauung*," a view of the world, and perhaps more than any other country in our culture recognize the significance for everything that we do. What I am going to argue is that our view of the nature of the world has been undergoing a fundamental change. A great deal of the dislocation that we all sense, and discomfort, is the result of the fact that most of us are standing with one foot in each age. And as the ages separate, it begins to hurt increasingly, and sooner or later we are going to have to put both legs in the same place. Perhaps today we can accelerate that process. Now, the age out of which we are coming, for reasons that I will try to make clear, I am going to refer to as the "Machine Age". As I have indicated I believe it started with the renaissance.

The importance of the renaissance is something that has been lost in history and the magnitude of the change, which took place during it, from the preceding age, the middle ages, is lost. But it is incredible! During the medieval period, the focus of man's intellectual life was on the phenomena of death, not life. He was concerned with what happens after life, not with life itself, or the environment in which it took place. For very good reason! Expected life was 27 years. The average person only lived to be 27 years old. 40% of the children born did not survive childhood. The average nuclear family suffered two deaths on the way to maturity. Life itself was hard, full of deprivation and difficulty. There is no wonder that the central problem on everybody's mind is: My God, what is life all about? Why are we made to suffer so much? The answer which religion gave was that life is preparatory to something that comes afterwards. The focus of the intellects of the time was on what comes afterwards. There was no interest in the mystery of life. The great art of the time focused on heaven, hell, the Gods. Dante's inferno is a prime example of this preoccupation.

What happened in the renaissance was a conversion of focus from death to life. This is reflected in the word renaissance itself. It wasn't accidental that the period was called the renaissance. You all know what it means! What does it mean? Re-Birth! Birth! Reentry into the world! We entered the world in that period just exactly as a child does, full of curiosity and a desire to understand what was around us. That was a major transformation.

The magnitude of that transformation is almost impossible for us to grasp. Let me just cite one fact which gives you a sense of its magnitude. The first effort to systematically organize our knowledge of nature was made by Aristotle, in his book the "The Physics", which was written about 300 BC. And in that book Aristotle formulated the first gravitational hypothesis. It is amusing to us today.

What he said essentially is that if you have two objects of the same size and shape,

but different in weight. For example, suppose we had two balls of exactly the same size, one weighing one pound and the other weighing two pounds. Then he said that if we lift those two balls an equal height above the floor and drop them simultaneously, the two pound weight will reach the floor in half the time of the one pound weight. We know that is false. That is not what is interesting. What is interesting is that it was 1900 years before anybody thought that was interesting enough to test it and find out. It is almost incredible to us today, that somebody could make as fundamental a statement about nature, that would be considered to be so uninteresting as to fail to try it. Galileo did, in the incline plane experiment. So in the renaissance, we had this tremendous curiosity coming into being about the nature of nature.

Machine Age Thinking: Analysis

We proceeded exactly as a child does. If you take a child, and give him an object he has never seen before, whether it is a toy, a clock, a radio or a watch, and he wants to try to get some understanding of it, what is the first thing he does? After he tastes it, of course what does he do? -------. Takes it apart! Exactly! If a child is given something he doesn't understand, the first thing he does is take the thing and disassemble it, decompose it into its parts. The second thing he tries to do is to understand the behavior of the parts, he now tries to understand what these parts are doing. And then he attempts to assemble the understanding of the parts into an understanding of the whole. That is a three step process.

1) You take the thing you want to understand apart.

2) You attempt to understand the behavior of the parts, taken separately, and then

3) You attempt to assemble the understanding of the parts into an understanding of the whole.

That three step process is what we mean by analysis. **Analysis** became the methodology of the machine age. It became so firmly entrenched in our mode of thought that even today, most people can't think of an alternative to it. We use it synonymously with thinking. When somebody says to you: “I had a problem which I analyzed”, or says: “I had a problem which I thought about”. - What is the difference? You would have difficulty in saying. To analyze a problem and to think about it are taken to be the same thing. To analyze a situation, to study a situation, to think about a situation; these are simply synonyms.

For 400 years, this three step process became the basic methodology of inquiry. It led to a series of questions, the answers to which formed our view of the world, our weltanschauung. Let me show you how: The first and most obvious question which arises by the use of the analytical method goes somewhat as follows: Suppose somebody who has never seen an automobile is given one and he wants to understand. Well, begin by taking it apart. We come down here and we've got something called a carburetor. We want to understand the carburetor. We have to, before we can understand the whole. But how do we come to understand the carburetor? What do we have to do? Take it apart! So we take the carburetor apart, and now we have a valve down here. We have to understand the valve in order to understand carburetor, and the carburetor in order to understand the automobile. How do we understand the valve? By taking it apart!

Question: Is there any end to that process? That was the first fundamental question.

The answer that was given to that question was dictated by a pervasive belief, of the time. And that was that the universe is ultimately capable of being understood. That was a firmly held belief. In fact, in the middle of the l9th century, in a series of major meetings of the famous scientists of Europe, they published a forecast that by 1900, which was then about 15 years away, our understanding of the universe would have

been completed. We would by that time be able to describe in detail the state of the universe at any moment of time - past, present or future. They actually believed that! If one believes that even a part of the universe is understandable how do you have to answer the question: Is there any end to that process? It dictates the answer. What must it be? Yes there is! Why? Because unless there is a stopping point, such that when we get to understand the stopping points we then have the basis for understanding the rest of the universe, we can never get complete understanding. And so the first fundamental doctrine of the machine age was that everything that is experienced, and every experience of it, is ultimately reducible to indivisible elements. That doctrine is called "**Reductionism**". Everything in the universe consists of indivisible parts.

Stated that abstractly, many of you may not recognize the doctrine, but in the specific manifestations you are all familiar with it. In physics you learned in your high school courses that if you take any physical object and start to take it apart you ultimately reach a particle of matter that can't be further subdivided. What is it called? The atom!

The atomic theory is a reductionist theory in name. It says that everything in nature is reducible to particles of matter which have mass and energy and operate in a space-time coordinate system.

In your first course in chemistry, the first day of the course, the teacher handed you a table. Remember the table? What was it called? --- Periodic table! The table of elements. Mendeleev's table. The ultimate forms of matter, out of which everything else in the universe is composed.

In biology you learn that every living thing is reducible to a single element called the cell.

Psychology went through the same history, it is just a more exciting one, as it usually is. The first effort to systematize our knowledge of the mind was made by the German philosopher Leibnitz. He wrote a book, the name of which is lost from the language. The book was called "Monadology;" the study of monads. Do any of you know what a monad is? A monad is a psychic atom. Because Leibnitz argued that mind like matter is made up of atoms. The difference is they have no mass. They had energy and certain other properties, but not matter. The reason this word is lost to the language is that this doctrine was replaced by another, formulated by a contemporary of Leibnitz, who became the father of modern psychology. He is John Locke.

Locke argued that the mind at birth was like a blackboard that had never been used. A brand new blackboard. It was a receptacle which received information through the senses, which had the capacity of reflecting on what was entered on itself. He attempted in his understanding of knowledge to analyze it back to the elements of experience, which he called: "Simple Ideas". For example, the idea of red. He said this is an ultimately indivisible idea, it cannot be defined. He said: "You don't believe me; try to make a blind man know what red is". You can't. The only way you know what red is, is by looking at it. It is an ultimate experience. It cannot be defined. It is a simple idea. And then he tried to show how the simple ideas were combined to form more complex knowledge.

Subsequent psychologists came along and said Locke was great for cognition, but what about feeling. So we now have postulated the existence of a set of basic or elementary drives, instincts, needs. We have a whole psychology of needs. The most recent form is Maslow's work with his hierarchy of needs. Then a very curious thing happened. At the turn of the century a man by the name of Freud appeared who developed the first comprehensive theory of personality. How did he do so? By postulating the existence of three psychic atoms, endowed with energy, interacting to form the human personality. What did he call the atoms? The Id, the Ego and the

Super-Ego. Here we are, back with the monad! And the energy was called the Libido. So we have a completely reductionist theory of the human personality.

In every domain of human endeavor the first preoccupation was to identify the elements of which the phenomena under study were composed. That is the doctrine of reductionism. Now, if we take the thing to be explained, and analyze it, i.e. break it down. Suppose we get all the way down to its elements. The possibility of a complete understanding now exists. In order to assemble the understanding of the behavior of the elements, we must know how the elements are related. Therefore it becomes essential to say something about the nature of the relationship between things.

It is not surprising that in an era where it was believed that everything in the universe was reducible to fundamental elements, it was also believed that all relationships were reducible to one single simple relationship, and that it was sufficient to explain all phenomena in the universe. That relationship was Cause and Effect. The basic program of science became to explain the universe using only this relationship. This, too, is such a familiar concept, that we have forgotten what it means. So let me refresh your minds. One thing is said to be the cause of another if two conditions are satisfied:

1) The cause must be necessary for the effect, and

2) it must be sufficient.

What does that mean? -ping!- You just heard a noise! Did my striking the blackboard cause that noise? You have to establish two things to assert that it did. First, you must show that if I did **not** strike the blackboard you would **not** have heard the noise. That means you are demonstrating the *necessity* of my striking the blackboard. (For the noise). Secondly you would show that if I **do** strike the blackboard, you **must** hear the noise. That demonstrates the *sufficiency*. And if I can demonstrate that my striking the blackboard was both necessary and sufficient for the noise you heard, then I have established that one is the cause of the other.

We started in the renaissance a program for attempting to explain everything in the universe using cause and effect[4]. That lead to a series of questions, the answers to which completed our concept of the universe. Here is an effect that we want to understand. What we do is we look backwards to identify its cause. We now understand the effect. But what about the cause? Well, that is unexplained! To explain the cause, I must treat it itself as an effect. Therefore, it was argued, that everything in the universe is the effect of some cause. Everything in the universe is caused. This doctrine is called "**determinism**". Nothing happens by chance. It is clear why we had to accept this doctrine, because otherwise the universe would not be understandable. Since our program was to understand everything in terms of cause and effect, everything had to be the effect of some previous cause. But that created a couple of really serious problems for us. The first one was this: If I now treat this cause as an effect, that means that there is a preceding cause that explains it. But now I have got this cause unexplained. Therefore it must also be the effect of a preceding cause.

Question: Is there any end to that process? What must the answer be if you believe the universe is understandable? Yes! There had to be a first cause!

That argument was called the cosmological proof for the existence of God. It was the principal proof used to establish the existence of God. We argued that an understanding of the universe was only possible if there was a first cause. So that when we understood everything beyond that, and Him, we would understand the universe.

It is curious to look back retrospectively and observe, that our proof for the existence of God was derived out of our concept of the nature of the universe. It was a

necessary idea, given the set of beliefs that we had.

The second problem which arose, or at least characteristic of our view of the universe, was this: If the cause is sufficient for the effect, it provides a complete explanation. Nothing else is required. Because we don't need to know anything else to explain the effect. And that had an incredible consequence. The consequence was we didn't need the idea of the environment to explain anything.

Science developed an *environment free* concept of the universe. Now I know that sounds outrageous, in the light of today's focusing on the environment, but just look at the evidence. If I were to ask you to write down the most familiar laws of physics, my guess is most of you would write the law I have already referred to. It is called the law of freely falling bodies. The one formulated by Galileo. Now you may not remember the law. Some of you will: $S = \frac{1}{2} G T^2$. But I think most of you will remember what the word "Freely" means in that law. Why is it the law of *freely* falling bodies. Do you remember? ---- In a vacuum, absolutely right! What is a vacuum? A vacuum is the absence of an environment.

Every fundamental law of physics tells you how things will behave in the absence of an environment. There is even more revealing evidence. The physicist does his research in a place called the laboratory. What is a laboratory? A place that you keep the environment out of! So that you can study the effect of one variable on the other without the intervention of the environment.

Our concept of the universe was environment free. That didn't mean we didn't have an idea of what the environment was, but we didn't use it to explain anything. Finally, there was a question which led to the greatest enigma of the machine age, one that was never completely resolved. How in the world do you explain free will in the universe in which everything is caused. How can you explain the phenomenon of choice? There wasn't uniform agreement ever reached on that question. But there was uniform agreement about the following conclusion: That free will is not required to explain anything. Everything that we observe can be explained in terms of cause and effect. Therefore if there is such a thing as free will, it is extra-scientific.

The dominant view, however, not the pervasive one, but dominant, was that free will is an illusion. It doesn't exist. It is an illusion granted by a merciful God who recognizes that it makes life more interesting to believe that we have choice. One philosopher put it beautifully: "Man is like a fly riding on the trunk of an elephant, who thinks he is steering it. It makes life a lot more interesting."

And so free will was excluded from science and therefore the concept of purpose and choice were irrelevant to the understanding of the universe as we picture it. If we take those three doctrines and that method and put them together, what does the universe come out looking like? The answer is: "A Machine". It is not that the universe was **like** a machine. The universe **was** a machine. The most commonly used analog in the period, where scientists were trying to explain to others what the universe was like, - It repeatedly occurs in the literature - was that the universe is like a hermetically sealed clock. That is an incredibly revealing figure. First: It was hermetically sealed. What does that mean? No environment! The universe like everything else has no environment. Second: It is a clock. That means: It is a mechanism which operates with a regularity dictated by its internal structure and the laws of nature.

The universe was seen as a machine whose behavior was dictated by the structure of its elements and the laws of nature. No free will; nothing else is required to understand it. Now observe: Here is a fundamental premise. The universe is a machine created by God to do God's work. Every pulpit of every western religion in the world preached that doctrine. We are here to do His will. We are part of the machine He created to do His work. That is the first premise. The second premise goes way back into the origins of the Judeo-Christian tradition. It asserts, as Genesis

does, that man was created in the image of God. That means that every man is a demi-God. He is the most like God of anything on Earth.

Look at the inference which is obvious from those two premises. If the universe is a machine created by God, and if man is like God, what should man be doing? Obviously, creating machines to do his work! That was the origin of the industrial revolution. It was the deliberate effort by man to imitate God as he understood Him at the time. Every single characteristic of the industrial revolution derived from these views of the nature of the universe. Look how! The two essential ideas of the industrial revolution are machine and work. It was an effort to produce machines which would do the work of man. Therefore we have to understand two things: What a machine is and what work is.

Let us go back to work first. The one thing that renaissance man was absolutely certain of was that work is real. It is not an illusion. But everything that is real is reducible to atoms. Atoms have only two properties. Mass or matter, and energy. Therefore, work was defined as the application of energy to matter so as to change its properties. If you move an object, you work. If you transform coal into heat, that is work. It is the application of energy to matter that is work. What is a machine? A machine is any instrument which facilitates the application of energy to matter so as to transform it.

You will recall in chapter two of the physics book you saw somewhere in your life, that every machine in the universe is reducible to three elements. Remember? What are they? There are only three elementary machines in the universe. The lever arm, the incline plane, and the wheel and axle. Here we are again: reductionism. All machines are ultimately reducible to these three elements. With those two concepts you can see how the industrial revolution developed. Here is a job to be done. We are going to mechanize it. How do we go about doing it?

The first thing is we have to understand the job. What is the nature of the work to be done? If we don't understand it, where do we begin? Take it apart! Surprisingly, that was called work analysis: The decomposition of work, looking for what was called the work elements. Frederick Taylor called them the work elements. What is a work element? It is a task so simple in can't be done by two people. For example, tightening a screw. Have you ever had two people try to tighten the same screw? It is almost ludicrous to think of. That is a work element, therefore. Why did we look for work elements? Oh, the answer is easy! If we could reduce work to these simple elements, then we could facilitate the process of mechanization. It would be easier to mechanize the work elements in a complicated job. So we began to focus on the mechanization of these various work elements. We did not succeed in mechanizing them all. There were two reasons why we did not. In some cases we simply did not have the technology. In other cases we had the technology but it wasn't economically justified. In either of those two instances we put people in to perform the remaining tasks and then assembled them into an aggregation that became the production line. The spine of the modern factory.

The nature of the modern factory derives directly from our concept of work, machine and the method of analysis. This has two very important implications that we have only recently begun to appreciate. The factory is the exemplification of analytical thinking applied to work and machine. Therefore, if there is another form of thinking, would there not be another form of factory or work? And the answer is as you shall see: Yes, there is! And it does not look like anything we have ever thought of as a factory.

But for 400 years we did not entertain such a possibility. Secondly, there was a phenomenon which occurred. It is now referred to as the irony of the industrial revolution, which provided an encurtaince as probably the central problem of our time. It is curious, that in our effort to relieve man of the necessity of work, we

analyzed work to its elements, so as to facilitate mechanization. But we did not succeed completely, there were elements that could not be performed by machines, so we put man in to perform those elements. Result:

We reduced man to behaving as though he were a machine. We dehumanized human work. We made men behave as though they were machines in our effort to replace men by machines. And this has become responsible for the problem at H.E.W. (US department of Health, Education and Welfare). A recent publication called: “Work in America” cites as the central problem confronting this nation the alienation from work, which is a direct consequence of its dehumanization. We will take a look at that problem in some depth later on.

So here we are, very quickly, running through an era that you are all familiar with. I haven't told you a thing you don't already know. I have just tried to organize it a bit for you, and perhaps give you some fancy vocabulary to refer to it with. But you all know this because you absorbed it by osmosis; you are part of a culture in which you simply drank this in from the environment.

Evolution of Systems Thinking

What you may not be quite so aware of, however, is what has been happening since World War II. Because that is more subtle, it is very young, and therefore to attempt to analyze it, or even think about it, generally is pretentious. But we can't afford modesty any more. What happened? A new age doesn't emerge from a single event that moves in a straight line. What happens is something like this: You have a lot of directions of activity which begin to converge and then there is a recognition of a common core: A point of view which becomes a new view of the universe.

Therefore, if we wanted to go back historically we take any one of a very large number of lines leading to the recognition of the core. I am going to pick one that happens to be the one I lived through. You could pick others that would be just as good for demonstrating the point. So I go back to my graduate days, when in 1942 a book appeared, which was almost completely ignored, but retrospectively was of incredible importance. It was almost completely ignored for two good reasons. The first is: It was written by a woman. Who pays any attention to what a woman says if it did not have to do with the subject of sex. This one did not. Secondly, believe it or not, this woman was a philosopher. Who ever heard of a woman philosopher? Most of you would have great difficulty identifying a woman philosopher. This woman's name was Suzanne Langer. She wrote a book called: “Philosophy in the New Key”. That book reported the results of 20 years of research from the natural sciences. She had two conclusions. The first one made her look peculiar to the scientists of the day and the second one made her look crazy.

The first conclusion she reached was this: Science was giving up the notion that the universe was ultimately composed of particles of matter. And the scientists (of the day) said: “Where has she been? This is nutty, physics is still firmly entrenched in the atomic theory. It doesn't make any difference if you don't think that the atom is the ultimate element, but think the atom is made up of quarks, that is a detail. We still think that the universe is made up of particles. She is nuts! When they saw her second conclusion, they were sure of it, because she suggested what the new element was that was replacing the atom: The Symbol. How crazy can you be?

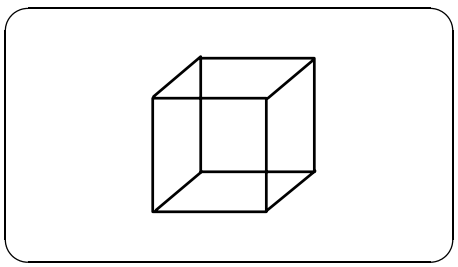
The symbol has no mass and no energy. How can you talk about the sun being made up of symbols, or a table or a chair or a wall being made up of symbols. So they simply discarded her. She was meaningless. I say they - most people. But one of her students, a young man by the name of Charles Morris took it quite seriously. In 1946 he wrote a book that came to Langer's defense. He said Langer was not wrong, she had a slight error of judgement, but she was essentially right. She was right in saying that the nature of reality is not to be found in atoms. We are coming to believe

that. She was wrong in believing that it was in symbols that we can find it. But she wasn't that wrong. Because it is not in symbols that we can find the nature of reality, but in their aggregation, in language, he argued. People did not laugh at Charles Morris. For good reason.

There are some of you in this room I can tell by appearance who were probably in school by the end of World War II. Those of you who were, will recall that the principal intellectual activity in the United States at that time focused around the newly emerging science of language linguistics. It was the big thing of the day. In fact, curiously, the largest selling nonfiction book in the United States between the end of World War II and 1950 was a book by Stuart Chase called: "The Tyranny of Words". A book about words!

The largest selling authors in the United States Were two men: Korzybski and Hayakawa. (The now infamous senator from your state). What were they famous for? They invented a field called: **Semantics**. The science of meaning. The largest selling imported book in the United States during this period was a book by Ogden and Richards from England, called: "The meaning of meaning". Why all of a sudden were we becoming preoccupied with language? The answer lies with the rediscovery of the work of a relatively obscure American anthropologist: Benjamin Whorf. Whorf is responsible for a hypothesis, remarkably called the Whorfian hypothesis. It was developed as follows: He was a comparative cultural anthropologist and he used the standard procedure for trying to study the difference between cultures. For example: At the time of his writings Japan was a new culture. We were very much interested in studying it and understanding it. The way you proceed in this is you take the vocabulary of our language, which is English, take the vocabulary of the Japanese language. List the words. Then you look for the words which mean the same thing. If you have the word "Chair" in English, you look for the Japanese word for chair. When you find it, you get the connecting line, and so on. When you finish doing all of this, two things become apparent.

There are words in English that have no Japanese equivalent, and words in Japanese that have no English equivalent. And it is by studying those words that you get to understand the nature of the difference between cultures. Not by studying the words they have in common, obviously! But Whorf did something beyond that. For example, in English there is a word for which there was no Japanese equivalent: "Perspective". There was no Japanese word for perspective. On the other hand there is a Japanese word, which when written in our symbols: "NoTan", for which there is no English equivalent. Therefore I can't tell you what it means. You have to take my word for it. (Laughter) So what, you say. It is the "So What" part that was fascinating. What Whorf did, (and I am telling the story almost allegorically), he went to Japan and showed the Japanese a sheet of paper, on which he had the following drawing:



He asked them what that was. Nobody said: "A Cube". When he described it they said: "That is a surface with a line down the middle with a top and a bottom approaching each other". That made Whorf very curious. So he collected a set of paintings of landscapes (from the west), took them over and put them on an art

exhibit. The Japanese are very curious about western art. They came in large quantity. As they left the exhibit, he asked them what their dominant impression of western art was. He was amazed! Because the Japanese said that the essential characteristic of western art is that it does not have a third dimension. It is all flat. On the other hand, how many of you have ever seen a collection of Japanese silk screens? Many of you have. What is your dominant impression of them? They are all flat! But to the Japanese, they are not! Because the Japanese have something called NoTan.

From that observation, Whorf drew the following incredible conclusion: We have always believed that the way you learn as a child is that you become familiar with something like tables. After the idea of a table emerges from experience, we develop the word: "Table" for it. He said that is absolutely wrong! He said you cannot experience a table until you have the word for it.

The concept precedes the experience. Therefore, if you want to know the nature of reality, you don't go back to the content of experience, you go back to language, which dictates the content of experience. That is why people did not laugh at Charles Morris. In language, you will find the nature of reality. But don't worry. It only lasted about a year, because there was a young scientist, a mathematician at Bell Labs, who knocked this for a loop. Unfortunately, he couldn't write in English, he could only write in mathematics. But he was smart enough to get a collaborator who could. The collaborator was a biologist by the name of Warren Weawer and together they published a little book in 1948, written by Weawer and this young mathematician, Claude Shannon, in which they argued: No, it is not in language that you will find the nature of reality, but Morris was not that far off, it is in communication, of which language is only an aspect.

Curiously, this doctrine was dead before it was born. Not the book. The book was tremendously important. But this particular argument was. Because Shannon's closest collaborator and friend, another mathematician at MIT was writing a book at the same time on the same subject, and he agreed with Shannon, except on this one point: That it is in communication that you will find the nature of reality. He did not believe that. He finished his book at exactly the same time Shannon did. But he was a little shrewder guy. In 1946, when Shannon finished his book, there was a terrible shortage of newsprint in the United States. You could not get a book published in less than two years. For that reason Shannon went to the University of Illinois press, where he could get the book published in 18 months. But the mathematician at MIT discovered that although there was a shortage of print in the United States, there was not in France, because France had been out of WW II for a much longer period than we had. So he took the book to France and he published in English. That book appeared about three months before Shannon's, actually at the end of '47 and it is famous for two reasons: [The first reason is that] It had the largest number of misprints of any book ever published in the English language. (Laughter). That is literally the case.

[The second reason is the content of the book] The book was authored by Norbert Wiener and it was called: "Cybernetics[5]" and in that book Wiener argued that the nature of reality is to be found in the analysis of control, of which communication is only a part. The significance of Wieners work was - It was the first time at least in my life, and in my perception - in '47 people began to say .. Something is up. Something fundamental is going on. We did not know what it was. Things were buzzing. Something really fundamental was happening, but nobody could articulate it. And it was not until 1951 that science went through what the psychologists call an AHA experience. The recognition of a point of convergence.

Retrospectively, when I set it up this way, you can begin to see what it is. There is a very important characteristic to this progression. What is it? We were behaving like all the kings men in Humpty Dumpty. We had started to put things together again.

Remember? Humpty Dumpty had a great fall, and all the kings horses and all the kings men, couldn't put Humpty Dumpty together again. Well, we were trying. In 1951 we recognized what we were up to with the appearance of a book by a German biologist. The content of the book was almost irrelevant. But the central concept was immediately recognized as the focal point of a new view of nature. The book was written by Ludwig von Bertalanffy and was called: “General Systems Theory”. It was the concept of a System, which immediately sparked recognition of something fundamental.

What is a System?

For that reason I am going to refer to the new era as the Systems Age. In order to understand the magnitude of the revolution, we have to understand what a system is. Let us take a look. What is a system? It is a set of two or more elements, which satisfy three conditions. Before we go on and look at the conditions, we should note that this is already a very important assertion. What does that tell you about a system? It is not an irreducible part! It can be taken apart. It is not an atom. It is a set of two or more elements which have the following characteristics:

First: Every element has an effect on the behavior of the whole. Every part effects the performance of the whole. For example take the human body, which is the most familiar system for most of you. The heart affects the whole, the brains, the stomach, the pancreas, the liver. Every part affects the whole.

The **second** one is the following: That the way each part affects the whole, depends on what at least one other part is doing. That is: The parts are interdependent. The way the heart affects the body depends on what the lungs are doing; if the lungs stop functioning, the heart cannot continue to operate. If the lungs don't work, the brain won't operate. If the brain doesn't work, the heart won't operate. They are inter-connected. The way they affect the whole depends on at least one other part. The parts are inter-dependent.

It is the **third** characteristic which is the central one and the most revealing one about a system. If we take the elements of a system, line them up and then sub-group them in any way whatsoever - it doesn't make any difference - at random, alphabetically, however you want to, we form subgroups. Then those sub-groups of elements will always have the first two properties. Namely, every sub-group of elements will have an effect on the performance of the whole, and there will be no independent subsets. Every sub-set's effect on the whole will be dependent on the performance of some other sub-set.

Therefore: A system is a whole which cannot be divided into independent subsets. So what! you say. Well, that results in some very interesting properties.

First: Every system has properties that none of its parts do. You can run, play the violin, make love and do all sorts of things that no single part of your body can do.

Hence: A system is a whole, which when taken apart loses its essential properties. And consequently it is a whole which cannot be understood by analysis.

Therein lies the nature of the revolution. The recognition that the universe is populated by things, by wholes, which cannot be understood by analysis. When you take a system apart and try to understand the behavior of the parts, you can do it, but what you cannot understand is the essential properties of the whole.

Systems Thinking: Synthesis

And so a new method of thinking was required. It began to emerge in the 50's. Not surprisingly, it was technically referred to as “Synthesis”. More popularly, as a result of a book[6] written by a man who is going to be here for lunch today (Dr. West

Churchman, University of California at Berkeley), it is generally referred to as "Systems Thinking". What is Systems Thinking. Very simply, it is 180 degrees inversion of analytical thinking.

Let me explain. There is something you don't understand. Remember what you did in analysis. You take it apart, explain the parts and then assemble the understanding of the parts into an understanding of the whole. Explaining a system is exactly the opposite. Instead of taking the thing to be understood as a whole, which is to be taken apart, you start by taking it as a part of a larger whole. So the **first step** is to identify a whole, of which the thing to be explained is a part. 180 degrees! The **second step** is to explain the whole. The larger part, this thing. Then the **third step**: You explain this, which is to be explained, in terms of its role or function in the whole of which it is a part. This is diametrically opposed to analysis. In analysis you go the other way and you explain by reference to structure.

In synthesis you go up instead of down and you explain in terms of function, not structure. I will give you a simple example which means a lot more than the generalized statement. The thing we are trying to explain is something you are all familiar with: A university. If you are an analyst, the way you'll proceed is as follows: The University is a whole which consists of parts called the colleges. Right? Sure! Colleges of course are reducible, they consist of elements called departments. Departments are wholes that consist of elements called students, faculty and subject matter. So we break down until we finally get to the elements. Students, faculty and subject matter. Now you explain what a student is. As hard as it is, you make some effort. Explain what a student is. It is even harder to explain what a faculty member is. Then you define the subject matter. Now we can define what a department or a class is, which is an even smaller element: It is an encounter in which faculty who presumably know a subject attempt to transmit their knowledge about a subject matter to students, who don't know it. The department is a configuration of courses about the same subject matter. A college is a configuration of departments with related subject matter. And so on up you explain the university. You explain the university by **how** it operates. Its structure.

What does a synthesist do? He starts by saying that the university is a part of a larger system called the educational system. He explains what education is. Then he explains the university by its role, or function in the educational system. There is no reference to a structure.

Those are two very different approaches. They are both valid, obviously. They don't do the same thing. It is the recognition that they don't that was important. It turns out that analysis doesn't explain the university at all! What it does is tell you **how** a university operates. It provides knowledge or know how. But it does not explain and you don't understand it. Synthesis does!

Synthesis answers the question: "**Why**"? Analysis answers the question: "**How**"? This process, this new way of thinking, does not displace the old thinking. It augments it. We haven't got rid of analysis. But it begins to make us understand that by analyzing a system, you do not explain it. You describe it. Systems analysis is a method of describing how a system operates, not explaining why it operates the way it does. It requires synthetic thinking to do that. There are certain principles which are implied by this mode of thinking that have incredible implications to management, which we are going to explore over the day. Let me show you the first of them, the most critical one. The following assertion can be rigorously proven. It is a very complex proof and I am going to prove it to you by example rather than in general. It says this: If I take a system and I divide it up into its parts, and I make every part operate as efficiently as possible, then there is one thing I can be sure of about the system as a whole. What do you think that is? The system will **not** be operating as efficiently as possible. That is completely counter-intuitive and is

opposed to the entire educational philosophy of management.

Because the basic mode of management is: When confronted with a complex situation,

1) break it down into manageable components, - departments, functions, product lines, and whatever you want. Then

2) arrange that each one run as efficiently as possible and

3) the whole will be run as efficiently as possible.

That is absolutely false.

It doesn't mean that you are running as inefficiently as possible, but it says that when every part is operating as efficiently as possible, the whole is **not**. Now why? Well, I say we can prove it rigorously, but we don't have to.

We will use a proof that Galileo marvelously called a thought experiment. It is an experiment, the results of which are so obvious that just by thinking about it you can see what they are. You don't have to do it.

I read in the New York Times a while back that there are 142 makes of automobiles in the United States. Let us buy one of each. Bring them to a large garage. Hire a bunch of automotive engineers. Ask them to do the following things. You say every automobile has a carburetor, but tell us which one has the best carburetor. They run a series of tests over the 142 cars and come out and say that Rolls Royce has the best transmission. We make a note: Transmission: Rolls Royce. Then we take the horn. They come out and say the Volkswagen has the best horn. We make a note. One by one we take every part required for an automobile and by their testing they tell us which is the best part available.

When they are done, we give them the list which now has each part required for an automobile, and the best one available. We tell them to take those parts off the cars and assemble the best possible automobile. Now you laugh. Of course. Why? We don't even get an automobile. Not only don't we get one that works well, we don't even get one. Why? Because the parts don't fit.

In a system, the performance of the whole is not the sum of the actions of the parts taken independently of each other. It is the resultant of the interaction of the parts. Not the sum of the independent actions of the parts. Therefore, the normal mode of management and of planning, as you shall see, which is analytical, however good it is, is not as good as it could be. One of the things we are going to look at, before the day is over, is what is synthetic thinking as opposed to analytical thinking like and about.

So we have synthesis replacing analysis. Now what about these other doctrines? You can begin to see at least some of the consequences. If in order to explain the university, I have to go to the educational system. Then I obviously have the question: How do I get to understand the educational system? What is the answer? I have to go to a larger system, don't I? Society! Now, how do I understand society? Well, I have to go to a larger system.

This doctrine is called "**expansionism**". It is diametrically opposed to reductionism. It asserts that whereas for 400 years we believed that you could not understand the universe until you understood the elements out of which it was composed, we now argue exactly the reverse.[7]

You cannot understand the elements of the universe until you understand the whole, of which they are a part. Now it goes from the whole to the parts, not from the parts to the whole. That raises the same question in reverse that we had in the machine age. When we start expanding in this way, is there any end to that process?

Fortunately we are spared the need to answer that question. Why? In 1920 John Dewey, a great American philosopher, wrote a marvelous book called: "The Quest for

Certainty", in which he announced that man's belief that we would ever understand anything in the universe was dead, that we now believe that complete understanding of anything was an ideal that we could continually approach but never attain. Everything would be known with some uncertainty. Now, we did go through that transformation as a culture. We don't believe that we will ever understand the universe any more. The moment we don't, we are relieved of the necessity of saying there is or there isn't an end to the process.

However, if you want to it is now a matter of choice. You can say: Yes, there is an ultimate whole that contains everything. You can call it the universe if you want to. Some people prefer to call the whole that contains everything by a different word. Know what it is? God. It explains an interesting phenomenon of the last twenty years. Why have the youths of the United States and England and France and Germany suddenly become so interested in Zen Buddhism, Hinduism and a lot of other religions of the world? Because their perception of God is systemic. God is not the element which created the universe. God **is** the universe. God is a whole, of which we are a part.

In the Judeo-Christian tradition, we are a part of the thing created by God, but not a part of Him. In the eastern religions, everybody is a part of Him. While the eastern religions were perceived as being systemic in character they run into other problems that we begin to have trouble with. We are at the very early stages of a major revolution in theological thinking. There is no doubt that the Judeo-Christian tradition will go through major transformations in the next couple of decades. That is an aside.

The fact is we don't have to assume that there is a single whole that contains everything. You can if you want to or not. It doesn't make any difference any more. What about these other doctrines? I wish there were time to take you through the history of this because in the history of science this is one of the most exciting stories I know of.

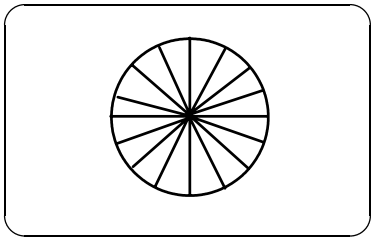
What happened to cause and effect? Briefly, about 1898 a young man with an incredible background, (he had an undergraduate degree in engineering) went to Harvard to take a masters degree in psychology. He got converted into philosophy for his doctorate under William James. He got his first teaching appointment as an instructor in philosophy at the university of Pennsylvania. In 1898 he wrote an article proving that science had been cheating for 400 years. But nobody paid very much attention. His name was Edgar Arthur Singer Jr. In what sense did he show that science was cheating? He said: Science, although committed to a program of using nothing but cause and effect to explain everything, was actually using two different relationships and calling them by the same name. He used two examples. He took the acorn and the oak tree and the mother and child.

He said: Is the acorn the cause of an oak? No! Why not? It is clearly necessary. You cannot get an oak tree without an acorn. But it is equally clearly not sufficient. If I take an acorn and put it in the ocean, I don't get an oak tree. If I put it in the arctic ice cap, the desert, I don't get an oak tree. Therefore, it is necessary, but not sufficient. A mother is not the cause of a child, despite what women's liberation says. She is only necessary, not sufficient. Therefore she is not a cause.

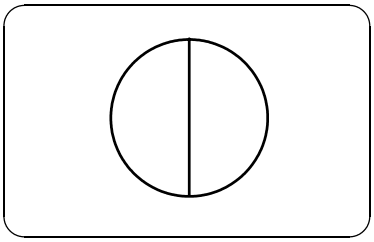
Science had cheated. It recognized this distinction, but it did it in an underhanded way. It called this relationship non-deterministic causality. Or probabilistic causality. And that is an outright contradiction. The one thing causality cannot be is probabilistic or non-deterministic. That is nonsense.

Therefore Singer said this is a fundamentally different relationship. He gave it a new name. He called it: "Producer Product". He said the acorn is a producer, and the oak is its product. He went on from there and created an argument that I'll try to explain to you by example.

He said the universe is like an orange. Suppose you have never seen an orange. You come to somebody who has one in their hand and you say: What in the world is that thing. He says: It is an orange. What is it like? Wait a minute, I'll get a knife and I am going to slice it so you can see. The somebody takes the orange, slices it down the middle and what you see is this:



You are all familiar with it. Ah, you say. Now I understand what an orange is. Fine. Then a third person comes in the room and says: What are you two people doing? One guy says: “I am trying to show him what an orange is; he has never seen one before.” The third person says: “Why don't you slice it the other way?” He says: “Why, it won't make any difference!” Maybe it will. And so he takes the orange and slices it the other way. What do we see?



An entirely different view of the same thing.

Singer argued that if we take the universe and slice it with Producer Product we will get an entirely different view than we get if we slice it by Cause and Effect[8]. It is the same universe, but it will enlarge our comprehension of it. He spent his life doing exactly that. He found two important things. First: When I slice the universe this way, look at what happens. Here is the oak, and I want to explain it. So I come back looking for its producer and I identify the acorn in the history from which the oak came. Do I have a complete explanation of the oak? No! Why not? Because the acorn was not sufficient. Therefore, to get a complete explanation, I have to find what the other necessary conditions are. Right? The weather, temperature, moisture there are a whole set of other necessary conditions which collectively constitute the what? The environment.

So in Singers view, whereas for 400 years the environment was required to explain nothing, in this view the environment is required to explain everything.

Science becomes environment full instead of environment free. That was the first major concept.

Perhaps even more importantly, in a proof that is very complicated, which I cannot reconstruct here, he shows that in a mechanistic view of the universe, the concept of free will has to be discarded, because it is not compatible with the notion of cause and effect. But when we look at the universe through the eyes of Producer Product, not only is it tenable, but it can be incorporated as an objective phenomenon.

Choice, purpose, and freedom become objective characteristics of systems which are subject to scientific study. This doctrine he called: “Teleology”. It is simply derived from the Greek and means purposefulness.

Singer's work, at least the basic part of it, was done by 1910 or -11. He lived until the

early 60's. He was, by the way, a teacher of both Churchman's and mine. He was ignored, largely.

A curious coincidence: In 1951 an English biologist George Sommerhoff completely independently, (he had never heard of Singer), rediscovered these same results. He came out with a book published by Oxford University called: “Analytical Biology”, in which he had exactly the same results as Singer but completely independently and with a different language. He didn't call it producer product, he called it directive correlation. But he was ignored also.

In 1954, an event occurred which led to the rediscovery of Singer and the emergence of Sommerhoff. A very curious event which Norbert Wiener had a major hand in. Norbert Wiener had two major collaborators. One was a physiologist from Mexico, Arturo Rosenblueth, the other was a logician at the institute for advanced studies, Julian. H. Bigelow. In 1947 the three of them began to study a new type of machine which had emerged in WW II. --The self guided missile, the automatic pilot for ships and airplanes. They began to look at machines that controlled other machines. They did a series of three articles. The first appeared in 1947 and the last in 1954. These three articles appeared in the Journal of Philosophy of Science. In the last one they reached some absolutely incredible conclusions.

They showed that whereas for 400 years in our efforts to understand man, we treated man as nothing but a complicated machine. Biology was called Mechanistic Biology. Man was nothing but a complicated machine.

They showed that we now had machines which could only be understood by looking at them as though they were men. What an incredible reversal! They gave these machines a name. They did not know anything about Singer or Sommerhoff. They called these machines teleological mechanisms. Purposeful machines. Now here we are again. That is an outright contradiction. There is no way a machine can be purposeful. It is in the nature of a machine not to be purposeful. So suddenly, in the middle of the 50's science was confronted with a dilemma.

Here are machines which can only be understood by looking at them as though they were purposeful beings. How can you explain it? Then Singer and Sommerhoff were discovered.

The answer was: Here is a single thing, which if you slice it one way looks like what? A machine. Slice it the other way, and it looks like a purposeful system. These are not incompatible concepts. They are different ways of looking at things, each having certain advantages.

The Systems Age

What the systems age represents is a recognition that a large class of problems, which we could not deal with effectively with a mechanistic view of the world, can be dealt with in a view of the world in which we see it as expansive and purposeful.

What I'd like to do is pull together now several things to bring this into focus for the next 15 minutes or so, and then give you a chance to question as much as I have covered so far. Then I will move directly into planning. It is clear from a number of the questions that were raised during the break, that some of you did not quite get the point that I tried to make about the transition from the machine age to the systems age. I pointed out that there are many different lines into the systems age. I picked one. I took the line starting with Langer down through Morris, Shannon, Wiener and so on. But one could have started anywhere. One could start in physics and see exactly the same transformation occurring through statistical mechanics, relativity theory and so on. Or if one wants to, one could start with the emergence of operations research in '37, cybernetics subsequently, management science and all the way through. You can trace that transformation there as well. That is only **one** way

into the systems age. Not **THE** way.

I selected it deliberately. I did because I wanted to explain something about the post-industrial revolution, which can only be understood because of this sequence of transformation.

There is an industrial revolution associated with the systems age, just as there was with the machine age. But it is a very different revolution. It has a curious history, because the origins of it technologically go back to the middle of the last century, with the development of the telegraph. The telegraph was a very curious machine, because it wasn't a machine. Yet nobody recognized it. A machine was defined as an instrument for the application of energy to matter. But that is not what a telegraph was about. It incidentally used some energy, but that was almost irrelevant. What the telegraph was, and what its descendants were - the telephone - the wireless - the radio - television and now the laser - is a technology which has nothing to do with work as we understood it. That was a technology of symbol transmission. What those machines did was transmit symbols or to use a psychological term, they were machines for communication.

At the same time, there was another technology emerging, which had exactly the same characteristic. It too was not recognized as being fundamentally dissimilar from the technological developments of the machine age. With about the middle of the last century electricity began to emerge as a major source of energy. It had been around for a long time, but as a game. When we began to use it seriously, one of its critical properties created problems for us. We could not see it. It was a little dangerous to try to touch it to find out how much of it there was going through a wire. So we developed instruments to do it for us. A new technology of instrumentation emerged, which did no work. What it was, was a technology for generating symbols. It was a symbol generating technology. Symbols which represent the properties of objects and events, are called: “Data”. Therefore, in contemporary language, these were data generating machines. They were machines which observed. Every automobile is loaded with them on the dashboard. Your gasoline gauge symbolically tells you the amount of gasoline in your tank. It is not a machine which does work. It conveys information to you about something else.

These two technologies developed to a very high degree of sophistication without constituting a revolution. The reason was that in a sense we were building a technological arch that consisted of three stones. We had put in the two in the sides. On the one side we put communication, on the other side observation. But we had not dropped the keystone in. Until we did, we could not rest a revolution on it.

That occurred, depending on where your academic loyalties are, either in '44 at Harvard or '46 at the University of Pennsylvania. I have looked into this thoroughly, and I can assure you objectively that it was '46 at the University of Pennsylvania. (Laughter) It was with the appearance of a gadget called the ENIAC. The first electronic digital computer[9]. A computer was also not a machine. It was not about the application of energy to matter. What it was about, was symbol manipulation. It manipulated symbols logically. What is that? John Dewey told us what it was in a series of books in the 20's on how we think and the logic and theory of inquiry.

John Dewey said the logical manipulation of symbols is thought. Therefore it is not surprising these came to be called thinking machines. That doesn't mean, of course, that they cover the entire gamut of thinking, but what they do is mechanically think. This keystone was dropped in at precisely the time when we began to look at things taken together instead of apart.

The similarity, the commonality of these three technologies, namely that they all had to do with symbols, began to make people speculate about the capacity of the three technologies taken jointly. When we take them jointly, something became apparent. If we have something here, that we want to control, then it is clear there are three

things we have to do in order to control it.

First, we have to know what is going on. We must be able to observe the thing that we want to control. And that is generate data. We have machines that can do that for us now.

Secondly, we have to be able to take that data, those symbols and process them so as to convert the data into what we call information. Useful symbols! This conversion process can be done by computers, which are all about the manipulation of symbols. The information is in turn an input to a process that is required that we call decision making.

Third, we can transmit the data and the information by the first technology, the technology of communication, so this transmission can be mechanized. Turns out that the principal decision making consists of the logical manipulation of symbols, and therefore this too can be mechanized, issuing what we call instructions.

Here we have a control cycle. Therefore these three technologies together were recognized as making it possible to mechanize control, to automate.

Automation is fundamentally different from mechanization, because it has to do with the replacement of man by machine as a source of control, of mental work, as opposed to physical work.

Whereas the first industrial revolution was about replacing man's muscle by machine, the second is about the replacement of his mind by machine. This raises a whole series of interesting questions that this age is going to have to face about what is left for man to do, if we were to ever succeed. Although nobody expects we will even mechanize completely let alone automate. What has been happening since the early 50's through automation is something which is fundamentally different from what happened during the mechanization era. In a sense it is considerably more threatening to man's self image than the industrial revolution was, although that was threatening enough.

If we try to summarize what all this has led to, it has led to what might be called the paradigm of systems thinking, that can be explained somewhat as follows.

We have something we want to understand. For several centuries our natural inclination was to assume the thing to be explained as a machine. Then we proceeded by analysis to explain it.

We now start by taking the thing to be understood as a system. More importantly, we tend to look at it as a purposeful system.

This represents a fundamental inversion of thinking, because as I have already indicated, during the machine era, we took things that today you would consider purposeful, like man, and simply considered them to be complicated machines. We subsumed purposeful systems as purposeless machines.

Today, we tend to do the inverse, and say you can only understand a machine as an instrument of a purposeful system. Therefore our focus is on the systems that use the machine, rather than on the machines themselves. So we focus on purposeful systems, but a particular kind. The kind of greatest interest to us are purposeful systems which contain parts which are also purposeful. Purposeful parts. Other systems perhaps. That type of a system is called a group.

Recall that the explanation of a system lies in determining its role or function in the larger whole, of which it is a part. Suppose that the function of these parts are different. I.e. that we have a functional division of labor among the parts, the purposeful parts of a system. Then we have something that we call an organization.

An organization is a purposeful system with purposeful parts that have a functional division of labor among them[10]. It is fundamentally different from an organism, which is also a purposeful system, whose parts also have a functional division of

labor. The basic difference lies in the fact that the parts of an organism do not have purposes of their own. The whole has a purpose of its own, but not its parts.[11]

Management in the Systems Age

In an organization, the parts have purposes of their own[12]. This way of looking at things, gives rise to the recognition that management of organizations has three fundamental problems, instead of the one that has traditionally been studied as a part of management. We have, in effect, the system we are interested in, the subsystems which are parts of it, and the larger, containing system. Sub-system, system and supra-system, or environment, as we more commonly refer to it.

The three levels that are involved in any systems analysis, give rise to the three fundamental problems that management has to be concerned with. Of these, as I have indicated, one has been well recognized.

First: What is management? Management is a subsystem. It is a part of a system which has the function of controlling the system of which it is a part. Management is always from within. You can direct a system from without, but you don't manage it from without. Management is a function of a part of the system. Control from within. Therefore, one of the functions of management is the effective direction of this system toward systemic objectives[13]. This we might call a self-control problem. This is the traditional problem recognized for management around which most management education revolves. How do you run a system so that it accomplishes its objectives? And I won't say anything more about that.

It is the other two that are of primary interest. Because we have recognized now that management has two other fundamental responsibilities.

Second: How do we run this system in such a way as to more effectively serve the purposes of its parts[14], and by so doing serve the purposes of the whole[15] of which they are a part. That problem is called the humanization problem. It is probably the most pervasive problem in the world today. The women's liberation movement, the generation gap, alienation from work, the race problem, the third world problem are all humanization problems. The central crisis of our time tend to be problems of this type. They all have the following common characteristic:

Purposeful elements of a system organize themselves to protest the treatment which they are receiving from the system of which they are a part. They accuse the system of which they are a part of not effectively serving their purposes and they expect such service. That gives rise to the humanization problem. We are going to see that problem appear in many guises before we are finished today.

The **third** problem is the supplement to that one. How do you run the system in such a way as to more effectively serve the purposes of the containing system, and do so in such a way as to effectively serve the purposes of the system itself? That is called the environmentalization problem. It is equally pervasive in the world. The consumer's movement, the energy issue, ecology issues are all environmentalist issues, in this sense of environmental, because they consist of elements in the containing system organizing to protest against the way the system is serving their purposes, but these are elements outside the system, rather than inside. So the consumers of the corporation are organizing to protest the way that the corporation serves its purposes. Or people concerned with the physical environment of the corporation are doing the same thing.

So management today is increasingly finding itself confronted with three sets of problems. Not only

1) the effective direction of the corporation towards its objectives, whatever they may be, but the

2) efficient service of the objectives of the elements of the corporation, the purposeful parts. The humanization problem. And

3) exercising what is increasingly referred to as the social responsibility of the corporation, which is a requirement imposed on it by virtue of its being a part of a larger purposeful system. What are its responsibilities to the whole, of which it is a part?

So it is this complex of three interacting problems, that planning will ultimately have to address itself to.

Questions & Answers

I want to make the transition at this point from the general background into a discussion of planning. Before I do, I'd like to give you a chance to say anything you want to about anything I've said up to this point. Any problems or discussions or objections or anything else.

Question: You set us up by saying that when we are straddling the two eras, you generate pain. But you haven't talked about the acceptance of some of this transformation. We glibly talk about systems, but some people have trouble swallowing the systemic approach to anything.

Dr. Ackoff: Well that is true, of course, people had trouble swallowing the mechanistic approach when it first began to emerge. In a sense what we have been doing, as I have said, very prophetic or presumptuous is like sitting in 1650 and talking about the machine age. There is no assurance that 10 years from now, we will look back on this thing the same way we are looking at it now. People will undoubtedly go through reanalysis and new understanding. But on the other hand you can see a very major transformation.

I was telling someone during the break a story, which involves West Churchman, which is the best indicator I have seen on how different things are today than they were 10 years ago. I give a basic course in systems. There are three required books in the course and one of them is West's book on the systems approach. It is the best book I know of for giving a general introduction to systemic thinking. In the last couple of years my students have been complaining about that assignment. They clearly don't like the book. So I got curious, because that book has been very important in my development. So I got a group of them together one day and I said: “You know, what is the trouble?” And they said: “We know all that.” You see, they have been raised in a different era. What seems so radical a transformation to us, they simply absorbed by osmosis from their environment already. It is not literally true that they know it all, but they sense it all. They didn't as little as 10 years ago. So we have a new generation that is coming along that will be thinking systemically naturally, not by conversion. We are still with a generation, you and I, that will have to make the conversion consciously.

Question: How widespread is the recognition of systemic thinking overseas, particularly in different cultures like the eastern countries or say Russia?

Dr. Ackoff: It is fairly extensive, and each culture sees it differently. The eastern culture said: You are finally catching up to us. That is one view that they take because they can with a great deal of justification argue that they have in a sense been thinking systemically for a long time. What they have not done is brought systems thinking and science together. That I say is the unique contribution here. The concept of the system and its use as an organizing notion is certainly not the invention of the West. This is why I pointed out to you the tremendous resurgence of interest in the eastern religions, which are systemic religions, instead of atomic religions, such as ours would be, or reductionist religions. But there is a great deal of systems thinking throughout the western world, particularly in Russia.

Unfortunately, it is not teleological. In Russia the thinking is systemic, but it is mechanistic systems. Not teleological. Maybe that will come. But it has not been completed here, we are still very much in a period of transformation.

Question: In the systems way, you indicated that it really did not matter that you accepted an ultimate ending to the approach, that you could go on and on and on. I did not quite follow that, because ultimately it seems you have to get to a point where you have to have an answer to the final question.

Dr. Ackoff: If you believe that the universe is ultimately understandable completely, then you would have to argue that there is a single whole which contains everything. Because then the only way you can get complete understanding is to understand that whole. If you don't believe that the universe is ultimately understandable in any perfect sense, then you are not obliged to close that series. Because you can always get more understanding by going to a larger system. That is what the doctrine of expansionism asserts. If you want to assume that there is a larger system, fine, but as Immanuel Kant in his: "Critique of Pure Reason" showed, it is as impossible to conceive of a larger system that contains all others, as it is to conceive of an endless series. They are both inconceivable. Without that you don't really know anything because everything is relative. In other words, you move into another, larger system and then into another larger system and so on.

It is quite different to assert that I don't know anything with certainty, than to assert that I don't know anything. I know a great deal, but I don't know anything with certainty. Progress is the reduction of uncertainty. But its elimination is something we believe as an ideal that can be continuously approached, but never attained. Oh, we are not in a state of ignorance, very definitely. ---

For a continuation of this seminar transcript, see the next title in this series:

VARIETIES of PLANNING

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1 This refreshing account of our society's transition from Machine Age Thinking to Systems Thinking is excellent background information for Perceptual Control Theory (PCT) and The Deming Management Philosophy. This commentary with sometimes opposing viewpoints is provided from the perspective of PCT, introduced by William T. Powers in his seminal work: Behavior: the Control of Perception. Aldine de Gruyter, NY, 1973, revised paperback Benchmark Publications,New Caanan, CT 2005. Dr. Ackoff, among others, reviewed this work. See books and papers available from Living Control Systems Publishing.

2 This wise comment relates well to the PCT emphasis on Modeling and Scientific Thinking.

3 In PCT terms, we would say that the King provides constant reference signals during his reign. The next King provides a new set of reference signals.

4 This is known as the Cartesian dualism. It still has a major influence on our thinking in the 1990's. René Descartes lived 1596-1650 and made major contributions in his day. He is known for the quote: "I think, therefore I am," and his major work: "*De Homine*" was published in 1637.

5 PCT in its earliest developments was influenced by Norbert Wieners thinking.

6 Churchman, C.W. *The Systems Approach*. New York. Delacorte Press. 1968

7 To be useful, this concept will require a clear theory or model which describes the functional relationships between the systems in question.

8 PCT provides yet another way to slice the universe.

9 Notice that digital technology suggests a very different paradigm than analog control systems do. The digital nature of today's computers may be a major reason "Information Processing" etc. has not been very successful in modeling thinking and the behavior of living organisms. Living organisms appear to PCT theorists to be analog, not digital in nature. The PCT model is an analog model. (Digital signals vary in discrete steps, such as 0 and 1. Analog signals vary smoothly in a continuous range).

10 Here, the understanding of PCT differs from Dr. Ackoff's presentation:

Not all systems have purposes! Purpose is intent! Purpose or intent is the key quality of CONTROL. Therefore, I equate Purposeful Systems with Control Systems, for the purpose of these specific, technical comments on the text. Please do not construe these comments as lack of caring for the family, society, company, or environment. The issue is purpose; the deliberate intent built into the system under discussion.

Some systems are animate, governed by deliberate, built in, intent or purpose. Typically, these are living organisms, but can also be the teleological machines Dr. Ackoff has mentioned.

Other systems are completely inanimate, following the laws of nature, with the different elements of the system influencing each other, but without any intent in the system itself. A major example is the Solar System.

Some systems are made up of organisms interacting. These systems are not purposeful. Any intent or purpose resides only in the individual organisms that are elements of the system. Examples of these would be a forest or eco-system, Dr. Ackoff's university, society and nation, a company, family and any other social unit.

Finally, some systems are constructs of human perception only. The "Legal System" for example, or an "Economic System." These clearly - upon reflection - have no intent or purpose of their own, and do not act on their own, but merely are descriptions of the results of interactions of many purposeful individuals, each interpreting his/her own purpose or understanding of justice or economy and taking individual action.

Social "hierarchies" and "systems" are made of interacting independent control systems, and so do not have at all the same character as the hierarchies of coordinated control within an individual which the PCT model suggests.

To the extent that individuals have similar purposes, one can get a strong impression that a "System" is acting purposefully, where no independent purpose exists except as (perhaps similar) constructs in many individual minds.

For a further discussion of how organizational "Systems" can be understood as the interaction of individual purposeful control systems, see "*PCT Psychology and Social Organizations*" by William T Powers, available from Purposeful Leadership™.

11 In the PCT view, organisms are full of purpose, down to and including individual cells. This is conceptually in harmony with the discussion of teleological machines.

12 Specifically: yes! Individuals have purposes. But the organization does not. The organization is not a control system. It is only a system. The elements of the system just interact. There is no intent or purpose in the system as such, only in the individuals.

13 PCT has no quarrel with this, as long as it is clear that this control - the purposes of management - comes from and is directed (shared with others) by the individuals in management according to their personal purposes.

14 Indeed, the purposes of individuals!

15 A commonly held, agreed purpose of the cooperative effort. This "purpose of the whole" is interpreted and understood by each individual. The concept of a "purpose of the whole" is thus a construct in each mind of all the individuals who have anything to do with the whole. It does not exist as such outside these individuals. Needless to say this construct will be different in each individual. This common construct is a requirement for cooperative effort. Therefore, corporate culture and vision/mission statements become very significant for effective cooperation in an organization.